

CANADIAN INNOVATION POLICY: THE CONTINUING CHALLENGE

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Declaration

I, Shirley Anne Scharf, have submitted this dissertation “Canadian Innovation Policy and the Developmental Network State: A Case Study” under the direction of my thesis advisory committee, members of whom are listed below. The dissertation has been submitted to the Department of Public Administration to be approved in partial fulfillment of the requirements for the Degree of Doctor of Philosophy in Public Administration at the University of Ottawa.

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Abstract

This dissertation undertakes to cast a new and discerning eye on the continuing enigma of Canadian federal innovation policy. Towards that end the dissertation employs the Developmental Network State (DNS) framework and pursues the question of whether the DNS can be used to explain why Canada -- and specifically federal innovation policy since 2000 -- has seemingly been unable to increase national Research and Development investments and positively impact Canada's rate of innovation. Theoretically the dissertation argues that the DNS framework can be used to mend the gap between National Innovation Systems literature with its proclivity for an undertheorization of the state and historical institutionalism, which while robustly conceptualizing the state, has been less engaged with the innovation problématique. While admittedly including some modest conceptual sharpening of the framework, the argument draws on four key pillars of the DNS: policy durability over time; targeted resourcing that can enable innovation; thickening of triadic networks among business, academe and government and incentives for capitalization. The research methodology encompasses both qualitative and quantitative (particularly in the sense of economic) techniques and includes 54 in-depth interviews conducted with innovation leaders across the nation. With respect to the evidence assembled around the health of the Canadian innovation system, OECD indicators over the period of the 2000s generally show deteriorating trends, although investment in Higher Education R&D (HERD) is very much the stalwart exception. As for the four lines of inquiry investigated regarding federal policy, the issue of policy durability in large part reveals an increasing number of priorities overlaid at times with exceedingly ambitious objectives and the ongoing challenge of fashioning a more enduring federal strategy. As for targeted resourcing, while federal investments have been both sustained and substantive and while there has been particular attention to macroeconomic stability and research infrastructure, there has been a continuing pattern of oscillation between a focus on research and one on commercialization. With respect to triadic thickening of networks, the evidence continues to reveal the relatively shallow nature of collaboration -- this despite robust funding, institutional mechanisms for networking and an ongoing priority on this issue by government. Here again however business financing of HERD stands out as the exception. In contrast, on incentives for capitalization there has been significant progress, although access to late-stage capital remains a challenge. Additionally, the study undertakes an examination of two sectors -- Artificial Intelligence (AI) and pharmaceutical manufacturing, employing a "quasi-experimental" technique that examines impacts of policy initiatives over a period that dates back to 1987. In the case of AI, the enabling conditions of DNS do coalesce to form a robust innovation ecosystem. In the case of pharma, policy efforts have not been so sustained or holistic and innovation indicators duly tell this tale of deteriorating trends. In sum, what emerges is that federal innovation policy in the Canadian context has developed in rather truncated form -- and it has tracked within the confines of more historically adept and enduring strategies such as upstream Research and Development and fiscal policy. Indeed, the pillars of the DNS framework serve to illuminate the dissonance between policy intent and impact, highlighting the unique nature of federal innovation policies as they have endeavoured to establish the agendas, funding, networks and capital that can provide a formula for advancing Canada on this front. This case study also suggests that the DNS itself may need honing -- specifically that policy durability is not only a sufficient condition for innovation but in fact an anchoring one enabling other dimensions to follow suit.

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List of Acronyms

ACEG	Advisory Council on Economic Growth
ACST	Advisory Council on Science and Technology
AI	Artificial Intelligence
AIR	Artificial Intelligence and Robotics
BDC	Business Development Bank of Canada
BERD	Business Enterprise Expenditures on Research and Development
BL-NCE	Business-Led Network of Centre of Excellence
CBAC	Canadian Biotechnology Advisory Committee
CBS	Canadian Biotechnology Strategy
CCA	Council of Canadian Academies
CCEU	Cabinet Committee on Economic Union
CERC	Centre of Excellence for Research and Commercialization
CETA	Canada-European Trade Agreement
CFI	Canada Foundation for Innovation
CIFAR	Canadian Institute for Advanced Research
CIHR	Canadian Institutes of Health Research
CSA	Canadian Space Agency
CSTA	Council of Science and Technology Advisors
DARPA	Defence Advanced Research Projects Agency
DNS	Developmental Network State
DPR	Departmental Performance Report

DRR	Departmental Results Report
FTA	Free Trade Agreement
GERD	Gross Domestic Expenditures on Research and Development
GDP	Gross Domestic Product
GC	Genome Canada
GFCF	Gross Fixed Capital Formation
EPO	European Patent Office
EU	European Union
GBARD	Government Budget Allocations for R&D
GOVERD	Government Expenditures on Research and Development
HERD	Higher Education Expenditures on Research and Development
HI	Historical Institutionalism
IC	Industry Canada
ICT	Information and Communications Technologies
IMC	Innovative Medicines Canada
IP	Intellectual Property
IRIS	Institute for Robotics and Intelligent Systems
ISED	Innovation, Science and Economic Development
JPO	Japan Patent Office
LSVCC	Labour Sponsored Venture Capital Corporation
MNE	Multinational Enterprise
MSTI	OECD Main Science and Technology Indicators
NAFTA	North American Free Trade Agreement

NCE	Networks of Centres of Excellence
NIS	National Innovation System
NRC	National Research Council of Canada
NBAC	National Biotechnology Advisory Committee
NRC	National Research Council Canada
NSERC	National Science and Engineering Research Council
OECD	Organization for Economic Co-operation and Development
PMAC	Pharmaceutical Manufacturing Association of Canada
PMPRB	Patented Medicines Prices Review Board
PRECARN	Pre-Competitive Applied Research Network
PPP	Purchasing Power Parities
R&D	Research and Development
RD&D	Research, Development and Demonstration
RIS	Regional Innovation System
SFT	Speech from the Throne
SME	Small and Medium-sized Enterprise
SBIR	Small Business Innovation Research
SRED	Scientific Research and Experimental Development Credit
SSHRC	Social Sciences and Humanities Research Council
S&T	Science and Technology
STIC	Science, Technology and Innovation Council
USPTO	United States Patent and Trademark Office
VC	Venture Capital

VCAP	Venture Capital Action Plan
VCCI	Venture Capital Catalyst Initiative
VOC	Varieties of Capitalism

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Introduction

Introduction

The issue of strengthening Canada's economic and industrial base has been central to Canadian policy since Confederation. However, particularly within the last twenty years the role of innovation and its linkages to productivity, economic growth and prosperity have been the particular focus of attention on the national stage. The question of Canadian innovation – the pace of innovation relative to comparator nations and Canada's capacity to bridge the gap between basic science and full-scale commercialization – have continued to stymie government policy-makers, academics and practitioner researchers alike. Moreover, this situation has continued to challenge Canadian government policy and its ability to successfully impact innovation indicators and to influence the robustness of a national innovation ecosystem. That the pandemic of late has now been overlaid on this issue has only further exacerbated the problem, laying bare the innovation gap with which the Canadian government – and polity – were wrestling. More importantly, it has imprinted even greater urgency on attending to this challenge with both holistic and effective instruments and policies.

The Canadian experience does stand in sharp contrast to the experiences of leader nations such as Israel (Conference Board 2017), South Korea (OECD 2017), Sweden (OECD 2016) or now China (Applebaum 2011; OECD 2017) on the innovation front. Further, it stands in direct contrast to the American experience where pro-active government policy has been identified as a catalyst for innovation in a range of domains as diverse as semi-conductors and “blockbuster” drugs. Captured under the notion of the Developmental Network State,¹ this framework links a

¹ See especially Block (2008, 2011); Block and Keller (2011a; 2011b); Keller, Block and Negoita (2017); Mazzucato (2013, 2015a, 2015b [2013], 2018); Mazzucato and Semieniuk (2017).

key set of government strategies and policies with not only innovation success but a rapid and sustained pace of innovation over the post-World War II period in America. It is this issue which the research project undertaken here trains its sight on, taking on the question of the relationship between Canadian, and specifically federal, government policy and Canada's innovation performance.

La Problématique: The Policy Landscape

That said, primary to the dissertation is a focus on the role of Canadian federal public policy in addressing the challenges of innovation since 2000, specifically in terms of intensifying Research and Development (R&D) investment, strengthening standard indicators of innovation, thickening the industrial, academic and government networks that can propel technological change, and commercialization, and creating a robust national system of innovation that can deliver innovation results. Towards that end, the dissertation leverages the Developmental Network State (DNS) framework² which has more recently evolved within the American context. Central to the discussion will be a focus on key federal policy initiatives that can potentially propel innovation -- specifically, durability and consistency in policy efforts over time; resourcing of innovation initiatives that is targeted (and that is neither diffuse nor easily leveraged for other more general corporate needs than R&D) and incentives that can demonstrably change the density of innovation-based clusters and networks. In the latter case, these may be of a Science and Technology (S&T) nature or directed at downstream activities in development, demonstration and commercialization. Also included under this rubric will be government-incented capitalization, particularly with respect to late-stage capital.

² See *supra*, ff1.

Prior to undertaking this journey, however, it is first useful to situate the research inquiry identified here in its larger policy landscape and, as such, the research problem -- “la problématique” -- resonates with some significance on several fronts. For one, the issue of comparative advantage, the linkages among economic growth, productivity and innovation, the centrality of R&D investment as an “input” (OECD 2015b, 3) to innovation and the dynamism of a new “deterritorialized” (Paquet 1998) knowledge economy have been central to international economic discourse and policy attention over the last several decades. The OECD has particularly focused on this domain over the years, devoting substantial effort to the innovation issue (OECD, 1999, 2015b, 2019, the biannual *Science, Technology and Industry Scoreboards* and *Science, Technology and Innovation Outlook* reports, the OECD country *Reviews of Innovation Policy*). Moreover, recent academic contributions have dedicated special attention, and journal issues, to these questions (*Oxford Review of Economic Policy*, 2017, 33 and *Industrial and Corporate Change* 2018, 27 (5)); 2019 especially issues 1 through 5). Indeed, Nelson (2020) too has recently weighed in on his seminal work with Winter on evolutionary economics and innovation with a “sharpened” perspective.

Nested within this larger global backdrop, from what may be seen by the numerous Canadian reports and commissions undertaken over the last two decades, innovation in the Canadian context also measures up as an issue demanding of our attention. Canada’s ability to close its innovation gap with international competitors and to spur economic growth has been a topic of engaged national debate and study since at least the turn of this century.³ (The gap itself refers to not only the underinvestment in Research and Development which Canada manifests on

³ Advisory Council on Economic Growth (ACEG) (2017); Council of Canadian Academies (CCA) (2009); Expert Panel on Commercialization (2006); Independent Panel on Federal Support to Research and Development (Jenkins Report) (2011); Science, Technology and Innovation Council (STIC) (2009, 2011; 2013; 2015); also the series of publications by the Advisory Council on Science and Technology (ACST) (1999a, 1999b, 2000, 2001).

a number of OECD indicators,⁴ and particularly the gap in business investment, but the implications this has in turn for productivity, economic growth and “prosperity” writ large.)

As one expert panel has reflected:

... business innovation in Canada lags behind other highly developed countries. This gap is of vital concern because innovation is the ultimate source of ... long-term competitiveness....The ability to conjure up new products and services, to find novel uses of existing products and to develop new markets – these fruits of innovation are the tools that will ensure Canada’s success in the twenty-first century (STIC 2015, E-1).

Indeed, a continuing series of government-sponsored commissions, expert panels and advisory groups have reflected widely on this issue, with a diversity of recommendations and exhortations for dealing with the challenge quickly.⁵ All, however, have been seized with the shallowness of innovation in Canada and essentially the continuing “stickiness” of this policy issue.

Further, with respect to academic scholarship, the import of this research problem also unfolds on multiple levels. To be sure, this is a particularly fertile period in which to examine the innovation problématique – and it is has awakened a new generation of scholarship very much apart from Schumpeter’s (1950 [1942]) earlier conceptualization of innovation dynamics. In particular, the relatively recent work on the Development Network State (DNS) puts a powerful lens on the way in which public policy – at least within the United States – stimulates, propels and sustains innovation across numerous sectors, including high-tech, biotechnologies and pharmaceuticals and nanotechnology. In undertaking an analysis of Canadian efforts at

⁴ See the discussion in Chapter Two on Research Methodology.

⁵ See Advisory Council on Economic Growth (2017); Advisory Panel for the Review of Federal Support for Fundamental Science (2017) (Naylor Report); Council of Canadian Academies (2009, 2012, 2013a, 2013b, 2018); Expert Panel on Commercialization (2006); Independent Panel on Federal Support to Research and Development (2011); Science, Technology and Innovation Council (STIC) (2009, 2011; 2013; 2015). The series of publications by the Advisory Council on Science and Technology noted in *supra* ff 3 were less focused at that time on the enduring nature of the issues and more setting out terrain for change.

innovation policy, leveraging the DNS, it enables an examination of the appropriateness of this framework beyond the American context.

Equally of relevance, the research problem of Canadian innovation policy distinctly enables us to zero in on the specifics of the policy process. It provides an opportunity to empirically trace the policy as it is formulated, and at times prioritized, and as it is manifested within the implementation stages. And, very much apart from the Multiple Streams Frameworks of Kingdon (2011 [1984]) or the Advocacy Coalition Framework (Sabatier and Jenkins-Smith 1993; 1999; Sabatier and Weible 2007), it will centre on the question of the “durability” and persistence of that policy – as institutionally expressed in particular departmental or agency footholds within the government; as it has undulated across various policy priorities; and in actual impacts on innovation indicators.

Objective and Research Questions

The Research Objective

As noted, the research objective is to squarely tackle the issue of Canadian innovation policy over a twenty-year time span, examining the factors that may be responsible for the challenges Canada continues to experience. In undertaking this task, the Developmental Network State framework and the four pillars on which it essentially turns – mission consistency, targeted resourcing, thickening of innovation networks and access to risk-based capital – will be applied to the evolution of federal public policy and the analytic strength the framework offers for grasping the Canadian situation will be assessed. And while the mission and priority-setting element necessitates some conceptual sharpening for comparative application and the network element stands to be more informed by thickening than brokering, these are modifications in the DNS and not a new rendering. In short, then, this research analyzes federal innovation policy in

an effort to reveal the factors – and the fault lines – that may have propelled or impeded innovation in the Canadian context. And it is intended to address a gap not only in the international literature around innovation policy but also to be the first to apply the DNS framework on Canadian terrain.

The Research Question

Given this larger backdrop, the central research question to be addressed is the following:

Can the Developmental Network State framework be used to explain why Canadian, and specifically federal, public policy since 2000 has seemingly been unable to increase national Research and Development investment, moving the scale on standard OECD innovation indicators and positively impacting Canada’s rate of innovation? ⁶

Four Domains of Research

Four critical aspects of national Canadian innovation policy from 2000 onwards will be pursued, each as a separate sub-question and each aligning with the dimensions raised in the DNS. The intent is to operationalize each of these in a practical, empirical manner that can be examined both through qualitative means as well as the necessary statistical and budgetary indicators.⁷ Ultimately, the goal is to provide grounded data and insights that can be distilled for comparative analysis. These four domains of research centre around the following.

1) From the period starting in 2000 is there evidence of sustained priority-setting around innovation imperatives and what can be characterized as policy “durability”? ⁸

⁶ See Research Methodology in Chapter Two.

⁷ The statistical and budgetary indicators used here are not to be construed as typical quantitative methods. Rather, the latter are understood in the traditional sense of conducting statistical analysis to ascertain correlations between variables or conducting regression analysis to assess the robustness of those correlations. As Goertz and Mahoney (2012) point out in distinguishing quantitative and qualitative methods of inquiry, “quantitative research is grounded in inferential statistics (i.e., probability and statistical theory)” ... (2012, 2).

⁸ The term is employed by Patashnik (2003); also Lockwood (2013).

- 2) **Is this priority-setting accompanied by “targeted resourcing”⁹ focused on priorities and Science and Technology areas that show the potential for success?**
- 3) **To what extent are policy initiatives focused on thickening clusters of innovation activity across industry, academe and government laboratories, strengthening linkages that can incubate ideas and lead to commercialization?**
- 4) **Have these efforts been twinned with government-incented and particularly late-stage capitalization that can bridge the gap between invention and innovation where products or processes have become market-ready?** Commonly known as the “valley of death,” this final stretch from invention to commercialization is crucial and is highly dependent on venture capital -- not only for its funding of development and demonstration but also the extensive networks and business expertise that are brought to the table.¹⁰

Structure of the Dissertation

With these lines of inquiry in hand, the dissertation unfolds on several fronts. The first section lays out the theoretical and methodological framework for the research, but also key here is to establish the Canadian context. Chapter One takes on the theoretical issues, proposing to “mend the gap” between theoretical efforts that could benefit either from a strengthened conceptual grasp of the innovation “problématique” or from a more substantive and inclusive focus on the issue and its implications -- especially for nation-states. More specifically, the deeply rich and diverse comparative work of National Innovation Systems literature does not locate the state and its associated policies as a central player in the innovation equation, instead

⁹ The term is employed by Block (2008).

¹⁰ On the import of venture capital, not only for early stages of development of products, but also late-stage and its ancillary benefits around managerial expertise and networks, see the Advisory Council on Economic Growth (2017); CCA (2018, especially 159-160); and Independent Panel on Federal Support to Research and Development (2011).

(and particularly true to its Schumpeterian roots) putting the emphasis on the “firm.” In contrast, historical institutionalism contributions, while “bringing the state back in,” have largely sidestepped the innovation question, focussed as they are on the import of sweeping, historically-embedded questions – democracy, national transformations and indeed revolution and various incantations of the liberal democratic and welfare state. This chapter explores how the Developmental Network State framework provides a means to integrate the respective strengths of these two streams of literature and also recalibrate to a more fulsome grasp of innovation policy. The chapter then lays out the guiding pillars of the DNS, including components where its comparative leverage could be conceptually sharpened. So too is Canadian scholarship with both its contributions and certain lacuna reviewed in this larger context.

Chapter Two attends to the methodology employed in the research: the battery of economic and statistical measures selected to assess innovation in Canada, and in relation its national comparators, as well as how each line of inquiry will be operationalized and the sources to be used. Similarly, the Artificial Intelligence and pharmaceutical manufacturing case studies are identified, as is the “quasi-experimental” method (Campbell 1969; Cook and Campbell 1986) that will be deployed here to assess interactions of policy and innovation over time. Additionally, it reviews the methodology employed in undertaking 54 in-depth interviews with “innovation thought leaders” across the country.

Chapter Three “takes the pulse” of the Canadian Innovation System, speaking to the various commissions and advisory groups who have both lamented the “state of the nation”¹¹ with respect to innovation and have advocated for change, recommending extensive policy changes. But this chapter also deals with the economic indicators that starkly present the

¹¹ This refers to the mandate provided to the Science, Technology and Innovation Council (STIC) who reviewed these issues on a biannual basis starting in 2008; see STIC (2009, 2011, 2013, 2015).

Canadian standing on innovation and R&D expenditures (among other factors) as pertains to the two decades under study. The indicators are particularly instrumental in revealing the health of the system, including certain strengths and especially clear and continuing weaknesses.

Section Two then tackles the four lines of inquiry in the dissertation. Chapter Four is focused on the consistency and policy durability dimension, as it plays out over respective political administrations from 2000 to 2020. And it trains its sights not only on the aspect of priority-setting and policy coherence per se, but also the means by which administrative capacity can shore up, or short-circuit, policy intent and how that has evolved over time. Chapter Five, in turn, takes on the critical issues of “targeted” resourcing. It traces the truly substantive resourcing that federal policy has dedicated to innovation initiatives as well as the manner in which respective research thrusts or commercialization focus have cross-cut the 2000 to 2020 era. The chapter is an effort to unsheathe the enduring features of international strength and prowess that have been built on the innovation front and, equally critical, the ruptures that have occurred.

Chapter Six then turns attention to the third pillar of the DNS framework, specifically thickening the triadic linkages of industry, academe and government to form robust innovation networks. The chapter opens with a discussion of the current statistical map of collaboration among these networks, albeit a map characterized by a lack of continuity in methodological approach and measures. It then unfurls the various initiatives and federal institutional vectors that have been nourished, both through funding and priority-setting, and assesses the implications of the current (and historical) state of affairs for the DNS thesis. Chapter Seven explores the issue of government-incited venture capital, examining the issue of “patient” and late-stage capitalization so critical to innovation but also that of seed and start-up funding for

new ventures. Each line of inquiry is further informed by the 54 interviews undertaken on the respective issues of concern. The results of these conversations, both qualitatively and to the extent statistical findings are presented, are woven into the fabric of each chapter and are used to triangulate with the evidence assembled to that point.

Finally, Section Three in Chapter Eight on Artificial Intelligence and Chapter Nine on pharmaceutical manufacturing presents the case studies. As noted with respect to the “quasi-experimental” methodology to be used, the case studies constitute a more robust effort to probe causal sequencing between federal policy and innovation. To that end the chapters trace federal policy interventions – or lack thereof – over a considerable period of time going back to the 1987-1988 period when federal efforts in both cases were particularly initiated. Moreover, the cases stand as a valuable study in contrasts, AI as the emerging domain which has successfully ramped up to international attention and pharma as a mature sector beset with its own challenges – ones particularly revealed in this current conjuncture. Indeed, in that latter context, while the dissertation has focused on a 2020 end date for the evidence to be assembled, in the case of pharmaceutical manufacturing, the research has been allowed to expand into 2021 given the current R&D and vaccine relevance.

Concluding remarks are then offered regarding this testing of the Developmental Network State framework on Canadian terrain: what it tells us about the linkages between activist state policy and innovation outcomes; what it may reveal or at least suggest around necessary and sufficient conditions for a robust national innovation ecosystem; but also what it may obscure. And an effort is undertaken to assess the leverage the framework brings not only to comparative work on the policy-innovation dynamic but also to the policy process itself and the telling space between policy intent and impact. Lastly, in the spirit of wrestling with “wicked

problems”¹² and situated within a domain embedded in “art,” “craft” and “science,”¹³ the conclusion provides some reflections on the practical policy implications for the Canadian situation, an issue of paramount import today.

Considerations and Contributions

The Federal Role

Before beginning, however, it is important to highlight a few considerations. This study, though focused on national – specifically federal -- public policy, does take place against the backdrop of a federated state and the interplay that would suggest. That said, however, this is not to indicate that the focus on the federal domain is not a worthy analytic endeavour. To understand Canadian innovation policy is to grapple with the federal nature and implications of wide range of initiatives. It is to discern the substantive, and at times, quite massive federal investments that have occurred over the years particularly in sustaining and refurbishing the research environs. It is to reveal the grandeur at times of the innovation goals established and both the continuity and rupture to which those goals were subjected, as well as to probe the role of federal institutional capacity in engendering networks and facilitating innovation. And it is to see the more recent valuable endeavours on the venture capital front – at least with respect to early stage and startup. These are important dimensions which enable the assessment of impact.

Additionally, as we shall see, the various commissions and advisory committees and councils that traversed these decades on the innovation front have clearly perceived the import of the federal role and, more importantly, the limits that endured with its policies as well. Their

¹² The term comes from Rittel and Webber (1973).

¹³ Raadschelders (2011a, 2011c, 143); see the discussion below.

analyses and recommendations have been geared repeatedly to the federal dimension – and the need for bold action on this front. So too have critical Canadian scholars trained their sights on the federal field¹⁴ – not just with respect to innovation but with regard to public policy and its inherent “ideas, structure and process”¹⁵ writ large.

Further, we would maintain that this study constitutes an initial cut into federal innovation policy using the DNS framework and is intended to lay out the broader contours. It is not intended to be an unequivocal, definitive exercise but rather an initial foundation for conceptualizing and evaluating the dynamics of federal policy – and seeding the ground for further work. Finally, and probably most critically (as will be seen in Chapter Four) federal efforts over the years have been oriented to some very big and ambitious objectives -- and thus even by their own standards, it is worth investigating the extent to which the implementation of federal policy has delivered intended effects. Indeed, principally, this is a narrative about policy intent and impact and both the disjunctures and alignment that involves.

Situating within the Study of Public Administration

As a further, although by no means least consideration, it is important to situate this inquiry within the larger study of public administration, albeit an exercise that is not a simplistic undertaking. Certainly, public administration has been riven and consumed at times with its own challenges. Indeed, successive contributions have struggled with its identity, at times likening this to one of “crisis” proportions (Kettl 2000; Ostrom 2008, Raadschelders 1999; 2011a; 2011b; Zalmanovitch 2014). At minimum, it is contested terrain and study of the field is by no means

¹⁴ Castle and Phillips (2011); Doern (1983); Doern, Castle and Phillips (2016); Doern and Kinder (2007); Doern and Levesque (2002); Doern and Sharaput (2000); Doern and Stoney (2009) with the exception of Wolfe in this edited volume who focuses on the regional dimension); Phillips and Castle (2010, 2012); Phillips and Herte (2018). Paquet (1998) and De la Mothe and Paquet (2000) are the notable exceptions to this tendency, Paquet especially being focused on the global sites for innovation.

¹⁵ The phrase is from Doern and Phidd (1983).

captured within the confines of one defining Kuhnian paradigm, replete with consensus on ontological and epistemological assumptions, common methodology and a community of scholars trained in applying and refining work within the discipline.

Without pursuing the larger history of this issue, a few dimensions of the challenge vested in this field of study are worthy of discussion. Public administration has been variously defined as “art”, “craft” and “science” (Raadschelders 2011a; 2011c, 143), art being the “tacit knowledge” and “indwelling” to which Polanyi refers and that instinctively leads.¹⁶ Craft in contrast speaks to the practice and practices of governance and the concomitant challenges that arise as administrators wrestle with issues that defy both priority-setting and skillful implementation of solutions. Finally, it has been frequently defined as science – borne out in universal-type generalizations that can be brought to the study of administration and founded on concepts of empirical inquiry and causal sequencing akin to the natural sciences.

The field also has been witness to deep schisms that have played out in sometimes heated exchanges and indeed vitriolic debates. Admittedly even Wilson’s (1887) initial efforts to sever administration and its practices from “politics” set up a dichotomy that intended to corral the study from the impacts of politics and politicking – a debate that still resonates today. The most noted, of course, were the Simon/Waldo exchanges with Simon taking aim precisely at the “proverbs” (Simon 1946) of administration around efficiency dependent on traditional notions with respect to hierarchy, span of control and organizational purpose. Indeed, Simon’s unabashed logical positivism¹⁷ argued for Newtonian (Simon 1946, 53) rigour, with scientific

¹⁶ Polanyi (Michael) 1966, especially 3 – 25; see the reference to Polanyi in Raadschelders (2011). Raadschelders himself describes art within the context of public administration as “philosophizing about.” Interestingly Riccucci puts the issue in more binary form, the study of public administration being caught between “art” and “science” (Riccucci 2010 6-19) and positions it more in ontological terms we would suggest, art being “intuition and experience” as opposed to “scientifically derived knowledge” (*Ibid.*, 15).

¹⁷ See Riccucci on Simon (2010, 6-20); also Whetsell and Shields (2015).

concepts articulated, methods defined and the field of study subject to “experiments” complete with controls that could generate clear conclusions. Waldo on the other hand retreated from the notion that the variable and unpredictable nature of the human condition could be treated with such scientific precision and that administration was necessarily infused with norms and values (Waldo 1948; also the discussion in Whetsell and Shields 2015). Decision in itself implied choice and moral judgement.¹⁸ As for the divide over the applicability of science to the field of public administration, it too has continued to play out with postmodernists, interpretivists and those skilled in the practice of hermeneutics indeed challenging the positivist notion of knowledge (Box 2005; also 2002). Knowledge for them is socially constructed and their contributions eschew the very concept of observed reality.¹⁹

Without belabouring the point, overlaid on these divides have been a variety of other factors. The unique character of nation-states and their embedded traditions have certainly occupied the field (Raadschelders 2011c). The US especially has tracked within the guideposts of positivism, scholarly work having taken a decidedly quantitative turn indeed to the detriment of even the study of ontological and epistemological differences within academe and for those training for a profession in administration.²⁰ Britain on the other hand has evidenced a more pragmatist and “atheoretical” bent (Hood 1990; Raadschelders 1999; 2011a; Rhodes 1996), seized as it has been with fiscal crises and rationalizing the welfare state, although more recently it has been trained on concerns of managerialism and governance – the latter as it traverses

¹⁸ In fact, it may not be a step too far on a smaller plane to suggest that the Finer (1941)/Friedrich (1940) debates around accountability echoed these divisions as well, Finer arguing for the rigorous means by which external control could be exercised over the individual and Friedrich persuaded that the administrator – the agent – was informed by an informal moral compass – to her profession and to the community at large.

¹⁹ On post-modernism, interpretivism, hermeneutics and critical theory and its philosophical underpinnings, see in particular Alvesson and Sköldbberg (2018).

²⁰ See especially McCurdy and Cleary (1984); Raadschelders (2011c, 147-148); White (1986); White, Adams and Forrester (1996); and for an excellent discussion of the issue, albeit also somewhat dated, Whetsell and Shields (2015).

society and withers traditional loci of authority (Rhodes 1996). As for continental Europe, it has evidenced a deeper philosophical engagement and traditions steeped in the law, although in the French case the critical nature of public action has surfaced more strongly.²¹

There have been of course concerted efforts to wrestle with these divisions and attempt to construct a core and logic around the study of public administration. Ostrom (2008) for example -- and arguably drawing from Tocqueville²² -- denied that one paradigm could exist within the field and reverted to the looser notion of association grounded in democratic tenets.

Raadschelders too has created a “framework” focussing on the enduring questions of what, who, why and how of “governance.” And while it may draw from Lasswellian influence (Lasswell 1935) or even the early pluralism of Dahl’s *Who Governs* (1961) in that endeavour Raadschelders has rejected more defined philosophical and methodological underpinnings, providing a structure in which the field can unfold to academic, practitioner and citizen alike (see Raadschelders 1999).²³

Admittedly, scholars were seized more with this “crisis” of public administration in the decades of the nineties and early aughts. Currents that have emerged, however, have centred around the diversity that must be brought to public administration and the pluralistic endeavour

²¹ See Zittoun and Demongeot (2009) on the traditions of legal studies in French political science and how this coloured “administrative science” and public policy studies. With respect to the American case, it should be noted that divisions have been equally grounded in radically different visions around the nature of government inherited from the Founding Fathers. Be it the Jeffersonian emphasis on small and local government or the Hamiltonian emphasis on a strong and central executive – these intellectual currents have continued to course through the American landscape -- traditions that as Kettl as so elegantly captured speak to an American polity “deliciously well organized not to prevent conflict but to channel it.” (2000, 28).

²² See Ostrom (2008), especially 147-149 and 163.

²³ It is worth noting that others have undertaken what may be described as more strident, and less enduring, initiatives: that public administration, in the tradition of the German scholar Von Stein, must revert to “a concept of the state” -- a concept rather ambiguously defined (Rutgers 1994). Or it is maintained that diversity is a “delusion” at once conflating the interdisciplinary nature of public administration with positivism (Mainzer 1994) or even a much earlier effort to span the notion of public in a variety of administrative and organizational venues that in fact expunges much of the “public” per se (Henry 1975).

this must be. For a variety of reasons – historical embeddedness of the nation-state; the legacy of philosophical (or indeed more atheoretical) traditions; a field impinging on the wide ramifications of government and governance; and a domain not singularly constituted by academe but the terrain of practitioners and citizen -- this field of study is inherently characterized by its fluidity and is not subject to clear demarcations. Indeed, Raadschelders holds that the domain of public administration is “interdisciplinary” and that it in fact gains sustenance in “drawing on widely dispersed sources of knowledge, as well as by using multiple methods of inquiry” (Raadschelders 2011b, 919-920; Raadschelders 2019, 80-81). Riccucci too has joined this dialogue, advocating for a “heterogeneity” dependent not on *a priori* assumptions but on the topic at hand -- namely, the “purpose of the research and the questions asked” (2010, 125). As for interpretivists, their approach specifically rejects one defining and universalizing construct.²⁴

Nor have such voices only come of late. Writing in 1947, Dahl cautions that public administration needs to be informed (in addition to transparency around values) by deep comparative work which eschews generalizations drawn from narrow, parochial study or universalistic claims that ignore national conditions and difference:

There can be no truly universal generalizations about public administration without a profound study of varying national and social characteristics impinging on public administration, to determine what aspects of public administration, if any, are truly independent of the national and social setting.

It follows that the study of public administration inevitably must become a much more broadly based discipline, resting not on a narrowly defined knowledge of techniques and processes, but rather extending to the varying historical, sociological, economic, and other conditioning factors that give public administration its peculiar stamp in each country (Dahl 1947, 11).

²⁴ While admittedly focused on public policy and not public administration per se, see Fischer (2003) and Fischer and Gottweis (2012) on “discursive” policy analysis and praxis.

In short, public administration is a more open and embracing endeavour. It is not necessary to search out one form of unity or coherence within the field and to religiously follow this path with respect to research and inquiry. If anything, what construed attempts at “unified science”²⁵ signal is the opposite, with diverse approaches and “heterodoxy” bringing enrichment to the public administration domain. It may well be enough to embrace that pluralism -- positivist and postmodernist, practitioner and scholar alike -- for it feeds an area of scholarship profoundly engaged with society’s “wicked problems” and in need of diverse lenses trained on these concerns. It is from this larger, more inclusive tradition that this research draws.

Contribution to Knowledge

Finally, as for the contribution to knowledge which this dissertation hopes to make, it is intended to enhance understanding on five fronts. Firstly, it seeks to transcend the isolation that has occurred between evolutionary economics scholarship and historical institutionalism, building a bridge to the analysis of innovation through the Developmental Network State framework. Secondly, as earlier noted, in applying the DNS framework, this would be the first effort to use this in a Canadian context. Indeed, to date DNS has been grounded in, and originated from, its focus on American innovation efforts. From a published perspective, there appear only to be a few other case studies done of Ireland (Ó Riain 2004, 2011), China (Applebaum 2011) and Chile (Negoita and Block 2012). In this sense, the dissertation would be contributing to comparative knowledge around the DNS in another distinct national setting.

Indeed, it could be argued that the DNS may not translate well onto other national experiences. Its focus on pro-active, heavily-funded and research-directed efforts by the American state has been wrapped in a national security blanket which, it is claimed, has

²⁵ The term explicitly used by Whetsell and Shields (2015, 438) is “unity of science.”

insulated these R&D efforts from the “rhetoric” of small government. Moreover, DNS contributions make this argument for essentially the post-war World War II period onwards – from the Manhattan project to the AI cognitive algorithms of “Alexa.” In that sense, the Canadian example, which has definitively not operated within this larger context of predominating national security concerns, is an extremely interesting test case of the framework and its applicability beyond its original setting. Further, the findings gleaned from this research are intended to inform the conceptual DNS framework itself, particularly around the conditions which are critical or supplementary to innovation success and the means by which these interpellate the uniqueness of the national experience. And if it is a step too far to posit with all the rigours of “set-theoretical” logic (Goertz and Mahoney 2012) which pillars of the framework are necessary and which are sufficient for success, nevertheless the evidence assembled can be used to feed back into the framework, bringing perspective to these issues and their comparative use.

Thirdly, this work is also an effort to strengthen the DNS in terms of its comparative conceptual reach. To be sure, there will remain a focus on the critical elements of targeted resourcing of nodes of S&T development, the densification of networks of industry, academe and government that propel innovation, and “patient” capitalization along the innovation continuum. But it is also the intent to deepen this theoretical approach by focusing on the “durability” and continuity of policy over periods of time – an aspect that given the American context around national security is essentially assumed rather than problematized.

Fourthly, the objective is to use the DNS to contribute to Canadian discourse around the federal state’s policy-making and the innovation problématique. While clearly a deeper dive into the literature will be warranted, Canadian policy or systems literature around innovation has had

much less engagement with comparative endeavours -- Paquet's contributions on the withering of the nation-state notwithstanding (1998). An argument can be made that academic literature (and we are definitively not including economic literature trained on issues of industrial structure or market failures) to date has centred around two streams. It has tracked the substantive failings of federal innovation policy as it has evolved.²⁶ Or it has subjected the conditions that animate innovation in Canada to rigorous theoretical and empirical analysis cast at the "meso" level, be that regional or clusters.²⁷ In either case, however, it has not leveraged broader comparative frameworks to locate the commonality -- or uniqueness -- of the national, and explicitly federal, Canadian experience.

As for the body of work undertaken by various councils, commissions and third-party think-tanks over the last two decades here the work is a direct effort to advise the federal government on the underinvestment in innovation that has occurred or the renewed investment (even in areas of strength such as higher education) needed to keep up with comparator nations (ACEG 2017; Naylor Report 2017; Competition Policy Review Panel 2008; CCA 2009, 2012, 2013, 2018; Jenkins Report 2011; STIC 2009, 2011; 2013; 2015). These reports necessarily flow from their oftentimes government-sponsored mandates and represent the profound insights of practitioners in wrestling with the nation's concerns around innovation, and the feasible solutions that can break the underinvestment cycle. For good cause, however, these are not theoretical undertakings on the nature of policy around innovation.

²⁶ See Castle and Phillips 2011, 2016; Doern 2006; Doern, Castle and Phillips 2016; Doern and Kinder 2007; Doern and Levesque 2002; Doern and Sharaput 2000; Kinder and Dufour 2018; Phillips and Castle, 2010, 2012; Phillips et al, 2017; Phillips and Hertel 2018); Quirion, Carty, Dufour and Jabr (2016).

²⁷ See Bradford and Wolfe (2017); Bramwell, Nelles and Wolfe (2008); de la Mothe and Paquet (1998, 2000); Denney, Southin and Wolfe (2021); Hubbard and Paquet (2010, 2013); Niosi (1998, 2003, 2010, 2018a, 2018b); Niosi with Bas and Zhegu (2014); Niosi with Manseau and Godin (2000); Paquet (1998, 1999); Paquet and Roy (1995); Wolfe (1998, 2002a, 2002b, 2009); Wolfe and Gertler (2016a, 2016b); Wolfe and Lucas (2005); Wolfe and Nelles (2008).

Lastly, the work hopes to bring a tighter policy lens to the innovation issue, attending to the counsel of those who focus on “policy process” theories (Weible and Sabatier 2018). True, the research here does not fit tidily, nor is it so intended, into the various theories and frameworks proffered up by this community – the Multiple Streams Framework (Kingdon 2011 [1984]; Herweg et al. 2018; Howlett et al. 2015) or Punctuated Equilibrium (Jones and Mortensen 2018) or the Advocacy Coalition Framework (Sabatier and Jenkins-Smith 1993; 1999; Sabatier and Weible 2007) to name a few. Even the Policy Feedback Theory employed by Mettler and SoRelle (2018) with its distinguishable roots in historical institutionalism stands apart, focused as it is on the intersection with civic voice and democracy. But both the importance of testing comparative models in different national settings (Weible 2018) and the import of an analysis not just of effects but longer-term *outcomes* are aspects that need heeding and to which this case study, it is hoped, can apply. As Tosun and Workman have succinctly put it: “With the exception of the budgeting tradition in PET (Punctuated Equilibrium Theory), comparative policy research has paid relatively scant attention to comparative outcomes (2018, 238).” This dissertation has taken the liberty to lay claim to that advice and, despite operating outside the traditional boundaries of these policy process models, is undertaken as a smaller contribution to the larger policy endeavour.

Conclusion

It is then within this broader context that the effort pursued here recognizes the value of using a new lens on innovation policy – one that is porous to different theoretical roots and attempts to leverage DNS as the mending of such around this issue and equally one open to qualitative renderings as much as economic data that inform the study. Hopefully, it is in the spirit of this larger heterogeneity and comparative effort with which public administration, and

policy process theory, must reckon that the inquiry undertaken here may be viewed. It is with these reflections in hand that we begin this inquiry.

PART I: THE BUILDING BLOCKS

Chapter 1

Innovation, Historical Institutionalism and the Developmental Network State: Mending the Gap

The Problématique

The issue of comparative advantage, the linkages among economic growth, productivity and innovation, the centrality of R&D investment as an “input” (OECD 2015, 3) to innovation and the dynamism of a new “deterritorialized” (Paquet 1998) knowledge economy have been central to international economic discourse and policy attention over the last several decades.¹ Within this context, particularly critical has been the role of state policy and its capacity to propel the inventions of science through to innovation and commercialization and thus nurture trajectories of national economic growth.

Towards that end, this contribution centres around the question of sharpening the conceptual tools available for appropriating the dynamics of innovation and specifically national innovation policy. It will respectively examine some of the critical contributions that have been made to the understanding of innovation – and more generally to the role of state policy – in an effort to grasp the strengths of these streams of literature, as well as where they are found wanting. The chapter will begin by briefly reviewing the seminal contributions of Schumpeter (1950 [1942]) but also, in counterpoint to this, the writings of Shonfield (1965) – still

¹ The OECD has particularly focused on this domain over the years, devoting substantial effort to the innovation issue (OECD, 1999, 2015, 2019, the biannual *Science, Technology and Industry Scoreboards* and *Science, Technology and Innovation Outlook* reports, the OECD country *Reviews of Innovation Policy*). Moreover, recent academic contributions have dedicated special journal issues to these questions (see especially the *Oxford Review of Economic Policy* 2017, 33 and *Industrial and Corporate Change* 2018, 27 (5)).

preoccupied with the issue of nineteenth and twentieth century economic progress but from a different lens. It will then examine and juxtapose the more recent National Innovation Systems (NIS) literature which takes on the question of innovation – and the dynamics that instill technological progress and growth – with the scholarship around historical institutionalism (HI), both as it has originally been cast as well as a “second wave” of reflection within the HI genre. Both the NIS and HI streams are found to be wanting however: the former for its undue focus on the firm, to the exclusion of a fully considered role for state policy and the latter for having remained largely aloof from the innovation problématique.

Our argument will then reach widely into the literature of the Developmental Network State (DNS) which has directly centred on the twin questions of innovation and innovation policy – and will explore its capacity to bridge the divide between NIS and HI streams of scholarship. It will also give due consideration to the modifications and refinements that may be necessary for the Developmental Network State framework to transport more easily to a wider comparative and particularly Canadian context. And, in so doing, it will pose four lines of inquiry: “targeted resourcing” by the state around nodes of technological development; thickening of networks that can propel clusters of growth; late-stage capitalization that can span invention to innovation and priority-setting that articulates both policy coherence and institutional grounding. With these conceptual tools in hand, it is hoped the thesis and its theoretical underpinnings can move towards mending the gap between NIS literature and HI and equally that it may heed Evans’ advice about transcending “stale state-versus-market debates” trapped in a time warp of “nineteenth century theorizing” (Evans 2011, v). Finally – and additionally – the chapter then pauses to reflect on Canadian scholarship and the innovation lens and how adoption of the DNS perspective can bring fresh insights to this issue.

Classics: Innovation, “Creative Destruction” and The State

Admittedly, while both Schumpeter and Shonfield are concerned with the momentum that fuelled “modern capitalism,” these contributions stand in sharp juxtaposition to each other. Indeed, they articulate very differing views of both the causes that propel innovation and growth as well as the role that the state and public policy plays – or does not play -- as it enters the innovation equation. To be sure, however, both are important not only for their efforts to unmask the gears of economic growth but also for the lines of argumentation that still resonate within National Innovation Systems literature and the echoes still heard in historical institutionalism. In fact, as we shall see, Schumpeter’s line of inquiry still very much bounds NIS debates around innovation and the import of public policy.

In terms of squarely centring on the issue of innovation and technological progress, the initial formulations by Schumpeter set out a clear path as to how this dynamic works and is in fact dependent on what he calls “creative destruction” (Schumpeter, 1950 [1942], especially 81-86). The argument is well-known. Schumpeter maintains that historically “prolonged periods” of “economic activity” (*Ibid.*, 67-68) starting indeed from the 1780s indicate cycles of “violent” destruction and reformulation, each time bringing in their wake technological progress (*Ibid.*, 67-71). The progress involves “revolutions” primarily in new methods of production but also in new markets or new forms of industrial organization (*Ibid.*, 83)² that “reshape the existing structure of industry” and transform into new waves of economic growth and advancement. As he concludes:

The opening up of new markets, foreign or domestic and the organizational development from the craft shop and factory to such concerns as U.S. Steel illustrate the same process of industrial mutation ... that incessantly

² See also Schumpeter (1934, 66). As Nelson and Winter have pointed out Schumpeter’s definition of innovation was quite “broad” (1982, 277-278), an aspect that has oftentimes been overlooked by later generations of scholars, with an undue emphasis on innovations in products and processes; also Nelson (2013, 189).

revolutionizes the economic structure *from within*, incessantly destroying the old one, incessantly creating a new one (*Ibid.*, 83).

The reduction in prices, increased output and productivity and, with less costly consumer goods, an increase in the standard of living are the extensive evidence he uses to make his case.

Certainly, as he defines it, it is counter-intuitive, not only in the fact that the virulence of the process can bring forth progress but also in that the main economic (and certainly in his later work the monopolistic) actors through defensive postures can advance the process as well.

Indeed, Schumpeter breaks with the classical economists (whom he defines as Mill, Smith and Ricardo (*Ibid.*, 75, ff. 2)) around notions of perfect competition being critical to the capital accumulation process and in fact argues that it is monopolistic practices of large firms³ that work to dampen the violence of these cycles and provide a form of insulation against the depth of economic swings. It is these which in so doing “steady the ship” (*Ibid.*, 87). Whether it be buying up patents to suppress and control innovation within the market, or long-term procurement strategies, or “rigidity” in pricing that hedge against risk, or simply holding back on new investments in an anticipated downturn, the “restrictive” practices of these monopolistic firms are critical. They enable an “orderly advance” with respect to innovation and economic progress.⁴

The complexity of Schumpeter’s work and where it leads him -- that in fact capitalism will not survive and that its newest variant will be its own undoing – is in fact not of key relevance to our argument. Rather it is important to keep the lens trained on what is central to Schumpeter regarding innovation and *that it is firm-centric*. The virulence of “creative destruction” that initiates technological advance, twinned with the defensive practices employed

³ See below, ff.6 below for Shonfield’s discussion of the early and late Schumpeter and the evolution of his position.

⁴ See in particular his argument on monopolistic practices in *Ibid.*, 87-106.

by monopolistic firms to dampen the cycles, enable more stable investment to progress and the accumulation process repeats itself, propelling innovation and development. As for the state and the role of public policy, Schumpeter treats these as relatively vacuous entities. Not only are public policies not critical to the inherent process of “creative destruction” but policies they do formulate can be seen as limiting the inherent cycle of growth.⁵ Granted Schumpeter was writing before the great wave of post-war growth and planning but that he defined the state out of his argument meant, in many ways, he too had not reached that far beyond “nineteenth century theorizing.” Interestingly, Shonfield has critiqued Schumpeter around the somewhat more minor variations in his argumentation⁶ but the central premise remains. It is that technological advance is in fact dependent on the vagaries of and “violence of capitalism” and state policies to tame the inherent nature of this process will be misguided. As for the defensive postures taken by firms to avoid economic losses, these entrepreneurial calculations may be seen as constituting a very early form of “institutionalized” innovation (Shonfield, 1965, 53) that propels the process forward. It needs saying however these calculations and practices are *qua* firm endeavours and they are not dependent on, nor conditioned by, the state.

In contrast to Schumpeter, Shonfield (1965)’s work comes much closer to the importance of institutionalism, or at least “institutionalized innovation,” and particularly the role of public policy being part and parcel of technological and economic progress. His argument rests on several fundamentals. He starts with the premise, in reviewing the data of the 1950s and 60s,

⁵ See Shonfield (1965, 53) on this aspect where he points out Schumpeter’s “warnings about the danger of soft public policies which would damp down the business cycle and mitigate the creative destruction of a slump”

⁶ See Shonfield (1965, 52-54 and especially ff 25) on the role of economic cycles in propelling innovation. Still on this point of the role of “creative destruction” in economic cycles, and the criticality of this to “capitalist growth” Shonfield concludes that, despite some changes in “emphasis” and the fact that Schumpeter foresaw an era of mature capitalism wherein “economic ups and downs which accompany innovations will be greatly reduced and may possibly be eliminated altogether” (*Ibid.*, 53), these do not fundamentally change Schumpeter’s position. The point is important for Shonfield as it is of course the issue of “calculated” “certainty” which post-war state planning could provide to which he turns his attention.

that economic growth has developed at an unprecedented rate raising output, productivity and incomes (*Ibid.*, 8).⁷ Such has been this “engine of prosperity” it even allows Shonfield to ruminate on whether capitalism can be called such any more. He does eschew this notion quite quickly – hence “modern capitalism” and he acknowledges large swaths of enterprise are left to private venture capital (*Ibid.*, 3). But he makes three critical points about the modern era he is writing about in terms of innovation itself and its “acceleration,” the state management institutions that steer and sustain it and the comparative evidence that makes his case.

Firstly, with respect to innovation, Shonfield argues that the prosperity of the immediate post-war period has been largely dependent on trade and comparative advantage (and a building boom that followed in the fifties), international trade driving investment and concomitantly raising productivity (*Ibid.*, 44 and 63). Secondly – and unlike Schumpeter -- while he acknowledges the role of technological innovation as being central to “development of modern capital,” where he differs is in the “vast importance of the authoritative calculations made by postwar governments”-- i.e. the role of the state (*Ibid.*, 52-54).⁸ Shonfield’s argument takes different forms – that the robust nature of planning enables “entrepreneurial” certainty⁹ and drives the innovation process forward, that commitment to full employment shores up sustained levels of demand, that the new welfare state with pensions and education additionally sustains growth and demand (what he calls social welfare). He even argues the setting of goals and planning objectives can temper Schumpeter’s “entrepreneurial uncertainty” that can drag the growth process down.

⁷ See especially *Ibid.*, 3-18 and 61-67 for his argument.

⁸ See also *Ibid.*, 61- 67 and also his chapter on “the changing style of private enterprise,” 358- 384.

⁹ *Ibid.*, 53. For Shonfield’s perspective on the emphasis which Schumpeter puts on “uncertainty” in explaining why growth may slow, see also *Ibid.*, ff 25.

Of third import, where his work ultimately focuses are the political institutional arrangements of post-war Europe that have been skilled in sustaining this prosperity. He contrasts the experience with the US where fiscal policy has worked against the amplitude of recessions, either being too late or too aggressive in its in-built fiscal stabilizers and thus creating an environment that has exacerbated the downside of economic cycles. Writ large, the feebleness of American planning institutions and public policy have not functioned with the same robustness or effectiveness as in the early post-war European nations.¹⁰ So be it the “étatist” policies of France or the ongoing efforts of British fiscal policy to mitigate against stop-go turns in the economy or indeed the more embryonic early planning efforts of Germany, which if not full-throated Keynesianism nevertheless revolved around finance loans and subsidization, Shonfield clearly and unequivocally places public policy as the central feature in providing the stabilizing force for growth and innovation. True, his argument is somewhat weakened by efforts to subsume the American experience in the same theoretical paradigm as Western Europe at that time and to write off certain exceptions. But what Shonfield accomplishes in understanding innovation is that its parameters and tempo do not solely revolve around the capital accumulation process that drives it. Rather he posits the space for institutional analysis and the role of public policy – if not always as primary as a key factor in managing processes of change. It is in fact a subtle and nuanced position that even signals the work that would come later around interfirm collaboration and the centrality of early science to “usable” commercialization.

¹⁰ On the American experience, see especially *Ibid.*, 13-18; on the British case, 14-15.

National Innovation Systems: The Literature, The Gap

NIS: Seminal Contributions

The literature on National Innovation Systems witnessed a burst of activity largely around the late eighties and nineties, primarily revolving around the contributions by Freeman (1988), Freeman and Soete 1997, Lundvall (1988, 1992), and Nelson (1988, 1993a; also 2005a, 2005b, 2005c) and, while it tended to give somewhat more credence to the role of the state particularly in its research capacity than the Schumpeterian rendition, nevertheless both the state and universities were still cast in an ancillary role. Certainly Nelson's (1993a) path-breaking compendium of fifteen-country case studies pushed back on the view that linear investments in high-tech R&D would simply produce results in national economic performance. Rather, countries were characterized by a wide "set of institutions whose interactions determine the innovative performance ... of national firms" (Nelson and Rosenberg 1993, 4). And the case studies deftly make this argument, pulling out the contours that national institutions, policies and culture have imprinted on systems of innovation, at times over centuries. Be it the depth of the "state-capital alliance" in France with a lineage going back to Colbert (Chesnais, 1993), or the robust scientific and technological institutions of Germany twinned with historic industry linkages (Keck 1993, 117-118) or the more problematic legacy of Britain as a mercantilist, trading nation (Walker 1993), these institutional legacies are deemed to shape national economic "prowess" -- or lack thereof.

Only in the American case does this case study by Mowery and Rosenberg (1993) note the radical breakthrough that came after World War II with the massive injections of federal investments borne out of national security concerns which reshaped the national innovation

system.¹¹ Even here however the military “spillover” effects that those investments had and which propelled technological advancement in computers, in semiconductors and in aerospace are seen as waning and certainly by the seventies, if not as early as the late sixties, technological leadership was being overtaken by Japan and Germany.

To be sure, Nelson and contributors are extremely thoughtful about the heuristic value of the “national innovation system” construct. This is not a grand theoretical project but rather is grounded in empirical institutions evoking a common “understanding” and approach. Nelson, writing with Rosenberg, acknowledges the “shadiness and to some extent the arbitrariness of both the institutional and national borders”¹² and how the increasing fluidity of the latter do challenge the concept of national itself. But in the end the view is that this approach has meaning, does highlight national differences and similarities and sets out a net so to speak that captures the “variegated” nature of these institutions and indeed “community of actors.”¹³

Nor is this where Nelson et al. may be found wanting. In fact, the critiques around their use of national innovation system as outdated, given the growth of sub-national economic regimes, the “deterritorialization” of knowledge, regional and indeed sectoral systems of innovation (Paquet, 1998) and locally-based clusters of economic activity, can be mitigated if the NIS approach is seen as complementary to more regionalized systems of innovation (Edquist 2005; Malerba, 2005). Moreover, there is a strong cautionary note sounded in this work about the need for more and deeper forms of comparative analysis and that certainly on the issue of

¹¹ Also on the US experience, Nelson (1993b, 509).

¹² Nelson and Rosenberg (1993, 15); *Ibid.*, 19 on the “variegated” nature of institutions. See as well their other reflections, namely: “Indeed, a problem with the broader definition of innovation is that it provides no sharp guide to just what should be included in the innovation system, and what can be left out.” (*Ibid.*, 5); also chapter 16, especially “... the basic notion of a “national innovation system” that oriented the project is a complex and somewhat problematic one.” (Nelson 1993b, 506).

¹³ Nelson and Rosenberg (1993, 5) and especially “Nonetheless, our belief was that nations continue to be meaningful units of observation.” (Nelson 1993b, 506).

innovation and national economic performance correlations cannot be presumptive (Nelson, 1993b, 505-523).

Despite the rich institutional swath this work cuts however what is still left wanting is inside the “black box” of the state itself. Both universities and government agencies and public policy are seen within the system as “supporting” institutions¹⁴ with the role of the firm as primordial and principal locus of innovative activity. Moreover, to the extent state action is appropriated it tends to be through the lens of anti-trust policy and Intellectual Property governance, as with the US – where, for example, 1956 jurisprudence had the twin effects of lowering entry barriers by smaller, start-up firms and at the same time strengthening internal capacity and resources of large firms on R&D (Mowery and Rosenberg, 1993). Or it is seen through the grooming of national champions, as with France, oftentimes with poor economic results (Chesnais 1993). As for the instruments of military procurement and commissioning used to spur innovation in the American case following the onset of the Cold War, this tends to be treated as a very historically specific outlier – one which appears as telescoped within a couple of decades and which was seemingly running its course by the early seventies (Mowery and Rosenberg 1993). In the end, the US experience, military efforts notwithstanding, is typically cast as one of “restrained government” (Nelson 1993b, 508). At the centre of this remains the firm – particularly ones equipped with large R&D facilities (Nelson 1988, 309).

With Freeman and Soete, here too is a tome of massive historical sweep, analysing critical sectors of “science-related technology” that have defined progress since the Industrial Revolution -- electricity, chemicals, oil, electronics -- and how these in turn have been overlaid on national growth trajectories. À la Schumpeter (although in more nuanced terms), they too

¹⁴ See Nelson and Rosenberg (1993, 5); also “the bulk of the effort in innovation needs to be done by the firms themselves” (Nelson 1993b, 510).

highlight the convulsive nature of the accumulation process (1997, 330), with rhythms of development which create time lags and “learning processes.” Moreover, they clearly recognize the NIS as the “unique combination of interacting social, economic and technical changes within the national economic space” (*Ibid.*, 313) ¹⁵ which contribute to the growth of “clusters of radical technical innovations” (*Ibid.*, 330). The work equally takes them on a deep dive into the microeconomics of firms (*Ibid.*, 193-285), enabling them to conclude that innovation is not a function of aggregate size of firm nor direct linear investment in R&D.

However, two problems stand out here. For one thing, while they caution against “static efficiency”-- public policies that do not recognize the dynamic nature of the innovation process and its specificity in terms of R&D, capital stock, the production process, industry and sector – they do not proffer further direction to policy-makers on how to develop or frame policies that can take into account the very microeconomic parameters they are studying. Nor do they present further insights on how transformations in industrial relations or managerial organization or even (akin to the regulationists (Boyer 2015; Boyer and Saillard 2002; Lipietz 1987)), new patterns of international regulatory regimes may accompany technological transformation.¹⁶ Indeed, the call at the end for the need to understand the interplay between society and “science-related technology” (*Ibid.*, 430) and to move beyond the narrow band of economic impacts still does not move beyond “normative” goals that focus on “dealing with and adjusting to change” (*Ibid.*, 432).

For another – and more critically – their efforts to theoretically appropriate institutional distinctiveness and, within that, state efforts in dealing with innovation reference a wide range of

¹⁵Also see the reference in Edquist (2005,183) to Freeman (1987).

¹⁶ See *Ibid.*, 330 where Freeman and Soete list the wide range of factors at play in implementation of new technology – in this case they are specifically referring to “information technology.”

variables and become quite diffuse. Thus, do Freeman and Soete in defining the NIS include not just the state but “education and training institutions, science, technical institutes, user-producer interactive learning, knowledge accumulation, adapting imported technology, promotion of strategic industries, etc.” (*Ibid*, 298)¹⁷ -- a dimension which does not advance the definitional aspect greatly. Given this, not surprisingly, when capturing the intrinsic nature of the British and American regimes and what specifically differentiated them, the comparative integrity of this exercise starts to break down. The British case features state policy, access to capital (from different sources including landlords), liberalization of trade and the American one highlights the absence of feudalism, the nature of the infrastructure (rail), mass production techniques and import of S&T (*Ibid.*, 296 Tables 12.1 and 12.2). So too does the comparison between Japan and USSR and factors responsible for innovation fail to harken back to the discussion – and variables involved -- in the British and American experiences.¹⁸

That said, it is important not to be pedantic in this critique. The breathtaking sweep of history which Freeman and Soete tackle in terms of national systems of innovation, how they compare these regimes internationally and how they maintain a distinct and localized stamp even in the face of globalization are the larger theoretical currents on which to build. But what is striking is if the state role, or lack thereof, infrastructure and production methods and associated industrial relations are all part of the institutional innovation formula, they need to be consistently compared and contrasted. Otherwise, efforts at appropriating the role of public policy – and arguably other institutional dimensions of the National Innovation System -- become historically specific and indeed territorially dependent.

¹⁷ Here they are referencing List (1841).

¹⁸ See especially *Ibid.*, 303, Table 12.4 and, more generally 295-315 on the distinctive elements and cross-country comparisons of national systems of innovation.

With respect to Lundvall (1992), here an even broader understanding of the nature of national innovation systems is distinct, one that focuses on the interactive and “learning” nature of user-producer relationships where the “most fundamental resource in the modern economy is knowledge” and its “production [and] diffusion” (1992, 1-2; also 2013, 30). Lundvall acknowledges the important role that public policy has to play in enabling the learning environment but the foundations of this paradigm are based on a “structure of production” tethered to the “user-producer relationship” (*Ibid.*, 10) and he too posits innovation as resting “mostly” within the firm or springing from interfirm collaboration (*Ibid.*, 14). As for the state, Lundvall is certainly not of the same persuasion as Nelson¹⁹ as to the misguided nature which there can be to government intervention. But the notion of the state as giving directionality to innovation agendas or a specific conceptualization of the state in its own right are not projects he takes on in this earlier work.

All told then, the seminal efforts on National Innovation Systems have continued to *undertheorize* the state and the role of public policy – and the firm, albeit “embedded” in larger institutional structures, remains very much centre-stage in these initiatives. Moreover, looking beyond these seminal thinkers, at least not until more recent endeavours, have discussions advanced this picture much. Scholarship has either broadened the NIS notion even further, expanding it to limits that essentially can rob it of its specificity – i.e., “all important economic, social, political, organizational, institutional and other factors that influence the development, diffusion and use of innovations” (Edquist 2005, 183). Or it has limited it to the role of

¹⁹ Nelson (1988) is particularly critical of the American experience with military funding of R&D and efforts to “plan and coordinate the development of broad technologies” (322). He argues that not only have civilian “spillovers” been limited but government efforts themselves he sees essentially as inept and “frighteningly misguided and disgracefully mismanaged” (*Ibid.*, 322-323); also Nelson and Rosenberg (1993) for a more nuanced version of the argument.

government in reducing “bottlenecks” in the innovation process and providing the necessary research infrastructure and skills (Fagerberg 2005). Moreover, other schools of scholarship have developed, principally around the necessity of viewing the NIS alongside the sectoral systems or transnational ones. Indeed, some have taken this latter issue even further arguing that the notion of the nation-state has become less meaningful in the context of “footloose” MNLs, devolution of power to more regional and sub-national structures, and generally “deterritorialization of knowledge” (Paquet 1995, 1998). In all, as Fagerberg has insightfully claimed, innovation studies have been overlaid with a “certain degree” of conceptual “fuzziness” (Fagerberg 2005, 21; Edquist 2005, 186-187). Certainly, with respect to the state and the role of public policy this argument can be made.

There may be a variety of reasons for this undertheorization of the state in the innovation studies and systems literature. The imprint of Schumpeter himself – and more specifically his later work in *Capitalism, Socialism and Democracy* on the capacity of large firms and the centrality of their R&D organizations to innovation -- has in many respects dominated not only the genesis of the literature but the way in which later critiques have counterbalanced his position. Moreover, while Schumpeter had depicted the firm-centric nature of innovation happening within the context of an “inert environment,” the response to this particularly by Nelson and Winter (1982) and Rosenberg (1994) has been on the institutional and systemic factors in which the firm is located and the way in which those interactions shape the innovation cycle. Indeed, the predominant concern in the disciples of Schumpeter (and Schumpeter himself) had not been around the role of the state but rather in developing an evolutionary theory

of economics²⁰ that pushed back on the neo-classical thinking of atomistic individual actors twinned with perfect competition.

Other factors have also contributed to this bias away from theorization of the state. There has been the “conceptual diffuseness” that has coloured innovation studies; the lack of a critical theoretical “core” (Lundvall 2013) and the empirical uncertainty by scholars on whether state interventions such as the *Bayh-Dole Act*, liberalization of IP law and strong anti-trust efforts in fact did produce innovation “results” (Mowery and Sampat 2005, Mowery et al. 2001, 2004; Vallas et al. 2011). Additionally, there has been the view that military expenditures in R&D in the US case had opportunity costs and the leverage provided for civilian “spillovers” had run its course arguably by 1972 (Nelson 1988, especially 323) or at least by the mid-seventies (Mowery and Rosenberg 1993). Further was the fact that Europe has seen many failed missions with respect to state intervention in the name of innovation. All of these have contributed to a more limited perspective on the state and a view, at least until relatively recently, that “when it comes to developing new technologies for the market, the role of governments must be more modest” (Lundvall and Borrás 2005, 609).

What is of import is that recent endeavours have started to take up this challenge, calling for an innovation studies agenda that specifically incorporates many critical new components including engagement on the role of government, and public intervention. Mazzucato (2013, and especially 2018) has particularly engaged with this scholarship, taking issue with the market-failure and neo-classical approach to innovation studies where public policy is viewed as basic science – a “public good” -- or generic subsidies to R&D or investment needs which the market will not provide. Indeed, she has specifically argued for the criticality of “strategic” and

²⁰ On this term, see the seminal works by Nelson (2005c; 2008) and, most critically, with Winter (1982); also Verspagen (2005).

“mission-oriented” state agencies that propel growth. Referencing the major and successful investments that were provided by the American state²¹ in the post-war period in information technologies (semiconductors and computers), biotechnology as well as nanotechnology -- and specifically referencing the work of Block and Keller, Vallas et al. (on biotech), Motoyama (on nanotech) and the extensive work of Mowery²² -- she maintains that in fact the state role has not been one limited to “basic science.” Rather public policy in these sectors, as seen through the lens of an “entrepreneurial state,” has spanned the breadth of the innovation cycle, from basic to applied research to development and commercialization.

Moreover, she has specifically taken on the role of the state within the NIS literature and posits the need for a new paradigm. She explains:

Part of the problem here is how the State’s role is perceived. In particular, the role of the State in the innovation ‘eco-system’ continues to be focused mainly around ‘creating the conditions’ for innovation, under-emphasizing its role in investment in areas of high risk and uncertainty This is because despite the achievement of the ‘systems of innovation’ perspective ... the role of the state is still mainly understood in terms of traditional neo-classical ‘market failure’ theory. (Mazzucato, 2013, 195-196).

And, her engagement has begun to have resonance within the innovation studies community – Fagerberg (2013), Martin (2013) and indeed Lundvall (2013) arguing for a forward-looking research agenda that includes “the entrepreneurial state” and more generally for an innovation scholarship that remains “porous” to new thinking.²³

²¹ There is reference to Israel, Finland and to some extent Europe but the examples given primarily revolve around the US post-war experience.

²² It should be noted that in addition to his original contributions in Nelson (1993) Mowery with colleagues has published consistently on the mission-oriented nature of R&D in the American context and the value this may also have for new technology challenges, as for example around climate change; see especially Foray, Mowery and Nelson (2012); Mowery (2010); Mowery, Nelson et al. (2010); Mowery and Simcoe (2005), Mowery and Sampat (2005).

²³ It should be noted in passing that there is another strain of what basically can be seen as economic globalization literature that essentially posits “the demise of national state capacity” (Crouch and Streeck 1997). This is very distinct from the evolutionary economics literature and in fact proffers up the standard vision of the deregulatory aspects that gutted the traditional fordist regime of mass production and rising wages and productivity in Western

NIS: Collaboration and the “Triple Helix”

Before leaving the NIS literature, there is another dimension that needs to be highlighted in the context of the DNS paradigm and which can be leveraged in the case of Canadian innovation policy. Specifically, there has been the growth of a rich and broad literature around the import of collaborative networks and linkages across the innovation system or as Etzkowitz had adeptly named it -- across the “triple helix” of industry, academic and government “agencies” (Etzkowitz, 1998, 2003). In an insightful review of innovation studies literature, Fagerberg et al. (2012) found that fully one-third of that literature has revolved around “innovation systems.” It is not the intent here to review that literature but a few key points must be made.

Certainly, within this context the lens has been trained on the “new economy” firm that, in shedding old standards of vertical integration and hierarchy, is engaged in a range of collaborative R&D, strategic, and financial networks. This may increase with the type of industry structure – where knowledge is fragmented and disparate and where there is increasingly complexity and/or increasing access to open forms of software and ‘radio’ architecture required for innovative breakthrough. Typical examples are the “new economy” (Lazonick 2005)²⁴ firm in the semiconductors, computer and especially the biotech and pharmaceutical industries where past knowledge will not directly contribute to breakthroughs in “blockbuster drugs”²⁵ and network diversification is important. Indeed, it embeds a dynamic in

industrialized societies (Boyer 1995; 2015; Jessop 1999; Lash and Urry 1997; Strange 1997; also Kettl 2000). There are several deep concerns with this stream of literature – it tends to generalize quite broadly and foregoes the value of extensive economic underpinnings to back the arguments (see even Weiss 1997 on this). It also tends to sidestep the question of innovation. The focus is on a withering nation state and a distributionally inequitable society – not the dynamics that can charge and recharge innovation. And finally, for all its difference from traditional economics, it too can be seen as narrowing the state and state policy to a very limited range.

²⁴ Lazonick in use of this term is referring to the ICT economy and industries – however this author has included biotech.

²⁵ Also on this point see Malerba et al. (2016),

terms of growth of the firm and “leadership” status which makes it even more “central” to the innovation process (Powell et al. 1996, Powell and Grodal, 2005, especially 65-69). Beyond technology and industrial structure, however, networks have also been seen through a larger historic lens. Mowery (with Bruland 2005), for example, has argued, admittedly largely on the basis of the US experience, that there has been a Third Industrial Revolution dating from post-WWII era onwards which has been typified by a denser form of “collaboration among different institutions.” Similarly, has the issue been more recently cast as the need for sharply honed policy instruments enabling innovation systems to reach their full potential (Weber and Truffer, 2017).

To be sure, Mazzucato has taken the systemic argument to task for still relying too heavily on the notion of public policy “fixing” market failures by essentially patching up vulnerable and ineffective NIS linkages; nevertheless what it indicates is the criticality of brokering and collaboration functions within the innovation process. What it continues to signal, long after Schumpeter’s notions of the importance of diversity in the innovation process and Lundvall’s emphasis on the reach of interactive learning, is the centrality of systemic linkages within and among public and private agencies – across not only technology and R&D but across financial, strategic and organizational components as well. To conclude, it is not unwise to draw on the analytic strength of these insights in the context of studying the Canadian innovation landscape.

Theorizing the State: Historical Institutionalism

“Bringing the State Back In”

If NIS literature has been focused on the firm, the literature of historical institutionalism – and under the original rubric of neo-institutionalism -- has been squarely directed at the

question of the “state”. Aside from the larger focus which at times appears in this work on the different variants of national Keynesianism and macro-economic policy that have evolved, this school²⁶ does not specifically focus on the innovation problématique. It does not train its sights specifically on the “creative destruction” associated with disruptive technologies, nor the types of institutional systems of innovation that evolve in the national polity. Nor does it largely focus on the targeted public policies that may be used to incent growth and productivity.²⁷ What this meso-theoretical journey by late twentieth century social scientists does instead is to recentre the state as a rightful object of analysis and to set state actions in empirically understandable and historical comparative contexts. And critically the historical institutionalists do directly address the state *qua* a set of institutions with the capacity to both formulate and implement policy, to imprint through its legacies the continuity of policy, to seize upon historical conjunctures as times of transformation and indeed to shape the conflicts and strategic alliances of societal groups and classes themselves.

²⁶ This school, at least in its earlier forms of historical institutionalism in the eighties and early to mid-nineties (and what at times was referred to as neo-institutionalism) included several seminal works, most importantly the broad collection of articles in Evans, Rueschemeyer and Skocpol (1985) in *Bringing the State Back In* in which the authors essentially threw out the challenge to rethink social science; also Esping-Andersen (1985, 1990); Evans (1995); Katzenstein (1985); Hall (1986); Hall (1993) Orloff (1993); Steinmo, Thelen and Longstreth (1992); Zysman (1983) and Stepan (1988) Skocpol has of course been a major contributor in this regard, including Skocpol (1973 and her first foray into this field); 1979, 1980, 1985, 1988, 1992, 1995; 1996, 2003b); as well as Skocpol with Amenta (1985, 1986); Finegold (1995); Ikenberry (1983) and Weir (1985); also the contributions in Weir, Orloff and Skocpol (1988). Interestingly, Block was himself engaged in some of these debates at the time. See Skocpol 1985, ff15 on Block’s position on state autonomy. Some would also put Nordlinger (1981) in this camp as well at least with respect to the autonomy aspect of the state. For an excellent overview of historical institutionalist literature as it has dealt with the welfare state – its “core” elements and as it has developed to respond to critics, see Lynch and Rhodes (2016), also Hall (2016). With respect to Lynch and Rhodes however this author would position Skocpol and her enormous contributions somewhat more strongly, both in taking up this debate (as early as the seventies in responding to Barrington Moore – Skocpol (1973) and leading it throughout the decades of the eighties and nineties.

²⁷ We take up this this argument later in discussing the “second wave” of historical institutionalism but it should be noted that the engagement on macroeconomic issues and industrial strategy has largely centred around the works of Hall (1986; 2015) Hall and Soskice (2001) and Katzenstein (1985a, 2018b and 1987); Zysman (1983) and to some degree Evans (1995).

The school clearly cuts a wide berth although it can be easily argued that the seminal work here is by Evans, Rueschemeyer and Skocpol in *Bringing the State Back In* (1985). Squarely taking aim at “society-centred” (Skocpol 1985, 4-8; Evans et al., 1985) theories that have preoccupied post-war social science, they contend that these approaches tend to a societal reductionism and “grand theory” (Skocpol 1985, 28)²⁸ that both robs us of the “dialectical” nature of state and civil society and critically misses the potential autonomy of the state. Their critique is indeed expansive. Neo-Marxism in its various forms reduces to the state acting on behalf if not at the behest of capital or simply positing the state as “embodying” class relations. The structural functionalist developmentalists wax on about the deterministic patterns of industrial convergence, or lack thereof, among nations without thought to national specificity. Even relatively sophisticated forms of pluralism in American thought simply ascribe weight to social agents, the latter having an unimpeded capacity to “shape politics” and states becoming akin to “analogues of ... competing social interest[s.]”²⁹ The point is clear. Such sweeping generalizations do not allow for a nuanced understanding of the state, grounded in historical comparative context and the societal-centred assumptions essentially eliminate potential autonomy of the state through “definitional fiat.”

Where the historical institutionalists do take intellectual sustenance is in the original rendering of the state by Weber and Hintz. They certainly define the state as a “continuous

²⁸ Also see the critique against reductionist “grand theoretical perspectives” in Skocpol (1979, especially 3- 43). Interestingly Skocpol largely exempts early contributions by Block from this, whom she argues pushes the boundaries of what constitutes (in his paradigm at that time) relative autonomy (Skocpol 1985, ff15). This author would suggest that these early contemplations on the state by Block are best articulated in *Revising State Theory* (1987). Notably, Block’s later contributions evolved into a more fulsome role for the state and state endeavours.

²⁹ See the sharp critique of pluralism in Skocpol (1985), and especially 4, but also Evans, Rueschmeyer and Skocpol (1985) for a broad critique of competing theoretical perspectives, neo-Marxist and Weberian (in “vulgar” form) alike. On this latter point while Skocpol et al. do dismiss the more “vulgar neo-Weberian” approaches that take a binary conceptualization to the state, defining it as “strong” or “weak” (*Ibid.*, 350-353), they do pay homage to Weber himself.

administrative, legal, bureaucratic and coercive system” structuring relations between “civil society” and the state.³⁰ That said, their argumentation rests on three key pillars. Firstly, the state can have the capacity to formulate independent and autonomous goals, and through its resources, the expertise of its “loyal and skilled officialdom” and specific policy levers (be it automatic tax stabilization or deficit financing), the state has the structural capacity to proceed through to implementation. Secondly, those same state structures and policy legacies can create a continuity in moments of great historical conjuncture that push the polity along a certain trajectory. This is best seen for example in the various works by Orloff, Skocpol and Weir on the variants of the New Deal and the historic making and remaking of the more limited American welfare state (Orloff 1988, 1993; Skocpol 1988, 1992, 1996; Weir 1988, 1992b; Weir, Orloff and Skocpol, 1988; Skocpol and Amenta 1985; 1986). Or it is clearly demonstrated in comparative studies such as that of Britain, Sweden and US and their respective economic responses to the Great Depression (Orloff and Skocpol 1984; Weir and Skocpol, 1985; Skocpol and Ikenberry 1983).

The school is ripe with other examples. The comparative work by Hall (1986) focuses on the institutional capacities of the French and British states -- rendering planning efforts respectively successful or futile. Esping-Andersen (1985, 1990) takes on welfare state policy regimes and in so doing traces the state’s capacity in its different liberal, corporatist and social-democratic forms to impact labour markets and influence the “ordering of social relations” (1990, 23). There is of course the enormous undertaking by Skocpol (1979) herself on the

³⁰ Skocpol (1985, 7). Skocpol here is quoting Stepan (1978); also Skocpol (1979), 3-43 and especially her statement that while states must function within the constraints of “socio-economic relations,” as well as “national and international economic dynamics, ... [n]evertheless the administrative and coercive organizations are the basis of state power as such (*Ibid.*, 29).

French, Russian and Chinese revolution (in counterpoint to Barrington Moore, 1966) and the imprints of “bureaucratic and monarchist regimes” on revolutionary politics and the polity. Comparatively of course the argument takes its hardest forms in terms of the capacity of coercive power of the state to define nation-building (Stepan 1971, 1985, 1988; Tilly 1985; Trimberger 1978). What welds this all together however are the independent imprints state structure, officialdom and policy have on the polity writ large.

Thirdly, and equally critical to the historical institutionalist theoretical framework, is the impact of the state itself on the “workings of politics.” Not only do state policies have lasting continuity impacts but in fact they can influence and condition the social groups competing for state resources, with intended and unintended consequences. So, for example, in the Sweden-American comparison of responses to the Great Depression did the ability to carve out an agrarian/worker alliance lead to stable consensual politics that further developed the Keynesianism and social security of the Swedish state. In contrast, the diminished Keynesianism of the American venture with subsidies and tax policies and the fragmented brokerage politics -- even patronage politics -- of the US enable large agrarian interests to push back on further expansion of American macro-economic policy. There is a Polanyian (1957 [1944]) tone here to the dialectical nature of state and society and the “double movements” that reverberate for societal interests and for state policy. All told it carves out an historical space for understanding the institutions and “institutional patterns” of the state that moves beyond the more reductionist notions in societal-centric theory and indeed gives access to the “black box” of state policy-making. Further, and most importantly, what this theoretical reframing and deep historical and comparative analysis undertaken by HI scholars lends itself to is the “heuristic principle” that states “*may* be autonomous actors” (Skocpol et al. 1985, 356).

That said, however, the challenges with this approach – at least as it has been originally conceptualized are equally well known. It has been critiqued for the stasis implicit in its earlier rendering and for its reliance on exogenous forces as causes of change (Lecours 2002; Lynch and Rhodes 2016; Schmidt 2010). Moreover, the efforts to remain at a meta level and to remain steeped in historical context can become all-encompassing. The empirical and historical – the “macroscopic” effort to understand the “broad institutional patterns of divergent national histories” (Skocpol 1985, 18) -- hold the danger of slipping into the descriptive to the point where the comparative efforts to understand these patterns could rest simply on what is historically unique and empirically accessible.

Finally, there is a teleological element here that needs to be reckoned with – the lasting imprints of historical sequencing and the ability of past state structures and practices to frame the future. To be sure there is recognition of open conjunctures where states with staid patterns will lead -- where states will “transform” and “retransform” but especially in the American case we are struck by how state patterning persists. We are transfixed on how the initial confluence of the modern state, non-programmatic parties and white male suffrage and the particular fragmented and decentralized locales of power in the modern state apparatus have continued to define the constraints of American policy making. Quite simply history continues to make history and it is open to question why the framework can not take account of periods of conjunctural openness, specifically “war, depression, and ...reconstruction”³¹ that could define more precisely the state’s insulation from historical factors.

³¹ This phrase is actually that of Block’s (1987, 87) and he refers to it in the context of “exceptional [historical] periods”.

HI: Confronting Critique

More recent endeavours by HI scholars have contributed mightily to expanding the horizons and overcoming the challenges of the early forms of HI. Indeed, a “second wave” (Hall 2016, 38) of HI literature has directly confronted the critiques of determinism, the issue of stasis and change, and the lack of attention to power relations as expressed through the political and the resources that accompany it.³² Specifically, Hacker³³ has taken aim at the bias implicit in the literature on the institutional legacies of the welfare state, particularly as the repository of positive institutional feedbacks. He points out that there needs to be more critical emphasis put on the “hidden” dimensions of the welfare state and how policy agendas are in fact constructed and what they do and (silently) do not contain. Pierson (2016) has particularly accommodated these critiques, focusing on the coalitional relations of power and agents of power and how these forces substantively influence decision-making. Streeck and Thelen (2005) have also embraced the concept of bringing power and contestation “back into” the HI perspective.³⁴

As well, this “second wave” of HI wrestles directly with the issue of institutional change as it had been originally cast – both in terms of its reliance on exogenous forces and open conjunctures in determining change as well as in terms of strength of institutions as a “causal force.” Articulated most strongly in the work of Thelen (2003, 2004, 2014), together respectively with Streeck (2005), Mahoney (2010, 2015) and Conran (2016), as well as Hacker (2002, 2005), Pierson (2016), Hacker and Pierson (2006, 2007, 2010) and Hall (2016), this perspective takes issue with the notion of institutionalism as based on a cycle of “punctuated

³² The contributions here are extensive. See the discussion below for the references regarding the key work on institutional change, but also more broadly in this “second wave” are: Skocpol (2003b); Pierson and Skocpol (2007), Pierson (2001, 2003, 2004); Lynch (2006); Culpepper (2011, 2016); and Hall and Soskice (2001).

³³ See especially, Hacker (2005).

³⁴ See Hall (2016) for an excellent discussion on the contributions by Streeck and Thelen, particularly with respect to post-conjunctural change.

equilibrium” – long cycles of institutional stability, even stasis followed by open rupture and exogenous forces of change. Instead, what has been argued is that there are endogenous – and evolutionary -- sources of institutional change. This can be in the specific form of policies or institutions writ large as they are *layered* on top of one another. Or it can be manifested as policy becomes unhinged and *drifts* apart from its original objectives and socio-economic context. Additionally, there can be conscious efforts by “social coalitions” to convert institutions and develop new interpretations of rules and governing principles that coincide with a new power structure.³⁵ Yet despite the more nuanced versions of institutional change and power “contestation” which this HI literature evokes, the problem is that the literature has been almost exclusively trained on the Western industrialized welfare state. And it has definitely not used its conceptual strengths to tackle the question of innovation.

Exceptions to this can be found in the works of Shonfield (1965), Hall (1986) and Hall with Soskice (2001). However, as has been seen, Shonfield, whom historical institutionalists claim as their own (Hall and Soskice 2001), is almost exclusively focused on the post-war planning efforts that he deems, at least for Continental Europe, to have been the fount of economic growth and success. Like Hall’s *Governing the Economy* (1986), this is very much trained on the issue of macro-economic policy rather than innovation per se. As for the *Varieties of Capitalism* contribution (Hall and Soskice 2001), certainly that is much more nuanced. Arguing that industrialized capitalist economies cleave into the Anglo-American model of “Liberal Market Economies” (LME) or the “Coordinated Market Economies” (CME) models of Continental Europe, Hall and Soskice specifically trace the institutional linkages that span out from firms at the centre of this and how these linkages lace through a variety of mechanisms

³⁵ The best synthesis of Thelen’s position can be found in Conran and Thelen (2016) and Streeck and Thelen (2005) and Thelen (2003).

dealing with the welfare state, industrial relations, and indeed the corporate nature of governance within firms. Extrapolating from this, they then maintain that the institutional webs that define LMEs are associated with radical innovation and those that characterize CMEs are linked to innovation of an incremental nature (*Ibid*, 25-26).

There are however two key problems with this line of argumentation. The bifurcation on the basis of LME or CME is proffered without much statistical underpinning and, with the exception of patent data,³⁶ certainly not a reliance in any extensive way on detailed OECD data related to the nature of radical versus incremental innovation. Nor is there any debate with the major economic thinkers in this field (Rosenberg 1982, 1994) and how innovation itself is shot through with time lags and incrementalism that defies even Kondratiev's (1984) "long waves" of technology dominance. Moreover, in terms of the state role, it tends to reduce government policy to needing to align with the dominant political economy model -- thus should innovation policy in LMEs be directed at incenting competition, and in CMEs with strengthening the coordination and type of corporatist arrangements implicit in their functioning (Hall and Soskice 2001, 25-26). In a sense, at base, it brings us back to the problem seen in economic institutional literature -- the firm here is still central and state policy is an adjunct to this. As Hall and Soskice argue, the "central role of the firm as the agent of economic adjustment" is essentially the fulcrum on which national comparative advantage turns (*Ibid.*, 1-5). Indeed, it brings us back to the original question of finding a theoretical framework of explicit government policy -- complementary to HI thinking on the import of the state -- that is trained on the question of innovation.

³⁶ On the patent issue, see also the discussion in Witt and Jackson (2016).

All told then, HI even in its “second wave” has particularly trained its sights on a wide range of issues associated with “varieties of capitalism” and different forms of the welfare state. The type of industrial relations, the nature of training, social security regimes, the existence of corporatist structures and whole question of whether in a post-2008 era distinctive patterns of state formation have converged on neo-liberal trends; even the nature of civic engagement (Mettler 2007; 2011; Skocpol 2003a; 2011): fundamentally what this literature displays is a primordial focus on the state as social protector. Even in this latter context HI has reframed those issues showing how beneficiaries of social policies in the US and Britain can push back on fiscal austerity (Pierson 1995 and 2001) or how the French state can redirect its traditional *dirigisme* towards means testing within more constrained economic circumstances (Levy 2007, 2015). But, with the exception of the contributions mentioned above around the macro movement of political economy (and the accompanying recognition that the traditional Fordism model of production of post-war economies has broken down), issues of economic growth, national innovation systems and how they sustain national development are largely overlooked, at least within the context of Western industrialized economies. Historical institutionalism has not tackled the institutional richness of innovation systems through a comparative historical lens.

Moreover, with respect to the issue of the “varieties of capitalism” literature or “comparative capitalisms” (CC) while it is not our intention to reflect on this in any sustained manner, a few brief considerations need to be made. To be sure, VOC contributions have pride of place in pushing back on convergence theories (of modernization or neo-liberalism) and recognizing the institutional differentiation that mediates the economy or as Crouch and Streeck so ably put it ““talk back”” (1997, 2) to economies. However, a few concerns should be registered. For one, while HI does harbour VOC elements within it, and while as noted below

Thelen (2014) has provided the most encompassing and theoretically rigorous approach in this domain, this literature is much broader ³⁷and the two should not be necessarily conflated. Further, the literature – however narrowly defined or broader it may be – is subject to certain critique around, as Jackson and Deeg (2006) put it, its many “typologies.” Certainly, it can oscillate between the bimodal characterization of Hall and Soskice (2001) to a multi-faceted set of models (Amable 2003) to the approach that every case is unique --³⁸making testing of the theoretical assumptions more problematic and especially creating challenges around cases that do not fit certain moulds. Indeed, empirical verification of the CME and LME approaches has certainly been questioned -- with counter evidence that the hypotheses on national performance are not sufficiently borne out (Allen and Aldred 2009; Etzerodt 2021; Zachary Taylor 2004; Witt and Jackson 2016; also the earlier Hall and Gingerich 2009 response).

Moreover, it can be argued that the VOC literature is primarily focused on a variety of institutional configurations – complex and nuanced and interactive³⁹ as they may be – that are situated as the independent variables. And that the latter – financial systems, corporate governance, industrial relations, collective bargaining; training, innovation -- essentially condition and influence the diversity in national economic performance. For our purposes what is less evident, however, is not the issue of innovation as explanator but rather the factors and conditions – state policy included -- that make for its unique embodiment and development in national settings.

³⁷ See the extensive discussion by Jackson and Deeg (2006) where CC becomes a catch-all for NIS literature à la Nelson, Porter and comparative advantage, Schmitter and neo-corporatism and indeed even the regulation theory of Boyer to name a few. While CC certainly is recognizable from debates in the eighties as issues around national economic performance (especially regarding German and Japanese success) emerged, as well as debates in this field rallied in the early and mid 2000s, such a broad inclusion may well be a bridge too far. It may well be too much to sweep the different configurations of capitalism as mediated by the nation-state into one encompassing VOC literature.

³⁸ See Jackson and Deeg (2006) – their Figure 3.

³⁹ See for example, Hall and Gingerich (2009) on the institutional complementarities that interact.

Finally, there are concerns that in this literature, there is an element of lingering stasis and that once historical trajectories are set, there are essentially “lock-in” effects around different models that make change harder to grasp (Bruff and Horn 2012; Crouch and Steeek 1997; Hay 2020; Jackson and Deeg 2006; Thelen 2014).⁴⁰ The argument is levelled that theoretically at least an equilibrium sets in; thus are changes refracted through the prism of the existing “variety” hardening even further the elements in the respective coordinated or liberal or other political economy. Thelen however has taken on this issue and in her work on *Varieties of Liberalization* (2014) has put forth a more nuanced and tightly reasoned argument very much in keeping with her position on HI and endogenous change. Arguing that liberalizing forces do have impacts she maintains that these can be “more counterintuitive” (*Ibid.*, 2) than traditionally seen.⁴¹ Examining the institutional domains of vocational education and training, labour markets and collective bargaining, she demonstrates how continued reliance on a coordinated form of market economy can lead to increasing inequity and how reliance on a liberal market economy can be accompanied by strengthened “social solidarity.”⁴² Innovation however is not a terrain of study. The lens is trained on the critical question of globalization and the nation-state and the social-political coalitions that forge response to liberalizing forces.

That said – and to return to the issue at hand – what can be called this oversight by HI around innovation to a certain extent is a result of HI’s emphasis on the “big questions”⁴³ of comparative history: namely, the origins and evolution of states, revolutions, democratization, civic engagement, post-war stability, the neo-liberalizing trends which followed that stability and

⁴⁰ See particularly Hall and Thelen (2009) on the relevant critiques at the time.

⁴¹ The exact phrase is “more counterintuitively.”

⁴² Interestingly, Streeck’s work more recently has evolved into quite a distinct position – arguing for convergence around liberalizing forces and more specifically the view that “there simply is no ‘primacy of politics’ under capitalism (2016, 231).

⁴³ There is a particularly insightful discussion in Skocpol (2003b, 409-411) on the new questions which comparative historical analysis raises, and indeed demands.

growth, and indeed new state-building projects such as the EU. HI was concerned with both recentring the debates around the inclusion of autonomy and the state and later with addressing the critiques that were levelled at it. Nevertheless, what HI brings to the table, especially as articulated in a more recent “wave” of thinking is an extensive, nuanced and even more empirically and theoretically grounded set of tools for understanding the import of policy and more broadly the institutions of the state. And if it comes equipped with big macro tools for that analysis it is incumbent on us to find the “meso-level” of analysis that will enable a detailed study of state policies around innovation, technological development and growth.⁴⁴

In short, in contrast to NIS what HI scholarship has done is to give primacy to the importance of public policy and the state’s institutional networks as its impacts society and society. Administrative and fiscal capacity, policy networks, resourcing, macro and micro economic strategies and expertise within the state itself: all are critical for understanding the full deployment of resources and activities the nation state may leverage. And to that end, this literature is particularly instructive in ensuring that any efforts at defining a national system of innovation are cognizant of the role of state structure and policy in impacting the economy – and in influencing (although not determining) conditions for success or indeed failure.

⁴⁴ Arguably, the contention that HI is focused on the big “macro” perspective must come with certain unequivocal caveats. To be sure, Pierson’s theoretical work (especially 2003, 2004), is focused on the “big, slow-moving” “macro-social processes,” but on the other hand his work on the welfare state (1994) is anything but, instead displaying very in-depth, detailed lines of argumentation on how the US and Britain engaged with austerity, the social coalitions formed and the reverberating impact on state policy. Moreover, the HI field, this author would suggest is certainly riven. Tilly too (1984), like Pierson’s theoretical approach, evidences this big macro focus.

In contrast, Skocpol, Weir, Orloff and arguably Hacker do not fall into that same category. Their focus is very historically grounded and Skocpol on several occasions has noted the importance of avoiding “grand theory” (1985, 28; also 1979) and not traversing the path of “functionalist holism” (1995, 103). As for Thelen, at the risk of synthesizing too tightly, she is more focused on the time and evolutionary components of institutions (2003, 2004, 2014) than the macro per se, although admittedly together with Mahoney she refers to Comparative Historical Analysis as including “macroconfigurational explanation” (Mahoney and Thelen 2015, 28). Those comments noted, however, there is a tendency in HI to the macro which can, if not employed wisely, occlude: hence the need here to wed to meso-level tools.

All said, then, we are ultimately left with a dilemma. The rich evolutionary economics literature trained on the institutions of innovation has been framed within a context that essentially undertheorized the state. The streams of historical institutionalism that could give access to state policy have seemingly remained aloof from the interplay between the innovation/growth dynamic and the policy imprints that potentially at least can shape it. Both HI and the NIS literature roundly reject the notion of atomized individuals and markets propelling growth, and history (Evans 1995; Nelson and Winter 1982) but interestingly the two literatures have remained distinctly apart – each inhabiting their own disciplinary silos.

Moving Forward: The Developmental Network State

DNS: Its Essentials

A promising means to address this issue – these two solitudes so to speak – can be found in key efforts that have centred around the concept of the Developmental Network State (DNS).⁴⁵ The framework specifically draws on the notion of a triadic innovation system but cast within a theoretically fulsome role for the state – and for government policy. Indeed, the argument is premised on the concept of a “developmental network state” that has accelerated critical innovative disruptive technologies, in semiconductors, in genomics and in nanotechnology to name a few. Thus, it can be leveraged as a means to mend the theoretical gap which is seen between HI and NIS.

Admittedly, DNS contributions to date are still rather sparse and the theory is more of a conceptual framework premised largely on the American post-war experience. Certainly, it has not drawn the attention of a very broad community of scholars as yet or established the rigour

⁴⁵ See in particular Block (2008, 2011, 2012); Block and Keller (2011a, 2011b); Fong (2001), Fuchs (2011); Hurt (2011); Keller (2011); Keller, Block and Negoita (2017); Mazzucato (2013, 2015a, 2015b [2013], 2018); Mazzucato and Penna (2015a, 2015b, 2016); Mazzucato and Semieniuk (2017); Vallas et al. (2011); Schrank (2011); Schrank and Whitford (2009); Whitford and Schrank (2011); Whitford (2005); Whitford and Zeitlin (2004).

that can create the basis for any Kuhnian paradigm. But two points are essential here regarding its utility. For one thing, DNS, to a significant extent, can be cast within the larger framework of historical institutionalism – and the criticality of state capacity and functions. Additionally, DNS and Block in particular, provide the conceptual meso-level tools to grasp the key dimensions of innovation policy that, at least within the American polity, proved to be remarkably successful.

The argument moves forward on several fronts. Drawing on a wide body of empirical evidence it maintains that what the American polity has witnessed over the last four decades is the evolution of a densely compacted and essentially “noded”⁴⁶ innovation system spanning a “triple helix” (Block and Keller 2011, 157-158)⁴⁷ of government, university and private entities. Characterized by “flexibility,” “experimentation” and essentially a decentralized “web” of collaborative relations these networks can concentrate resources, draw on local knowledge, accelerate technological development and respond rapidly to the intensifying pace of both product and process innovation cycles. Indeed, what has evolved is seen as decentralized production patterns which have not only grown alongside “competitive markets or vertically-integrated corporations” but have begun to displace the latter.⁴⁸

However, what is most critical to the DNS argument is that nested within this innovation system is a broad array of **activist state policies** which not only buttress the innovation system but enable government to “play ... an absolutely central role” (Block 2011, 3). Thus, despite the

⁴⁶ Although Block refers to “nodes,” “noded” is this author’s term in order to more ably capture the process of densification this entails. However what Block is referring to is the heavily networked nature of the DNS with ‘collaborative networks- --cooperative sharing of expertise,’ “decentralization,” “partnership,” at the heart of the innovation process and within that government officialdom, policies and funding playing a critical role (Block 2011, and especially 6-23). Note that the collaborative network component is more openly profiled in Block (2011) than (2008) – where here the principle is the same but the emphasis is on technological ‘brokering’ and of course the ‘facilitation’ role the state plays; see also Whitford and Shrank (2011) and (Whitford, 2005).

⁴⁷ Block and Keller (2011) here are referring to a body of literature around the “triple helix” concept. The latter has been developed particularly by Etzkowitz (1998, 2003) and Etzkowitz and Leydesdorff (2000); however Block also references the seminal works by Powell et al. (2005) and Saxenian (1994) and of course Piore and Sabel (1984).

⁴⁸ See Evans (2011, vi) who is actually quoting Whitford and Schrank.

“rhetoric” of “market fundamentalism” (*Ibid.*, 1-3) that has informed American public discourse particularly since the Reagan era, government agencies have significantly shaped and funded the direction and efforts of central technology leaps.

Certainly, the evidence presented for this is extensive but what the DNS framework is keenly aware of is the institutional layering -- the institutional “inflection points” -- that have defined government efforts over time, creating a regime that pursued technological goals and engineering feats and invested in scientific and technological “expertise.”⁴⁹ It is argued that state initiatives from the beginning of the Republic focused on infrastructure -- canals and rail -- and the applied science of agriculture. In turn, World War II saw a massive injection of funding into military and technological capacity, establishing in its aftermath a critical array of federal laboratories focusing on key technologies, namely atomic, nuclear, semiconductors, molecular biology, the laser as well as a growing stable of government officials dedicated to what they term as the “science state.” But what truly spurred the government initiatives that led to the big breakthroughs was the post-Sputnik era and in particular the creation of the Defence Advanced Research Projects Agency (DARPA) – an initiative by the Pentagon in 1958 to meet the needs of defence through a more rapid and targeted investment and procurement process. Essentially DARPA established a new decentralized model for S&T investments as well as for scientific exchange and collaboration, engendered competition among start-ups which could rapidly innovate, directed research with clear goals and phased funding that built on clear results and broke the dependence on the slow pace of large military procurement at the hands of large corporations. Moreover, this model was replicated in agencies associated with the national security and intelligence-gathering mandate and was in turn succeeded in the eighties by a

⁴⁹ See especially Block (2011, 4-15).

number of key legislative initiatives and programs that worked to replicate its principles.⁵⁰

Among these initiatives, particularly instrumental in seeding and funding breakthrough technologies has been the Small Business Innovation Research Program (SBIR) of 1982 (Block and Keller 2011).

It is important to not overstate the success of these ventures and most of this remained vested within technology sectors that had grown out of the national security mandates -- computer, biotechnology, even nanotech. However, the DNS contributors present a rich array of case study evidence that the government was engaging in activist efforts to evolve a flexible, rapid and results-oriented innovation system.⁵¹ To be sure, these contributions are fully seized with the American experience but it is important to distill the key elements that can be applied in the context of a Canadian case study. Towards that end -- and drawing widely on the DNS literature – *three key functions* by government can be discerned.

Of first import, there needs to be “*targeted resourcing*” by state policy-makers towards key technologies and nodes ripe for innovation, with clear “benchmarks established” around goals and funding that can propel these technologies forward. Directed to small business ventures, as much as multi-million dollar efforts targeting key sectoral areas of computers, semi-conductors, or pharmaceuticals (as has been the American case), the key here is funding built around specific initiatives that initially propel the development of technologies or help to

⁵⁰ For a full review of the numerous range of initiatives and programs, see especially Block (2008); also on these years the important contributions by Berman (2008) and most critically Mowery and Sampat (2005), Mowery and Simcoe (2005), Mowery (2010); on the SBIR see Block and Keller (2011) and Lerner (2009).

⁵¹ See Block (2008, 2011, 2012); Block and Keller (2011b); Fong (2001); Fuchs (2009, 2011); Hurt (2011); Kattel and Mazzucato (2018); Keller (2011); Keller, Block and Negoita (2017); Mazzucato (2013, 2015a, 2015b[2013], 2018); Mazzucato and Semieniuk (2017); Newfield (2011); Schrank (2011); Schrank and Whitford (2009); Vallas et al. (2011); Vallas and Kleinman (2008); Whitford (2005); Whitford and Schrank (2011); Whitford and Zeitlin (2004).

unblock “choke” points as these may arise. Further, it is twinned with an aggressive approach to pulling that funding if established benchmarks are not hit.

Block explains:

Targeted resourcing involves government officials identifying – often after considerable consultation – important technological challenges, the solution of which would open up important economic possibilities. Officials then provide funding and other resources to groups that have promising ideas for achieving breakthroughs....This kind of targeted resourcing requires that funders exert considerable discipline over the technologists. They have to set benchmarks and withdraw funding from those groups who fail to show adequate progress in meeting goals (Block 2008, 172).

DARPA clearly exemplified this model. Indeed, in his earlier work in 2008, Block almost exclusively used this model to conceptualize and frame the key elements he outlines in the Developmental Network State.⁵² But there are other key examples of civilian programs that follow the pattern of targeted and goal-oriented funding, twinned with a competitive process that regularly monitors success or failure of a project and releases funds accordingly. Critical among these has been the aforementioned Small Business Innovation Research (SBIR) initiative, launched through explicit legislation in 1982 and still part of the stable of “targeted” funding programs which American federal authorities have.⁵³ Aimed specifically at small high-tech start-ups and focused on releasing innovation potential, SBIR mandates key federal entities with substantive research budgets to put aside a percentage of their budgets for funding for small, “independent” firms. The program in fact has been highly successful, particularly for a relatively modest annual budget of \$2 billion and has funded hundreds of start-ups bringing technologies to market. It is telling that in a review of a 1975 to 2006 data set focussing on U.S. award-winning

⁵² Not that he did not use other civilian examples, SBIR among them, but the original thinking was around the military initiative and the insulation the national security mandate offered to experiment with programs in this fashion.

⁵³ See the discussion in Block and Keller (2011), especially 165-166 on the guidelines and the Program’s impacts.

innovations across a wide swath of industrial sectors, Block and Keller (2011b) found that approximately 25 per cent of domestic award winners each year were the recipients of SBIR funding. As to the larger point of “targeted resourcing,” as the authors conclude, the data show a “dramatic increase in the federal government’s centrality to the innovation economy” (Block and Keller, 167).

Secondly, what has been laid out in the model is the criticality of “*brokering*.” Whether “technological” or “business” essentially it was “the ...activity of connecting... different groups together so they c[ould] ... take advantage of each other’s knowledge” (Block, 2008, 173-174) or, in the case specifically of business, brokering alliances to bring products to market and achieve access to financing. Be it DARPA in the early days actually holding workshops with key players on semi-conductor design (Block 2008, 174-176; also 181-182) or the key role later played in meeting the limits of Moore’s Law with scientific inquiry into photonics (Fuchs 2011), national security agencies have continued to play a pro-active role in creating the business alliances and S&T hubs that could foster innovation. So too have synergies been created in the biotechnology sector, spawning breakthroughs in blockbuster drugs (Vallas et al. 2011) and, in the nineties, “explicit” networks constructed by federal authorities to give impetus to the National Nanotechnology Initiative (Motoyama et al. 2011; Mazzucato 2015b [2013]). The analytic value of the “brokering” function by federal authorities is clear: without it scientific discovery in the lab can languish and the crosscutting and multi-sectoral efforts needed along the innovation chain will not necessarily organically evolve.

Thirdly, is the attention paid to *capitalization needs along the innovation continuum*, and particularly the injection of venture capital funds required to move lab discoveries to market (Mazzucato 2013, 2015a, 2015b [2013], 2018; Kattel and Mazzucato 2018, Mazzucato and

Semieniuk 2017; Block 2008). Often described as the “valley of death” where scientific discoveries may languish in the innovation cycle, what is apparent in the American accounts of the “developmental network state” is how readily the government (federal, state and local) stepped in to ensure needed financing occurred. In the case of the CIA, the latter actually created its own venture capital fund – In-Q-Tel -- with this model then disseminating out across other federal agencies (Keller 2011, 123-136). So too in the case of biotechnology (Mazzucato 2015b[2013], 73-77) or nanotech (*Ibid.*, 27-28; also 90-92) has government policy been adept at ensuring that start-ups have the infusion of capital needed for success. At issue here is the capacity of the “entrepreneurial” state to provide risk-based capital that can propel innovation based on longer investment cycles and time horizons not structured by short term returns on capital -- and before the full value of Intellectual Property can be exploited.

Aside from these three concepts, however, also traversing this DNS literature is the “*mission oriented*”⁵⁴ and directed nature of the government’s priority setting. Again, the case of DARPA is illustrative, the Program over the years consistently intervening in the computer industry to get the technology products needed and to ensure bottlenecks in the pace of innovation would not emerge. Sponsoring the creation of computer science departments; playing a key role in ensuring a ready pool of both academic and entrepreneurial expertise; providing “early research support” to start-ups; targeted efforts to spur the design of a prototype chip when traditional corporate R&D languished (Block, 2011, especially 7; Mazzucato 2015b [2013], 80-

⁵⁴ It is in fact Mazzucato who uses this term, particularly in reference to DARPA, (2015b[2013], 80-85); also see Mazzucato (2013, especially 195-196, and 2015a). With reference to Mazzucato’s key contribution to the Fagerberg et al. (2013) contributions on *Innovation Studies*, it is telling that the concept of the “entrepreneurial state” and an activist role for public policy make its way into the research agenda-setting that Martin (2013) and Lundvall (2013) put forward in their articles.

90; Mowery and Simcoe 2005, 269-273); all were part of the arsenal used to move forward on priorities and enable innovation.

Moreover, what is remarkable about this “mission-oriented” research was the consistency with which national security agencies pursued these goals. Key leadership either within the Department of Defence or later within the CIA set definitive objectives and directions, specifying computer architecture, interrelationships between technologies and the design breakthroughs that were sought (Fuchs 2011; Keller 2011).⁵⁵ Thus was DARPA funding responsible for the conceptual design of ARPANET, the predecessor to the Internet, semiconductor research that consistently contributed to the doubling of computer performance (either through the number of transistors per silicon chip or more recently multicore microprocessors), multi-touching scrolling and design of the human-computer “interface” (Mazzucato 2015, 93-119; also on the ARPANET, Mowery and Simcoe, 2005). Indeed, what is evidenced, both through the DARPA case and other programmatic ventures, is a mission mandate which in fact cuts across several decades of experience – and wherein public entities doggedly propelled much needed advancements forward even as the limits of technology performance, design and production began to emerge. Nevertheless, as discussed below, this mission-oriented component constitutes a weaker link in the DNS theoretical chain, untethered as it is to an understanding of policy durability that can be made concrete outside the American context.

⁵⁵ See especially Fuchs (2011) on the highly specific technical direction given by DARPA’s Robert Kahn for a “strategic computing program,” laying out Kahn’s “pyramid” that would encompass not only more efficient chip design but also computer architecture, networking, and indeed “machine intelligence” (2011, 138-139).

Challenges with the Model

All told, then, the DNS framework does offer a fulsome conceptual framework for appropriating innovation systems – and capturing the essentials of governmental policy. The Developmental Network State focuses on mission, targets resources, ably brokers the networks needed for advancement and capitalizes or enables capitalization at critical junctures and gaps along the way. That said, however, one has to be careful in drawing immediate conclusions that these elements can be directly transported to Canadian or other comparative terrain. Clearly the success (and the contributors to this literature consistently make this clear) has been coloured by the national security blanket in which it often has been wrapped – insulating the state from the usual critiques that these programs and ventures were breaking with market “fundamentals.”

Indeed, despite the wide sweep of the analytic framework and its resonance for the American polity, there are certain limits to its heuristic value. It primarily has been trained on the American institutional and government (federal, state and local) experience and its value as a tool for the type of broad comparative exercise exemplified by Nelson (1993) and collaborators on national innovation systems appears more limited. Commenting on the results of their analysis, Nelson -- well before the work of Block et al. – concludes that the “civilian” potential of innovation systems when the impetus is “military R&D” is most closely associated with opening up “generic technologies” (Nelson, 1993b, 514). For the American case this statement rings particularly true given the focus that was taken on the computer industry, genomics and nanotechnology writ large and the fairly open field in which “technologist” collaborators had to experiment and innovate. Further, whether the Developmental Network State -- the network nodes so to speak -- so closely associated with American post-war industrial-military complex can be successfully implanted in other national contexts remains an open question.

Certainly on this latter point the evidence to date has been less than compelling. The comparative contributions to the Block and Keller volume and the DNS project appear to be still relatively narrow, focused as they are on Ireland, China (Ó Riain 2004, 2009, 2011; Applebaum et al 2011), and some early developments in Chile as well (Negoita and Block 2012).⁵⁶ Setting aside China where attempts to compare such widely differing economic and political frameworks run in the face of usual comparative theory, even the Irish example does not hold up. While there was clear movement in the nineties to put in place network innovation policies, specifically Science Foundation Ireland and Enterprise Ireland, and what are called “state agencies promoting an indigenous innovation capacity” (Ó Riain, 2011, 198) the exercise in the end appears to have foundered. Undone by centralization processes within the Irish state that were not open to the DNS model and instead focused on foreign direct investment and by the efforts to make these newly minted state agencies largely self-funding, the experiment has unravelled. In the end, “Irish innovation policy in the 2000s has seen very limited success in the face of admittedly difficult conditions” (*Ibid.*, 199). The point is telling because it speaks to how easily state policies set outside the American context can become undone. As for the Chilean case, the evidence is by no means in although early and substantive economic advances in the agricultural sector have been made and this contribution particularly focuses in on the role of government policy in sustaining organizational networks and preventing “failure.” Admittedly, however, this too raises the comparative challenges of employing a conceptual framework that can attest to such different stages of national economic development, an issue that has been warmly debated certainly since Wallerstein (1974).

⁵⁶ Ó Riain (2011) does make passing reference to the experiences of Taiwan and Israel but these are not explored.

Applying DNS Comparatively

While DNS proffers an opportunity to bridge the divide between NIS and HI, its application in a comparative context could benefit from some conceptual sharpening. Specifically, the notion of “brokering” is rather thinly developed, based largely on the brokering efforts and role of governmental agents. As such it needs to be enriched with the notion of state policy aimed at definitively thickening the networks of entrepreneurs, scientists and government researchers that shape and synergize innovation. To assess whether government policy in its formulation and implementation actually impacts innovation networks, one needs to evaluate whether there has been demonstrable change, either in funding or in collaboration on research projects, or in research and “cluster” communities hooked into national and even international nodes of excellence.

Towards that end, this thickening of triadic actors – business, government, academe – needs to be accessed through a variety of consistent indicators – namely, the density of partnership and collaboration within key networks, particularly with respect to collaboration in patents, co-authored scientific publications and joint business, university and government projects and funding. Secondly, this analysis needs to be wedded to any patterns of sectoral predominance which may emerge, especially as they may coalesce around both mature, stable networks and that of emerging networks and “newcomers”⁵⁷ And thirdly, government funding of innovation networks and cluster activity and their propensity to stimulate innovation needs to be tracked and assessed – *over time*. As Rosenberg suggests in commenting on the nature and timing of innovation “in the twentieth century a gap of several years” characterizes this transition from science and “discovery” to full-scale commercialization (1994, 146).

⁵⁷ On the import of the mature and emerging divide for innovation, see Powell and Grodal (2005).

Thus, while certainly important, it is not enough to claim simply for the brokering role of officialdom or the importance of a “public space” for innovation as does Block (2011, 17).

Rather, the definition of this facilitating role on the part of state policy needs to be specifically articulated and broadened to include the policy efforts that can enhance triadic linkages – and the results that may be manifest, particularly in the implementation stages of the policy.

More critically, however, the framework is lacking in how it theoretically grasps the concept of policy continuity and “durability.”⁵⁸ Part of the problem is that the DNS effort has remained predominantly cast within the American context, with the exceptions, as noted above, to date largely being Ireland (Ó Riain 2004, 2016) and China (Appelbaum et al. 2011). Durability of policy and policy continuity, as the DNS argument goes, has essentially not been challenged within the American post-World War II period. Despite the market “rhetoric” around limited government, Block and colleagues contend that the cloak of national security has enabled the aggrandizement of R&D budgets and has even mitigated against substantive Congressional review. Moreover, a plethora of targeted programs from the focus of the Defence Advanced Research Agency (DARPA) on the development of computers and semi-conductors (especially Block 2008, but also Bonvillian 2018; Foray, Mowery and Nelson 2012; Fong 2001; Fuchs 2009, 2011; Mazzucato 2015b; Van Atta et al. 2003) to the funding of R&D excellence through the Small Business Innovation Research program (Block 2011; Block and Keller 2011), to the uniqueness of the CIA’s venture capital fund (Keller 2011) have underscored a “mission-driven” agenda that has had remarkable continuity.

In other comparative contexts, and especially in the Canadian case, however, that continuity can not be assumed as a premise within the framework. Rather, it an open question to

⁵⁸ See this concept in Patashnik (2003); also Lockwood (2013).

be empirically evaluated whether national R&D and innovation priorities have been characterized by policy breaks or ruptures that have created challenges for national innovation systems. Consequently, a more robust conceptualization would be to see the policy process as one where institutional footholds -- especially as expressed through administrative agency -- and policy continuity are specifically examined particularly at the implementation stage.

In this regard, work by Skocpol and Finegold (1982) on the administrative capacity of the state – in particular bureaucratic agencies – to not only formulate policy reform but to *sustain* its implementation is particularly instructive. Crucial to the implementation process are administrative “means” (*Ibid.*, 275) – resources but also institutional machinery and mandate. Also requisite is an “holistic” (*Ibid.*, 274) approach where momentum on reform and new priorities can be sustained. For Skocpol and Finegold the US Department of Agriculture during the New Deal featured all these components and lent themselves to both institutional resilience and programmatic “coherence”⁵⁹ in the face of juridical rulings and administrative squabbles, ultimately ensuring the success of the Agricultural Adjustment Act (AAA). Moreover, it stood in contrast to the case of the National Industrial Recovery Act where sharp divisions among its business clientele and political actors were channelled into and refracted through a weak administrative agency, undercutting the exercise in the end. And, in the case of experimentation with concerted industrial planning, this was not to be undertaken on this scale again.

Certainly, as with early variants of HI more generally, this argument around the autonomy requisite for state capacity is somewhat overdetermined. But there is a more nuanced and ultimately compelling aspect to this line of inquiry. That agencies tasked with sweeping reform must have a significant degree of institutionalization and coherence if policy reform and

⁵⁹ The exact reference is to a “programmatically coherent course” (Skocpol and Finegold 1982, 275).

durability are to have success. To leverage Pierson (2003, 2004) in another context, institution building must be present over the “longue durée.”

Similarly do Weir’s insightful contributions on employment policy and the “boundaries” to “innovation” reflect the weight which institutionalization may have in directing, and redirecting, policy reform. Specifically looking at the institutional fragmentation that followed the initial intent of Roosevelt’s New Deal and its attachment to “social Keynesianism” she meticulously traces the manner in which pathways for policy choice were reinvented, creating a schism between economic and “poverty” policy and ultimately undermining the impetus for reform. Her work is particularly telling on how institutional “roots” can, and do, bound policy decision-making, innovation and reform.

What is more, there is an ancillary dimension to the policy question which we would do well to consider – the flip side associated with failure. In Pierson’s (2004) elegant treatise on “intertemporal” dimensions of policy, of “politics in time,” he lists the cases where the assumed functionality of institutional design falls radically short. Short time horizons, breaks in the continuity of policy actors, “multiple” agencies creating “multiple” and often unintended “effects,” even the discontinuous patterns associated with organizational learning – indeed in general the opaqueness and complexity of policy in the face of efforts at instrumental design and ostensibly rational decision-making are highlighted. Pierson’s point is important. Institutional evolution is more complex and convoluted than can be discerned through rational instrumental lenses and to assume a policy agenda can be carried out on the wings of a “designed” institutional agency is an assumption more than the subject of empirical scrutiny. The advantage Pierson’s perspective offers is to take a closer look at questions of policy durability, assembling the relevant indicators which can be the wellspring of success.

It is worth noting in passing that it is not only the HI lens which proffers a vantage point on the depth of institutional anchor in enabling priorities and reform. Patashnik, seized with the same question of sustainability of policy reform, also argues for the importance of institutional “embeddedness” (2003, 211) as a primary factor in nourishing the durability and continuity of reform measures. It might even be argued that Lowi’s (2019 [1979]) seminal work – albeit seen through the lens of state capture – is focused on the way in which institutions, and the interests located within them, have a strong gravitational pull.

To conclude, the inquiry into policy durability needs to come armed with a few key dimensions for measuring the propensity for success. Specifically at issue is of course the administrative capacity and means together with the attendant expertise, mandate and policy coherence. But also there must be sharp cognition of the factors that disassemble or short-circuit or just challenge that continuity, be they the effects of multiple organizational agencies or rupture in the participation of certain organizational agents or even the immediacy of compressed timelines. Certainly, what should be distilled is that two aspects of the durability question need to be evaluated. Firstly -- and in fact broadly aligning with the fundamentals of the DNS argument -- there is the issue of *policy coherence* and how this is articulated within policy priorities: specifically, both how those priorities are formulated and how the potential for agenda-setting plays out *over time*. Secondly, the *administrative capacity* of the state and the means, expertise and resources it has for delivering on such priorities needs to be probed in some depth. Priorities without the attendant levers for state policy are vessels unanchored and more or less floating through periods of attempted reform. Such insights – gleaned from within the HI ambit – provide the Developmental Network State framework with richer and more honed

instruments to access and assess the “mission” – innovation relationship and the dynamics contained therein.

Mending the Gap

What then? To a certain extent the isolated spheres of HI and NIS are also a result of two very different disciplines, HI squarely within the political or at times sociological domains and the work on NIS occurring largely within economics or management literature. What is concerning about this isolation however is at a broad level the similarities these respective theoretical approaches espouse. Both articulate the weight (but not always the causal force) of institutions and the distinctive patterns of resilience that are maintained through history, through “time” and “space”. Both reject the atomistic and neo-classical model of the rational, self-actualizing and unbounded individual, optimizing economic and political outcomes and benefits. Evans’ work on “embedded autonomy” (1995) and Nelson and Winters’ work on evolutionary economics (1982) and nature of endogenous growth resonate with similarities.

Both streams of literature similarly wrestle with the tensions between globalization and convergence trends and the uniqueness of national sovereignty. Nelson, as has been seen, always questions the “shadiness” of these endeavours to define national innovation systems and of course substantial work in the HI field examines the tensions between national and more regional or global endeavours. Indeed, as a case in point, Berman’s (2016) insightful comments on the widening deficit and tensions between national and what she terms regional in the EU context are very prescient given the Brexit results that have since evolved. Further, essentials in this thesis have sought broader resonance in her more recent sweep of European history since the seventeenth century (Berman 2019). Undulating state forms and specifically democracies shape and are shaped by their institutional bearings, including the national – supranational divide. So

too on a broader conceptual level does Skocpol recognize the state as “Janus-faced,” poised between internal “class-divided social structures” and an “international systems of states,” and, as it seeks to build capacity, reckoning with each in turn (Skocpol 1979, 32-33). Moreover, this comparison between HI and NIS can be extended well beyond the issue of institutions per se. In the work of Hacker, there can be detected currents of convergence with the work of Block or Mazzucato around the tendencies to privatization of certain benefits and collectivization of risk – be it in terms of social policies or nature of technology gains. It is not ungainly then to leverage the strengths both may bring to the Canadian issue of innovation, innovation policy and the role of government within that.

In reviewing the similarities that can be found both in the HI and NIS literature, what is important about this insight is that it brings us back to the importance of a discourse that weds national innovation systems with institutional analysis, and the value of retraining theoretical efforts on the state. If the NIS literature can be faulted for undertheorizing the state – or at least viewing the state and public policy through a lens that understates its importance or, as in the American case, relegates it to a two-decade old anomaly -- HI clearly addresses that gap. It rightfully “brings the state back in” and requires us to analyse how the specifics of state policy shape and propel growth. And if it is largely focused on big macro and “slow moving” processes and variants of capitalism and the welfare state that does not dissuade us from drilling into a meso-level of analysis – precisely where the literature around the Developmental Network State is key.

The work being done around the DNS clearly draws on strengths of a NIS paradigm and situates growth within that critical context – and it includes the impacts that public policy has had on incenting technological development, freeing up IP for commercialization, creating

“collaborative public spaces”⁶⁰ for innovation and driving development forward from the invention stage to commercialization. But it does so with renewed emphasis around the state and particularly around the mission-driven, targeted efforts that American public policy has been taking since 1958. That it requires some theoretical refinement for transport to other comparative contexts – particularly around the assumption of continuity – should not dissuade against experimentation in other national settings.

This then brings us full circle to the elements that can be pulled from DNS literature – albeit with specific modifications and refinements -- and which are critical to studying the Canadian case. Specifically, it lays the theoretical basis for four distinct lines of inquiry around federal innovation policy since 2000: namely, the question of priority-setting and policy durability; the extent to which there has been evidence of “targeted resourcing” around priorities; the capacity of policy initiatives to thicken the linkages across industry, government and academe; and incentives for risk-based and particularly late-stage capitalization that can incubate ideas and enable the final stretch to commercialization.

To be sure, this theoretical undertaking is confined. It has been specifically targeted as a first test case of the DNS framework in a Canadian setting – one unequivocally separate from the national security concerns that have enveloped the American case. Moreover, it has been intended to strengthen the DNS framework in terms of its comparative reach. Most critically, however, it is hoped that this work can move in a small way towards mending the gap between NIS literature and HI, positioning inquiry that can reveal the role of the state and its policy imprints, albeit without sacrificing the intersection with the national innovation ecosystem and within that as well the “firm.”

⁶⁰ Block (2011, 22) who is actually quoting Lester and Piore (2004).

Canadian Scholarship: The Innovation Lens

In adopting this theoretical framework it is necessary to pause for a moment and reflect on Canadian public policy and political economy scholarship as it relates to innovation, and why frameworks advanced within this literature have not been specifically leveraged for this case study. This section directly addresses that issue, breaking down into two components. The first examines seminal contributions to the “meso” perspective of sub-national and regional innovation systems and the second deals with a large body of policy literature that essentially inhabits the institutionalist domain, examining Canadian developments in science, technology and innovation policy from that vantage point. Concluding remarks are then offered concerning the salience of the DNS framework for this study.

The “Meso” Perspective and Sub-National Systems of Innovation

Devolved Governance

With respect to the “meso” perspective, the seminal works that stand out in Canadian literature over the years are those of Paquet, Niosi and Wolfe⁶¹ and, of course, their collaborators. Paquet – clearly the most iconoclastic of the three – takes centre aim at the very construct of a national innovation system⁶² and the “techno-nationalism” of Nelson and associates in their comparative work on the dynamics of innovation, the role of the firm and its embeddedness within national institutions and history. And, with Paquet, including his work

⁶¹ See Paquet (1998, 1999); de la Mothe and Paquet (1998, 2000); Hubbard and Paquet (2010, 2013); Paquet and Roy (1995); Niosi (1998, 2003, 2010, 2018a, 2018b); Niosi with Bas and Zhegu (2014); Niosi with Manseau and Godin (2000); Wolfe (1998, 2002a; 2002b, 2009); Wolfe and Gertler (2016a, 2016b); Wolfe and Lucas 2005; Wolfe and Nelles 2008; Bradford and Wolfe (2017); Bramwell, Nelles and Wolfe (2008); Denney, Southin and Wolfe (2021). The usage of “meso” with respect to innovation systems is taken from Paquet (1998).

⁶² On this dimension, see in particular de la Mothe and Paquet (1998, 107): “Indeed, from a comparative point of view or from a real economy point of view, ‘the nation state’ perspective would appear to be too macroscopic and to illuminate rather badly the interface between the evolving techno-economic change system and the innovation system.”

with de la Mothe and Roy, three central tenets can be discerned. Of most import, with the new knowledge-based economy, there has been a “deterritorialization” (Paquet 1998, especially 58-62) of “wealth creation” as economies have moved away from tangible inputs such as natural resources and knowledge and information flows have predominated. To put it in even broader terms, (although they do not say as much) for Paquet and contributors, the relevance of the Weberian state at the intersection of territory and coercion, has receded from view. Caught in the twin pincers of “globalization” and “localization” (Paquet 1998, 60 and 68; also 1999; also de la Mothe and Paquet 1994 and 1998), the “nation-state” (Paquet 1998, especially 61) and its accompanying weight, geographic delineation and authority, have been submerged both by sub-national and supranational loci of authority but particularly by the regional or “region-state” (*Ibid.*). Critical for its regional economic development policies (particularly apparent in the Canadian case) and for its nurturing of -- and embeddedness within -- dense regional innovation systems, this new entity demands both conceptual, empirical, and more importantly organization “design”⁶³ attention.

Secondly, these developments have not only been confined to the eroding governance of the nation-state but have dispersed the traditional loci of economic activity in the market as well. To be sure, there has been delegation and “devolution” of authority to subnational units of authority at the regional and local levels, shattering the relevance of the nation-state premised on paradigms of “centralization” and control. But these changes can also be discerned in the “fragmentation” of economic activity where the hierarchy of markets has receded in the face of new and dynamic networks of activity.⁶⁴

⁶³ On this, see especially Paquet (2010).

⁶⁴ On these dual tendencies, see especially Paquet (1998); de la Mothe and Paquet (1998 and 2000, 5-34).

Thirdly, and somewhat akin to Rhodes (1996), governance itself has evolved, taking more “bottom-up” (Paquet and Roy 1995), communal and associative forms and revealing both the “dissonance” and dynamism that propel innovation. Defined by “communities of practice” (Paquet 1998, 64-68) innovation, creativity and especially “trust,” these networks thread through new governance forms and propel economic, social and political activity forward.⁶⁵ Thus are the lines between public and private blurred in their wake sculpting new cross-over networks that make adherence to traditional national and federal policies less effective and meaningful, and indeed in a sense anachronistic. Theoretically, this “meso” framework does not reside within the perceived confines of complementarity of states and systems or layering of national, regional and local. Rather it is fiercely and conceptually independent. It posits that traditional governance and associated innovation, particularly so for the Canadian experience, need shed its dysfunctional “pathologies” and embrace “learning,” the interaction of “play” and “experimentation” (Hubbard and Paquet 2010, especially 382 - 416). Innovation herein is specifically located within the “meso” lens and the new world of knowledge flows that is engendered.

The Regional Innovation System

In contrast to the Paquet contributions, Niosi and Wolfe (and collaborators), while clearly discerning fundamental change, are not so conceptually ruthless in their reflections on national public policy or the national innovation system. For them, it is more a matter of “layers” – a kind of stratification that builds to innovative activity. True national, regional, sectoral and local

⁶⁵ See for example how this is played out in the duelling tendencies at times of federal government thinking and its “many-coloured books” (*Ibid.*) of policies and budgets clinging to traditional economic and Keynesian endeavours whilst reckoning with the decentralist and regional economic efforts to be constructed.

systems can operate at cross-purposes. But they also can contribute to mutual efforts, national and meso policies and institutions incubating innovation and girding the networks that take hold.

To take each in turn, Niosi's work is, for the most part, trained on the "regional innovation system" (RIS) and the "hubs" of activity, once propelled by initial "endowments" and at times a certain degree of "chance" that coalesce within specific geographic boundaries. These boundaries, however, are not to be assumed at the outset. They may include various forms of the subnational (including "provinces, states, *lander*, municipalities" (Niosi 2018a, 10)) but this is an exercise that demands specific inquiry and examination. Moreover, here, the RIS does not supplant the National Innovation System. Rather it shares many of its features, also turning on the interplay of public and private actors – firms, universities, government laboratories – and the information dissemination and capital movements that sustain it.⁶⁶ And, most importantly (and in contrast with Paquet), it is viewed not in opposition to national systems but as "complementary to it" (Niosi 2018a 10). Further, as with the NIS, here too the firm is predominant (Niosi, with Bas and Zhegu 2014, 147).

The concern for Niosi and associates instead centres around the conceptually cluttered landscape that has developed around the RIS. On the one hand, it is characterized by large generalizations borne of specific industrial times and circumstances, be they Britain's industrial districts or Italy's competitive manufacturing regions (and we might add the focus on flexible specialization) or the Silicon Valley models that have evolved around advanced forms of technology. On the other, the RIS literature is not only particularly devoid of conceptual clarity

⁶⁶ See his definition of the regional innovation system as: Regional systems of innovation are sets of institutions (innovating firms, research universities, research funding agencies, venture capital firms, and government laboratories and other appropriate public bodies) and the flows of knowledge, personnel, research monies, regulation, and embodied technology that occur within a region (metropolitan area, subnational unit, or other) Niosi with Bas and Zhegu (2014, 16).

but also the rigour of sufficient “empirical” investigation. And as such it needs to turn towards more pronounced investigative efforts, specifically taking account of the geographic demarcations, tracing the linkages among institutional actors and how they stabilize and evolve and identifying the knowledge gaps of public policies which may distort intentions.

Thus does the RIS employed by Niosi, with Bas and Zhegu set out to address such issues, not only providing the conceptual sharpness and methodological approaches to be employed but also examining a wide range of Canadian regional innovation systems around biotechnology, ICT industries and the more traditional manufacturing domain of aerospace (Niosi with Bas and Zhegu 2014; also Niosi 2003, Niosi and Bas 2001). And what they find are the nuanced contours of Regional Innovation Systems. Biotechnology systems, clustering around Montreal and Toronto, have especially been incubated by publicly funded research universities and the plethora of company spin-offs that have been engendered as well as dense pools of medical research talent. Further, as these networks grew, they functioned as a magnet for venture capital seeking growth opportunities.⁶⁷ Aerospace has been demarcated by large physical plant and multinational anchor firms, heavily financed by public monies, that have in turn created regions of suppliers and clients. Software firms (with lower sunken costs at start-up) have on the other hand been particularly footloose and mobile, although they too have centred around a base of large R&D firms. Finally, the RIS has also been transported to the comparative plane,

⁶⁷ The Niosi 2003 article puts somewhat more emphasis on the role of large corporate partners, and particularly those intended for manufacturing rollout, in the later stages of growth for biotech firms. However, this contribution as well notes the role played by “universities and government laboratories” – almost as a necessary condition – for biotech firms getting started. “Interaction with research universities and government laboratories is almost always present in biotechnology start-ups.” (Niosi 2003, 749). Venture capital as an essential element is profiled both in Niosi, with Bas and Zhegu (2014) and in Niosi (2003).

particularly so in examining the models associated with developing countries and “new regional growth paths” (Grillitsch and Trippl 2018).⁶⁸

These are rich and detailed contributions that advance the RIS scholarship and, arguably, paradigm. However, two concerns need be registered. The “firm” within these dynamic systems still maintains a “commanding” presence (Niosi, with Bas and Zhegu 2014, 147) and thus is open to a similar critique that was earlier presented with respect to NIS contributions. True, the role of public policy bears more weight here – and is defined by learning capacity – and incubation can ride on the funding of research universities, but the RIS still centres on the Schumpeterian concept of innovation that finds its wellspring within the entrepreneurship of the firm. More importantly, however, for the purposes here – trained as they are on the belaboured efforts of national innovation policies that over the “longue durée” have been consistently challenged by the innovation gap – the subnational is not a sufficient starting point. The latter grasps the interplay of regional, institutional and both national and subnational policies -- and the “inertia” of these Regional Innovation Systems that can make national efforts skew to already existing metropolitan poles⁶⁹ – but what the DNS framework offers in its stead is a framework for tackling national policy head-on. This is not to suggest that the regional should not be employed, particularly in the future for undertaking an in-depth dive into domains such as AI and vaccine manufacturing and how this interacts with the DNS framework; but that is not the problématique at issue here.

Finally, it should be noted that Niosi, with Manseau and Godin in an earlier contribution did directly address the Canadian National Innovation System and the industries, universities and

⁶⁸ See in particular Niosi (2010) and (2018) where the latter volume has attracted many critical scholars in this field, including Malerba, Martin, Klepper, Fagerberg and Mazzucato (on the entrepreneurial state).

⁶⁹ On the inertia aspect, see in particular Niosi, with Bas and Zhegu (2014), especially 151-152 and on the policy impacts *Ibid.*, 153-158.

government labs of which it was composed (Niosi, with Manseau and Godin 2000). And it did lay out the historical efforts that the post-war period initially saw as the federal government invested in the NIS and in the publicly-funded labs to support it. But this work was not primarily engaged in federal policies as they have evolved, in fact concluding that by the 1990s “Ottawa’s efforts receded somewhat, and the NSI operated alone, like a plane flying on automatic pilot after an energy-intensive take-off” (*Ibid.*, 194). Certainly, this work was path-breaking at the time but it too stands within the larger ambit of the NIS framework. As for R&D and innovation developments that have undercut the promise detected in Niosi’s earlier work, it is precisely that issue on which this dissertation is trained.

Clusters and Innovation

With respect to Wolfe and contributors,⁷⁰ the innovation analysis is also geared to the “meso” domain, although here it is located even farther down at the more local “cluster” level. To be sure, one must use the word “local” in this context guardedly as this scholarship speaks directly to the “embeddedness” of local firms in global chains of knowledge production and dissemination. Nevertheless, as Wolfe explains:

Clusters operate within the distinctive features of the national and regional innovation system, and the process of cluster development is embedded within a complex set of economic, social, and institutional relationships at both the regional and national levels (Wolfe 2002a, 151).

Moreover, here too, the analytic framework employed takes sustenance from the evolutionary economics of Nelson and Winter and, before them, Schumpeter (Bradford and Wolfe 2017, especially 724) and particularly the “variable” manner by which developmental growth paths unfurl. This is not a predetermined trajectory dependent on local production and market “inputs”

⁷⁰ Seminal works include Bradford and Wolfe (2013, 2017); Bramwell, Nelles and Wolfe (2008); Denney, Southin, and Wolfe (2021); Gertler and Vinodrai (2009); Wolfe (1998, 2002a, 2002b, 2009); Wolfe and Gertler (2016a, 2016b); Wolfe and Lucas (2005); Wolfe and Nelles (2008).

and characterized by clustered territoriality – i.e., “proximity” -- that is associated with the works of Marshall (1890) and Porter (1990). Wolfe indicates that there can be no overriding conceptual framework that captures the dynamic and evolving nature of innovation clusters: “it is not possible to formulate a comprehensive theory of clusters ...” (Wolfe 2009, 181).⁷¹ Rather they are marked by unique constellations -- entrepreneurial actors, “external” institutions that nourish network robustness, disruptive new technologies -- and “interdependencies” that drive change (Bradford and Wolfe 2017; Bramwell, Nelles and Wolfe 2008; Denney, Southin and Wolfe 2021; Wolfe 2009).

Indeed, Wolfe and the scholarship associated with this school quite distinctly break with existing theories around cluster innovation, be it the geographic insularity of dependence on comparative advantage and factors of production (Marshall and Porter) or even evolutionary approaches that sequence the innovation process in a staged and linear fashion.⁷² More specifically, this school of thought subjects their theoretical reflections to empirical scrutiny, analysing 26 case studies of Canadian industries and clusters over a five year period (Wolfe, 2009 also Bramwell, Nelles and Wolfe 2008). Encompassing a wide variety of sectors including manufacturing, ICT and service industries -- everything from wine to wireless – and situated in a wide variety of regions within the country, the studies essentially point to four findings.

Firstly, although the firm and inter-firm linkages are critical, they are not so in traditional ways. As the Waterloo case study particularly demonstrates, knowledge accumulation and absorption and the robustness of the innovation cluster can spring from business linkages to an international “pipeline” (Bramwell, Nelles and Wolfe 2008). Firms are

⁷¹ Wolfe actually is referencing this insight to Asheim et al. (*Ibid.*, 181).

⁷² On Marshall and Porter, see Wolfe (2008 103-104); also Wolfe (2009, 180); on the life cycle approach as developed by Maskell and Malmberg and Klepper, see Denney, Southin and Wolfe (2021, 197-198).

not tied to one another as much to as to external clients and customers, with global integration into markets and chains of production. Secondly, it is particularly dependent on a rich and dense talent pool, fuelled largely by local academic institutions but also, to a certain extent, by an attraction to an entrepreneurial climate and “cachet” that has bred success. Thirdly, the role of associated “institutions” within the cluster is essential for both maintaining and enriching the cluster network. Nearby universities – creating talent, R&D alliances and tech transfer; contractor services providing R&D; specialized labs and to a lesser extent government laboratories; venture capital: all nourish the network with the necessary elements both for invention and for market. So too do widespread community and business associations enhance knowledge flows and cooperation, sustaining clusters that thrive on information “sharing” and “common purpose” (Wolfe 2009).

Finally, the “glue” that holds these networks together centres on a type of “civic capital” (*Ibid.*, especially 183-184; Wolfe and Nelles 2008) that is built up through firm leadership but also through the associated academic and community associations and the ongoing “learning” this encompasses. Indeed, in more recent work, the role of “entrepreneurial agent” is deemed critical is taking the ICT cluster in Toronto from one dependent on foreign multinationals to an ecosystem thriving with SMEs and companies which have scaled (Denney, Southin and Wolfe 2021). And while the transformation is by no means complete and there is no predetermined outcome, it portrays the manner in which clusters can evolve, girded by a broader “civic” and definitively entrepreneurial culture.

Despite the theoretical and empirical rigour which this school of thought displays there are however two concerns – at least for this research undertaking on Canadian federal policy. As with National Innovation Systems literature more generally, the firm (or rather in this case the

firms) still stand as the “main actors” (Wolfe 2002a, 148). To be sure, their functioning within these “embedded” clusters is a nuanced conceptual take on the issue, but government policies in their own right while important are seen more in an adjunct type of role and arguably in this perspective less critical. This is particularly so for those at the national level. It is not just that the public/private here melds into a larger “civic” undertaking and public policies are viewed through the prism of absorptive capacity of the cluster and the implications for network “co-production.” And it is not that Wolfe and collaborators – particularly so with Bradford – do not acknowledge the impact local economic development strategies may have or the important changes that have occurred in Regional Development Agencies now more attuned to local needs. It is that public policy is primarily located around the complementary (or indeed distorting)⁷³ role it may play for economic growth. There is an understated but still neo-classical impulse here. And there is reference to the import of the market and relegation of state efforts to picking up the slack (in Mazzucato’s terms the “risk”) when market mechanisms fail. Speaking particularly of the role of the Regional Development Agencies, Bradford and Wolfe conclude:

As such, the optimal federal role involves a deft kind of steering that invests in projects that would otherwise be postponed or abandoned if left solely to the market ... (Bradford and Wolfe 2013, 344).

As such, within this context, there is less theoretical space for positing the nature and impacts of national policy or (akin to historical institutionalists) connecting to the weight and institutional role of the state.

⁷³ On the challenges wrought by city government when its administrative structure does not align with cluster growth see in particular Wolfe and Bramwell on the Toronto case (2016).

The “Meso” Analysis: Contributions and Challenges

The contributions on subnational levels of innovation – the “communities of practice” or regional innovation systems or clusters of networks – that characterize this literature must be recognized for the extraordinary depth and empirical precision they bring to the innovation question. Of equal import is the deconstruction of governance – be it devolution or tiered or “dispersal” of authority -- that accompanies these analyses. Moreover, these contributions are situated squarely within the comparative literature on innovation systems, assessing the problematic gaps and conceptually tightening looser forms of theorization and ill-constructed generalizations. Indeed, in challenging the meso paradigm, they extend and empirically inform its conceptual reach.

That said, however, this “bottom-up” approach is a less compelling or even possible path for considering the broader consequences of policy, specifically as it plays out on the national stage. Paquet eschews such perspective. Niosi and Wolfe and those who operate within their orbit do not reject such considerations outright as much as they move to other terrain. For this school (or perhaps more accurately schools of thought) the intersection of the state and its policies with national innovation systems are simply not a worthy (*à la Paquet*) or sufficiently adequate (Niosi) or fully “grounded” (Wolfe) starting point. Indeed, for the purposes of this Canadian case study, the meso lens is still truncated for dealing with national policy. In this literature, the real dynamics and understanding of innovation must begin with the sub-national and meso-levels of analysis, including interpellation of even federal policy outcomes. Given the substantive dedication of resources and ongoing strategic efforts by the federal government to catapult Canada to the top rungs of international players in this field, however, there is need to come to grips with federal policy in the innovation domain. How national policy is shaped and

contoured, its principal pillars of operation and where it has succeeded -- and failed: these are critical questions which need to be addressed.

Innovation and “Policy Domains”: The National Experience

If the “meso” perspective does not turn on the national, the body of work associated with Doern and colleagues clearly does put the national domain front and centre stage. These contributions can be loosely seen as fitting within a largely institutionalist reading, focused as they are on “policy domains” and the institutions in which they are grounded. However, while the “meso” school focuses on the precise conditions under which innovation may succeed or fail and squarely addresses the extant theoretical literature and its accompanying assumptions – rigorous or ill-conceived – this Canadian institutional rendering provides a different focus. It is not just that its lens is largely national but that it provides a broad historical sweep of science, technology and innovation policy as it has evolved in a post-war context and inevitably led to competing trade-offs around public goods and market imperatives. Certainly, it provides a rich historical foundation on which to begin this research undertaking. But on the specific question of innovation -- and which conditions around mission, targeting of resourcing, thickening of networks and risk capital engender or imperil successful outcomes – the evidence here is not primordially attuned to this dynamic. As such, the quest to understand the policy pillars of innovation, particularly *over time* – and to do so with reliance on a framework positing at least a comparative perspective -- still provides much untilled terrain on which to begin this research inquiry.

That said, and admittedly referencing here only seminal works -- the Doern school broadly breaks down into three basic streams of analysis. To be sure, there are provocative snapshots of federal budgetary efforts and innovation agendas that appear over time in *How*

Ottawa Spends and which are primarily focused on the challenges associated with such endeavours (Castle and Phillips 2011; Phillips and Castle, 2010, 2012; Phillips et al, 2017; Phillips and Hertel 2018). But there are also the more historically grounded efforts that essentially anchor this school, examining in turn science, technology and innovation (STI) (Doern, Castle and Phillips 2016) and intellectual property (IP) (Doern and Sharaput 2000) policies as they have played out and continued to evolve over the years, as well as the social and economic forces helping to shape this evolution. Indeed, in the case of STI, the historical terrain covered occupies the last fifty years. And, thirdly, there is a current of analysis that, while certainly historical in its reach, more singularly focuses on science. Particularly articulated in the important and in-depth work on the role of federal public labs and “science-based agencies,” including the NRC, it reveals the cross-pressures and transformational agendas to which these federal labs have been subjected (Doern and Levesque 2002; Doern and Kinder 2007).

How Ottawa Spends and Budgets

With respect to the contributions around specific government Budgets found in *How Ottawa Spends* over the years as these relate to Science, Technology and Innovation, two features particularly stand out. These articles are of necessity – given the annual nature of the journal – sequential snapshots that drill down on particular dimensions but are, to a large extent less engaged in a wider historical reading. Secondly – and consequential to this – the different Budget analyses pursued are springboards for different factors in understanding causation behind the stunted nature of innovation in Canada.

Unquestionably the articles profile the declining Gross Expenditures on Research and Development (GERD) which the country has experienced, as do they note the challenges around business level investment. They also reiterate the issues around sufficient technology transfer

and the associated “socio-economic benefits.”⁷⁴ However, the factors responsible take many forms. It is variously assigned to functions of economic “scale” (Phillips and Castle 2010, 183-184) and the urban multipliers that can propel innovation or it is premised on “industrial structure” (Castle and Phillips 2016, 158 -159 and 162-163) that includes both multinationals and reliance on natural resources. So too is the issue of governance invoked – be it the appropriate administrative and financial capacity of departments and agencies or the unduly hierarchical and structured nature of budget process and accountability checks.⁷⁵ Even the more lumbering nature of Canadian governance is portrayed, in contrast with more fleet-footed American examples operating at the municipal level (Phillips and Castle 2010, 184). Political leadership is likewise questioned as is the seeming vacuum around innovation debates in times of electoral dialogue (Phillips and Castle 2012; Castle and Phillips 2016).⁷⁶ Further the long time lags between invention and results are viewed as contributing to a lessened political “enthusiasm” around innovation agendas (Phillips et al. 2017, 57; also Castle and Phillips 2016, 156).

There is however one consistent theme that resonates throughout these works and that is the need for increased investment -- and particularly public investment -- in R&D. Commenting on the fact that Canada is “sleepwalking its way to a lost decade” (Castle and Phillips 2011, 164) the conclusion drawn is that “While public investments in S&T have increased to some extent, more could have been invested and more could have been achieved” (Castle and Phillips 2011, 178). Or in commenting on Budget 2017 and advances that had been made is there the

⁷⁴ See for example, “transferring that knowledge into economic gains” (Phillips and Herte 2018, 132).

⁷⁵ With respect to the “divide between national policy and administrative efforts” see Phillips and Castle (2012, 96-100). On how institutional machinery changes and how horizontality could potentially support an innovation agenda and the “counterbalancing” factors that stand in the way, see Castle and Phillips (2016 152-153); on accountability also Phillips and Castle (2010, 183).

⁷⁶ See especially the comment regarding how “departments are responding in the absence of political direction” (Phillips and Castle 2012, 90).

perspective these improvements “can not compensate for low government expenditures on research and development (GERD) ... and weak productivity growth” (Phillips et al. 2017, 48).⁷⁷

Understandably, the *How Ottawa Spends* series is focused on the demand, and urgency at times, of immediate circumstances and the *realpolitik* of doing deep dives as those circumstances warrant. But the implications of these analyses for this research are threefold. For one, it opens up the space to embark on a different theoretical approach that probes the workings of innovation policy over time – and that subjects that policy to a consistent set of factors and methodological indicators – namely, policy duration, targeted resourcing, thickened triadic networks and venture capital. Secondly, such a new undertaking alleviates the tendency to rely on what are in many ways symptomatic of the innovation gap – the R&D expenditures -- and drill down into root causes. Finally, in setting the sites on policy durability and ruptures in priorities, it enables an evaluation not just of the research investment legacy left by the “Chrétien Liberals” that enmeshes future administrations and constrains their “degrees of freedom” (Castle and Phillips 2016, 156). But it opens up the lens to oscillations in priority-setting – i.e., science, commercialization and back again -- and the very real implication these ruptures have for successful and federally-fuelled innovation initiatives.

The Evolution of STI

With respect to the second stream of literature – and specifically that by Doern, Castle and Phillips (2016) -- here we come to a sweeping and in-depth account of the evolving nature of Science, Technology and Innovation (STI) policy, and associated governance, over the last half-century in Canada. Certainly, the work embodies a fairly complex and inclusive set of operating

⁷⁷ In this same vein, see also Castle and Phillips (2016, 163) on the “chronic underfunding of research” under the Harper administration; Phillips and Castle (2010, 174) in relation to government investments and “more money” being “clearly part of the solution;” also Phillips and Herte (2018, 132) about the “need to increase overall spending on R&D.”

concepts. Premised on the notion of policy forged in the context of an “innovation economy and society nexus,” the account opens up three lines of inquiry. It questions “how, why and to what extent” STI “policy, governance and democracy” have evolved.⁷⁸ It explores “where” that policy has “resided” and it examines the evolutionary patterns of “science-based” endeavours by government over these years. More specifically, however, these questions are explored through the workings of eight encompassing “policy domains,” from “macro” STI policy, to intellectual property to genomics and the Internet (to name a few) as well as 31 policy initiatives. And they are tracked through four “prime ministerial eras” (*Ibid.*, 3) starting with the first Trudeau administration and ending with that of Harper’s. The analysis then overlays on this subject matter a kind of thematic grid, analysing this policy journey from three different vantage points: ideational factors (“ideas” and “discourse”), the exercise of “economic and social power” and, in a rather unusual pairing, “time” and “conflicts.”⁷⁹

That noted, several considerations surface in assessing the import of this work for the undertaking here and the renewed foray into innovation policy which it brings. For one, the Doern analysis tends to ride on the “how” of STI policy evolution and the binary constructs and dilemmas that this historical review portrays. There is the intricate interplay between traditional industrial policy and that associated with the new knowledge economy – i.e., the brittle divisions of “old” legacies and “new economy” need.⁸⁰ There are the commercialization opportunities opened up by genomics and life sciences as much as the consequential ethical concerns that seep into public consciousness and concern. And there is the “permissionless” and revolutionary nature of the Internet and open communication which enables individual exercise of choice, if

⁷⁸ On the analytic framework see especially *Ibid.*, 3-15.

⁷⁹ *Ibid.*, 11-12. On the last element the specific quote is “time, temporal realities, and conflicts.”

⁸⁰ See *Ibid.*, 377-379; also 197-229.

not power, that challenges traditional forms of public regulation. So too does the analysis probe the various social and economic forces – global, popular, business, even lobbying by other public actors such as universities – which channel and redirect policy efforts in IP or biotech safety or in research infrastructural needs.

Yet, at the same time, there is much less compelling evidence regarding the actual impacts various STI policies have had on innovation itself. True, the Doern et al. contribution clearly indicates that federal innovation policies in Canada have failed. But the conclusion rests on the perspective that such policy has occupied at most a “middle” level priority in government circles and that in fact the macro STI agenda has been assigned to a “lower” order in seminal government statements – be they Throne Speeches or Ministers of Finance rising in the House for a Budget address (*Ibid.*, 128, 130). Moreover, this conclusion is particularly drawn from a qualitative reading of those statements⁸¹ as well as the “peripheral” status and revolving door to which Ministers of Science have been assigned (*Ibid.*, 101). As Doern, Castle and Phillips indicate:

As in the case with Throne Speeches, S&T themes and initiatives are rarely shown as highly ranked items in most Budget Speeches. Rather, they tend to be expressed in the body of the Speeches, sometimes themed separately but more often just quickly mentioned and listed as a general measure on the tax and spending side. (*Ibid.*, 107-108).⁸²

What is not examined here, however, is systematic review not just of Budgets but of STI expenditures over the years and how this resourcing has been targeted. Nor does it speak to how those policies have been integrally related to macroeconomic stability and competitive framework policies be they embedded in early deficit-slaying of Chrétien and Martin or that of

⁸¹ See in particular the discussion in *Ibid.*, 105-110 and especially Table 4.2 regarding “direct mentions.”

⁸² Indeed, even in the specific case of the 2000 Budget where “S&T and innovation” is portrayed as central, the import of this is lessened by weight assigned to “budgetary surpluses” (*Ibid.*, 108) which were ripe for expending.

Harper following the Keynesian pump-priming necessitated by the Recession. Nor is it sufficient to conclude that the Harper administration while exhibiting a commercialization focus nevertheless was still enmeshed in the “decision structures and institutions” (*Ibid.*, 109) of their immediate predecessors. Such a unifying lens narrows visibility and limits at least the potential conceptual grasp of shifting priorities – and the implications that too has for innovation success and failure.

To a certain extent of course this critique can be contested. Root causes of innovation impacts are not the real substance of the inquiry in which Doern et al. engage. The effort is much broader, locating the Canadian experience on STI through the annals of history -- from nation-building, to the welfare state, through to neo-liberalism and the current the STI “nexus” that inhabits that landscape. But that is also precisely the point: it leaves the door open to a pivot on innovation that does wrestle with these issues, seeking to systematically evaluate them and seeking to draw on a comparative framework that can proffer the conditions for analysis.

As for Doern and Sharaput’s (2000) work on intellectual property, this contribution may also be viewed as situated within this larger historical compass. Here too the purpose is to trace the shapes and changes of intellectual property as the ongoing trade-offs between IP in the service of public good or market imperatives are played out. Increasingly subjected to international protectionist impulses, intellectual property and particularly patent discourse, legislation and jurisprudence also reflect the competing force of social mores and ethical concerns that crystallize around private exclusivity to life forms. In terms of the case study undertaken herein on pharmaceutical manufacturing, however, the Doern/Sharaput work has much less resonance. In the case study here specifically under examination is whether federal

policy changes in IP in fact propelled R&D expenditures in the pharmaceutical sector – at least for a time – and whether this speaks to causal consequences.

Science and the Federal Role

Finally, with respect to the third stream of contributions in the Doern school which revolve around the federal labs, both the contribution on the NRC (Doern and Levesque 2002) and on the labs situated within federal departments (Doern and Kinder 2007) cast the net widely. In the case of the NRC the analysis goes back to historical antecedents in 1916. Similarly both analyses observe the lack of voice grounded in “political constituency” (*Ibid.*, 189) which could provide a more imposing presence on the national scene. Moreover, both contributions deal with the “transformations” wrought by changing federal priorities and frequent policy shifts that necessitate new focus, partnerships and expanded mandates. In the case of the NRC, the analysis lays bare the stalwart role the Council played during the interwar years and the early post-war period, being essentially the main S&T player in the Canadian context (Doern and Levesque, 159).⁸³ It equally portrays how through time this role has shifted to a more “network” focus and industry-oriented, applied R&D.

As for the eight laboratories and science-based agencies embedded in departments, the analysis here paints a much starker picture. Faced with both expanding responsibilities as well as deep fiscal cuts, labs have been caught in the cross hairs of competing pressures and circumstances. The influx of “S&T/innovation/commercialization” policies as well as environmental protection and sustainability, constrained budgetary envelopes (and often sourcing of new revenues), the forging of new academic and business “linkages” and at times oscillating

⁸³ See their comment regarding the interbellum period: “Canada’s research capacity in both universities and industry was so weak that the NRC was by default the pivotal national S&T institution.” (*Ibid.*).

departmental mandates: these factors have played out even as labs occupied the middle-level ranges of bureaucratic hierarchies with more limited access to hierarchical decision-making. The conclusion drawn is that the period around the turn of this century saw laboratories essentially subjected to both “benign and deliberate neglect, as new ideas and frameworks for assessing the values government S&T took hold” (Doern and Kinder 2007, 4).

To be sure, these two contributions on the NRC and federal laboratories, armed as they are with empirical depth and sharpened perspective, bring attention to a much-needed area of inquiry. However, in terms of the innovation questions undertaken here and the quest to wed NIS literature and historical institutionalism via a DNS framework, a few considerations are relevant. These works do not constitute just a third “leg” so to speak of a National Innovation System (together with industry and academe). Nor are they conceived as windows into the triadic thickening that may propel endogenous economic growth and innovation. They are simply not situated in such a theoretical context. At least for Doern and Kinder they are rooted in literature where science stands as a kind of “fifth branch of government” or “*scientific estate*” (Doern and Kinder 2007, 7). And they are focused on government agencies as they sustain ongoing pressures and accommodate their roles to the industry-led R&D or environmental protection or conservation mandates their parent departments harbour. Most importantly, these contributions depict agencies – NRC included – as they steer through competing demands, and legacies, and grapple with science both as a public good and one in support of private enterprise and markets. The challenge here is not the quest to understand innovation or lay bare its enabling conditions. Rather it is to construct anew a framework that foregoes “unidimensional”

(Doern and Kinder 2007, 20)⁸⁴ renderings of these federal entities and conceptually grasps the diverse paths of “strategic science in the public interest”⁸⁵ which are forged.

Moreover, if science-based institutions within the Doern literature struggle with national presence and import so too with science policy is there a similar cadence to the line of argumentation. Specifically, attention is focussed on the limited reach and, even more importantly, the lower rung which science has occupied within the broader federal government agenda, particularly as witnessed by the Science Council of Canada (SCC). Indeed, several insights and evidence are assembled in this regard: that the SCC was not sufficiently vested with the mandate to make a difference and that it was its under resourced. So too has the churn in science advisory councils and commissions over the decades as they are dismissed and then reconstituted (*Ibid.*; Quirion, Carty, Dufour and Jabr 2016) had dislocating effects on the impact which science policy could bring. Once again, however, a few considerations need be registered.

For one thing, these contributions focus on science policy *qua* science policy. True the SCC foreshadowed the innovation wave to come but the lens is not science, technology and innovation and how that has played out both on policy durability and innovation impacts. Further, it is important to take another measure of the scientific advisory bodies that are referenced. At least with respect to reports by the Advisory Council on Science and Technology in the late nineties⁸⁶ dealing with the need for research infrastructure, indirect costs of research for universities, skills and international engagement, these studies did have concerted impacts. Several of their recommendations immediately made their way into Budgets in the late nineties and early aughts, as for example with the largesse distributed to a new Canadian Foundation for

⁸⁴ The exact reference is “they [the labs] have tended to be treated unidimensionally ...” (*Ibid.*)

⁸⁵ The quotation is from the title (*Ibid.* 2007).

⁸⁶ See Chapter Four, “Setting Priorities: Pursuing ‘Excellence’.”

Innovation.⁸⁷ Finally, in moving the focus away from science and *to innovation*, it can be argued that the federal administrative capacity of Industry Canada and later Innovation, Science and Economic Development actually hardened and achieved greater import; certainly it was by no means relegated to the sidelines. While the Doern contributions clearly establish how science has been treated to a secondary role in the national agenda, the evidence harvested in this dissertation suggests that innovation has been subjected to a more discerning (albeit intermittent at times) eye.

All told, then, in term of Canadian scholarship, the national orientation of the “policy domain” literature in a manner complements the “meso” focus of the RIS and cluster literature, bringing a wider perspective to the issue. Yet, it is equally important to distill the differences for the institutionalist renderings of the Doern school are by no means engaged in a similar theoretical exercise to the “meso” contributions. This is not only because the policy domain lens is national or that these readings are situated apart from a comparative context, but also because they are not predominantly focused on the conditions -- necessary and sufficient – that trigger, enable and impede innovation.

Conclusion

In concluding, what this journey through Canadian scholarship portrays is than an open pathway does exist for a new and refreshed perspective on the innovation problématique. There is indeed the conceptual and empirical space to lever the Developmental Network State framework, both to grasp the Canadian struggle with commercialization and to methodically review the conditions that have stymied federal policy since the first volleys at the turn of this century. The “meso” contributions engaged with the dynamics of innovation systems and

⁸⁷ See Chapter Five, “Investing in World Class Research.”

impact; the institutionalist readings that speak to the national: neither occludes the potential for an undertaking wedded to innovation systems and state -- and national policy forged in that crucible.

Thus armed with these considerations it is possible to initiate a broader dialogue around the innovation lens in the Canadian context. And equipped with a DNS framework instrumental in mending the gap between the strengths of National Innovation Systems literature and the unique focus of historical institutionalism on the role of the state and public policy, this inquiry into the ongoing challenges of Canadian innovation can commence.

Chapter 2

Research Methodology

Introduction

This research has centred its focus on the innovation gap that has continued to challenge Canadian federal policy over the period from 2000 to 2020. In probing the reasons for this situation, as we have seen, the dissertation leverages the Developmental Network State framework – albeit somewhat modified for a comparative context and specifically Canadian terrain. That stated, however, it is particularly incumbent on us to develop a robust methodology that can peel away the evidence and that contains consistent standard indicators and operationalization that can undertake a true test of the explanatory capacity of DNS. Towards that end and not to limit the arsenal that may be used in that quest, both qualitative and quantitative methods have been employed – specifically, in the latter case, economic data largely from the OECD and statistical information provided through Statistics Canada sources. Quantitative methods in terms of large random-sampled surveys with the opportunity to test statistical correlations are not utilized.

The chapter itself is structured around six main features. Firstly, the research question and the critical sub-lines of inquiry or four domains of research that form the basis of the dissertation are reiterated. The chapter then turns to considerations that require a more in-depth framing of the thesis presented herein. In that context – and from an epistemological point of view -- the chapter considers the very nature of one Canadian case study and the challenges and strengths that may bring in assembling evidence to evaluate the DNS. Within this rubric of

considerations, however, the chapter also reflects on the import of the federal role in innovation policy as the object of study and the time period selected for analysis.

On a third front, the chapter then moves to deal with the broad number of internationally recognized innovation indicators required to address the current and historical issue of Canadian performance on innovation. And challenging as that may be to extensively probe what we have termed the health of the Canadian innovation system, this is a necessary building block in testing the DNS framework. Fourthly, there is discussion of the 54 thought leader interviews used to reflect on this problématique – including aggregate composition of the participants, the interview process and analysis undertaken. That in hand, fifthly, the analysis then pursues the four lines of inquiry that will be subjected to scrutiny and their respective operationalization. Finally, the discussion turns to examination of the two separate sectoral cases of Artificial Intelligence and pharmaceutical manufacturing, the policy puzzle they present and how the methodology employed may enable attention to causal implications of federal policy for innovation performance. Concluding remarks follow.

The Research Question

As indicated at the outset of this study, the central research question coursing through the work is the following:

Can the Developmental Network State framework be used to explain why Canadian, and specifically federal, public policy since 2000 has seemingly been unable to increase national Research and Development investment, moving the scale on standard OECD innovation indicators and positively impacting Canada's rate of innovation? ¹

¹ On the specific issue of innovation indicators and the methodology employed, see “Innovation Indicators” below.

Four Domains of Research

Towards this end, four critical aspects of national Canadian innovation policy from 2000 onwards have been pursued, each as a separate sub-question. The intent has been to operationalize each of these in a practical, empirical manner that could be examined both through numeric and qualitative means. Ultimately, the goal has been to provide grounded data and insights that can be distilled for comparative analysis. These four domains of research have centred around the following.

- 5) From the period starting in 2000 is there evidence of sustained priority-setting around innovation imperatives and what can be characterized as policy “durability”?²**
- 6) Is this priority-setting accompanied by “targeted resourcing”³ focused on priorities and Science and Technology areas that show the potential for success?**
- 7) To what extent are policy initiatives focused on thickening clusters of innovation activity across industry, academe and government including government laboratories, strengthening linkages that can incubate ideas and lead to commercialization?**
- 8) Have these efforts been twinned with government-incented and particularly late-stage capitalization that can bridge the gap between invention and innovation where products or processes have become market-ready?**

Considerations

Case Study Methodology

With respect to the issue of the use of small-N or single case studies as an investigative technique, there is of course an extensive literature on this issue,⁴ particularly in the wake of

² The term is employed by Patashnik (2003); also Lockwood (2013).

³ The term is employed by Block (2008).

⁴ See in particular the opening volley by King, Keohane and Verba (1994; 1995); also for the debate Collier (1995); della Porta (2008); Goertz and Mahoney (2012); Laitin (1995); Mahoney (2003); Pierson and Skocpol (2002); Ragin

King, Keohane and Verba's efforts in 1994 to squeeze qualitative research into the straightjacket of quantitative inquiry and its underlying logic. However, it is not our intention here to engage in highly technical debates concerning the bias introduced by selection on the dependent variable in qualitative work in terms of the "slope" of multivariate regressions or whether there is "symmetry" vested in the independent variable that may gird the integrity of the independent variable and subsequent correlations (see Collier 1995). Rather the focus is on the value which a case study provides for comparative analysis in the context of the Developmental State Network framework. Understandably a lot of the argument is drawn from those engaged in "comparative historical analysis" (Mahoney 2003) and specifically historical institutionalism which has remained resistant to the behavioural focus and quantitative methodology which dominated social sciences in the post-war period – at least within the American context. However, it is believed that these "historical method" (Skocpol 1979) insights are relevant to the task at hand.

One of course steps gingerly into these debates – even the periphery of these debates -- particularly on two fronts. Despite the focus on "meso-analysis" within HI it is of course primordially concerned with what Skocpol calls the "big questions" and their "real world" impacts (Skocpol 2003b; see also Mahoney and Rueschemeyer 2003) -- social revolutions, transformation of the state and especially in the US the unique variant of the welfare state that has laid claim there. Indeed, Polanyi's (1957 [1944]) great historical sweep of the intersection of state and economy through the ages – from ancient to the early ravaging effects of capitalism -- is also situated within this rubric of comparative historical efforts (Thelen and Steinmo 1992, 11) or at least is "in the spirit" of what the HI community draws from this perspective. Secondly, however, what the small-N comparative approach lends itself to is the causal inferences that can

(2008); Rogowski (1995); Steinmo (2008); Rueschemeyer (2003); Skocpol (1979, 2003b). We would also include in this, Thelen and Steinmo in their discussion of how "institutions are not just another variable" (1992, 9).

be drawn from “set-logic” examining impacts and outcomes and working “backwards” to understand the causes that propel them.⁵ Its rigour brings equivalency to the smouldering issue of whether qualitative work can truly probe causal influences and that in fact it must be submitted to quantitative logic to have meaning (à la King, Keohane and Verba 1994).

These issues are well beyond the scope of this inquiry. However, four points are germane here. For one, the case study and small-N case studies offer an opportunity to investigate in rich detail the issues and conditions that influence outcomes and particularly that lend themselves to “historically concrete” (della Porta 2008, 206) conclusions. They offer an opportunity to view the case study as an integral “whole” (*Ibid.*, 3) that seeks to grasp the dynamic interaction of its prevailing features and conditions. For another, they provide a temporal dimension to this endeavour that does not undertake snapshots in time but lays bare the processes and factors that have endured – and those that have not (see Pierson 2003; Pierson and Skocpol 2002; Steinmo 2008).

Thirdly, with respect to the critique of selecting on the dependent variable, this in fact misses the whole purpose of locating (not arbitrarily but through documented historical efforts as well) outcomes that prevail and show indicators of similarity. It is precisely by tracing through these and by holding the outcome constant so to speak, or at least attempting such, one can understand when different causes and conditions obtain. This is not to suggest, as Skocpol ably argues in her “revolutions” work, that it necessarily precludes the effort to contrast with differing outcomes.⁶ But it does provide a stable context for understanding which factors impact the

⁵ See in particular the rigorous logic laid out in Goertz and Mahoney (2012, especially 41- 49); also della Porta (2008 especially 203-208) who references Mahoney and Goertz (2006) but also likens it to Weber’s ideal types – which may be a more contentious undertaking.

⁶ See her discussion of how she has, in addition to using the US, China and Russia, used contrasting historical periods as with England, Germany and even the failed 1905 revolution in Russia (Skocpol 1979, 37).

specific issue under investigation – be it the large macro nature of state or societal transformation which is the domain of HI or arguably even the more precise targeting of specific government policy. Further, this supposed “bias” in case studies enables a search for “anomaly” that more generalist efforts at large numbers of randomly selected cases would be less equipped to capture. As Rogowski (1995) has ably argued, work such as that by Katzenstein (1985) on the adaption and success of small export-oriented economies would have simply gone unnoticed, hidden beneath accounts of large and export-successful nation-states. Or as Tarrow (1995) (despite his effort to still constrain qualitative inquiry within a large-N “frame”)⁷ argues, it equally lends itself to pursuing the unexpected -- the anomalies -- and conceptually grasping the “tipping points” that rupture historical trajectories. Fourthly, and this is a particularly important consideration – it enables the opportunity to refine concepts, theoretical approaches and we would suggest even frameworks, as those conditions and anomalies feed back into the overarching theoretical venture and as dynamism emerges between the theory and findings (Pierson and Skocpol 2002; Rueschemeyer 2003). That said, it is not to congeal analysis within the strictures of just qualitative but to convey the richness – even “thickness” that case studies can bring to the research effort. This is particularly so in the Canadian case where the question of industrial policy and associated S&T has bedevilled or at least challenged federal policy since the Special Senate Committee’s report on the matter back in 1970 (Senate 1970).⁸

The Role of Federal Innovation Policy: Its Import

Turning to a further consideration and specifically the main object of study in this inquiry – federal innovation policy – it might be contested that the dynamics of a federated state are such

⁷ See in particular his discussion of Tilly and the need to use large numbers of cases in the context of qualitative work (*Ibid.*, 472-473)

⁸ On the Senate’s Report *A Science Policy for Canada* see also the discussion in Doern (1972).

that addressing DNS through the lens of federal policy might not be a sufficient test of the framework. However, several arguments may be raised in defence of the position that has been taken. For one, simply on the basis of expenditures alone, the federal government has been a key actor on the innovation front for the last two decades. As the research in this inquiry reveals not inconsiderate amounts of funding have been dedicated to refurbishing and refurbishing science and technology and to incenting innovation. Key federal investments in research (Chapter Five, Annex A - 5, Figure 16), in federal network initiatives (Chapter Six, Annex A - 6, Figure 4), in health and life sciences R&D (Chapter Nine, Annex A - 9, Figure 2) as well as Artificial Intelligence (Chapter Eight, Annex A - 8, Figure 1), and in venture capital (Chapter Seven, Annex A - 7, Table 1): all speak to the largesse with which federal administrations have treated S&T and innovation objectives. Moreover, there has been the grand total of \$211.5 billion for federal expenditures on Science and Technology writ large (Chapter Five, Annex A - 5, Figure 5) over the course of the 1999-2000 to 2019-2020 fiscal period.

Furthermore, just in terms of weighting, federal funding has been significantly greater than provincial expenditures in this domain. Data by Statistics Canada (2015) on Gross Domestic Expenditures on Research and Development in Canada, the Provinces and Territories indicates the federal and provincial “distribution” or split on this dimension – and it is telling. In the case of the shares regarding “funding” of GERD, the federal government held 19.3 per cent, while the provincial proportion was 5.9 percent. In the case of GERD “performed” by the relevant sector, the shares weigh in at 8.6 per cent for the federal government and 1.0 per cent for provincial governments. Admittedly, the data is now somewhat dated, based as it is on national estimates for the period between 2005 to 2015 for the federal level and 2009 to 2013 for provincial and territories and unfortunately has not been replicated in this format since last

published in October of 2015 (<https://www150.statcan.gc.ca/n1/en/catalogue/88-221-X>). Still it does involve a significant time series and is not a simple snapshot and highlights the role of federal authority on this dimension.

On another front, however, for the various Commissions, Advisory Committees and Councils and Reports issued throughout the 2000s on Canada's innovation dilemma,⁹ they too clearly saw the federal role as deserving of their attention, be it “innovation marketplaces” (ACEG 2017) or triadic thickening of the Canadian innovation ecosystem or the more diffuse impacts of tax credits and specifically SR&ED. Recommendations and insights offered very much revolved around the nature of federal policy – gains made, opportunities lost and challenges wrought. So too has academic literature in the Canadian context had a focus on and cast a discerning eye with respect to federal initiatives. Certainly, this obtains in the case of the Doern school discussed earlier but also, even with the cluster approach of Wolfe or the regional perspective of Niosi, notably the lens is not provincial state intervention or policy but rather geographically grounded clusters that animate innovation.¹⁰ Indeed, in the case of Wolfe the cluster moves beyond even the domestic front as well to sustenance derived from international linkages (Bramwell, Nelles and Wolfe 2008).

Equally critical, even judging federal efforts on their own terms, the national priority-setting around innovation and the highly ambitious objectives articulated over the years which will be examined speak to the important dimensions of this field. The relation – and the potential coherence or disjuncture – between policy intent and policy impact warrant investigation and the

⁹ Advisory Council on Economic Growth (ACEG) (2017); Council of Canadian Academies (CCA) (2009); Expert Panel on Commercialization (2006); Independent Panel on Federal Support to Research and Development (Jenkins Report) (2011); Science, Technology and Innovation Council (STIC) (2009, 2011; 2013; 2015); also the series of publications by the Advisory Council on Science and Technology (ACST) (1999a, 1999b, 2000, 2001); and Naylor (2017). Chapter Three focuses on the work of these various commissions and reports.

¹⁰ See Chapter One, “Canadian Scholarship: The Innovation Lens.”

extent to which federal initiatives have had intended effects. And, as for the sectoral case studies analysed – AI and pharmaceutical manufacturing – using Campbell’s (1969) work, there is a path for assessing causal implications through timelines and policy differentiation. Overlaid on this, with Artificial Intelligence, where the federal/provincial dynamic is probably most pronounced, efforts have been made to dissect this relation, and as Chapter Eight discusses, assess the respective roles.

This is not suggest in any way of course that the federal/provincial relation on innovation is not a fertile and rich area for further investigation. Nor is it to indicate that this research inquiry will be definitive in examining the DNS framework in the Canadian context. It is to suggest however that this study is an effort to lay out the larger contours, accounting for the critical role of federal policy in the innovation policy.

The Selection of the 2000 to 2020 Time Frame

If the domain of federal innovation policy must be reckoned with in constructing this test of the DNS framework so too does the selection of the time frame form a critical element of the methodology. And on this front, the start of the 2000s saw an interesting alignment of a number of trends and policy initiatives that make a compelling case for starting this inquiry at the cusp of the 21st century. More specifically, what is witnessed are peaks from which key innovation indicators then declined over the following years. Evident as well is a federal policy pivot that proclaimed the import of innovation and accompanied this with the strategies and funding to launch.

In fact, while 2000 started to lay the foundation for the new innovation emphasis, 2001 proved to be the watershed annum both for economic indicators as well as for federal priority-setting and resourcing. And without shortchanging the chapter discussions which follow, two

dimensions can be sharply perceived. 2001 data represented a high for the following measures over the full time series from which these measures then declined, specifically: Gross Domestic Expenditures on R&D (GERD) as a percentage of GDP, percentage of GERD performed by the Business Enterprise sector, Business Enterprise Expenditures as a percentage of GDP, Government Expenditures on R&D as a percentage of GDP (although the same percentage was also repeated in 2002) and Information and Communication Technology (ICT) investments, total, percentage of Gross Fixed Capital Formation. As for percentage of Higher Education Expenditures on R&D (HERD) financed by the business sector, here the peak starts in 2000. Moreover, interesting as well, in the case of HERD as a percentage of GDP this as will be seen has been a strength for Canada but here the data point for a steadily mounting increase commences in 2001, as well as it does in the case of the percentage of GERD performed by Higher Education.¹¹

Intersecting with the economic data, for the federal government, 2001 was also a signal year. Certainly, the 2001 Speech from the Throne (SFT 2001) for the Chrétien government threw down the gauntlet for innovation, proclaiming no lesser goal than Canada becoming “one of the most innovative countries in the world” (*Ibid.*, 3). Moreover, as will be discussed in Chapter Four ambitious R&D and innovation targets were announced, a new *Innovation Strategy* built around “Achieving Excellence” was released (IC 2001b), as was a review of *Federal Science and Technology* and the ensuing path forward (IC 2001c): all in 2001. Similarly, the year saw a Budget that also made a \$7.4 billion investment on the S&T and innovation front for

¹¹ For the specific data see Chapter Three, Annex A - 3 : on GERD Figures 1 and 3; on BERD Figure 6; GOVERD, Figure 12: ICT, Figure 21; on HERD Figures 20 and 15 respectively; on GERD performed by Higher Ed, Figure 5. It should be noted that for GOVERD as a percentage of GDP (Figure 12) there is some very minor undulation in the descent for 2005, 2006 and 2009.

2001-2002 which the government indicated was “an increase of 25 per cent from the previous peak” (Finance Canada 2001, 109).

All said, there is good reason to slice into this research and the four lines of inquiry from the 2000 standpoint (and clearly from an economic standpoint starting at the beginning of the decade). Moreover, it is critical to get the historical take of 20 years – a time frame that can also take account of political difference and stripe of the administrations in question as well as pick up on the longer gestation period of innovation and technology when new initiatives are announced. Equally -- and unfortunately as events have unfolded -- 2020 and the havoc wrought by the pandemic have proved to an important marker for an end date in this study as well. That noted, it should be highlighted that the sectoral cases studies of AI and pharmaceutical manufacturing referenced below do take an even longer time frame to test the particular “quasi-experimental” techniques there employed.

Innovation Indicators

To access quantitative measures of the ‘health’ of the Canadian innovation system, both in terms of Canada’s own performance and vis à vis other comparator nations, standard OECD indicators have been employed for measuring investment in R&D and related indicators of innovation. The data has been tracked on an annual basis and examines the time span from 2000 on, which is largely accessible on a country basis, through OECD’s *Main Science and Technology Indicators* (<http://www.oecd.org/sti/msti.htm>), interim *Science, Technology and Industry Outlook* (<http://www.oecd.org/sti/oecd-science-technology-and-innovation-outlook-25186167.htm>) and *OECD Scoreboard* reports (<http://www.oecd.org/sti/scoreboard.htm>). As well, extensive patent statistics housed within the *Main Science and Technology Indicators* have been incorporated and analyzed.

Employing OECD data has several advantages: it is standardized and can be used for cross-country comparisons, not only among OECD countries but in fact among countries “worldwide” (*Frascati Manual* 2015, 4). The data is updated twice annually and thus enables a robust analysis of longitudinal trends. Where methodological gaps occur or where data is missing in a country’s annual indicators this is clearly specified. Moreover, the methodology for tracking innovation and R&D investments by business, government and academe has developed over the better part of fifty years and carries with it both a methodological rigour and gravitas as well as international recognition. Where gaps do occur in the research being undertaken, as noted below, data will be supplemented through other relevant sources. Operationalization of innovation in Canada over the period from 2000 – 2020 will thus use standard OECD indicators, clustered under the categories that follow.

Research and Development Investment

Of primary importance has been Gross Domestic Expenditures on R&D (GERD) as a percentage of GDP -- a “flagship measure” on R&D investment. As well, the separate components of GERD have been tracked – i.e., Business Enterprise Expenditures on R&D (BERD) as a percentage of GDP, Higher Education Expenditures on R&D (HERD) as a percentage of GDP and Government Expenditures on R&D (GOVERD) as a percentage of GDP (see MTSI database). It should be noted that where the term GERD intensity is used in discussing the data, this refers to “domestic expenditure on R&D expressed as a percentage of gross domestic product (GDP)” (<https://www.oecd.org/sti/msti-highlights-march-2021.pdf>). Specific OECD definitions of GERD and its components are referenced in Annex B - 2 below.

In terms of use of these innovation indicators, where it is relevant to more broadly position the economic data or to give a better sense of developments over time, OECD data on

indicators in terms of constant US 2015 dollars are also employed. Where appropriate as well, particularly in terms of comparative gains that some nations may be making over time, the author has also provided percentage increases over the base year in the time series – which is usually 2000. These calculations are based on the OECD data but are the author’s calculations.

Investment in Information and Communications Technologies (ICT)

ICT has been defined by OECD as a key “enabler” of innovation (*OECD, Science, Technology & Industry Scoreboard 2017*, 152) as well as a critical input for productivity gains and economic growth more broadly (OECD 2003),¹² and as such is also important to the analysis. To tap into this dimension, three standard measures have been used which the OECD has traditionally relied upon: R&D Expenditures by ICT equipment and information services industries as a percentage of Business Enterprise Expenditures (*Ibid.*, 152; *StatLink* <http://dx.doi.org/10.1787/888933619296>); ICT total investments as a percentage of gross fixed capital formation (GFCF) and patents in ICT-related technologies. This latter feature is particularly important for this research as patents are an important indicator used in tracking the use of AI R&D and technological growth. As such, it provides a base of comparison for investments in Canada between these two strategic and “enabling” sectors. As for ICT investment more generally, this had been deemed to be an area of concern in the Canadian context since at least from 2004 onwards and a contributor to the productivity gap with the United States (IC, 2007b, 27; IC 2006).

¹² See in particular the discussion in OECD 2003 and the range of impacts investments in ICT can have respectively on firm innovation and productivity and national economic growth.

Knowledge Generation

This category has focused on bibliometric measures, specifically the citation impact of scientific publications by Canadian researchers and the pre-eminence of the journals in which these articles appear (*OECD Scoreboard 2017*, 122-125). In addition, knowledge generation has been captured through the aggregate number of R&D researchers in Canada, as expressed through Full-Time Equivalents. As well -- and providing for a better means to compare relativity among countries and not just raw aggregate data -- the indicator for total researchers per thousand total employment is equally used. OECD data is inclusive of the national total for each of the, business, education and government categories (see OECD 2015, 151-177).

Capitalization

There is neither an internationally accepted “standard” definition of venture capital nor the stages of VC -- ie., whether start-up or late stage -- nor by industrial sector. Importantly, however, the OECD does provide a definition of venture capital, specifically.

Venture capital is private capital provided by specialised firms acting as intermediaries between primary sources of finance (insurance, pension funds, banks, etc.) and private start-up and high-growth companies whose shares are not freely traded on any stock market (OECD 2017, 158).

Moreover, the OECD provides parameters for varying stages of development and aggregates the collected national data accordingly. As such, then, key measures are available which indicate Canada’s position vis à vis international comparators and these have been used to probe the extent of venture capital in Canada over the years under study. Respectively calculated as a percentage of GDP, these include Total Venture Capital Investment as a percentage of GDP, Venture Capital Investment for Start-up and Other Early Stage and Venture Capital Investment for Later Stage -- all of which can be found in the *OECD Enterprise Statistics, Venture Capital*

Investments (https://stats.oecd.org/Index.aspx?DataSetCode=VC_INVEST). For the OECD, Total VC investment includes the sum of “early stage (including pre-seed, seed, start-up and other early stage) and later stage venture capital” (https://stats.oecd.org/Index.aspx?DataSetCode=VC_INVEST).¹³ It should be noted that the OECD database does provide a breakdown for seed capital but it has not been included as a separate indicator in this research.

Admittedly, there are gaps in this data, as most of the OECD countries do not start reporting until 2007, with the US and Korea being the exceptions. Also at issue are the varying “methodologies” employed by countries in pulling together their VC statistics, which can impact the “completeness” and “representativeness” of the data (https://stats.oecd.org/Index.aspx?DataSetCode=VC_INVEST), although the OECD does point out that this situation has “improved.” Nevertheless, the OECD database does offer a means by which to objectively appraise developments on the VC front, both domestically and internationally. Further, relevant analyses by the Business Development Bank of Canada (BDC) and the Canadian Venture Capital and Private Equity Association (CVCA) will be used to supplement our analysis.

Patents

Several indicators related to patents are used throughout this research inquiry. In examining Canada’s success and comparative positioning in patent filing, the OECD indicator measuring a country’s share of “triadic” patent families is used – i.e., “all patent documents filed in different countries to protect the same invention” (OECD 2001, 143). The *MSTI* database is “triadic” in that it includes all patents filed with the US Patent & Trademark Office, European Patent Office and Japan Patent Office. Additionally, when looking at the number of patents filed

¹³ The OECD does not hyphenate these terms for VC; for consistency, terms of early-stage and late-stage in referring to VC – when not directly quoting OECD or directly referencing their tables -- are hyphenated herein.

and annual increases over a time series, patent applications to the USPTO is employed. The USPTO database is used both for total patents filed as well as patents for specific technologies – namely Information and Communications Technology, Artificial Intelligence and Pharmaceutical Manufacturing. The USPTO data base here is important as it is the data series which also enables examination of international co-operation and co-ownership in patent applications. More generally, it should be noted that while the OECD does acknowledge limitations to patent statistics as a proxy for innovation, including the fact that not all patents will have commercialization potential, nevertheless patents have long been viewed as a data source “widely used to measure innovative activity” (OECD 2001, 134-137).

Collaboration

This measure has been defined to be quite extensive here, including patent co-ownership, co-authored scientific publications, and in cases of international collaboration publications broken down by domestic author or foreign author as the “lead.” With respect to the “triadic” patent data, one restriction exists in that there are “no indicators of international cooperation provided on-line for patent families.”¹⁴ That said, however, this is not unduly problematic for the research as the preponderance of Canada’s patent filings are with the US Patent and Trademark Office (USPTO) -- a venue in which filings are readily accessible and comparable not only for total patents but in a number of key technology sectors. Moreover, as has been seen, the USPTO data set provides continuity for examining total patents and the technology breakdowns.

The collaboration indicator has also been extended to include joint business, university and government initiatives, both from a tripartite perspective as well as bipartite -- business-university and business-government – dimension. Critical as well, joint funding among these

¹⁴ Author’s correspondence with OECD, 13 February 2020.

entities is tracked over the time series in question, specifically through the OECD measure of percentage of HERD financed by the business sector. Information on joint projects and funding also exists in a variety of Statistics Canada surveys undertaken on this subject from 1999 onward, a facet which is explored in depth in Chapter Six. Particularly useful are indicators centred around the extent of “co-operative arrangements” as broken down by enterprises, universities, and government as well as the most “critical” partner specifically for key innovation activities. Unfortunately the data has had a somewhat patchy quality to it both in terms of methodology and continuity in the time series. However, it is the most authoritative domestic source of information on this topic to date and the most detailed and comprehensive even in relation to World Economic Forum highlights and OECD statistics in regard to Canada’s collaboration landscape.

Analysis of Innovation Indicators

Armed with these indicators, the thesis has examined Canada’s annual performance over the period under study. Additionally, it has focused on an array of comparator indicators – specifically Canada’s relative position, on a particular measure, to the OECD average, the EU (28) average and when relevant EU (27) average, as well as the average for the leading OECD nation. Where the dataset has included non-OECD countries and the leading country is not a member of the OECD then the data for that nation is used. Also examined has been Canada’s relative position to the respective track records of the US and China and the annual averages for the top five countries. In cases where the US or China is the leading nation this is duly noted in the graph which is being presented. In the case of the annual averages for the category of top

five nations over the full time-series *these are the author's calculations and not those of the OECD*. The list of top five nations is provided in each of the graphs presented.¹⁵

It should be added that the use of the top five OECD countries (or when the dataset also includes non-OECD countries) as a measure of comparison for Canada is well-established, having been employed by STIC (2009, 2011, 2013, 2015). In toto, such an approach should be ably equipped to capture the nature – and, if necessary, depth – of the innovation challenge in Canada, as well as how Canadian trends align in a globalized world of heated international competition.

In-Depth Thought Leader Interviews

As has been earlier noted, another critical dimension part of this research has been centred around 54 “thought leader” interviews that were conducted with senior political and administrative decision-makers in the federal government, key industry leaders commercialization entities as well as academics engaged in dealing with innovation issues. Interviews were “semi-structured” (Luton 2010, 23) and probed the challenges with which the community is wrestling, including perspectives on the research questions that had been developed. More specifically, interview questions were designed to focus on the four sub-lines of inquiry in the dissertation. As such, the degree to which Canada has been successful in maintaining consistent priority setting around innovation investments, the extent of targeted resourcing, the thickening of networks that energize innovation and incentives that leverage capitalization – and particularly late-stage VC -- were the central thrust of these interviews.

¹⁵ Threshold methodology used by the author in the calculation of the top five country averages is provided in Annex B - 2, “Methodology Note: Thresholds” below. It should also be noted that in cases where the relation between Canada and other nations on a particular indicator is presented in numeric terms – as for example Canada’s GERD in 2001 was half that of the leading nation, Israel – these are the author’s calculations based on OECD data. (The GERD example is taken from Chapter Three, “GERD and Its Components.”)

Equally important and in fact positioned as the first question to participants was what they saw as “Canada’s biggest challenge in dealing with these realities and challenges” around innovation.

The specific interview questions both in English and French are provided below in Annex A - 2.

The Interviewees: Aggregate Composition

In all 54 interviews were conducted, usually lasting about 45 minutes although some ran to 50 and even 60 minutes and some, due to time constraints, were limited to a half-hour. As for the list of interviewees, this was distilled from public sources and did include:

- Federal Ministers of the Crown;
- senior officials within the federal government at Assistant Deputy Minister or Deputy Minister level (or their designated representative by acting personnel);
- CEOs and senior executives within firms at the forefront of innovation technology – i.e., Artificial Intelligence, Information and Communications Technology (ICT), but also more traditional manufacturing firms, such as in pharmaceutical manufacturing;
- senior executives within venture capital firms operating in Canada or organizations providing venture capital to firms -- both domestic and international or those who have had that experience;
- senior scientists or engineers who are or have been leading experts in innovation or have been engaged in national dialogue on innovation issues;
- CEOs or senior executives of commercialization entities, accelerations and incubators, including traditional natural resource industries and manufacturing industries as well as those at the forefront of AI and pharmaceutical manufacturing;
- Heads or CEOs of industry or professional associations;
- Presidents or Vice-Presidents of research and innovation in a select number of universities and colleges spanning the country;
- senior officials in federal government labs or research organizations who are directly involved in R&D activities.¹⁶

¹⁶ To preserve anonymity precise numbers in each of the categories mentioned are not provided, just the aggregate rollup noted below.

It should be stressed that the results of the interviews were compiled on an anonymous basis and were strictly confidential. Quotations by interviewees, when used in the dissertation, are thus only identified with the letter “T” and a number. As for the profile of the interviewees with respect to geographic region and sectoral make-up, this data is presented as an aggregate rollup in Chapter Four (Figures 1 and 2). It should be noted that the sectoral breakdown encompasses individuals from academe, commercialization entities, incubators and accelerators, non-profit entities and think tanks, government, industry firms or associations and those with some combination of industry, academic and government experience. Similarly, it should be noted that this was by no means a random sample but the author did undertake to have broad representation from across the country as well from different sectors. There was a designed effort to avoid any undue weighting from the National Capital Region where many government officials and associations are located. As such, the number of interviews was expanded substantially to 54 to gain that degree of representation and to also build into the data those with historical experience in the innovation domain. The dissertation proposal for the interviews and the methodology were approved by the Ethics Research Board at the University of Ottawa on 11 March 2020.

Extensive work was undertaken to gain participation in the interviews as the quest for participants collided directly with the massive lockdowns that occurred starting in March of 2020 with the pandemic. This was no mean task as the usual means of phone calls or even readily available e-mails were more difficult to locate. Moreover, considering the context as businesses closed, universities began to move to on-line capacity and government fielded the enormous objectives of the day, in fact in all the author reached out to 107 potential interviewees across the country. In the end, 54 participants provided the opportunity for an interview. It should be noted

that, of the 107, three other potential interviews were scheduled but did not occur due to circumstances that in the end did not allow. Interviews were conducted between April and September of 2020.

The Interviews: Techniques and Assessment

With respect to the process undertaken, all interviews except for one were recorded,¹⁷ with interviewees previously giving their official consent. The interviewees were given the opportunity to have the recording stopped at any time should they so have decided for that particular comment. This was only very, very rarely used. Answers were then transcribed by the author into written form, with the author reviewing all recordings at least twice. Answers to the specific questions asked were used for purposes of collating answers. Only in a handful of cases out of all responses to all questions was there such an organic unity between the specific question asked and comments during another part of the interview that these comments were leveraged. With respect to the means of evaluating and collating responses, the author did not use mechanistic techniques to assess the interviews but rather reviewed all the answers personally and collated accordingly. This provided an opportunity to listen to tone and emphasis as well as content and not just a counting of words. Additionally, it should be noted that quotations from the interviews are verbatim.

As for actual responses the data on this is quite robust. As can be seen in Table 1, in most cases 53 of the 54 individuals in the interviewee pool answered the question at hand. (This does include those answers where the participant felt they did not have sufficient information to respond and these cases are duly indicated when interview results are presented in the chapters which follow.) It should be noted, however, there was a conscious effort by the author to

¹⁷ In this particular case, the participant specifically requested that there not be a recording.

concentrate on the critical questions and as such there was not always time to address all dimension as for example with the supplementary line of inquiry in Question 3b around Budget 2017 and Superclusters. There was also one case where the participant had very specialized knowledge and it was decided at the outset with the participant that the interview would be structured around those elements.

With respect to the structure of the interview, Question 1 revolved around the biggest challenge Canada was facing on innovation but the other questions pursued the four lines of inquiry in the dissertation – namely, the issue of targeted resourcing and fragmentation in government programming, consistent priority-setting, critical mass and thickening of innovation networks and adequacy of venture capital, including late-stage capitalization. Given the extensive ground covered, the design of the interview questions did not include specific questions on the cases of Artificial Intelligence and pharmaceutical manufacturing. However, where respondents did have knowledge in these areas that did come to the fore. It need also be noted that the interview responses were of extraordinary quality, depth and insight as well as candour and often opened up a conversation about options and opportunities that needed to be pursued.

Survey of the “Triple Helix”¹⁸ Community: Implications of the Pandemic

Initially in the design of the thesis proposal, it was also intended to carry out a relatively small-scale survey of approximately 400 key government, industry and academic representatives in the innovation community in Canada to further strengthen research findings. Survey questions were to be similarly targeted towards the four lines of inquiry: continuity or discontinuity in

¹⁸ The term is employed by Etzkowitz (1998; 2003).

Table 1 Number of Respondents for Each Interview Question

Interview Question	Number of Respondents	Total Number of Interviewees
Q1. Canada's Biggest Challenge	53	54
Q2. Fragmentation of Government Programming	53	54
Q3a. Consistency of Priorities	50	54
Q3b. Budget 2017 and Superclusters	47	54
Q.4. Critical Mass	53	54
Q.5. Venture Capital	53	54

Canadian innovation policy over the 2000-2020 period; the robustness (or lack thereof) of government resourcing of innovation, perspectives on policy gaps that may have needed to be addressed for effective functioning of collaborative ventures within the triple helix; and the adequacy of venture capital in Canada. In the event, however, with the onset of the pandemic, this proved to be a bridge too far in terms of the possibility of assembling the numbers and organizations that could participate. As a result, however, the in-depth interviewee pool was broadened considerably to provide an additional measure of further robustness to research findings.

The Four Lines of Inquiry

Policy Durability and Priority-Setting

Moving on to the four lines of inquiry being evaluated in the dissertation and taking the policy durability element first, fundamental to the methodological approach has been a specific focus on the various priority-setting initiatives that the federal government has launched with

respect to science and technology, and innovation more widely – again from 2000 onwards. As such, the research reviewed all Throne Speeches, Budget documents (for the emphasis on certain priorities and not just resourcing) and strategic/framework as well as visionary documents that federal administrations have issued over the last two decades. The purpose of this exercise was to not only distill the priorities but to map whether there have been patterns of continuity in these efforts. Moreover, with respect to the implementation of innovation policy, there has been a specific focus on whether particular departments or government agencies have provided an institutional base and federal “voice” and indeed sustained directionality to S&T efforts.

This exercise has also necessarily involved delving into the archives of Innovation, Science and Economic Development (ISED) and formerly Industry Canada (IC) for key public documents that have been used to focus S&T and innovation resourcing and to frame national dialogue and debates. To round out this effort, it was also valuable to look at evaluations that have been undertaken by the Department around certain programs – particularly to determine whether there are relevant factors to be considered around issues of policy coherence.

It should be highlighted that the historical frame used to capture developments centred around the different political administrations over time – Liberal, Conservative and Liberal again¹⁹ -- and whether there were observable differences or continuities in approach and emphasis. However, this only functioned as a useful frame and, as will be seen, the research findings speak not only to particular patterns that have been emerged associated with different administrations but also to issues (as for example in the case of macroeconomic stability) where continuity between governments of different political stripes is readily observable. This is an

¹⁹ See Annex C – 2 on the respective party affiliations, Prime Ministers and terms of office of the various Governments of Canada during the period under study.

important dimension as the very notion of policy durability is one that transcends immediate political circumstances and orientation, and indeed politicking.

It is worth noting that initial discussions with practitioners in this field²⁰ had suggested the possibility of an alternative breakdown or framing of events. This would have centred first on a post-1995 period where the Canadian fiscal house was being “put in order,” a longer period following this focused on the “new knowledge economy” and its implications for Canada, and then more recent endeavours to directly stimulate innovation. In the latter case, this could have been seen as starting as early as 2010, with the commencement of the Jenkins Report (2011) or in fact could be aligned with more recent developments from Budget 2017 (Finance Canada 2017) onward around the import of innovation and “Superclusters.” However, it was decided that this lens might put too much of an economic policy cast on events and might occlude more nuanced aspects that did not fall within the strictures of these economic periods. Further, the timelines around when the “new knowledge economy” recedes and the emphasis on innovation begins would have been more complex to delineate. In the event, the framing around different government administrations does provide the openness to capture a broad array of developments on the science, technology and innovation front. This question aside, however, the research undertaken here relied on qualitative methods -- and was achieved through textual readings of the documents in question. As noted above, the in-depth interviews also informed this process and formed a valuable reservoir of information by which to further examine whether consistency in policy and priority-setting agendas and goals emerges.

²⁰ These discussions were initial exploratory efforts by the author and remain anonymous. The interpretation of these discussions is that of the author’s alone.

Targeted Government Resourcing of R&D and Innovation

On this issue, the research examined on what bases and to what level of funding this targeted resourcing can be found. Both the OECD (2015) and Canadian practitioner research (ACEG 2017; Expert Panel 2011; STIC 2015) point to two key areas in which targeted government funding can be critical to the success of innovation ventures. As such, the methodology drilled down on these areas, namely: *direct* government programming oftentimes supporting small business efforts and *indirect* or essentially non-designated forms of developmental tax incentives such as the Scientific Research & Experimental Development credit. Fortunately, both the data on direct and indirect funding is available not only through Government of Canada budgets, but also through OECD statistics, thus enabling a comparative perspective. Longer-term financial trends and relative proportions on these indicators have been analysed, particularly in the context not only of DNS but also international debate (Expert Panel 2011, 6-10 to 6-14; STIC 2015, 17) on the more diffuse benefits of tax credits. Especially relevant to this discussion on indirect funding is the OECD data on “indirect government support through R&D tax incentives as a percentage of BERD” (Chapter Five, Annex A - 3, Figure 8).

As for direct funding initiatives by government, the OECD’s Government Budget Allocations for R&D (GBARD) have also been examined. As GBARD may also include provincial and possibly municipal budget allocations,²¹ this indicator has also been triangulated with Statistics Canada data on explicitly federal Science and Technology expenditures over the years under study. Additionally – and a critical indicator of actual expenditures – annual Public

²¹It should be noted that, in terms of the OECD definition, the Government sector refers to “all units of central (federal), regional (state) or local (municipal) government ...” (OECD 2015, 100). However, it does exclude public corporations (which are incorporated into the Business enterprise sector), even if the Government has equity in these corporations or indeed even when the Government may own “all equity of such corporations.” Moreover, in the case of GBARD, local government allotments “may not be included” if not “deemed to be significant or if the data cannot be collected” (*Ibid.*, 323).

Accounts data on selected federal investments over the years has been mined. The Public Accounts data has proven particularly valuable not only in the case of targeted funding but in the case of initiatives around thickening innovation ecosystems as well for the AI and pharmaceutical manufacturing case studies.

Policy Incentives Thickening Innovation Networks

As noted in the theoretical chapter, the network concept in DNS is relatively thinly conceptualized -- based largely on brokering by government agents. As such, the emphasis in this research has been to develop indicators that can grasp the full richness of this concept, where ‘thickening’ of innovation clusters spanning industry, academe and government has occurred.

Towards that end, three methodological cuts into the issue were employed. Leveraging OECD, World Economic Forum and Statistics Canada data, the density of partnership and collaboration within key networks was analysed, particularly with respect to collaboration in patents, co-authored scientific publications and joint business, university and government initiatives and funding. To be sure, there are some particular challenges in accessing and evaluating cluster data. For one thing, there is a significant time break in the Stats Can data – and this is compounded by the lack of direct comparability in the indicators and specific questions for the innovation community which were used. Thus, while Stats Can did run a *Survey of Innovation* in 1999 (Statistics Canada, 31 January 2000), reporting on “frequency of collaboration” between the private and public sectors, later survey instruments were based on differing sources of information and/or differing methodological slices into the issue of collaboration. Thus, as will be seen in Chapter Six (Annex A-6, Tables 2 to 11),²² surveys at times were based on manufacturing or ICT service industries or even logging and manufacturing,

²² See also the discussion in Chapter Six: “Collaboration: A Patchy Landscape and Troubling Trends.”

although since 2014 the target groups have stabilized with the rollup of all industries within the North American Industry Classification System. So too have the measures for collaboration differed over time. Even the term *Survey of Innovation* was jettisoned in 2014 for *Survey of Advanced Technology* (Statistics Canada 11 December 2015), although that has since returned now to *Survey of Innovation* [and now] *Business Strategy* (Statistics Canada 26 March 2019; 26 April 2021).

That said, there were several ways of mitigating these methodological challenges. World Economic Forum *Global Competitiveness Reports* (2006-2007 to 2019) do provide cluster development and collaboration indices over the period from 2008-2009 onwards. The OECD (2017) also has unique time series data on collaborative practices. Moreover, despite its lack of continuity, Stats Can data does provide time points to assess the Canadian landscape on this issue. In this context, however, the in-depth interviews conducted in this study proved to be particularly salient.

Secondly, federal government funding of research networks, such as Networks of Centres of Excellence, Centres of Excellence for Commercialization of Research, and innovation “Superclusters” was assessed over the 2000-2020 time frame (gleaned through successive Budget announcements, annual departmental reporting, as well as a review of the Naylor Report (2017)). Specifics of the methodology employed can be found in Annex B - 2, Table 1²³ but central to this piece is annual departmental reporting. Funding has been specifically tracked through a meticulous exercise of reviewing all Industry Canada /Innovation, Science and Economic Development portfolio expenditures with respect to networking as indicated by the Program Activity Architecture in the annual Departmental Performance Reports or Departmental

²³ For ease of reference, the Table is replicated in Chapter Six but there is accompanied by the “Methodological Notes for Network Charts.”

Results Reports²⁴ over the 1999-2000 to 2019-2020 time period. This data was then triangulated with Public Accounts expenditures during these years, particularly important in that agencies within the portfolio are not reported upon in the annual departmental reports. Where any discrepancies exist, these are also duly noted. While such an exercise does not profess to access all possible cluster and networking funding at the federal level, the great preponderance of this lies within the IC/ISED portfolio, particularly given that the research councils, a number of relevant R&D foundations and third-party research institutes, as well as the NRC all fall within that portfolio's ambit. A review of Defence Research and Development Canada could have been used to supplement these findings but this proved to be extremely difficult to access given the security surrounding their activities.

Thirdly, the results of in-depth interviews and the case study evidence were critical components of the methodology for tapping into cluster activities. Not only did they indicate how network initiatives are perceived at the level of industry, government and academic leaders but the case studies also provided valuable historical evidence on the challenges and successes that Canada's innovation network landscape has witnessed. Indeed, the results of the interviews proved to be a particularly rich source of information in piecing together this part of the puzzle so to speak, given certain gaps in Stats Can data on this subject.

Policy Incentives and “Patient Capital”

For a robust operationalization of this concept, both public sector funding of venture capital *and* the capacity of public dollars to leverage private sector venture capital were examined. Successive budgets and annual departmental reports were used as data sources, as

²⁴ Nomenclature was Departmental Performance Reports (DPR) up until 2015-2016. Thereafter, they were called Departmental Results Reports (DRR).

well as reports by the Business Development Bank of Canada. Most critically, however, the OECD Venture Capital Investments data base provides fulsome international indicators of capitalization at every stage of development. As such, Canada's status with respect to VC investments as a percentage of GDP has been provided for start-up and other early-stage needs, later-stage venture capital and totals of all VC development stages. Additionally, the analysis has also included the names of countries not reporting either "stage" breakdown of investments or, as in the case of China, not reporting for VC at all. And while DNS, to a significant extent, does target the issue of late-stage capitalization, it is quite important to rely on these OECD categorizations, plumbing both early start-up capital and late-stage given the historic shallowness of the VC market in the Canadian context. Moreover, here again, the in-depth interviews were very valuable in terms of perspectives on this issue and the challenges with VC that remain.

Two Sectoral Case Studies: Artificial Intelligence and Pharmaceutical Manufacturing

Rounding out these quantitative and qualitative efforts – and in order to provide sectoral depth to the national focus of the research -- two case studies have also been undertaken.²⁵ The cases are selected to reflect an emerging and "enabling" area of innovation – Artificial Intelligence – and a more mature domain – specifically, pharmaceutical manufacturing. Moreover, both cases offer a compelling policy puzzle central to the thesis.

The case studies arguably are the most methodologically complex piece in the thesis with respect to carving out a distinct and comprehensive approach to understanding the various dimensions of the federal role in the case of Artificial Intelligence and pharmaceutical manufacturing. In turn, the case studies examined the extent to which there is evidence of three aspects at play in the thesis – priority-setting, targeted resourcing and thickened innovation

²⁵ OECD (2015) and Malerba (2005) point to the import of sectoral analysis for understanding innovation.

networks. Most critically, however, the case research undertook an in-depth inquiry into whether causal factors can be drawn from the analysis.

Economic Import of AI and Pharmaceutical Manufacturing Sectors

In the case of AI, this is generally deemed to be an “enabling and strategic” technology (CCA 2018, 2012; Naylor 2017), one central to innovation and to economic growth more generally. Canada is already well positioned in this arena, with both highly respected and lauded scientists (e.g, Geoffrey Hinton and Yoshua Bengio who shared the A.M. Turing Award in 2018 with Yann LeCun (<https://www.itworldcanada.com/article/canadian-godfathers-of-ai-win-2018-turing-award/416363>) and regional concentrations of research activity in Montreal, Toronto, Waterloo and to some degree in Vancouver. Moreover, the case is particularly interesting as the AI sector has of late experienced some deteriorating trends in performance with respect to publications as well as patents (CCA 2012, 94-96, 106-109; CCA 2018, 59-62; Naylor 2017, 40-43), thus potentially signalling some concerns around the sustained nature of innovation in this field.

In contrast, pharmaceutical manufacturing is a much more mature sector and one more indicative of Canada’s manufacturing base. However, while the industry had once witnessed in the nineties a very significant increase in Business Enterprise R&D investment -- primarily as a result of changes to patent law²⁶ – those BERD indicators have since undergone a decline (STIC 2013, 45; Figure 3, Annex A - 9, Chapter Nine). Indeed, pharmaceutical trends in R&D investment in many respects have tracked developments in Canadian manufacturing more generally and thus may provide clues to the larger innovation issues with which Canadian innovation policy is wrestling. Moreover, pharmaceutical manufacturing is closely aligned with

²⁶ See Chapter Nine, particularly “Patents and Protection: The Historical Experience” and “Innovation Indicators.”

traditional Canadian S&T strengths in medicine, stem cells and regenerative medicine (CCA 2012; 2013; 2018) and thus may hold implications for alignment between national and sectoral policies on both the industrial and S&T fronts.

The Policy Puzzle

With respect to AI, given its relatively thriving nature in Canada, one might expect to see evidence of policy initiatives that supported AI development – through consistency in policy priorities, or targeted resourcing or network thickening. If such evidence were found, this would support the arguments in the Developmental Network State framework – and that these policy conditions helped to induce growth of the sector and innovation. If there were no such evidence, then it can be argued this would work to falsify the arguments in the thesis. Conversely, in pharmaceutical manufacturing, given the deteriorating performance on R&D investment and innovation more generally, an absence of DNS conditions might have been expected. Should this absence not be found, *despite the decline in pharmaceutical performance*, then it would do much to falsify the arguments in the DNS.

Operationalization of the Case Studies

The “Quasi-Experimental” Approach

With respect to the assessment and operationalization of the case studies, the exercise was crafted to undertake a “quasi-experimental” approach (Campbell 1969; Cook and Campbell 1986), testing if governmental investments in three of the factors being studied – priority-setting, “targeted” resourcing and thickening of networks – affect rates of innovation. For pharmaceutical manufacturing, innovation indicators were tracked through the usual means of R&D investments – specifically this time as R&D-to-sales ratios given available data sets – as well percentage of BERD performed in the pharmaceutical industry and Canada’s number of

pharmaceutical patent applications to the USPTO. Quite fortuitously, R&D investments were available from 1988 onward and OECD data on BERD and patents from 1987 onwards. As for AI, here too patent applications to the USPTO were used although given the more recent emergence of AI, data was available from 2000 onward. However, statistics on BERD and R&D investment were not – or at least could not be located in the usual OECD sources. In their stead, another OECD measure, “Estimated VC investments in AI start-ups based in OECD countries, by year,” was used and, while the time series is more limited from 2012 to 2020, it is extremely current and evidences important trends. Also to be highlighted is that all datasets used included not only domestic trends but also international comparators, enabling a strengthened examination of Canada’s standing in these respective fields. Results from some of the in-depth interviews were used to round out the case study research, as was Government of Canada documentation on priority-setting around these two sectors.

With respect to the “quasi-experimental” approach taken, two methodological issues are raised by this approach – which the research does address. The first was the question of how to determine the time lag between the development of “basic” science to full commercialization. For that, we have drawn on Rosenberg’s respected contributions in this field (and his definitive challenge to both Schumpeter (1950 [1942]) and Kondratiev (1984) on the nature and timing of innovation). Rosenberg maintains that “in the twentieth century a gap of several years” characterizes this transition from science and “discovery” to full-scale commercialization (1994, 146). Drawing on this insight, the sectoral case studies have been designed to sample the impacts of innovation policies over *time* and while originally just five-year intervals were thought to be sufficient, in fact the availability of *annual* historical economic indicators in the dataset has made the exercise significantly more robust.

Secondly, the quasi-experimental technique also raises the question of introducing a case study or studies as control. While it would have been preferable to have a case study where no measures of investment had been introduced by the federal government and where innovation could be tracked in that context, it is unrealistic to assume over the last twenty years the government has not invested at some point in key industrial and hi-tech sectors. Moreover, areas such as pulp and paper or aerospace or oil and gas have their own externalities (competitiveness, trade issues, environmental concerns) that would undercut any leverage as controls. That said, what Campbell has argued that, in the absence of laboratory conditions or comparable units where policy measures have not been applied, “controls ... may also be separate samples of times or stimulus materials” (Campbell, 1969, 84). Further, it is maintained (*Ibid.*, 75-78; also Cook and Campbell, 1986, 155-161 on “selection-maturation”) that tracking the impact of measures over an “extended times series” can be an antidote to questions around research design. *Consequently, then, the case study comparisons have not only focused on the post-2000 period but have examined the 1987-2000 period to assess whether differences in innovation rates varied during a time period when the government was less exercised with innovation policy as such.* As for the 1987 starting point, as Chapters Eight and Nine will detail, this is not just an arbitrary cut-off but in fact signals the first government investment in AI as well as the first major policy push around pharmaceutical R&D investment. Thus, quite fortuitously as well there is a common time frame around these case studies.

Assessing the Federal Role

In order to access and assess the extent of federal engagement around these case studies several sources and approaches were leveraged. Firstly, there has been an extensive historical look at the federal role. This entailed weeding through a wide range of articles and reports by

research institutes, Parliament and government as well as what little academic sources were available. Additionally, in-depth interviews (while not specifically targeted at AI or pharmaceutical) did prove to a valuable resource in enhancing the study of this period.

Secondly, in terms of targeted resourcing, two prime sources were leveraged: Public Accounts data tapping into expenditures for the period under study and Budget data covering the same time frame. Fortunately, in both these cases all historical data is electronically available. Both dimensions are critical as the Public Accounts provides actual expenditures and details lapses where this may have occurred, while Budgets set out the plans and priority-setting of the government at the time. Of course these were also supplemented with other sources -- news releases, Prime Ministerial and Ministerial statements, annual reports of key research institutes and key framework and vision documents on the part of federal authorities. Thirdly, networking data for the case studies has been tracked, focussing on entities and agencies both for scientific advancement as well commercialization -- and federal investment pursuant to those goals.

Also worthy of mention and in efforts to corral the specifically federal role, the research undertook to peel away federal funding of the primary incubator for AI, CIFAR, in relation to provincial and private sources. Moreover, given recent activism by the Government of Québec on the AI front, the separate domains of federal and provincial involvement, funding, strategic visioning and intersection points has been examined. As for pharmaceutical manufacturing, the larger structural conditions of pharmaceutical multinationals and important global trends in which Canadian innovation policy has operated are also duly noted.

In short, the array of indicators and historical treatment are considered robust enough to test this “quasi-experimental” approach against the DNS framework and indeed, for the dissertation, this constitutes a critical element for evaluating the causal implications of federal

policy on these fronts. Further, given the very substantive importance of both AI and pharma at the current conjuncture, it also offers a vista into the future as to conditions propitious for innovation and growth.

Conclusion

In sum, then the methodology employed directly targets the research question and sub-questions which form the basis of the thesis. The logic behind the methodology was to leverage a wide battery of methods that could access historical and current documentation, statistical and economic indicators – particularly as they relate to Canada’s international standing on innovation -- and this study’s own data drawn from interviews targeted to the Canadian innovation community. The methodology also provided a reckoning of the national dimension on innovation with a detailed probe into two specific sectors and causal factors that could be drawn from that.

While the study of national innovation indicators and system – and the attributes of innovation policy – make for an exceedingly complex and interactive domain of study (Verspagen 2005, especially 509), the purpose here has been more singular. It is to lay bare the main trends and developments as they relate to the policy levers of the Canadian federal government and its consistent efforts since 2000 to target both the innovation gap in Canada and the factors that fuel it. Such is undertaken to test the robustness of the Developmental Network State framework.

Annex A – 2: Interview Questionnaire

Questions for In-depth Interviews

Introductory Remarks by the Principal Investigator

Canada has been consistently challenged by the innovation ‘paradox’ as Council of Canadian Academies called it. Canada continues to invest in Research and Development and a variety of reports and commissions and advisory councils have recognized that our S&T fundamentals are strong. However, our indicators on standard forms of R&D investment such as Gross Domestic Expenditures on R&D as a percentage of GDP or Business Enterprise Expenditures as a percentage of GDP are weak and closing the business innovation gap remains a challenge.

I have been looking at OECD data from 2000 onwards and Canada has seemingly been unable to positively impact our rate of innovation. Canada’s ratio of Gross Domestic Expenditures on R&D to GDP consistently dropped through these years from a high of 2.02 per cent in 2001 to 1.69 per cent in 2015 (and the same in 2016) and in fact 1.55 per cent by 2018.¹

Data on business enterprise investment in R&D tell a similar story - the gap is even wider with international comparator nations - about half that of the OECD average.

Questions for the Participant

You are uniquely positioned given your experience and background and current activities to assess these issues and trends around innovation.

1. In your view, what do you see as Canada’s biggest challenge in dealing with these realities and challenges?
And on the policy front do you think we are doing enough to address this?
2. One of the areas that reports throughout the 2000s – specifically, the Science Technology and Innovation Council, the Jenkins Report, the Advisory Council on Economic Growth -- have focused on has been the relatively fragmented nature of government programs and federal programming and the need to invest strategically.

Do you think these concerns are a fair appraisal of the challenges Canada has had with innovation policy?

3. Another area that has merited debate is the need for federal policy to consistently target key priorities around R&D investment and innovation.
 - a) Do you think federal policy has been sufficient in this regard?

¹ Note this data was retrieved from OECD MSTI on 12 January 2020 – as such it differs very slightly from Figure 1 in Chapter Three which was retrieved from the OECD on 3 November 2020. The OECD does at times make revisions.

b) It can be maintained that the Government of Canada's 2017 Budget Plan, particularly with the rollout of the Superclusters, set out to address some of these concerns and stimulate innovation.

Do you think with these initiatives we have finally begun to 'break the back' on this problem?

Are there other initiatives that are lacking that could further propel innovation in Canada?

4. An important incentive for innovation is the strength of critical mass and clusters of innovative activity – i.e., bringing together big corporate players, SMEs, start-ups, university researchers, venture capital and government labs in networks of innovation

a) Do you think Canada is doing enough to create that critical mass?

b) If the participant indicates that Canada is not doing enough, the follow-up will be:

So in your view what initiatives need to be undertaken, by government, business and universities?

5. One of the areas that several reports have commented on is the need for more venture capital (VC) for Canadian entrepreneurs – not only for injection of capital but also for the managerial expertise and networks venture capitalists can bring to the table. Moreover, one of the areas that is deemed to be most in need of VC is late-stage capitalization as firms expand.

Would you agree with this perspective? If so, what other measures do you think are needed to strengthen our capacity in this area?

Questions pour des entretiens approfondis

Remarques introductives de la chercheuse principale

Le Canada a toujours été mis au défi par le « paradoxe » de l'innovation, comme le disait le Conseil des académies canadiennes. Le Canada continue d'investir dans la recherche et le développement. Divers rapports, commissions et conseils consultatifs ont constaté que nos principes fondamentaux en ST sont solides. Cependant, nos indicateurs sur les formes de placement traditionnelles en RD tel que les dépenses intérieures brutes en recherche et développement en pourcentage du PIB ou les dépenses des entreprises en pourcentage du PIB sont faibles et il est encore très difficile de combler le déficit d'innovation des entreprises.

J'ai examiné des données de l'OCDE à partir de 2000 et le Canada n'a apparemment pas été en mesure d'influencer positivement notre taux d'innovation. Le ratio des dépenses intérieures brutes du Canada en RD au PIB a diminué de façon constante au cours de ces années, passant d'un sommet de 2,02% en 2001 à 1,69% en 2015 (et le même en 2016) et était à 1,55% en 2018.

Les données sur l'investissement des entreprises dans la RD nous racontent une histoire similaire – l'écart est encore plus grand avec les pays comparateurs internationaux – environ la moitié de la moyenne de l'OCDE.

Questions pour le participant

Vous êtes idéalement placé grâce à votre expérience et vos activités actuelles pour évaluer ces problèmes et tendances.

1. À votre avis, quel est le plus grand défi du Canada face à ces réalités et défis?
Et sur le plan politique, pensez-vous que nous en faisons assez pour y remédier?
2. L'un des domaines qui a été ciblé par des rapports tout au long des années 2000 – en particulier le Conseil des sciences, de la technologie et de l'innovation, le Rapport Jenkins et le Conseil consultatif en matière de croissance économique est la nature relativement fragmentée des programmes gouvernementaux et la nécessité de constamment fixer des priorités clés en matière d'investissement dans la RD et l'innovation.

Pensez-vous que ces préoccupations constituent une évaluation juste des défis que le Canada a dû relever avec la politique d'innovation?

3. Un autre domaine qui a mérité un débat est la nécessité pour la politique fédérale de cibler systématiquement les priorités clés en matière d'investissement en RD et d'innovation.
 - a) Pensez-vous que la politique fédérale a été suffisante à cet égard?

b) On peut affirmer que le plan budgétaire du gouvernement du Canada de 2017, particulièrement avec le lancement des supergrappes visait à répondre à certaines de ces préoccupations et à stimuler l'innovation.

Pensez-vous qu'avec ces initiatives, nous avons enfin commencé à « casser les reins » de ce problème?

Y a-t-il d'autres initiatives qui font défaut et qui pourraient dynamiser davantage l'innovation au Canada?

4. Une force incitative majeure pour l'innovation est la force de la masse critique et des grappes d'activités innovantes – c'est-à-dire le regroupement de grandes entreprises, de PME, de jeunes entreprises, de chercheurs universitaires, de capital-risque et de laboratoires gouvernementaux dans des réseaux d'innovation.

a) Pensez-vous que le Canada en fait assez pour créer cette masse critique?

b) Si le participant indique que le Canada n'en fait pas assez, la question de suivi sera : À votre avis, quelles initiatives doivent être entreprises par le gouvernement, les entreprises et les universités?

5. L'un des domaines discutés par de nombreux rapports est le besoin de plus de capital-risque (CR) pour les entrepreneurs canadiens – non seulement pour l'injection de capital, mais aussi pour l'expertise en gestion et les réseaux que les investisseurs en capital-risque peuvent apporter à la table.

De plus, l'un des domaines jugés les plus nécessaires de CR est la capitalisation à un stade avancé à mesure que les entreprises se développent.

Seriez-vous d'accord avec cette perspective? Dans l'affirmative, selon vous, quelles sont les autres mesures nécessaires pour renforcer nos capacités dans ce domaine?

Annex B – 2: Definitions and Parameters

OECD Definitions

All definitions cited here are directly sourced from the *OECD Frascati Manual 2015*, Annex 2, “Glossary of terms.”

BERD

Business enterprise expenditures on R&D (BERD) represents the component of GERD incurred by units belonging to the Business enterprise sector. It is the measure of intramural R&D within the Business enterprise sector during a specific reference period.

GBARD

Government budget allocations for R&D (GBARD) encompass all spending allocations met from sources of government revenue foreseen within the budget, such as taxation. Spending allocations by extra-budgetary entities are only within the scope to the extent that their funds are allocated through the budgetary process. Likewise, R&D financing by public corporations is outside the scope of GBARD statistics, as it is based on funds within the market and outside the budgetary process. Only in the exceptional case of budgetary provisions for R&D to be carried out or distributed from public corporations should be counted as part of GBARD.

GERD

Gross domestic expenditures on R&D (GERD) is total intramural expenditures on R&D performed in the national territory during a specific reference period.

GOVERD

Government expenditures on R&D (GOVERD) represents the component of GERD incurred by units belonging to the Government sector. It is the measure of expenditures on intramural R&D within the government sector during a specific reference period.

HERD

Higher education expenditure on R&D (HERD) represents the component of GERD incurred by units belonging to the Higher education sector. It is the measure of intramural R&D expenditures within the Higher education sector during a specific period.

Methodology Note: Thresholds

In terms of calculating the annual averages for the category of “top five countries” the author employed standardized thresholds. In the case where a country appeared in the top five when the data was sorted, *if the country was missing 25 per cent or more of the data entries* for the whole time series on that specific indicator, *the country was excluded from the top five*. The next country down with 75 per cent or more of the data entries for the time series was then used.

There was one exception to this in all of the research, involving the historical times series for the percentage of BERD performed in the pharmaceutical industry (Chapter Nine, Figure 3). As the data went back to 1987, many countries were missing data in the early years. As a result, the methodological standard for being excluded in this case was if the country was missing one-third of the data entries.

Finally, albeit only infrequently used, there was one other threshold employed. Where the average for the top five countries missed two data entries for that particular year, the average for that particular year was excluded. As an exemplar, here again this applies to the percentage of BERD performed in the pharmaceutical industry, where the average for the top five countries for 1987 to 1990 respectively as well as 2019 are excluded.

Table 1 Industry Canada/Innovation, Science and Economic Development Strategic Outcomes and Program Activity 1999-2000 – 2019-2020

Reporting Period	1999-2000	2000-2001	2001-2002	2002-2003	2003-2004	2004-2005	2005-2006	2006-2007
Strategic Outcome*	Improving Canada's Innovation Performance	Improving Canada's Innovation Performance	Improving Canada's Innovation Performance	Improving Canada's Innovation Performance	Improving Canada's Innovation Performance	An Innovative Economy	An Innovative Economy	An Innovative Economy
Program Activity	Increased recognition of innovation as a critical success factor in all sectors	Increased recognition of innovation as a critical success factor in all sectors	Increased recognition of innovation as a critical success factor in all sectors	Increased recognition of innovation as a critical success factor in all sectors	Increased recognition of innovation as a critical success factor in all sectors	Policy Sector – S&T and Innovation	Policy Sector – S&T and Innovation	Policy Sector – S&T and Innovation
Program Activity	Expanded knowledge base, especially in fields with good opportunities	Expanded knowledge base, especially in fields with good opportunities	Expanded knowledge base, especially in fields with good opportunities	Expanded knowledge base, especially in fields with good opportunities	Expanded knowledge base, especially in fields with good opportunities	Industry Sector – S&T and Innovation	Industry Sector – S&T and Innovation	Industry Sector – S&T and Innovation
Program Activity	Accelerated commercialization and adoption of innovative processes and products by Canadian organizations	Accelerated commercialization and adoption of innovative processes and products by Canadian organizations	Accelerated commercialization and adoption of innovative processes and products by Canadian organizations	Accelerated commercialization and adoption of innovative processes and products by Canadian organizations	Accelerated commercialization and adoption of innovative processes and products by Canadian organizations	Spectrum, Information Technologies and Telecommunications Sector -- S&T and Innovation	Spectrum, Information Technologies and Telecommunications Sector -- S&T and Innovation	Spectrum, Information Technologies and Telecommunications Sector -- S&T and Innovation
Program Activity		Increased development and application of eco-efficient practices and technologies in Canada	Increased development and application of eco-efficient practices and technologies in Canada	Increased development and application of eco-efficient practices and technologies in Canada	Increased development and application of eco-efficient practices and technologies in Canada	Communications Research Centre – S&T and Innovation	Communications Research Centre – S&T and Innovation	Communications Research Centre – S&T and Innovation
Program Activity						Technology Partnerships Canada – S&T & Innovation	Technology Partnerships Canada – S&T and Innovation	Technology Partnerships Canada – S&T and Innovation

Industry Canada/Innovation, Science and Economic Development Strategic Outcomes and Program Activity 1999-2000 – 2019-2020 (cont'd.)

Reporting Period	2007-2008	2008-2009	2009-2010	2010-2011	2011-2012	2012-2013	2013-2014	2014-2015
Strategic Outcome*	An Innovative Economy	An Innovative Economy	Science and Technology, Knowledge, and Innovation Are Effective Drivers of a Strong Canadian Economy	Science and Technology, Knowledge, and Innovation Are Effective Drivers of a Strong Canadian Economy	Advancements in Science and Technology, Knowledge, and Innovation Strengthen the Canadian Economy	Advancements in Science and Technology, Knowledge, and Innovation Strengthen the Canadian Economy	Advancements in Science and Technology, Knowledge, and Innovation Strengthen the Canadian Economy	Advancements in Science and Technology, Knowledge, and Innovation Strengthen the Canadian Economy
Program Activity	Policy Sector – S&T and Innovation	Science and Innovation Sector – S&T and Innovation	Canada's Research and Innovation Capacity	Canada's Research and Innovation Capacity	Science, Technology and Innovation Capacity	Science, Technology and Innovation Capacity	Science, Technology and Innovation Capacity	Science, Technology and Innovation Capacity
Program Activity	Industry Sector – S&T and Innovation	Industry Sector – S&T and Innovation	Knowledge Advantage in Targeted Canadian Industries	Commercialization and Research and Development Capacity in Targeted Canadian Industries	Information and Communication Technologies Research and Innovation	Information and Communication Technologies Research and Innovation	Information and Communication Technologies Research and Innovation	**
Program Activity	Spectrum, Information Technologies and Telecommunications Sector -- S&T and Innovation	Spectrum, Information Technologies and Telecommunications Sector -- S&T and Innovation	**	**	**	**	**	**
Program Activity	Communications Research Centre – S&T and Innovation	Communications Research Centre – S&T and Innovation	Communications Research Centre Canada	Communications Research Centre Canada***	***	***	***	***
Program Activity	Technology Partnerships Canada – S&T and Innovation	Industrial Technologies Office – Special Operating Agency	Industrial Technologies Office – Special Operating Agency	**	Research and Development Financing	Industrial Research and Development Financing	Industrial Research and Development Financing	Industrial Research and Development Financing

**Industry Canada/Innovation, Science and Economic Development Strategic Outcomes
and Program Activity 1999-2000 – 2019-2020 (cont'd)**

Reporting Period	2015-2016	2016-2017*	2017-2018*	2018-2019****	2019-2020****
Strategic Outcome*	Advancements in Science and Technology, Knowledge, and Innovation Strengthen the Canadian Economy				
Program Activity	Science, Technology and Innovation Capacity	Science, Technology and Innovation Capacity	Science, Technology and Innovation Capacity	Science, Technology, Research and Commercialization	Science, Technology, Research and Commercialization
Program Activity	**	**	**	**	**
Program Activity	Industrial Research and Development Financing	Industrial Research and Development Financing	Industrial Research and Development Financing	Companies, Investment and Growth*****	Companies, Investment and Growth*****

*From 2016-2017 onwards the ISED Departmental Results Report lists only Results and not Strategic Outcomes.

**Blank spaces indicate that the previous year's category of Program Activity is no longer listed in the DPR or DRR or is no longer listed under the Strategic Outcome associated with innovation.

In the case of Spectrum, Information Technologies and the Telecommunications Sector, this PA actually moved under the Strategic Outcome of A Fair, Efficient and Competitive Marketplace.

*** Between 2011-12 and 2013-14 Communications Research Canada Program Activity is rolled up under Information and Communications Technologies Research and Innovation.

In 2014-2015, the program then moves under Spectrum, Telecommunications and the Digital Economy which was housed under the Strategic Outcome of The Canadian marketplace is efficient and competitive.

**** In the Departmental Results Reports for 2018-2019 and 2019-2020, the term Program Activity is not used; rather the term Core Responsibility is used to describe initiatives.

***** This Core Responsibility includes the Strategic Innovation Fund

Annex C –2: Governments of Canada

Governments of Canada: Affiliation, Prime Minister and Term of Office

Political Affiliation	Prime Minister	Term
Liberal	The Right Honourable Justin Trudeau	2015-11-04 –
Conservative	The Right Honourable Stephen Harper	2006-02-06 – 2015-11-03
Liberal	The Right Honourable Paul Martin	2003-12-12 – 2006-02-05
Liberal	The Right Honourable Jean Chrétien	1993-11-04 – 2003-12-11

Source: Parlinfo, Library of Parliament, Parliament of Canada “Prime Ministers of Canada”
https://lop.parl.ca/sites/ParlInfo/default/en_CA/People/primeMinisters

Chapter 3

The Health of the Canadian Innovation System: Taking the Pulse

Introduction

In order to set the stage for an examination of the DNS framework in the Canadian context, essential to this exercise is an understanding and examination of the health of the Canadian innovation system – to take its pulse so to speak. For that purpose, two approaches are applied, both to get a sense of the manner in which this subject has coursed through national dialogue and debates as well as to probe the economic and statistical data germane to innovation for the two-decade period under study. Consequently, this chapter breaks along the following lines.

On the one hand, the chapter reviews the various expert panels, studies and reports undertaken over this period to get a perspective on how the innovation problematic was viewed and the key concerns that were identified. While critical and, while we will find it resonates with issues identified in the DNS framework itself, that in itself is not sufficient. Certainly, these various studies presented in-depth analysis and a vibrant examination of the innovation problématique, but for good reason they were differentiated by diverse mandates (commissioned as they were by the federal government), often different methodologies for data gathering and most critically, for our purposes, by different snapshots or slices in time. It is thus incumbent on this inquiry to also take a further dive into the strengths and vulnerabilities of the Canadian innovation ecosystem employing the battery of innovation indicators that have been laid out in the research methodology. Moreover, in keeping with the issue of time lags in innovation itself, and in ensuring a robust examination of the indicators, it is important to examine these for the 2000 to 2020 period or at least to when data has been accessible for the research process. Thus,

the chapter pivots on a kind of triangulation of the challenges and indeed prowess at times vested in Canada's innovation ecosystem, leveraging the extant studies and this dissertation's own inquiry.

Surveying the Canadian Innovation Landscape: Issues of Concern

Starting in 2007 and throughout the intervening years, Canadian public policy-makers have been witness to a series of in-depth analyses and assessments of this country's innovation ecosystem in its many dimensions. Topics have been many and extensive: Science and Technology, "fundamental" science, Research and Development and particularly Industrial R&D, government programming, connectivity and linkages among the ecosystem actors, venture capital markets, Canada's positioning in terms of global competitiveness, the country's economic relation to and dependence on the US and the implications that bears. Cutting through these various initiatives all, however, harboured more widespread reflections on Canada's innovation ecosystem in a highly competitive global context and, and where such mandates warranted, oftentimes carried specific recommendations to policy-makers by which to address the challenges faced.¹

To be sure, the various participants in these exercises had been charged with different mandates and have undertaken their respective initiatives at different times. The Science, Technology and Innovation Council (STIC) had been created in 2007 to function as external advisors to the Government of Canada, a mandate that encompassed both confidential advice on ST&I and regular reporting on the "State of the Nation," i.e., "measuring Canada's ST&I

¹ The Science, Technology and Innovation Council (STIC) issued reports on a biannual basis from 2008 to 2014 (STIC 2009, 2011, 2013, 2015); also the large number of publications by the Council of Canadian Academies on S&T, the state of Industrial R&D in Canada, on innovation and on Canada's position within the global economy (CCA 2006, 2009, 2012, 2013a, 2013b, 2017, 2018); Competition Policy Review Panel (June 2008); Review of Federal Support to Research and Development – Expert Panel Report (2011), (Jenkins Report); Advisory Council on Economic Growth (ACEG) (2017a, 2017b); and the Advisory Panel for the Review of Federal Support for Fundamental Science (2017), (Naylor Report).

performance against international standards of excellence” (STIC 2013, iii). And while STIC’s commission lasted until 2014, so too in 2007 was the Competition Policy Review Panel struck to investigate for the Minister of Industry the country’s “competition and foreign investment policies” and the solutions that could enable country to be “more competitive” (Competition Panel 2008, 1). Distinctly different, the charge for the Jenkins Report in 2010 was a “comprehensive review” of federal support to R&D and the implications of that for innovation in Canada (Jenkins 2011, E-1). Less than a decade later the Advisory Council on Economic Growth was mandated to investigate the innovation issue and how it could be “unlocked” to “drive scale and growth” (ACEG 2017).

Throughout these years as well, the Council of Canadian Academies (CCA) produced an array of extensive reports on the state of S&T in Canada, Industrial R&D and a specific analytic dive into the issue of *Innovation and Business Strategy: Why Canada Falls Short* (CCA 2009) which focused on longer-term fundamentals and not just the impact of the Great Recession. Established in 2006 as an independent think-tank and at arm’s length of the government (although receiving a ten-year funding envelope in 2005)² unlike the other bodies it did not produce public recommendations, but their analyses speak to issues regarding the long-term fundamentals in the Canada innovation ecosystem. More recently, the Naylor Panel (2017) has also been tasked with a review of Canada’s “fundamental science.” While, admittedly, this is a somewhat different charge from the other bodies, the policy issue of basic or “fundamental” science to innovation remains as critical a debate and area for scholarship since Vannevar Bush’s earlier musings on this subject in 1945³ (and the causal relations then perceived between research

² CCA 2013 2006 indicates GOC funded CCA with ten-year funding for \$30 million – to function at arm’s length from GOC.

³ While Bush’s thinking on the linearity of moving from basic science through R&D to innovation has of course since been challenged on many fronts – particularly that the relationship is not static but in fact a dynamic process --

and innovation). Finally, and most recently in the wake of COVID-19, the government in 2020 created the Industry Strategy Council (ISC) to take stock of the economic situation and specifically the “impact” for industry implications and opportunity (ISC 2020).

With the exception of the Naylor Report and the Industry Strategy Council and their respective separate tasking, however, central to all these studies are the critical linkages and feedback loops among S&T, Industrial R&D,⁴ innovation and Canada’s “economic prosperity.” Further, with remarkable consistency and consensus in their analytics and conclusions as well as ask – and for most a keen awareness of the others’ contributions to this national dialogue -- these reports zero in on both the strengths and (many) weaknesses of Canada’s innovation ecosystem.

Certainly, the clear consensus among these reports, panels and studies throughout this period was that in terms of investment in R&D, Canada’s position was in fact deteriorating relative to other nations. STIC’s review of the data in their 2012 report showed that, with respect to Gross Domestic Expenditures on R&D (GERD) as a percentage of GDP, Canada had fallen from sixteenth among OECD members in 2006 to twenty-third by 2011 (STIC 2013, 10). Similarly, several years later the CCA pointed out that the country’s performance on R&D intensity -- GERD as a percentage of GDP -- had “consistently declined” between 2001 and 2015 (CCA 2018, 11).⁵ Nor did any of these reports at the time mince words concerning this situation. There was no “burning platform” for firms to adopt innovation (ACEG 2017, 5); firms needed to be opened up to the brisk gales of international competition (Competition Policy Review Panel

his contribution to public policy on the criticality of science to innovation and a nation’s economic and social progress was enormous. His work, *Science, the Endless Frontier, A Report to the President on a Program for Postwar Scientific Research* (1945) was instrumental in the creation of the National Science Foundation in the US in 1950. Not surprisingly, the Naylor Report (2017) does quote Bush in their reflections on the import of basic “curiosity-driven science” and investigator-led research. This is not to suggest in any way however that the Naylor Report articulates a view that assumes linearity in the innovation process.

⁴ CCA (2013) refers to Industrial R&D and they probe this issue on a variety of indicators. However the OECD measurements they use for this are BERD, see especially 13-49.

⁵ See also the discussion of R&D in *Ibid.*, 10 - 19.

June 2008);⁶ and business investment in R&D Canada by 2015 had fallen to 22nd among OECD nations (ACEG, 5) – essentially a “middle of the pack”⁷ ranking. As for the Conference Board, they were in fact more scathing in their assessment – originally giving Canada a D in their “report card” on the state of innovation and more recently moving to a C, based on an inclusive methodology comparing Canada to a host of other nations.⁸ Furthermore, over these years, the messaging from the various panels and reports consistently heightened in concern, initially recognizing the economic events of 2008-2009 were impacting factors and that a longer-term view about getting the fundamentals right needed to be taken. Several years later the tone was much more intense. STIC (2015, 2) found the evidence and the “performance story” “disturbing,” despite efforts to address investment. By 2018, the CCA had an even more potent messaging: not only had Canada reached a stagnation point in its R&D⁹ but the investments that Canada had *previously* been made in R&D were in fact at risk. As the Message from the Chair noted:

... while Canada’s performance in R&D has retained momentum gained from prior investments, its future is now jeopardized by both relatively low levels of R&D and by the propensity of successful Canadian innovations, entrepreneurs, and researchers to leave the country to pursue opportunities for commercialization and growth elsewhere (CCA 2018, viii).

As we shall see below the response to this less than healthy state of the innovation ecosystem was for strong recommendations addressing federal programming, “risk capital” and the import of clusters and “innovation marketplaces.” But what is particularly arresting about reviewing this practitioner literature is how consistent the warnings were and the repetition with

⁶ A slightly more muted form of this argument can be found in CCA (2018).

⁷ The Jenkins report initially used this phrase (Jenkins 2011, 1-2) but the phrase is later used by STIC (2015, 2) as well.

⁸ See Conference Board of Canada (2018), *How Canada Performs*.

⁹ CCA (2018, 12). See their reference to GERD and their assessment that “Canada is one of only a few OECD countries ...with a compound annual growth rate close to 0% for this time period” [2006 and 2015].

which they occurred. Moreover, equally at issue – as our inquiry later in the chapter will illustrate – was how tenacious the decline was in Canada’s investments in R&D and on a host of ancillary innovation indicators.

Federal Government Programming for Business Innovation

As has been indicated, one of the key themes that emerges in these studies and reports is the need for direct support to business on the part of government that would be targeted and strategic. The Jenkins Expert Panel, mandated in 2010 specifically to review federal support to R&D and to “optimize the contributions of the Government of Canada to innovation and related economic opportunities for business” (Jenkins 2011, E-1) particularly took this issue on. Calling for a total reboot of the organizational machinery needed to coordinate federal programming in this arena, the Expert Panel squarely critiqued the government on a number of fronts. Federal efforts were characterized by a wide and diverse plethora of programs – sixty in all -- which were lacking in co-operation and co-ordination not only among departments and agencies within the federal house, but as well with provinces and territories. Business enterprises, particularly SMEs, found the fragmented nature of programming particularly “bewildering” as they attempted to “navigate” its shores (*Ibid.*, E-8). Most critically, a “clear business innovation mandate” housed under one entity and with focused priorities were needed to overcome the existing situation.

Further, while the Expert Panel had been mandated to assess the relative “effectiveness” of the various programs, they found the comparative evaluation “tools” for such an assessment were missing. As they noted, “standardized performance and outcome indicators do not exist for the roughly \$5 billion of business innovation programs in the review, and the supporting

information is not retained in a common form or database” (*Ibid.*, 5-1).¹⁰ Nor was it possible to provide an assessment of indirect versus direct business support on the part of public policy, for here too the bases for comparison were wanting.

As a result, the Panel’s recommendations on this issue cut a wide berth, calling for a new Industrial Research and Innovation Council (IRIC) which would in fact have that targeted and “clear business innovation mandate,” and “sharply focussed mission” (*Ibid.*, E-9). The new IRIC would house a number of initiatives needed to address critical gaps in the innovation continuum, including the Industrial Research Assistance Program, a “commercialization” focus and associated pilot, assistance to firms in accessing programs that fitted their needs as well as the development of a talent strategy that could provide firms with the type of R&D and managerial personnel they required. Programming was to be streamlined and “consolidated” and most critically government and program delivery agents would be equipped with the means to assess effectiveness and “impact” of efforts that were being undertaken. All of this was to operate within the context of a “whole-of-government” approach on innovation policy and the federal government was to assign clear ministerial responsibility for the portfolio which could enable the federal house to speak with “a clear federal voice” (*Ibid.*, E13 and 8-4, 8-5).

While the extensive machinery overhaul recommended were not taken by the government of the day – at least not on this front -- several years later the Advisory Council on Economic Growth (2017) similarly recommended the need to “rationalize” government’s federal innovation programs, also echoing the concerns about firms’ ability to access the broad number of programming initiatives and the “sometimes duplicative” nature of the programs themselves (ACEG 2017, 29-30). The ACEG did not engage in a recommendation for a large-scale

¹⁰ See the extensive discussion on this issue (*Ibid.*, 5-1 - 5-18).

machinery of government approach but their messaging was clear. For too long the federal government had allowed a disparate range of initiatives that were not addressing Canada's innovation gaps and challenges, particularly those around business investment and commercialization. As we shall later see it would only be in 2017 that the call for rescaling, consolidation and a targeted mission around innovation would evoke a clear response on the part of government and the machinery around this was put in motion. Nevertheless, it is worthy of note that the Industry Strategy Council recently established by the government in 2020 in the wake of COVID, has continued to join the refrain. More specifically, it has called for a reboot -- the need to "[r]ecapitalize, expand, and modernize key government programs" in order to incent business investment and innovation (ISC 2020, 37-38).

Risk Capital

As with the question of directed government programming, equally significant, the availability of equity financing or "risk capital" was deemed to be a key factor impeding innovation in the Canadian case – or as the CCA indicated in "translating technological innovation to wealth creation." Commissioned reports and studies throughout the 2000s, at least until 2018, consistently found that equity financing on a very wide range of indicators was not as fulsome or robust, or as structurally sound, as the case in other comparator nations. As well, for most of the 2000s, this challenge continued to revolve around both early-stage angel financing critical for start-up firms as well as later-stage venture capital funding that could contribute to growth of anchor firms and exploitation of IP assets.

The blunt assessment by these various reports, particularly captured in the unvarnished words of the Jenkins Report, was that equity financing was "subscale" (Jenkins 2011, 7-13).¹¹

¹¹ Also see on venture capital (STIC 2009, 2011, 2013, 2015; CCA 2013 and 2018; and ACEG 2017).

Characterized by fragmentation, diffusion, underinvestment and poor performance, these deep-seated issues were creating a “vicious cycle” (*Ibid.*, 7-13)¹² where high-growth firms did not have access to sufficient capital and venture capital firms in turn were not getting competitive returns on investment. The Jenkins Report was particularly pointed on this issue, noting that by 2011 the situation had led the Business Development Bank of Canada to conclude that the Canadian venture capital industry was actually “broken.”¹³ Admittedly, this conclusion followed the 2008-09 Great Recession but the venture capital market in Canada exhibited historical trends that went well beyond cyclical undulations. As the CCA in 2009 also adeptly summarized, Canadian VC firms were “significantly smaller than their U.S. counterparts, raise[d] smaller funds and ma[d]e smaller investments” (124).¹⁴ Neither for the critical “angel” stage which was required to cross the “valley of death” to commercialization, nor the important expansion stage that was seen as leading to growth and “wealth creation,” was Canadian equity financing the requisite “breeding ground” for success (*Ibid.*, 119). And while some years later there was growing evidence that equity financing was improving for angel capital and the start-up phase, nonetheless sub-optimal trends did continue. Indeed, by 2016 when the Canadian VC market had experienced its “seventh straight year of ... growth” average Canadian deal sizes stubbornly remained at twice less than that in the US (CCA 2018, 158-159).

Needless to say, these conditions contributed to the anomaly of Canada ranking second in the OECD on the number of firms receiving VC investment in 2009 but ranking twenty-first in average deal size in that year. The Jenkins report particularly zeroed in on this phenomenon, noting that between 2003 and 2011, private VC funds “disclosed” 255 technology related deals

¹² Jenkins is actually referencing a BDC report.

¹³ BDC, *Venture Capital Industry Review* (2011). See the discussion of this issue in Jenkins Report, 2011, 7-11-7-20.

¹⁴ See their extensive discussion of this issue, CCA 2009, 119-135.

over \$10 million, with Canadian funds accounting for only about one-third of the deals in the \$10 - \$20 million range and accounting for *none* of the deals above \$40 million (Jenkins 2011, 7-16). In addition to being diluted over a large number of firms and posting low dollar investments, Canada VC also directed more of its efforts toward the start-up and early stages, and languished on the equally critical dimension of late-stage expansion firms. By 2016 not only were later-stage deals in the US found to be 71 per cent larger than comparable deals in Canada, but later-stage deals in the Canadian case had fallen 35 per cent in size from 2013 levels (ACEG 2017, 18-19).

All of this of course resulted in strong recommendations (both by Jenkins and the Advisory Council on Economic Growth) for public policy to incent more robust and aggressive capital mechanisms not only for angel investment but also for the equally critical later-stage venture capital. For smaller deals, there was to be a BDC-funded angel “sidecar” that could “ride along” private investment (Jenkins 2011, 7-17 – 7-20). So too was there was a need for a BDC-driven substantial injection of funds that could leverage private dollars (*Ibid.*, 7-17) or at least a public brokering role which could help realize a “business growth fund” (ACEG 2017) – either of which would be targeted at investments over the \$10 million threshold.

Admittedly, as we shall see, more recently there has been developing a healthier environment for start-ups and several new funds with a variety of mandates and investment sources are starting to be put in place. Further, Canada has risen on the OECD ranking with respect to VC as a percentage of GDP,¹⁵ though these developments have been underpinned not only by more aggressive growth on our part but also by falling VC levels in Europe. Be that as it may, what the various studies and reports throughout this period demonstrated was the critical

¹⁵ See the discussion in Chapter Seven, particularly “Availability of Venture Capital: The Trends.”

significance of the VC market in Canada and the challenges capital availability posed for critical stages in the Canadian innovation ecosystem.

“Connectivity”¹⁶ and Clusters

Finally, of note in this review of practitioner evidence were the insights regarding linkages across the innovation system. STIC in particular in each report they issued warned that that collaboration across the “three pillars” of the innovation eco-system was lacking and the system was not functioning holistically, a factor which they clearly saw as a drag on innovation. Firms were not engaging in sufficient collaboration among themselves or with public partners. In manufacturing for the period between 2001 and 2004 Canada ranked twenty-fourth among OECD countries on this measure – and the country’s limited collaboration spanned the private sector (firms with other firms), as well linkages with Higher Education Institutions (HEI) and government research institutions (STIC 2009, 27). True, STIC did not always consistently report on collaboration measures throughout these years, sometimes using survey data and other times OECD rankings. But the picture was clear. The necessary knowledge transfer from universities as well as government labs to business was not occurring to the extent needed – not through research partnerships or collaborative “innovative activities” that “joint[ly]” developed “new products, services or processes” (*Ibid.*, 27), nor through licensing, nor via technology spin-offs that could exploit the full potential of IP. Moreover, the issue was applicable not only for small firms but for large as well.

To be sure, the Council acknowledged that straight-up quantitative indicators limited understanding in this field. Essentially, not enough was known about the collaboration process itself and numeric counts while useful did not give insight into best practices, or failures, or what

¹⁶ The term is used by ACEG (2017, 5).

was successful in different industry sectors. Moreover, throughout the years of their reporting they highlighted successful “clusters” where linkages between “science” and “business” were systemic, integrated and focused on clear goals, initiatives such as Montréal’s “Biotech/Pharmaceutical Cluster” (STIC 2009, 28) or Waterloo’s Perimeter Institute for Theoretical Physics (*Ibid.*, 30).¹⁷ But these were exceptions.

The Council was direct, even unabashed, in their conclusions -- and theirs had been a consistent message throughout their tenure. While acknowledging that public policy could be formative in fostering “cluster growth” (2009, 28), the heavy lifting was to be done by all “players” in the system, public and private alike.¹⁸ They needed to step up and “assume responsibility” enhancing collaboration and intensifying the linkages that could overcome Canada’s “chronic challenges” in knowledge transfer and commercialization.¹⁹ The lethargy and “complacency” (STIC 2013, 3) that inhabited the system needed to be excised. “Critical mass” with firms, HEIs, VC and government labs need to be assembled and concentrated in loci of activity to enable successful innovation and growth, and the balance sheet for all of this would be in addressing Canada’s the innovation gap across Canada’s BERD investments. STIC did not lay out the specific detailed policies required on the part of public actors but taken together their recommendations for closing the innovation gap, embracing “risk” and “ambition,” leveraging

¹⁷ See discussions on collaboration in STIC (2009 9-12; 26-30); (2013 19-25 and 103-104) and (2015 1-4 and 41-44).

¹⁸ On this issue see the respective discussions in STIC (2009, 1-4; 2011 5, 9-10; 2013, 101-104; 2015 1-4 and 41-44). As they conclude in their *State of the Nation* 2014 report:

“All ST&I players share responsibility to reverse Canada’s poor business innovation performance and grow its knowledge and talent advantages. Effecting change is demanding and complicated; but the need is urgent and compelling. Only with concerted action can Canada achieve the ST&I success needed to secure our future.” (STIC 2015, 4).

¹⁹ The reference to these chronic challenges is in STIC 2013, 2; also see their analysis of the issues around knowledge transfer, *Ibid.*, 69-76.

public dollars to build global leadership in “targeted areas” were designed *in toto* to strengthen the integration and holistic functioning of Canada’s national innovation system.

However, it was the Advisory Council on Economic Growth which recently took on this issue full force. Arguing for a bold initiative by private and public sector alike, they argued what was needed in Canada’s innovation system were “innovation marketplaces.”²⁰ Designed to address the gaps in Canada’s innovation continuum, to create a platform for global scale-up and to address the “complacency” in business investment that sustained a “low-innovation equilibrium” (ACEG 2017, 5) these innovative marketplaces were to be centred around “clusters” of strength with dense forms of connectivity. It was to be modelled on such international approaches as the American ARPA-E – itself a spinoff from the original DARPA efforts. The marketplace would target common sectoral and “business challenges” and coalesce around an array of prestigious research institutions, large anchor firms, start-ups and established SMEs, government labs or institutes, and of course VC firms. All the main stakeholders in the innovation environs would be active, creating a tight chain of commercialization and “early adoption.”

The Council was quite specific about the nature of such an initiative, and there were tightly defined roles for private and public entities alike. While the marketplaces were to be driven – or in fact “pulled” by market forces, nevertheless, the role for public policy was critical. The latter would be instrumental in incenting stakeholders to coalesce around common goals and would provide funding as initiatives moved through a gated process based on strict evaluation criteria and measures of success. All told, the Advisory Council’s recommendation was testament to the importance of collaborative linkages and clusters of networks that could enable

²⁰ See Advisory Council on Economic Growth (2017), 2-5 and 8-16 on their analysis and recommendation regarding innovation marketplaces, including the specific gating process involved which is noted below.

“research capacity,” create supply chains with first users and most critically advance commercialization and overcome the sub-optimal forces that were preventing Canada from reaching global “scale.”²¹ Moreover, it is hard not to discern the makings of the Superclusters that were later announced in Budget 2017.

The Practitioner Perspective: An Assessment

Despite these key thematic currents within their respective analysis, this is not to suggest however that there was a monolithic approach to the problematic of innovation and related S&T, R&D or competitiveness that coursed through these studies. To be sure, *Compete to Win* undertaken by the Competition Policy Review Panel (2008) was particularly seized with the imperative of opening up the Canadian economy to more robust competition on a number of policy fronts, as a catalyst to innovation. And while the CCA focused on the traditional barriers that impeded our innovation process in Canada, they too echoed these competitiveness concerns, actually assigning the label of “fat-and-happy” (CCA 2013, 145) at one point to describe Canadian business at one point. As the CCA argued, healthy profit margins and an economic environs less exposed to global competitive pressures insulated Canadian business from undertaking the substantive investments in R&D that fuelled the innovation and commercialization process.²² Moreover, in a seminal article in 2016, the then inaugural president of the CCA, Peter Nicholson, argued that Canada has been characterized by a “low-innovation equilibrium” now challenged by the “tectonic forces” of global competition. Similarly, did the Naylor Report chart its own course, focused as it is on returning to appropriate

²¹ On the import of scaling, see especially *Ibid.*, 4-5

²² These were recurring themes by the CCA but see especially 2009, and the respective conclusions in 2013 and 2018.

governance and funding models for “basic science” and finding a better balance between creative discovery and publicly-directed priorities.

Moreover, while there was ample identification of the challenges facing the country, it is important to point out that many of the studies of this era also recognized the “solid foundation” of “talent and knowledge production” – indeed the bedrock of science -- (STIC 2009, 2011, 2013, 2015; Jenkins 2011) on which the Canadian innovation ecosystem rests. On a range of indicators the studies spoke to the Higher Education Research and Development (HERD) expenditures and performance that were testament to the “excellence” -- including magnitude, impact and growth -- of Canadian S&T fundamentals. Further, this played itself out on global rankings with Canada placing second in 2006 on the OECD HERD intensity indicator (STIC 2008, 30) and then dropping off somewhat as other nations invested more aggressively in Higher Education R&D. Still, even with some modest fluctuations, by 2014 Canada ranked as seventh in the OECD in terms of its HERD-to-GDP performance (largely behind Scandinavian countries) and ranked as first in the G7 (Naylor 2017, 33). Notably, here again, there was not full concurrence on this issue, with the Naylor Report in particular pointing to trends of erosion in traditional scientific fields in which Canada held international respect (and a topic discussed in more depth below). Yet, despite such differences what particularly strikes the student of innovation and public policy is still a remarkable concurrence inherent in these studies whether focused on streamlining and directing federal programming, proffering recommendations that would course-correct for all parties in in the innovation system or taking on public policy initiatives that would open business up to risk and ambition – and move Canada into the ranks of leader in an international context.

Interestingly, though these themes are easily discerned in this body of practitioner analysis and study, with respect to mission-oriented research the picture is much less clear. The latter was not a domain that was extensively tackled by the panels and reports throughout this time period, at least not to the extent that other issues coursed through the considerations of this period. True, CCA queried the “limited alignment” they found between Canada’s S&T strength, IR&D strength and areas of economic prowess.²³ Further, all efforts through these years voiced a concern for “strategic” and “coherent” investments by the array of actors in the innovation ecosystem. But as for the type of DARPA-inspired mission-oriented research that the DNS pulls from -- with sustained public policy engagement on critical path goals that led to technology breakthrough and commercialization (be it in defence, or ICT or pharma) – the Canadian work we have reviewed does not engage on this level. That said, however, the studies and considered recommendations of this period in large part did speak to a fragmented innovation landscape.

The Health of the National Innovation System: Critical Indicators

As noted at the outset of this chapter, in order to compensate for the different mandates and methodological approaches employed throughout these various studies, as well to update the data and at times broaden the approach taken, the intent has been to undertake a further inquiry into the state of the innovation ecosystem. To be sure, some of the studies in question often did cover extensive ground. With respect to the Science, Technology and Innovation Council (STIC), these reports spanned 2008 to 2012 and indeed, in the case of the Council’s *State of the Nation* for 2008, engaged in a brief retrospective on R&D displaying 1997-2007 data (STIC 2009, 15). Moreover, with respect to the issue of knowledge creation (discussed below), this

²³ CCA 2013, xv – xvii, 127-148 and especially 130-138.

inquiry has also relied on data gleaned from the Council of Canadian Academies and the Naylor Report.

That duly noted, however, what follows is a dive into critical indicators on the health of Canada's innovation system, using standard aggregate data²⁴ and stretching from 2000 to the latest data available at the time our research accessed the OECD databases which in most cases runs to 2018 or 2019. To briefly recap (following the discussion in Chapter Two), indicators are clustered under the following fields:

- Gross Domestic Expenditures on Research and Development (GERD) and its components:
 - o Business Enterprise Expenditures on Research and Development (BERD),
 - o Higher Education Expenditures on Research and Development (HERD) and
 - o Government Expenditures on Research and Development (GOVERD)
- Innovation indicators related to investment in Information and Communications Technologies (ICT) and Artificial Intelligence (AI);
- Knowledge creation as expressed through standard bibliometric measures, as well as on numbers of Research and Development researchers in Canada;
- Knowledge transfer as expressed through a range of data on patents.

Collaboration across industry, academe and government as expressed through a range of indices, as well as capitalization as expressed through venture capital (VC) standings are presented in Chapters Six and Seven respectively. Aggregate data for the case studies of Artificial Intelligence and pharmaceutical manufacturing can be found in Chapters Eight and Nine.

It is to be acknowledged that even with this array of indicators, this is still a limited – albeit significant -- list in terms of the wide breadth and depth of measures available for innovation. (See OECD *Frascati Manual* (2015a), *Oslo Manual* (2018b), *Main S&T Indicators*

²⁴ See OECD *Frascati Manual* (2015a) and *Oslo Manual* (2018b).

(<https://www.oecd.org/sti/msti.htm>), the various *Scoreboards* (2007, 2009, 2011, 2015, 2017) and *Digital Economy Outlook reports* (2017, 2020). However, it draws from the OECD's standard measures and data bases and has made a concerted effort to capture the most salient expressions of national innovation. The intent here is to lay the economic background for testing the DNS framework and reflect the continuing challenges around innovation for Canada -- not to focus on the full variety of indicators that track Canada's R&D and innovation trends. Nor is there any intent to undertake a specific analysis or examination of these indicators as they link back to the unique industrial structure of Canada beyond key observations made by commissioned studies to date or by perspectives articulated in the 54 in-depth interviews with senior innovation leaders across the country. The main thrust of this thesis remains focused on the variables associated with the DNS paradigm.

Rather, what has been specifically undertaken is a review of the data on the above indicators which focuses on the period from 2000 to the latest data available, with a cut off of 2020 for the time series. In most cases, the full data set runs to 2018, although as will be seen, frequently Canada did have 2019 entries. Tracking occurs on annual basis. Additionally -- and as earlier laid out in the Methodology chapter as well -- the analysis turns on several key features. Following the basic principles behind STIC's approach on this question on most indicators Canada's position vis à vis the five leading OECD nations, or where relevant, non-OECD nations have been identified.²⁵ This has been complemented with indicators for OECD totals, EU (28 nations) or where the OECD has so indicated EU (27),²⁶ as well as China given its astonishing growth for the past two decades. Finally, for the purposes of comparison, generally

²⁵ See STIC 2013 and 2015. We are not just focused on OECD comparator nations however. Current OECD data in the *Main Science and Technology Indicators*, as noted below, enables us to examine non-OECD countries as well which is critical for the case of China.

²⁶ There are a few cases where this reflects EU27.

included as well is the data for the leading country on any particular indicator in order to give a sense of Canada's relative standings – and oftentimes quite disparate proportionality. Where the US or China is the leading nation on a specific indicator, the graph is simply presented in that manner and specific data on a second ranked nation is not provided. Rankings for the leading country and for the top five nations have been identified on the basis of an average over the time period in question, calculated by the author, except where otherwise specified. In certain cases, constant dollar expenditures (as provided by the OECD) have been reviewed to give a sense of progress or lack thereof – something that is particularly germane to the Canadian case given the investments undertaken over the years in Higher Education and in government-funded R&D.

While it is recognized that there could have been more detailed approaches, this array of indicators is a valuable cut into the data, taps into a wide array of issues and of equal significance gives a valuable historical perspective. Finally, in using OECD data sets, there is the great advantage not only of consistent time series data but access to OECD and non-OECD nations as well. OECD also provides indicators of critical time series breaks or new statistical definitions which can skew the data. More specific methodological notes can be found in each of the Figures presented in Annex A - 3.

GERD and Its Components

Consistent with the studies previously undertaken on this issue, GERD intensity for Canada (Figure 1)²⁷ -- i.e., R&D expenditures as a share of GDP – has been on a consistent downward trend since the country topped out at 2.02 per cent in 2001 at the peak of the high-tech boom. Even then Canada's GERD as a percentage of GDP was less than half of the leading nation – Israel -- but nevertheless the country was a relatively strong contender coming in very

²⁷ Unless otherwise specified, Figures referenced in this chapter are located in Annex A - 3.

close to the OECD at 2.14 per cent, above the EU average at 1.69 per cent and within closing distance of the US at 2.65 per cent. However, these gaps have consistently widened both with the US and OECD, as well as with the five leading countries. As for the EU, GERD data here has been marginally higher than that of Canada's since starting in 2011. Perhaps most critically by 2018 Canada's R&D intensity had fallen to 1.56 per cent and then to 1.54 per cent by the following year (although the latter admittedly is provisional data). All of this is reflected in international rankings where the country has consistently been in "middling" territory and which experienced a decline as well. Specifically, for the 2000-2018 period among OECD nations Canada stood at 17th with an average of 1.82 per cent for the full time series.²⁸

With respect to BERD intensity (Figure 6), in terms of international comparisons, the picture is even more arresting. At the peak in 2001, Canada's BERD was 1.25 per cent of GDP, a point at which the country was still operating below the US (at 1.91), the OECD total (1.47) and of course well below Israel (3.38) -- indeed logging in at only 37 per cent of Israel's BERD standing. By 2018, Canada's BERD had now fallen to .80 per cent -- a standing well below all countries including China and where Canada stood at only 18 per cent of Israel's BERD intensity and just over a quarter (27 per cent) of the top five countries. As for rankings, over the full 2000-2018 period, Canada remained in that "middling" territory, with a position of 22nd.²⁹ An analysis of the aggregate expenditures in constant 2015 US\$ and PPP\$³⁰ (Figure 7) illuminates trends more clearly as well. Calculations, as seen in Figure 8, are based on the magnitude of increase over the base year of 2000. What is unique about this -- and aside from the explosive

²⁸ Author's calculations.

²⁹ Author's calculations

³⁰ PPPs refers to Purchasing Power Parities. The OECD defines the term as "the rates of currency conversion that equalize the purchasing power of different currencies by eliminating the differences in price levels between countries... The indicator is measured in terms of national currency per US dollar" (<https://data.oecd.org/conversion/purchasing-power-parities-ppp.htm>).

growth of almost 1400 per cent by 2018 on the part of China – is that throughout the period under study there are spikes of modest increase over the base year (in particular 2004 to 2007 and 2016), even while BERD intensity was dropping. Canada was investing more in BERD throughout these years (and there is not evidence of negative numbers for the Great Recession years) but Canada’s relative standing vis à vis comparator nations was still dropping.

Other indicators related to both GERD and BERD tell a similar story. Specifically, the percentage of GERD performed by the business enterprise sector (Figure 3) reflects a declining performance relative to comparator nations. On this indicator Canada has fallen from 60.30 per cent in 2000 to 50.90 per cent in 2018, a record which garnered a ranking of 26th among OECD and non-OECD members over this time period³¹-- clearly “middle-of-the pack” territory.

Moreover, this performance stands in stark contrast to that of Israel and China where the reverse trends of growth are evident and where the Canadian percentage of GERD performed by business over the 2000-2018 period is actually two-thirds that of Israel. As for the US, EU (28) and OECD, what is notable here is the relative stability of the business enterprise share of GERD over the time period in question. So too with respect to the percentage of GERD financed by the business sector is Canada’s standing on a modest downward slope – coming in at 66 per cent of the top five countries for the whole 2000 – 2018 period and by 2018 registering only 54 per cent of the top five countries (Figure 2).

Surprisingly, as well, even the percentage of BERD financed by business itself (Figure 9), after a relatively steady growth up to 2011, has been on a downward trend. Indeed, Canada’s numbers stand in sharp opposition to Japan where, as the leader in this field, it has logged in with

³¹ This ranking is based on the author’s calculations. It should be noted that non-OECD countries typically included in OECD *MSTI* data are the following: Argentina, China, Romania, Russia, Singapore, South Africa and Chinese Taipei).

a disparate twenty-four percentage point spread versus Canada (98.40 per cent versus 74.12 per cent) for 2018. The top five countries evidence similar trends, although the US and OECD totals do show modest declines as well. Accompanying these developments, there has been a significant ascent in the percentage of BERD financed by government (Figure 10) from 2.29 per cent in 2000 to 6.45 per cent in 2019. Additionally – and representing international capital – Canadian BERD financed by the “rest of the world” after falling during the Great Recession and its aftermath (2008-2012) has now seen an upswing (Figure 11). This latter indicator is however more difficult to interpret. On the one hand Israel -- an innovation leader -- displays an exceptional growth in foreign financing of BERD over this period, topping in at almost 60 per cent in 2017. On the other, the US while displaying a very modest increase (for the data that is available) has continued a pattern that will show up in patent data as well – keeping domestic leadership as primordial.

In contrast to GERD and the BERD components, the picture on HERD paints a more positive portrait. Canada has consistently ranked much higher on this indicator and as Figure 15 portrays, Canada had a HERD intensity significantly higher than the OECD total, EU total, or the US over the full time series – with US at only 55 per cent of Canada’s HERD intensity. Canada also slightly outpaced or remained steady with the five leading countries at times in the early aughts, specifically in 2002 and in the 2004 to 2007 period, at which point this trend reverses and the gap starts to widen. Nonetheless, this is one of the few indicators where Canada still ranked among the top five countries for the full times series. Overall, then the HERD intensity has been a consistent strength throughout these decades, with the country maintaining HERD-generally in .66 per cent of GDP territory.

Despite the seeming stability on this indicator, however, the nation's international ranking has been dropping. By 2015 the position among OECD countries had fallen to seventh (OECD *Scoreboard* 2017, 100), this after a period from 2006 to 2008 in which Canada consistently ranked third among OECD members.³² Certainly, Canada has pursued an aggressive growth strategy with respect to HERD, investments rising (based on current Canadian dollars) from \$5.8 billion in 2000 to \$14.6 billion by 2019 – an increase of 153 per cent (Figures 18 and 19). Moreover, the growth in these investments also shows robustness in constant US dollars with an increase of approximately half that at 77 per cent over the 2000 – 2018 period (Figures 16 and 17). Yet, as STIC generally pointed out some time ago, other nations have been pursuing equally or even more aggressive strategies with respect to R&D expenditures on higher education, as evidenced both in constant dollars and in national currencies. National currencies particularly amplify these trends (Figures 18 and 19), with Korea registering an explosive 351 per cent increase over the 2000 to 2018 time frame and the top five countries coming in at a growth of 239 per cent. Of course, all of this paled in contrast with China which registered a phenomenal increase of 1800 per cent over the years in question and even when translated to constant US\$ (2015) comes in at half that number – 902 per cent (Figure 17).

Finally, with respect to HERD it is important to note that cross-funding between the private sector and higher education institutions has been relatively strong in the Canadian case, as measured through the percentage of HERD financed by the business sector (Figure 20).³³ And while here again China has outclassed all the other players on this dimension, Canada has been operating above the EU (28), OECD and US. On a similar note (albeit with respect to

³² Note that STIC (2009, 30) had drawn on OECD *Main Science and Technology Indicators*, 2008 data and found Canada was second in 2006. However, the OECD *Science, Technology and Industry Outlook* 2016 positions Canada now as third in 2006 on HERD as a percentage of GDP.

³³ This issue will be discussed in more depth in Chapter Six.

performance rather than financing) as Figure 5 illustrates, the percentage of GERD performed by the Higher Education sector has registered a substantive ascent, moving from less than a third of GERD (28.18 per cent) in 2000 to over 40 per cent (41.21 per cent) by 2019. By 2018, and in contrast to the usual trends that are witnessed, the OECD was only 41 per cent of Canada's standing, with the US (at 31 per cent) even lower. All of this of course is a testament to the continuing strength of the country's S&T fundamentals.

Despite the rather stalwart performance on HERD, however, another critical component of Gross Expenditures on R&D – namely government expenditures on R&D as a share of GDP or GOVERD – tells the usual Canadian story (Figure 12). For one thing, GOVERD has dropped from .21 per cent of GDP in 2000 to just over half that at .11 percent both in 2018 and 2019 and the Canadian share is generally low compared to other OECD members. By 2018 the country only registered 34 per cent of the GOVERD intensity of the top five countries, 38 per cent of the US, half that of the EU and somewhat under that share at 46 per cent with respect to the OECD average.

Moreover, in contrast with BERD and HERD, here expenditures in constant 2015 US dollars – after peaking at 2.79B and 2.77B in 2009 and 2010 respectively – have declined (Figure 13). The decline at first has been steady but then it experienced a prominent dip from 2015 onwards, particularly orbiting at or around the -25 per cent mark over the base year of 2000 (Figure 14). Similar as well to other indicators, the top five countries have seen exponential growth, with China logging in at a chart-crashing 459 per cent increase over the 2000-to-2018-time frame. Clearly, despite government efforts to invest in R&D – particularly in the first decade of the 2000s -- it seemingly has not substantially impacted GOVERD intensity and

interestingly, as could be anticipated with the DNS paradigm, US shares of GDP on this indicator have remained relatively strong throughout this period.

ICT as an Innovation Indicator

Turning to other key indicators of a vibrant national innovation system, the OECD has clearly identified Information and Communication Technologies (ICT) as “key enablers of innovation” (*OECD Scoreboard 2017*, 152), tracking this data on an annual basis through a number of mechanisms. And, in this case, the telling signs for the Canadian system are somewhat mixed.

With respect to total ICT investment as a percentage of gross fixed capital formation (GFCF), Canada’s numbers actually dropped over the 2000 to 2014 period and, at 8.92 per cent of GFCF, ICT investment was well below the top five OECD countries, Canada standing at 53 per cent of the top five average (Figure 21). Interestingly, more recent data does show a more sustained – albeit extremely modest upward trend line – from 2015 onwards, with Canada logging in on the GFCF indicator at 10.72 per cent and 10.53 per cent for 2018 and 2019 respectively. Moreover, this was sufficient to position the country on this indicator at 63 per cent of the top five for 2018 and close to 70 per cent (68.5) over the 2000 – 2018 time frame. Still, as has been frequently seen with innovation indices, this continued to place the country in “middle” territory, with a rank of twelfth for the 2000 to 2018 period out of twenty-six nations.³⁴

As for the critical measure of R&D expenditures by ICT equipment and information services industries, Canada has fared somewhat better. While in 2015 Canada operated below

³⁴ Ranking based on author’s calculations. Data source for this as represented in Figure 22 is OECD, *National Accounts Statistics - National Accounts at a Glance*. Interestingly Germany, Japan, Korea do not appear in this data. Nor do they appear in data that was gleaned originally from the *MSTI* indicators back in January 2020 (data extracted on 19 Jan 2020 21:24 UTC (GMT) from OECD.Stat). Inquiries with OECD on data sources have not provided further information.

the threshold of high performers where these ICT industries account for over 50 per cent of BERD in their respective countries (and in the case of the US over 40 per cent), still at 30.7 per cent the country was able to rank eighth among OECD members (*OECD Scoreboard* 2017, 152; StatLink <http://dx.doi.org/10.1787/888933619296>). Whether due to a lingering legacy associated with early 2000 strong contenders such as NORTEL and Blackberry or whether Canada with that early lead continued to invest in ICT would need to be the subject of further research, but at least on this indicator Canada had standing among the top ten countries.

Patents

With respect to one of the most standard measures of innovation activity and a telling indicator of the extent of knowledge transfer that is occurring along the innovation continuum is the number and share of patents that are being produced. Certainly, patents – “an intellectual property right relating to inventions in the technical field” (Dernis, Guellec and van Pottelsberghe 2001, 130) can not be seen as the penultimate test of innovation and are best viewed as a proxy rather than direct indicator of innovation. As the OECD has cautiously opined, patents have a “**close** (if not perfect) ... *link to invention*” (*Ibid.*, 136). Moreover, Schumpeter was even more forthright on the nature of the patent process, attributing it to the stable of “monopolistic practices” that especially large corporations used to “insure” the value of their investment under circumstances of rapidly changing technologies (Schumpeter 1950 [1942], 88). Nevertheless, the data on patents is extensive, provides a very valuable source of information and is internationally recognized as a critical indicator of invention.

Among the array of measures which the OECD employs, and of particular relevance to the Canadian context, is a country’s share of “triadic patent families” where country is defined as the country of residence of the inventor(s). The measure specifically refers to a “set of patents”

filed to “protect the same invention” and the triadic nature references the three key patent offices that exist internationally – namely, the Japan Patent Office (JPO), the European Patent Office (EPO) and the United States Patent and Trademark Office (USPTO) with which such patents are registered. Additionally, patent applications to the USPTO provide a valuable aggregate count of total numbers, as well as extremely useful breakdowns of technology areas, including Information and Communication Technology, Artificial Intelligence and pharmaceuticals. All of this provides both rigour and consistency in data comparisons and meshes well with a later discussion of international cooperation in patents in Chapter Six.³⁵ Each of the measures will be considered in turn.

As can be seen in Figure 26, Canada’s share of triadic patent families has been relatively steady, experiencing peaks between 2007 and 2009 and then dropping back into similar territory of the early aughts, although admittedly even the difference between peak in 2008 (at 1.33 per cent) and 2018 (at 1.09 per cent) is relatively small. All of this of course stands in sharp contrast to Japan with Canada’s standing in 2018 registering only 3.35 *per cent* of that country’s lead. Even with the top five countries for 2018, Canada’s position was just a few percentage points higher at 7.72 per cent of the top five share on triadic patent families. Nor does this really change over the 2000 to 2018 period, with Canada logging in at 7.34 per cent of the top five average.

So too do total patent applications to the USPTO (Figure 24) evoke similar trends, although understandably Japan is now replaced by the United States as the leading country. True, Canada did see a growth of 54 per cent over the base year of 2000 but such was not enough

³⁵ Based on the author’s inquiries, the OECD has indicated that no indicators of international cooperation based on triadic patent families is provided on-line (13 February 2020).

to radically change its comparator status (Figure 25a).³⁶ Akin to triadic patent statistics, in 2017, Canada registered only 4.57 per cent of the leader's standing (down from 5.89 per cent in 2000), although the Canadian position was significantly strengthened vis a vis the top five – specifically at 14.17 per cent of top five for 2017 and essentially the same at 14.55 per cent for the full time series. Interestingly, all categories on this index experienced downturns during the latter part of the time series, although it was most pronounced for the European Union (28), OECD and United States. As such, it is telling that Canada was unable to leverage this situation to significantly improve its relative standing.

When it comes to the breakdown of patent applications to the USPTO by technology, the data does evidence slightly more disparate results however. Certainly, ICT patent applications to the USPTO did experience a significant increase of 71 per cent over the base year of 2000 (Figures 22 and 23a).³⁷ But when compared to competitor nations, the filings had essentially plateaued. Here too, by 2017, Canada was just 4.16 per cent of the American leader, down even from 5.75 per cent in 2000. Moreover, a similar plateauing effect is seen with respect to the top five countries, Canada's ICT filings just 11.93 per cent of the top five in 2017, with this too having slightly descended from 12.66 per cent in 2000 and the higher 13.96 per cent for the total time series. As for filings to the USPTO for Artificial Intelligence as will be seen in the case study around this issue, here the results have been more robust.

Knowledge Creation

Finally, as has been well identified with respect to Canadian expertise in knowledge creation – specifically in research publications and dedicated areas of specialization – Canada

³⁶ For ease of reference, Figure 25b displays the trends without China.

³⁷ Again for ease of reference, Figure 23b displays the trends without China.

punches well above its global weight. As the OECD *Scoreboard* (2017) attests, with respect to what they call “quantity and quality of scientific production” Canada in 2015 claimed 11.5 per cent of publications among the “world’s 10% most-cited publications” (StatLink [http://dx.doi.org/ 10.1787/888933618783](http://dx.doi.org/10.1787/888933618783)). Indeed, Canada actually ranked twelfth on this score among OECD and non-OECD nations (StatLink [http://dx.doi.org/ 10.1787/888933618783](http://dx.doi.org/10.1787/888933618783)), coming in relatively close to the leader, Switzerland with 15.3 per cent and the US at 13.9 per cent. True, there has been a slight drop from 12.4 per cent in 2005 but nevertheless these statistics represent significant accomplishments, particularly given that the numbers are not normalized for size of population³⁸ and that Canada in fact has only .48 per cent of global population.

Further, when indicators drill down into areas of scientific specialization, Canada logs some impressive standings. Specifically, in the field of neuroscience in 2015, Canada held 12.6 per cent of the ten percent top-cited publications and a position of 1.73 on the relative specialization index OECD employs (StatLink <http://dx.doi.org/10.1787/888933618764>). As the OECD explains, the specialization index captures when “economies that have field distributions very similar to that of the entire world exhibit specialisation values very close to 1” (OECD 2017, 122).³⁹ With respect to Canada, this means that the country logged in at 73 per cent above the world’s standing. Moreover, this indicator positioned Canada second in ranking and only

³⁸ Canada has only about 38 million in population (https://www150.statcan.gc.ca/n1/en/subjects/population_and_demography/population_estimates), representing .48 per cent of the world’s population <https://www.worldometers.info/world-population/canada-population/#:~:text=Canada%20population%20is%20equivalent%20to%200.48%25%20of%20the%20total%20world%20population>

³⁹As the OECD indicates, “the relative specialization index has been calculated as the ratio of a given field’s share in a country’s total scientific production relative to the world’s equivalent. A ratio higher than 1 signifies a high degree of specialisation, with the field’s share in that country exceeding the relative importance of the field in overall global scientific output, as captured by the Scopus database” (StatLink <http://dx.doi.org/10.1787/888933618764>; also see OECD 2017, 122).

slightly below the leader of Israel at 1.78 and ahead of the US at 1.63. Admittedly, other fields fared less well, with Canada at .93 for computer science and .84 for materials science, but on the index for biochemistry, genetics and molecular biology Canada still came in above the world's equivalent at 1.05.

As for the issue of total researchers, Canada has performed relatively well on this indicator as well. To be sure, the country's increase of 47 per cent in researchers over the 2000 to 2017 period while impressive was far outclassed by China at 150 per cent (and in fact 168 per cent for 2018) and even the EU at 79 per cent (Figures 27 and 28). Still Canada did come in close to the top five countries which had a 51 per cent increase over the 2000 base year. More critically, in terms of total researchers per thousand total employment, which evens the playing field so to speak, Canada illustrated its relative prowess with a standing of 98.5 per cent of the OECD average and over 90 per cent (91.5) with respect to the US, although only 58 per cent with respect to the top five (Figure 29). All said, then, akin to trends illustrated with respect to HERD the role of scientific production both in terms of quality and quantity has been a longstanding strength in the country's R&D arsenal.

It is worth taking into account, however, some deeper dives into this issue which have been undertaken and which definitely indicate some developing chinks in the armour. For one thing, with respect to growth in research publications -- and unlike the rapid ascent that Canada had experienced from the late nineties to the early 2000s -- between 2003 and 2014 Canadian research was only operating at 88 per cent of the world average in terms of the rate of growth. Overlaid on this were several other unique developments that not only concerned studies at the time but also cast into relief some emerging fault lines in the S&T underpinnings.

As the Council of Canadian Academies has pointed out, in terms of Canadian research strengths, Social Sciences and the Humanities have figured quite prominently (CCA 2018, xix). An assessment of S&T research strengths based on 2005 to 2009 data had identified six areas of prominence (and largely functioning with the top five countries in the world) -- namely, Clinical Medicine, Historical Studies, Information and Communications Technologies, Physics and Astronomy, Psychology and Cognitive Sciences, and Visual and Performing Arts (*Ibid.*, 52; see also CCA 2012, 49-53)⁴⁰. By the time the exercise was repeated with 2009 to 2014 data, not only had Historical Studies fallen off the list but it *had been accompanied by ICT and Physics and Astronomy*, with Public Health and Health Services, Philosophy and Theology and Earth and Environmental Sciences now moving into the ranks of the prominent.⁴¹ Admittedly, the second later assessment used a more sophisticated composite index including not only Average Relative Citations (ARC) but also the share of world publications and a Growth Index – but still that ICT and Physics and Astronomy would not make the grade is somewhat surprising. The exclusions are particularly concerning given that CCA’s 2012 S&T study had identified Physics and Astronomy as a “research opportunity” area for Canada based on measures of research specialization and citation (CCA 2012, 57-58). As for the field of ICT -- with research outputs that included an approximately 50 per cent share of Canada’s patents by Blackberry alone in 2014 (CCA 2018,80), stable ARC scores over the time frames in question and a unique alignment with ICT Industrial R&D -- this too was cause for concern. Interestingly enough, on an ancillary measure of research specialization, it was *Psychology and Cognitive Sciences, which*

⁴⁰It should be noted that CCA (2012, 51) lists the data has having been gleaned between 2005 and 2010 which is different than the 2005-2009 times series referenced in CCA (2018) above. It is the intention here to rely on the summary in the later CCA publication (2018).

⁴¹ Methodology and results are laid out in CCA 2018 (chapter 3, especially Figure 3.7 and 52-65). CCA repeated the ARC assessment over the time frames but then added in Magnitude and Growth for the composite index. See CCA (2012, 43) on the Specialization Index.

together with Philosophy and Theology, actually topped the list, logging in at about twice the endeavours of other countries and clearly outranking eighteen other Canadian research fields included in the analysis (CCA 2018, Figure 3.6, 49).

Even more telling, based on the composite scores of magnitude, impact and growth, the bottom quartile of twenty research fields included the following largely ‘hard’ S&T areas: *Mathematics and Statistics, Enabling and Strategic Technologies (including, biotech, nanotech and AI) and Built Environment and Design.*⁴² As for the best performers in the top quartile, these were Visual and Performing Arts and Psychology and Cognitive Science, *only then* followed by Clinical Medicine, in the latter case, despite having an ARC score 73 per cent above the world average (*Ibid.*, 50). Certainly, it is a telling comment on the strength of Canada’s S&T endeavours.

Finally, on the question of Enabling and Strategic Technologies, both CCA and the Naylor Panel found the results on a number of indicators to be “sobering” (CCA 2012, 94-96; CCA 2018, 59-62; Naylor 2017 40-43). Admittedly, CCA and the Fundamental Science Review did use slightly different taxonomies but their conclusions were similar. Canada’s share of global publications has been declining in these research areas and the rate of growth in Canada’s five top enabling and strategic fields was sub-par. Moreover, particularly on Artificial Intelligence (AI) where Canada had been a research leader -- and which as the OECD advises is a key indicator for innovation – the rate of growth was only three-quarters that of the world average and on a specialization index of research intensity, it was only 83 per cent of what would be expected for the world average (CCA 2018, 61). Even with respect to citation scores, on Artificial Intelligence China was becoming “highly competitive,” an interesting development

⁴² See chapter 3 in CCA 2018, esp. 36-65 and especially Figure 3.7 on the quartile breakdown of 20 Canadian industries.

given that in the case of China research output had been prodigious reaching 95 per cent of American output but a quality or impact gap had previously existed. So too in the sub-field of Regenerative Medicine where Canada had been prominent on stem cell research, global rankings were slipping on both magnitude and citations (Naylor 2017, 41). As the CCA concluded, while there were “isolated” exceptions, “the aggregate data reviewed by this Panel suggest that Canada is not currently a world leader in research on most emerging technologies” (CCA 2018, 62). The Naylor Report was even more blunt. Such developments were having a corrosive effect on our longer-term game as a nation and our comparative advantage:

In a nutshell, it appears that Canada has briefly claimed bragging rights in certain fields based on excellence in one or two centres, but systematically failed to build national capacity that would create an enduring advantage. (Naylor 2017, 43).

Conclusion

If the objective of this chapter was to establish the economic and statistical foundation by which the DNS framework could be assessed – and more specifically establish the extent and nature of the innovation gap in Canada and challenges posed -- certainly these elements are readily discerned. Indeed, on two fronts, the story unfolds. As shown, practitioner studies have consistently revealed the need for more honed and directed government programming, access to capital and clustered collaborative strength across the ecosystem. As well, the array of innovation indicators as presented over a largely two-decade time frame, especially around R&D investment and enabling technologies and the intellectual property of patents, speak to the congealed nature of innovation in Canada and the proclivity the indicators show for descent. In short, in this inquiry to unravel the factors that have impeded innovation in the Canadian case – and the consequent trends manifested – one thing is clear. The innovation gap over this time frame has been real and it has been persistent, despite repeated efforts by learned practitioners to

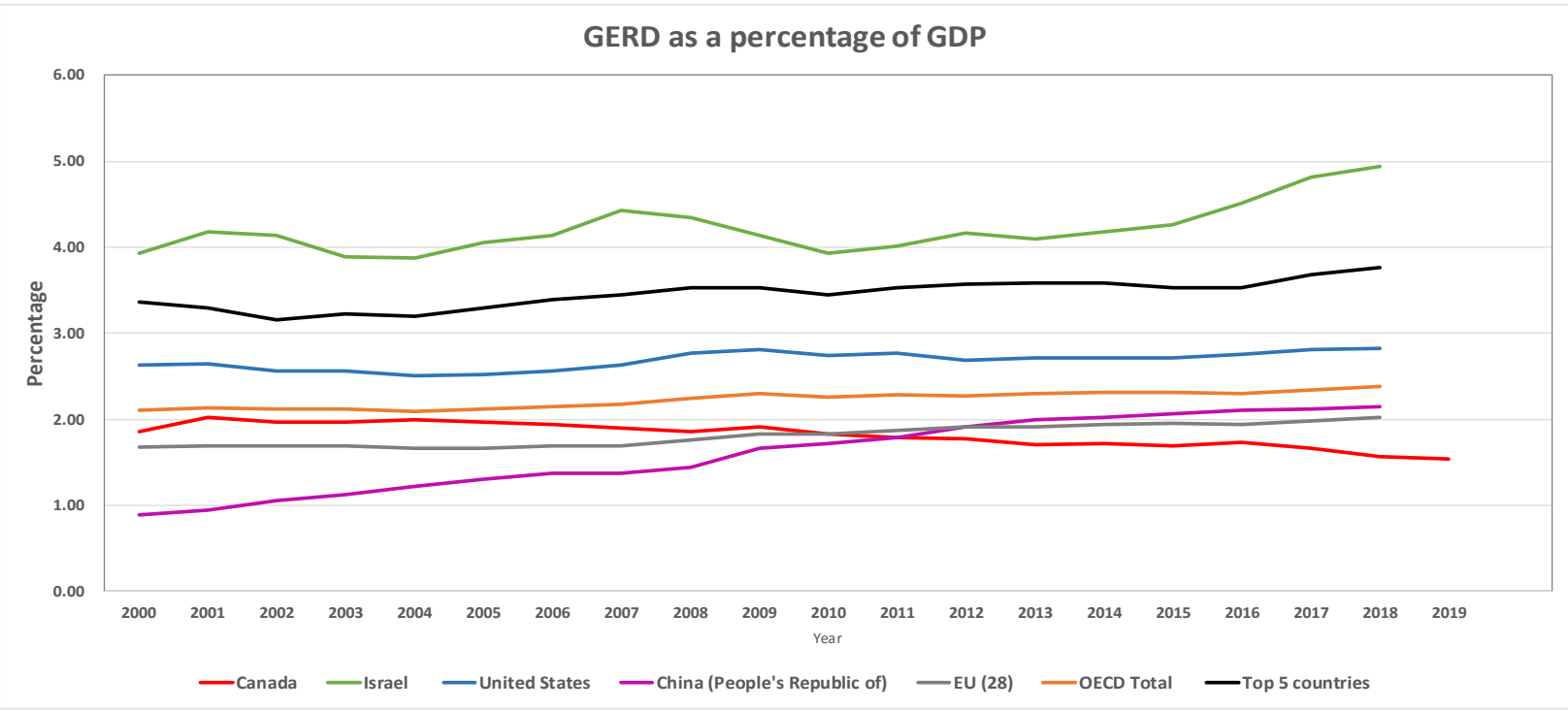
illuminate the issues at play. It is to that policy question – and the four lines of inquiry vested in this research – that we now turn.

Annex A – 3: Innovation Indicators

Figure 1 GERD as a percentage of GDP

Dataset: Main Science and Technology Indicators

MSTI Variables	GERD as a percentage of GDP																			
Unit	Percentage																			
Year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Country																				
Canada	1.86	2.02	1.97	1.97	2.00	1.97	1.94	1.90	1.86	1.92	1.83	1.79	1.77	1.71	1.71	1.69	1.73	1.67	1.56	1.54
Israel	3.93	4.18	4.13	3.89	3.87	4.05	4.14	4.42	4.34	4.13	3.94	4.02	4.16	4.10	4.17	4.27	4.51	4.82	4.94	
United States	2.63	2.65	2.56	2.56	2.50	2.52	2.56	2.63	2.77	2.81	2.74	2.77	2.68	2.71	2.72	2.72	2.76	2.81	2.83	
China (People's Republic of)	0.89	0.94	1.06	1.12	1.21	1.31	1.37	1.37	1.45	1.66	1.71	1.78	1.91	2.00	2.02	2.06	2.10	2.12	2.14	
EU (28)	1.67	1.69	1.70	1.69	1.66	1.66	1.68	1.69	1.76	1.83	1.83	1.87	1.91	1.92	1.94	1.95	1.94	1.98	2.03	
OECD Total	2.10	2.14	2.11	2.12	2.09	2.12	2.15	2.18	2.25	2.29	2.25	2.28	2.28	2.30	2.32	2.31	2.30	2.34	2.38	
Top 5 countries	3.36	3.30	3.15	3.22	3.20	3.29	3.39	3.44	3.54	3.53	3.45	3.53	3.57	3.58	3.58	3.52	3.53	3.68	3.76	



Source: OECD Main Science and Technology Indicators (https://stats.oecd.org/Index.aspx?DataSetCode=MSTI_PUB#)

Top 5 countries: Israel, Sweden, Korea, Finland, Japan

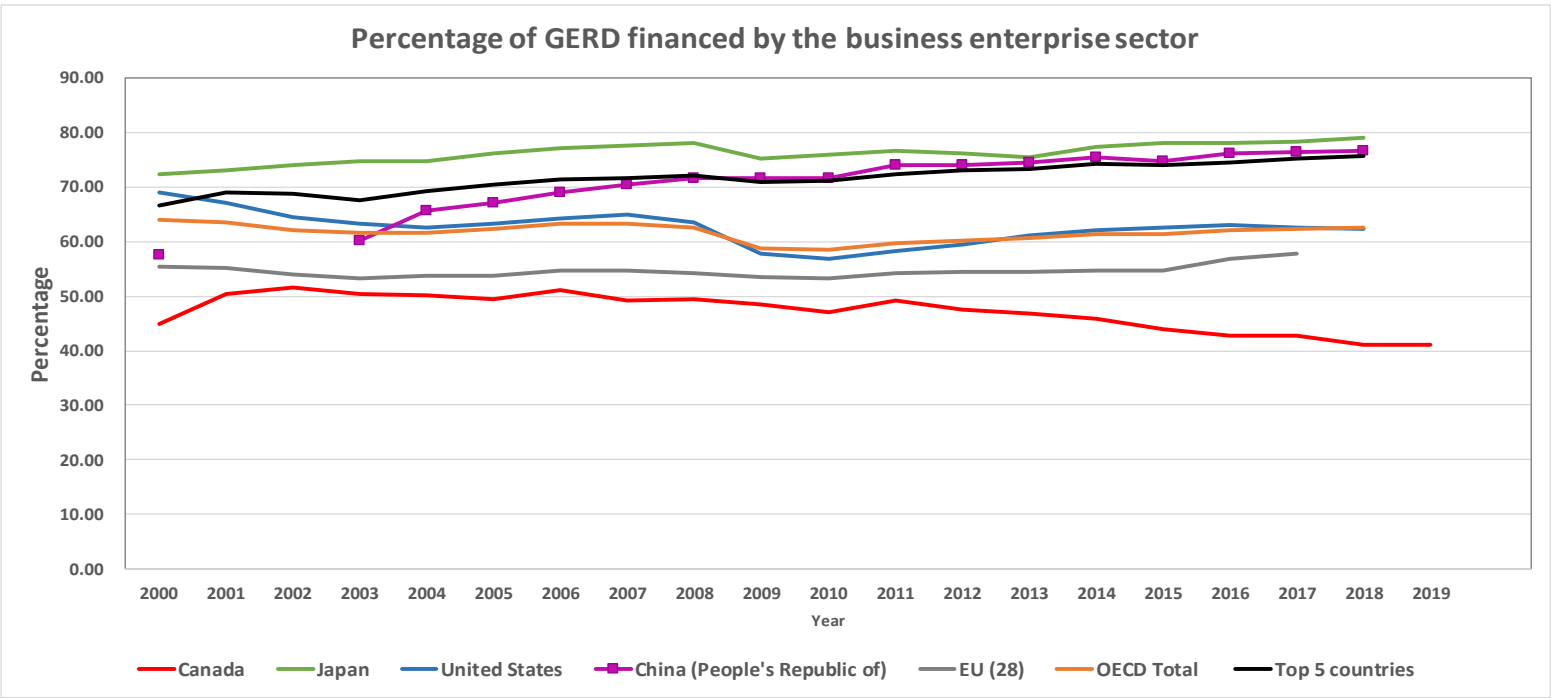
NOTE: OECD uses totals for OECD, EU(28); as such these are excluded from the top 5

Data extracted on 03 Nov 2020 01:21 UTC (GMT) from OECD.Stat

Figure 2 Percentage of GERD financed by the Business Enterprise sector

Dataset: Main Science and Technology Indicators

MSTI Variables	Percentage of GERD financed by the business enterprise sector																			
Unit	Percentage																			
Year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Country																				
Canada	44.87	50.30	51.48	50.33	50.18	49.34	51.15	49.19	49.46	48.52	47.17	49.15	47.43	46.70	45.75	43.95	42.70	42.67	41.12	41.00
Japan	72.42	73.05	74.08	74.65	74.81	76.12	77.07	77.71	78.17	75.27	75.93	76.52	76.12	75.48	77.26	77.97	78.09	78.27	79.06	
United States	69.03	67.21	64.54	63.34	62.59	63.31	64.28	64.88	63.52	57.90	56.93	58.37	59.53	61.12	62.00	62.54	63.15	62.48	62.37	
China (People's Republic of)	57.59			60.10	65.67	67.04	69.05	70.37	71.74	71.74	71.69	73.91	74.04	74.60	75.42	74.73	76.06	76.48	76.63	
EU (28)	55.37	55.16	53.89	53.36	53.79	53.71	54.63	54.57	54.27	53.46	53.15	54.32	54.40	54.47	54.61	54.67	56.74	57.78		
OECD Total	64.06	63.42	62.06	61.53	61.53	62.21	63.18	63.40	62.51	58.82	58.46	59.66	60.09	60.70	61.27	61.38	62.17	62.37	62.52	
Top 5 countries	66.64	68.96	68.71	67.63	69.35	70.50	71.36	71.72	72.13	70.81	71.24	72.43	73.00	73.31	74.20	74.13	74.49	75.28	75.74	

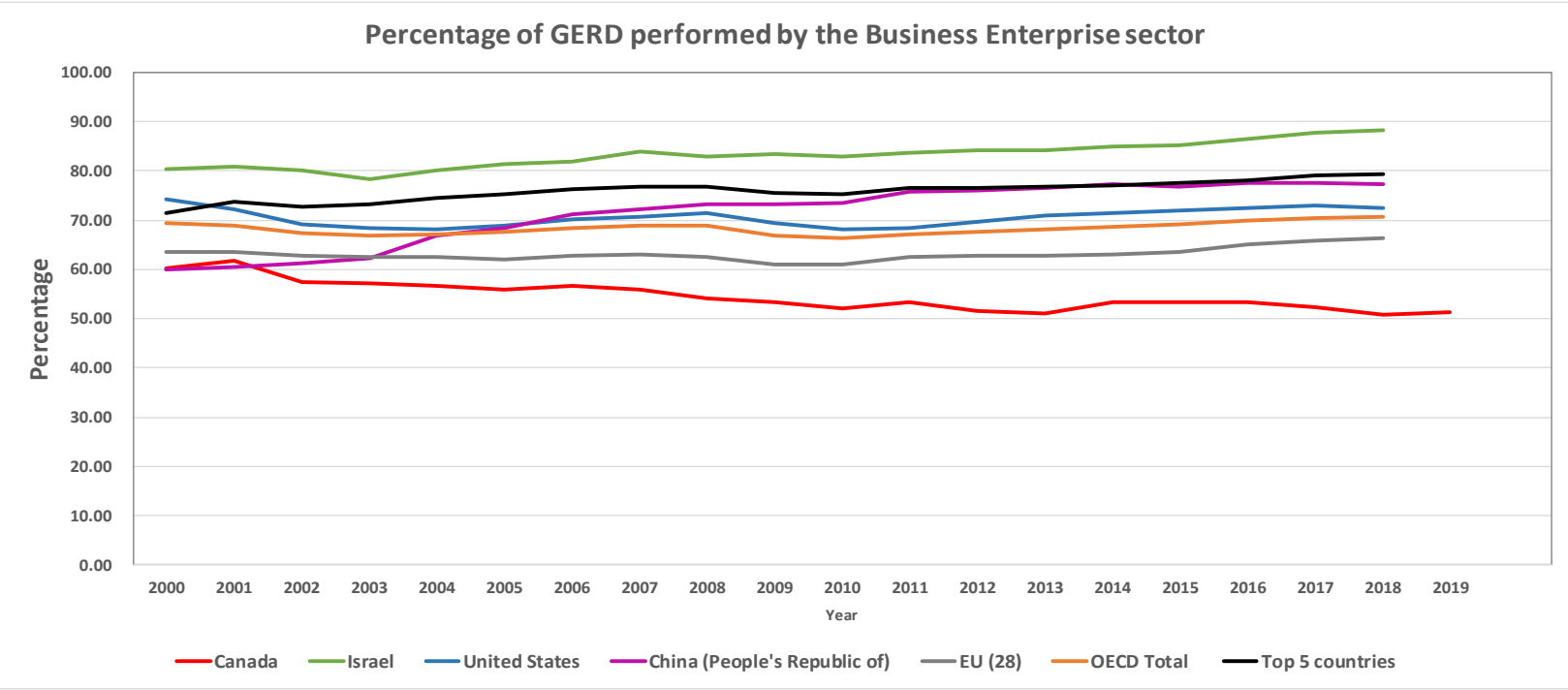


Source: *OECD Main Science and Technology Indicators* (https://stats.oecd.org/Index.aspx?DataSetCode=MSTI_PUB#)
Top 5 countries: Japan, Korea, Chinese Taipei, China, Germany. Excluded from the top 5 is Switzerland which is missing entries for 13 years.
NOTE: OECD uses totals for OECD, EU(28); as such these are excluded from the top 5
Data extracted on 03 Nov 2020 20:40 UTC (GMT) from OECD.Stat

Figure 3 Percentage of GERD performed by the Business Enterprise sector

Dataset: Main Science and Technology Indicators

MSTI Variables	Percentage of GERD performed by the Business Enterprise sector																			
Unit	Percentage																			
Year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Country																				
Canada	60.30	61.67	57.55	57.08	56.77	55.81	56.66	55.80	54.13	53.23	51.97	53.28	51.57	51.16	53.24	53.27	53.47	52.31	50.90	51.36
Israel	80.48	80.81	80.07	78.44	80.23	81.50	81.84	84.03	83.03	83.53	83.01	83.79	84.23	84.20	84.83	85.20	86.57	87.80	88.26	
United States	74.19	72.09	69.27	68.31	68.15	68.92	70.10	70.80	71.38	69.49	68.03	68.43	69.59	70.91	71.51	71.87	72.53	72.88	72.58	
China (People's Republic of)	59.96	60.44	61.18	62.37	66.82	68.32	71.08	72.28	73.26	73.23	73.42	75.74	76.15	76.61	77.30	76.79	77.46	77.59	77.42	
EU (28)	63.56	63.55	62.77	62.55	62.58	62.14	62.67	62.91	62.45	60.99	61.12	62.40	62.74	62.72	63.10	63.61	65.07	65.88	66.28	
OECD Total	69.29	68.91	67.38	66.98	67.09	67.62	68.48	68.90	68.89	66.87	66.37	67.14	67.66	68.17	68.74	69.07	69.82	70.43	70.59	
Top 5 countries	71.36	73.71	72.65	73.25	74.50	75.19	76.40	76.68	76.83	75.54	75.30	76.42	76.55	76.87	77.03	77.54	78.02	78.98	79.27	



Source: *OECD Main Science and Technology Indicators* (https://stats.oecd.org/Index.aspx?DataSetCode=MSTI_PUB#)

Top 5 countries: Israel, Korea, Japan, China, Sweden Excluded from the top 5 is Switzerland which is missing entries for 13 years.

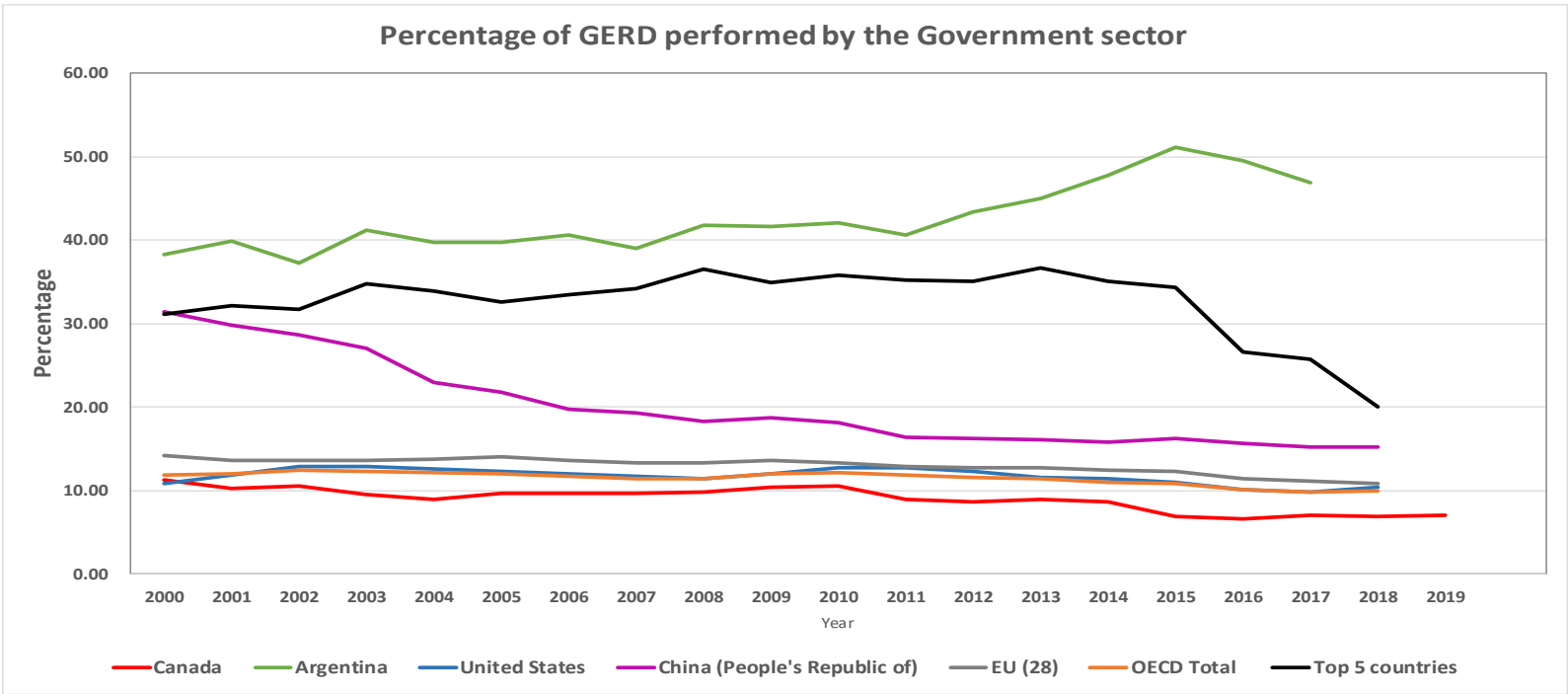
NOTE: OECD uses totals for OECD, EU(28); as such these are excluded from the top 5

Data extracted on 05 Nov 2020 21:41 UTC (GMT) from OECD.Stat

Figure 4 Percentage of GERD performed by the Government sector

Dataset: Main Science and Technology Indicators

MSTI Variables	Percentage of GERD performed by the Government sector																			
Unit	Percentage																			
Year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Country																				
Canada	11.24	10.28	10.50	9.56	8.90	9.70	9.73	9.74	9.76	10.45	10.60	9.00	8.57	8.88	8.61	6.96	6.65	7.07	6.90	7.03
Argentina	38.27	39.91	37.22	41.15	39.65	39.71	40.67	38.92	41.80	41.62	42.11	40.61	43.35	44.97	47.73	51.17	49.53	46.81		
United States	10.79	11.88	12.84	12.91	12.64	12.31	11.96	11.75	11.35	12.02	12.71	12.79	12.28	11.51	11.36	11.04	10.16	9.86	10.36	
China (People's Republic of)	31.47	29.74	28.68	27.09	22.96	21.79	19.70	19.23	18.29	18.71	18.12	16.33	16.27	16.16	15.80	16.16	15.70	15.22	15.18	
EU (28)	14.16	13.67	13.64	13.60	13.79	14.10	13.63	13.32	13.30	13.67	13.32	12.93	12.73	12.72	12.44	12.24	11.40	11.19	10.90	
OECD Total	11.88	12.06	12.40	12.35	12.22	11.95	11.66	11.38	11.37	12.02	12.21	11.88	11.62	11.38	11.03	10.81	10.08	9.88	9.93	
Top 5 countries	31.15	32.20	31.68	34.78	33.84	32.61	33.38	34.18	36.53	34.91	35.81	35.25	35.04	36.66	35.06	34.36	26.63	25.69	20.00	



Source: *OECD Main Science and Technology Indicators* (https://stats.oecd.org/Index.aspx?DataSetCode=MSTI_PUB#)

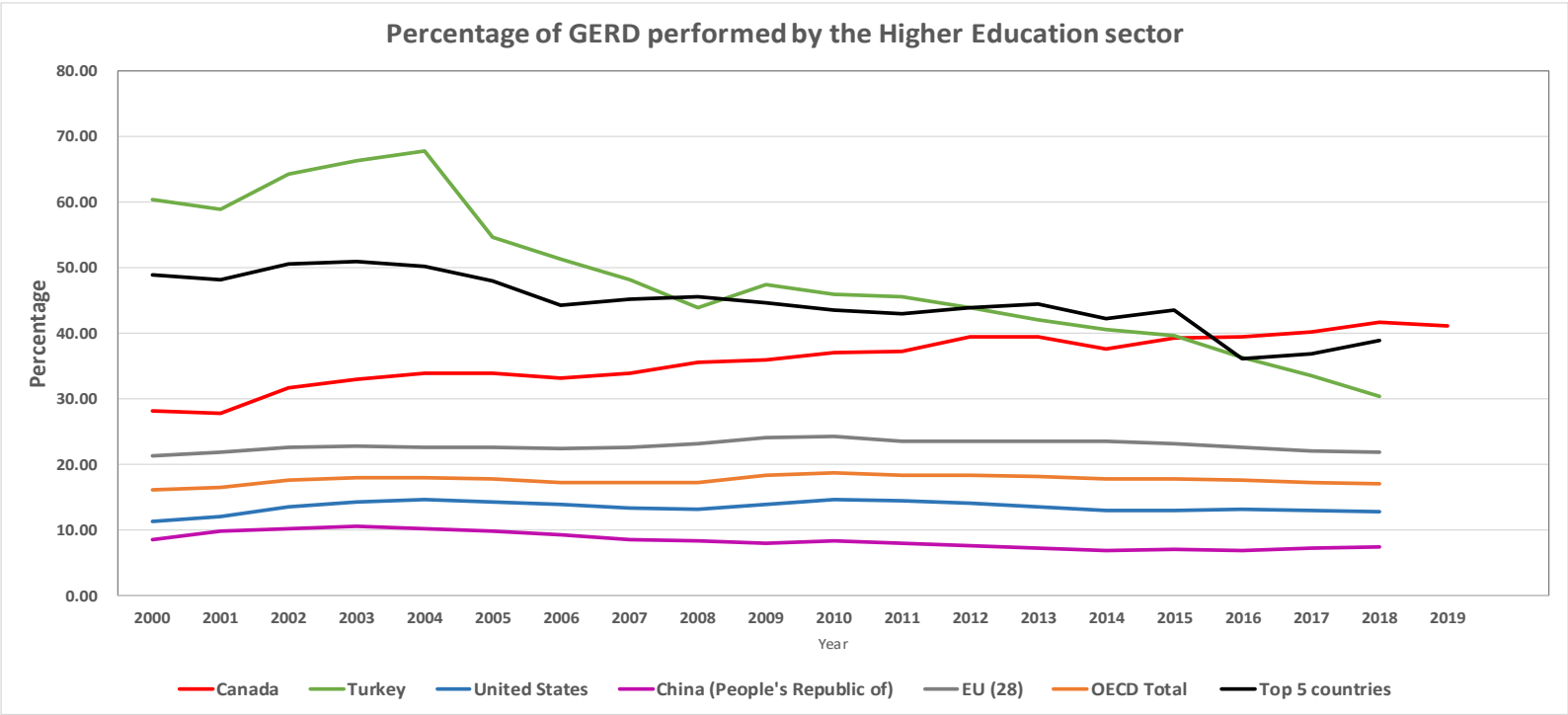
Top 5 countries: Argentina, Romania, Mexico, Poland, Slovak Republic

NOTE: OECD uses totals for OECD, EU(28); as such these are excluded from the top 5

Data extracted on 04 Nov 2020 22:47 UTC (GMT) from OECD.Stat

Figure 5 Percentage of GERD performed by the Higher Education sector

MSTI Variables	Percentage of GERD performed by the Higher Education sector																			
Unit	Percentage																			
Year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Country																				
Canada	28.18	27.77	31.67	32.98	33.96	33.96	33.10	33.92	35.53	35.91	36.99	37.32	39.39	39.47	37.70	39.30	39.44	40.13	41.73	41.21
Turkey	60.37	58.90	64.29	66.33	67.87	54.61	51.30	48.18	43.83	47.43	46.01	45.48	43.90	42.09	40.53	39.66	36.30	33.55	30.32	
United States	11.39	12.03	13.54	14.28	14.65	14.33	13.85	13.45	13.24	14.02	14.72	14.53	14.02	13.53	13.09	13.05	13.12	12.98	12.85	
China (People's Republic of)	8.57	9.82	10.14	10.54	10.22	9.89	9.22	8.48	8.45	8.07	8.46	7.93	7.58	7.23	6.90	7.05	6.84	7.19	7.41	
EU (28)	21.35	21.91	22.61	22.89	22.64	22.68	22.52	22.62	23.12	24.17	24.35	23.60	23.48	23.61	23.48	23.15	22.54	22.02	21.94	
OECD Total	16.10	16.56	17.59	17.98	18.01	17.75	17.32	17.23	17.26	18.39	18.70	18.45	18.32	18.13	17.88	17.74	17.68	17.30	17.10	
Top 5 countries	48.88	48.20	50.55	50.95	50.17	47.90	44.34	45.20	45.53	44.69	43.59	43.00	43.86	44.49	42.31	43.56	36.21	36.86	38.92	

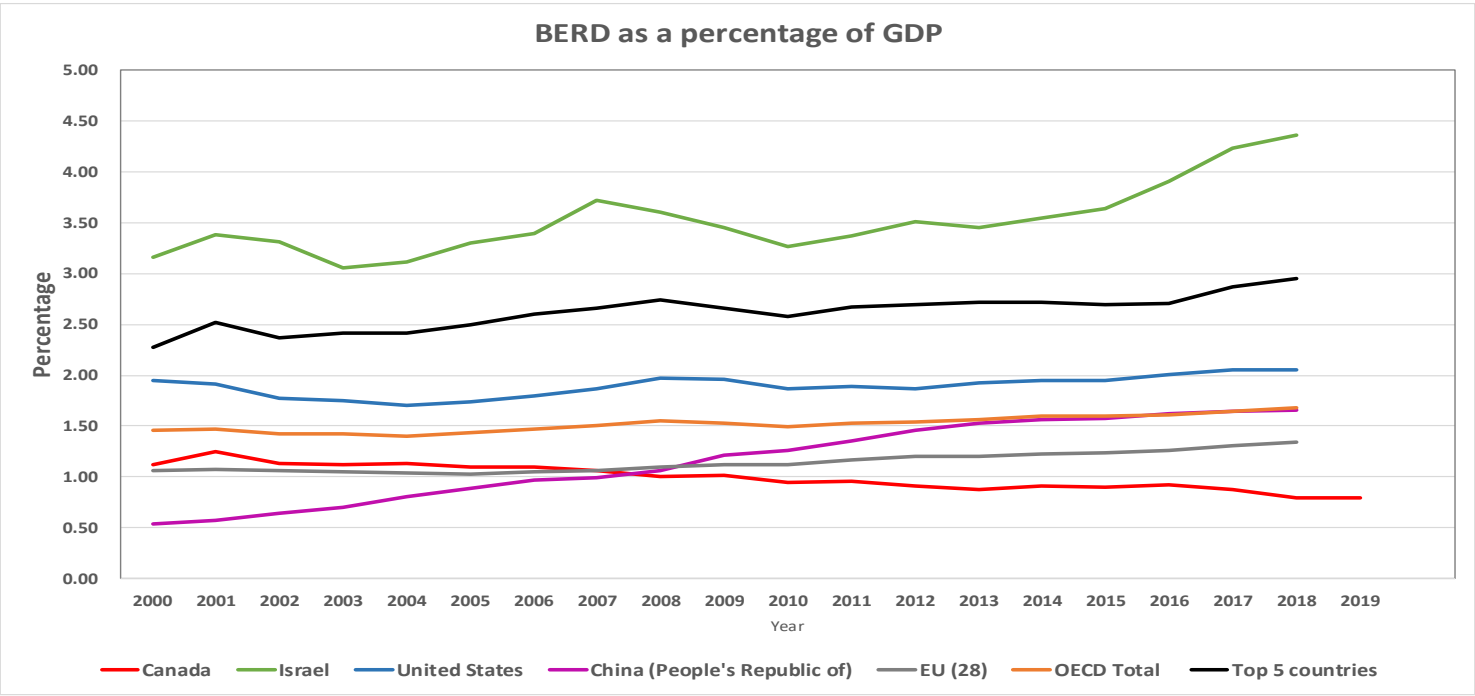


Source: *OECD Main Science and Technology Indicators* (https://stats.oecd.org/Index.aspx?DataSetCode=MSTI_PUB#)
Top 5 countries: Turkey, Lithuania, Latvia, Estonia, Colombia. Top 5 country average was not calculated for 2019 as there was missing data for 4 countries.
NOTE: OECD uses totals for OECD, EU(28); as such these are excluded from the top 5
Data extracted on 04 Nov 2020 02:45 UTC (GMT) from OECD.Stat

Figure 6 BERD as a percentage of GDP

Dataset: Main Science and Technology Indicators

MSTI Variables		BERD as a percentage of GDP																			
Unit		Percentage																			
Country	Year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Canada		1.12	1.25	1.13	1.12	1.13	1.10	1.10	1.06	1.00	1.02	0.95	0.95	0.91	0.87	0.91	0.90	0.92	0.87	0.80	0.79
Israel		3.17	3.38	3.31	3.05	3.11	3.30	3.39	3.72	3.61	3.45	3.27	3.36	3.51	3.45	3.54	3.63	3.91	4.23	4.36	
United States		1.95	1.91	1.77	1.75	1.71	1.73	1.79	1.86	1.98	1.95	1.86	1.89	1.87	1.92	1.94	1.95	2.00	2.05	2.05	
China (People's Republic of)		0.54	0.57	0.65	0.70	0.81	0.89	0.97	0.99	1.06	1.22	1.26	1.35	1.46	1.53	1.56	1.58	1.63	1.64	1.66	
EU (28)		1.06	1.07	1.06	1.05	1.04	1.03	1.06	1.06	1.10	1.12	1.12	1.17	1.20	1.20	1.23	1.24	1.26	1.30	1.34	
OECD Total		1.45	1.47	1.42	1.42	1.40	1.43	1.47	1.50	1.55	1.53	1.50	1.53	1.54	1.57	1.59	1.60	1.61	1.65	1.68	
Top 5 countries		2.27	2.52	2.37	2.41	2.41	2.49	2.60	2.66	2.73	2.66	2.58	2.67	2.70	2.71	2.72	2.69	2.71	2.87	2.95	



Source: *OECD Main Science and Technology Indicators* (https://stats.oecd.org/Index.aspx?DataSetCode=MSTI_PUB#)

Top 5 countries: Israel, Korea, Japan, Sweden, Finland

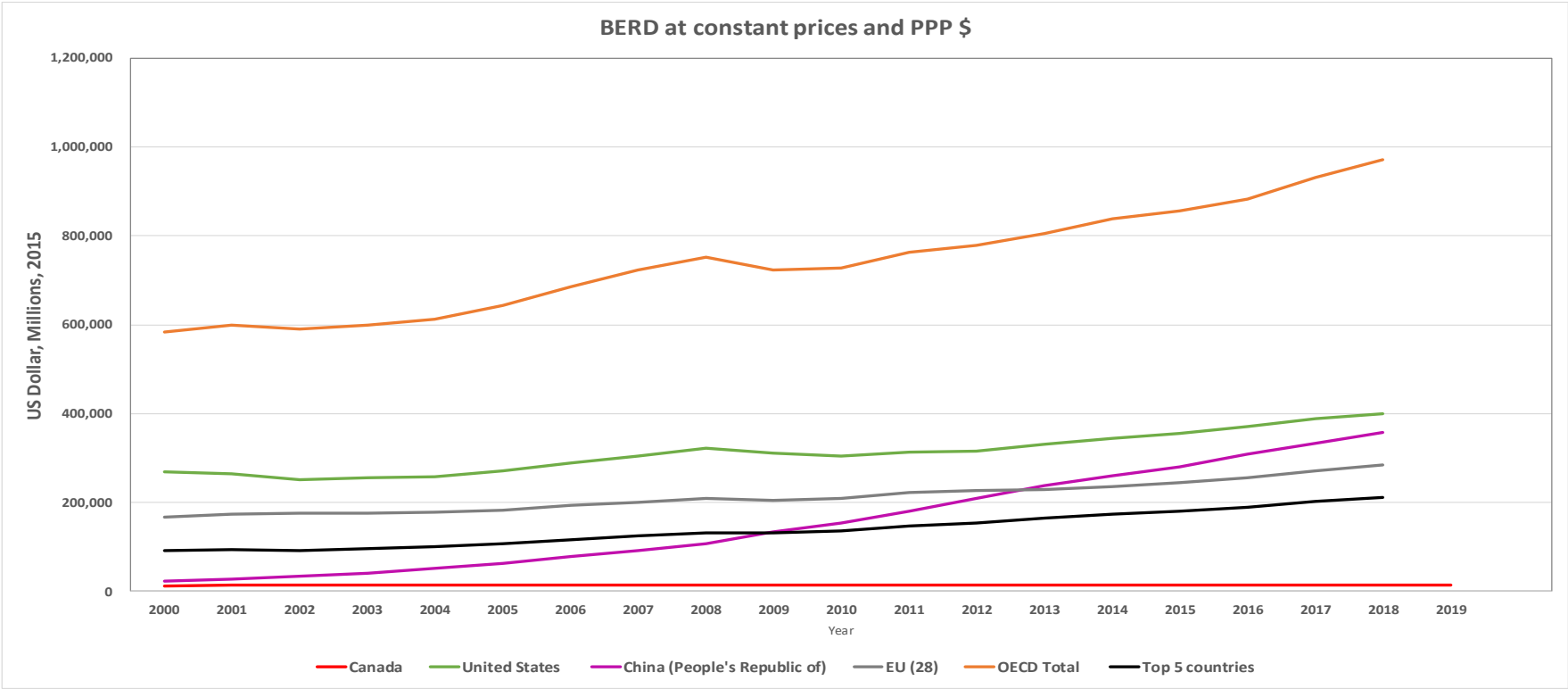
NOTE: OECD uses totals for OECD, EU(28); as such these are excluded from the top 5

Data extracted on 06 Nov 2020 16:25 UTC (GMT) from OECD.Stat

Figure 7 BERD at constant prices and PPP\$

Dataset: Main Science and Technology Indicators

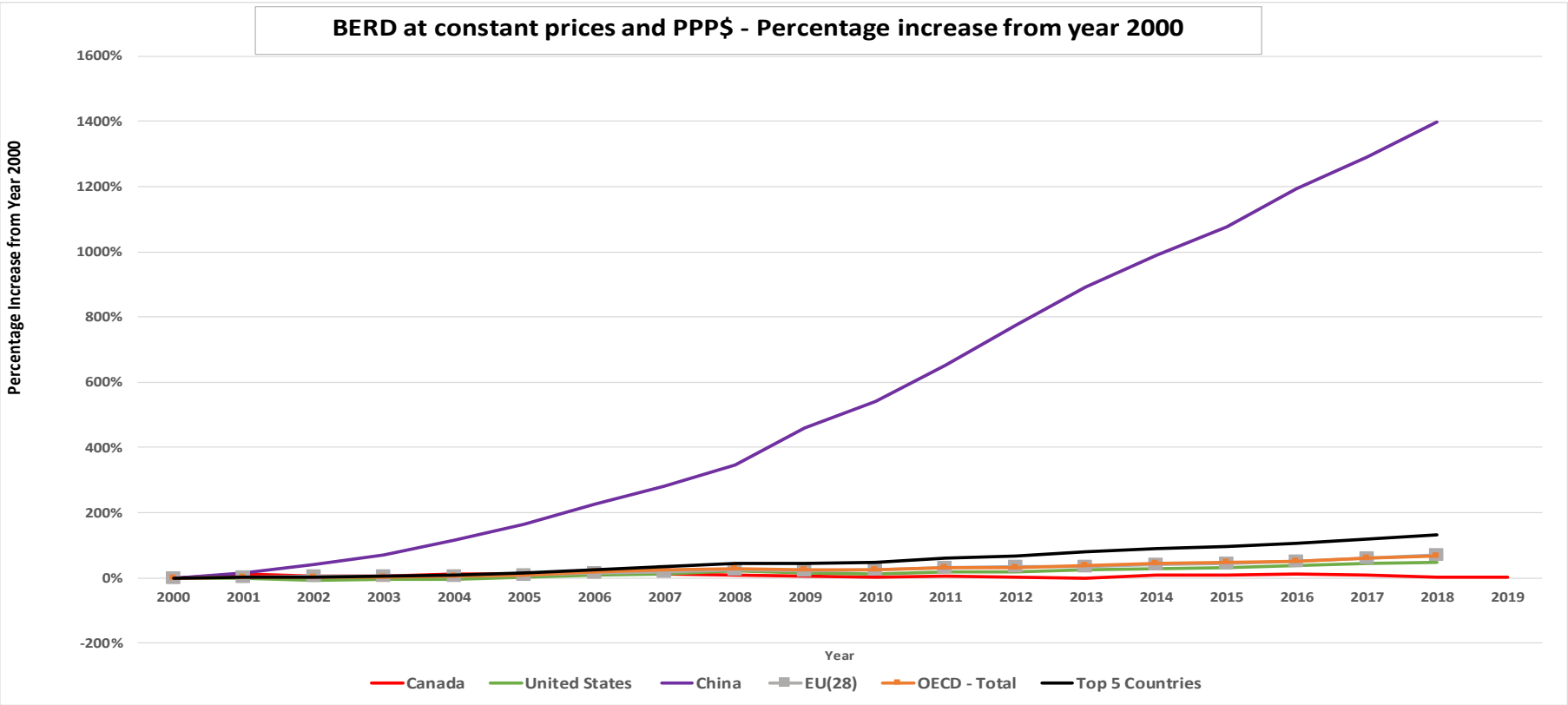
MSTI Variables	BERD at constant prices and PPP \$																			
Unit	US Dollar, Millions, 2015																			
Year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Country																				
Canada	13,363	15,129	14,188	14,297	14,878	14,898	15,301	15,069	14,393	14,198	13,602	14,086	13,757	13,439	14,461	14,386	14,890	14,508	13,488	13,655
United States	268,186	265,128	250,472	254,601	257,285	270,904	287,956	304,877	322,844	311,266	303,959	313,871	316,508	331,917	344,276	355,821	370,846	388,680	400,272	
China (People's Republic of)	23,926	27,505	34,187	40,613	51,961	63,704	78,170	91,153	106,623	134,238	153,291	179,962	209,620	237,456	260,233	281,113	309,047	332,924	358,106	
EU (28)	167,941	173,857	175,942	176,754	178,611	181,923	193,122	201,143	209,620	204,594	209,368	222,146	227,141	228,429	236,545	245,534	254,632	270,338	284,046	
OECD Total	583,562	599,350	589,616	599,897	612,288	644,200	685,729	723,742	752,764	722,184	727,550	763,382	777,366	804,490	837,395	856,708	882,800	931,901	970,621	
Top 5 countries	91,733	93,692	92,756	96,032	99,835	107,189	116,215	124,276	131,996	132,054	136,250	146,724	154,816	164,956	174,640	181,445	189,963	202,284	212,397	



Source: *OECD Main Science and Technology Indicators* (https://stats.oecd.org/Index.aspx?DataSetCode=MSTI_PUB#)
Top 5 countries: United States, China, Japan, Germany, Korea
NOTE: OECD uses totals for OECD, EU(28); as such these are excluded from the top 5
Data extracted on 06 Nov 2020 22:43 UTC (GMT) from OECD.Stat

Figure 8 BERD at constant prices – Percentage increase from year 2000

	Dataset: Main Science and Technology Indicators																			
MSTI Variables	BERD at constant prices and PPP\$ - Percentage increase from year 2000																			
Unit	Percentage increase from year 2000																			
Year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Country																				
Canada	0%	13%	6%	7%	11%	11%	15%	13%	8%	6%	2%	5%	3%	1%	8%	8%	11%	9%	1%	2%
United States	0%	-1%	-7%	-5%	-4%	1%	7%	14%	20%	16%	13%	17%	18%	24%	28%	33%	38%	45%	49%	
China	0%	15%	43%	70%	117%	166%	227%	281%	346%	461%	541%	652%	776%	892%	988%	1075%	1192%	1291%	1397%	
EU(28)	0%	4%	5%	5%	6%	8%	15%	20%	25%	22%	25%	32%	35%	36%	41%	46%	52%	61%	69%	
OECD - Total	0%	3%	1%	3%	5%	10%	18%	24%	29%	24%	25%	31%	33%	38%	43%	47%	51%	60%	66%	
Top 5 Countries	0%	2%	1%	5%	9%	17%	27%	35%	44%	44%	49%	60%	69%	80%	90%	98%	107%	121%	132%	

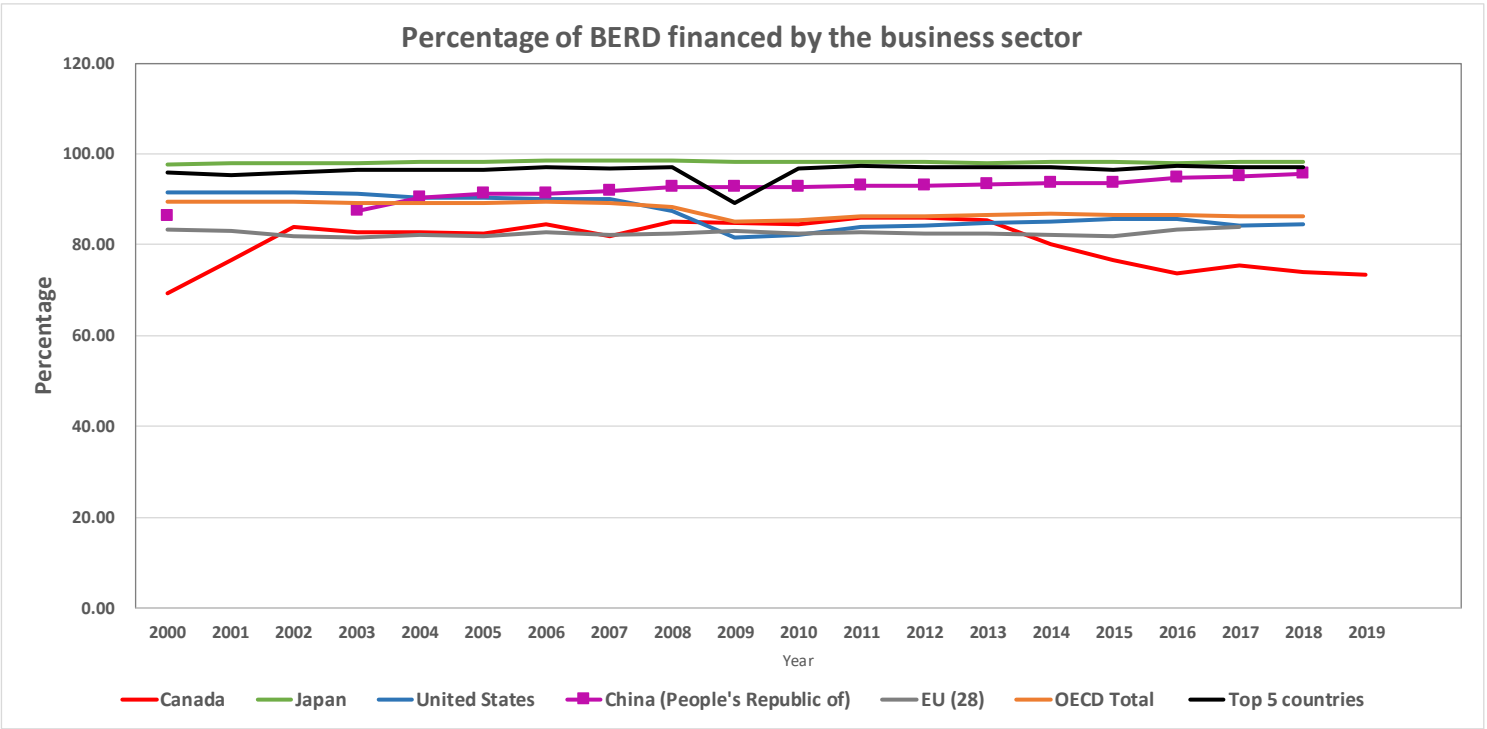


Source: *OECD Main Science and Technology Indicators* (https://stats.oecd.org/Index.aspx?DataSetCode=MSTI_PUB#)
Top 5 countries: United States, China, Japan, Germany, Korea. As the EU and OECD trend lines are in close proximity they are distinguished by markers.
NOTE: OECD uses totals for OECD, EU(28); as such these are excluded from the top 5
Original data extracted on 06 Nov 2020 22:43 UTC (GMT) from OECD.Stat; percentage increases are author's calculations

Figure 9 Percentage of BERD financed by the business sector

Dataset: Main Science and Technology Indicators

MSTI Variables	Percentage of BERD financed by the business sector																			
Unit	Percentage																			
Year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Country																				
Canada	69.28	76.62	83.94	82.67	82.77	82.48	84.66	82.02	85.15	84.69	84.55	86.00	85.87	85.34	80.04	76.56	73.81	75.36	74.12	73.34
Japan	97.66	97.88	97.92	98.12	98.24	98.31	98.49	98.47	98.55	98.21	98.21	98.27	98.23	98.09	98.35	98.28	98.08	98.20	98.40	
United States	91.44	91.63	91.54	91.13	90.27	90.31	90.19	90.13	87.49	81.68	82.16	83.83	84.13	84.75	85.26	85.57	85.63	84.30	84.50	
China (People's Republic of)	86.39			87.47	90.51	91.24	91.17	91.93	92.77	92.85	92.74	92.99	93.02	93.23	93.72	93.72	94.68	95.04	95.58	
EU (28)	83.41	82.93	81.91	81.54	82.07	81.96	82.67	82.24	82.43	82.94	82.44	82.63	82.36	82.60	82.34	81.96	83.35	83.95		
OECD Total	89.44	89.50	89.44	89.31	89.16	89.34	89.58	89.34	88.21	85.25	85.53	86.35	86.36	86.62	86.73	86.52	86.70	86.23	86.26	
Top 5 countries	95.83	95.24	96.06	96.55	96.42	96.53	97.03	96.83	97.19	89.35	96.84	97.38	97.17	97.04	97.24	96.51	97.37	96.98	97.08	



Source: OECD Main Science and Technology Indicators (https://stats.oecd.org/Index.aspx?DataSetCode=MSTI_PUB#)

Top 5 countries: Japan, Chinese Taipei, Colombia, Australia, Korea

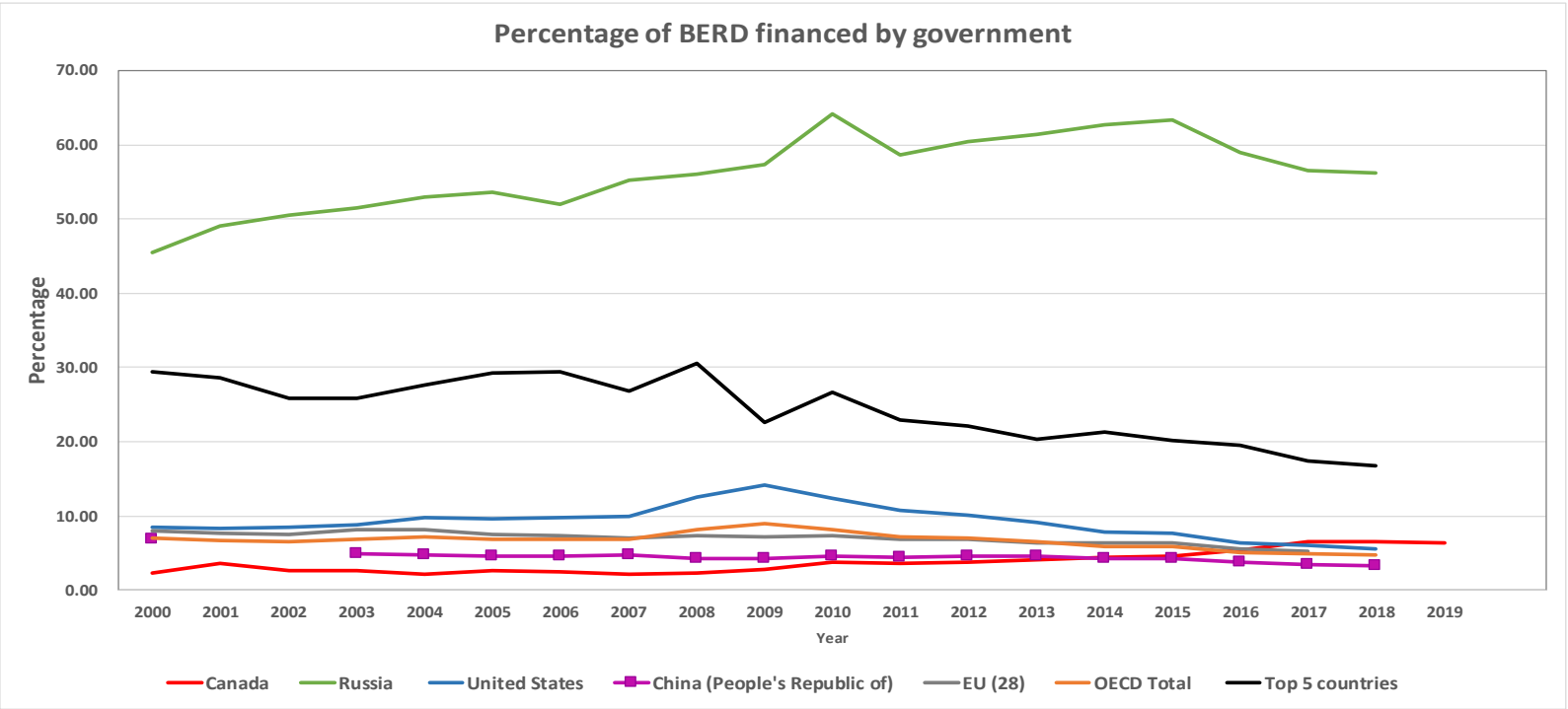
NOTE: OECD uses totals for OECD, EU(28); as such these are excluded from the top 5

Data extracted on 04 Nov 2020 16:14 UTC (GMT) from OECD.Stat

Figure 10 Percentage of BERD financed by government

Dataset: Main Science and Technology Indicators

MSTI Variables	Percentage of BERD financed by government																			
Unit	Percentage																			
Year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Country																				
Canada	2.29	3.56	2.61	2.62	2.18	2.64	2.52	2.09	2.34	2.82	3.73	3.59	3.84	4.11	4.48	4.62	5.39	6.47	6.57	6.45
Russia	45.45	49.04	50.57	51.53	52.96	53.56	52.02	55.28	56.04	57.37	64.18	58.67	60.44	61.48	62.67	63.41	58.96	56.59	56.21	
United States	8.56	8.37	8.46	8.87	9.73	9.69	9.81	9.87	12.51	14.08	12.31	10.76	10.18	9.16	7.83	7.62	6.39	6.10	5.58	
China (People's Republic of)	6.84			4.93	4.77	4.57	4.53	4.80	4.30	4.33	4.57	4.38	4.63	4.51	4.20	4.26	3.70	3.44	3.22	
EU (28)	7.97	7.71	7.43	8.09	8.18	7.44	7.29	6.96	7.35	7.12	7.32	6.88	6.82	6.38	6.43	6.35	5.52	5.22		
OECD Total	6.95	6.73	6.52	6.83	7.11	6.83	6.80	6.81	8.10	8.98	8.12	7.25	7.01	6.46	5.89	5.85	5.10	4.96	4.78	
Top 5 countries	29.34	28.65	25.85	25.80	27.72	29.30	29.46	26.80	30.55	22.62	26.67	22.90	22.19	20.26	21.26	20.24	19.45	17.43	16.84	



Source: *OECD Main Science and Technology Indicators* (https://stats.oecd.org/Index.aspx?DataSetCode=MSTI_PUB#)

Top 5 countries: Russia, Romania, Poland, Slovak Republic, Czech Republic

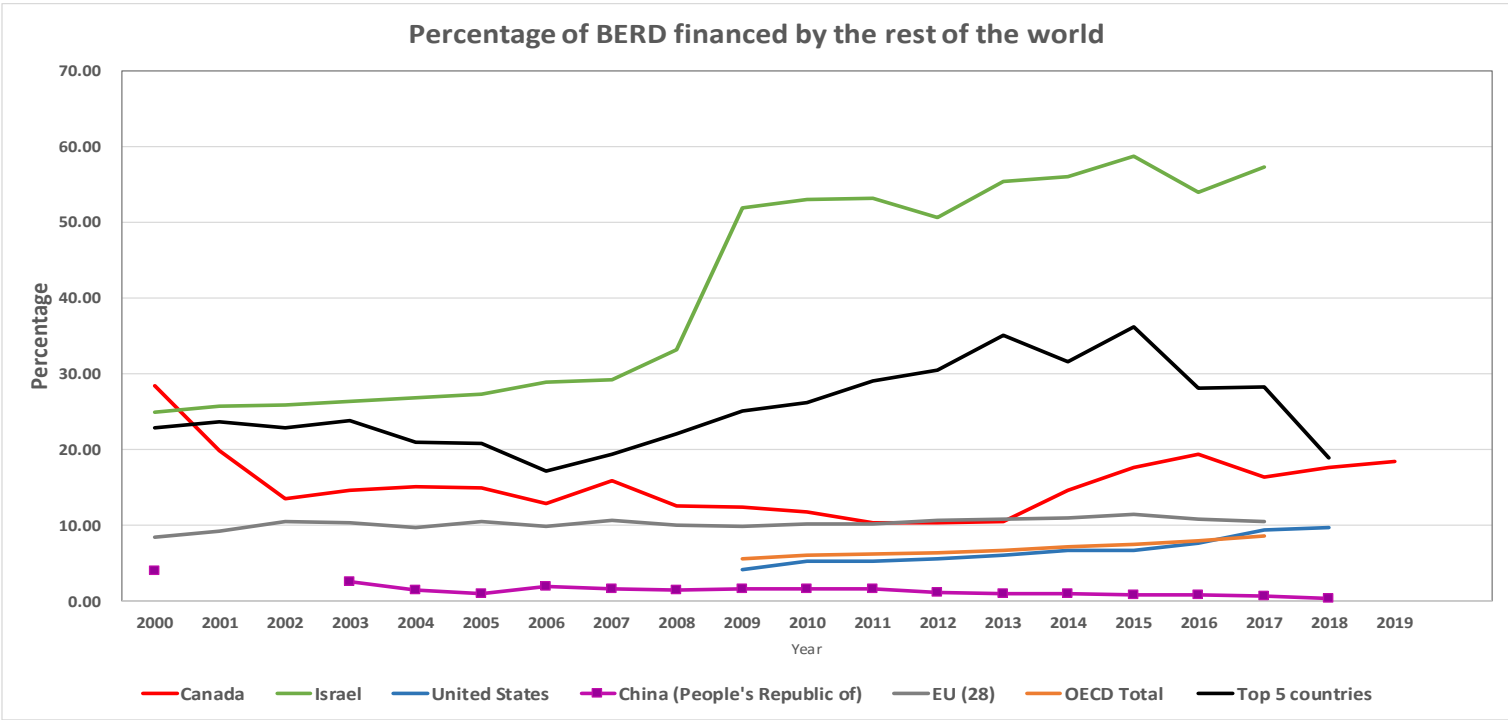
NOTE: OECD uses totals for OECD, EU(28); as such these are excluded from the top 5

Data extracted on 04 Nov 2020 14:14 UTC (GMT) from OECD.Stat

Figure 11 Percentage of BERD financed by the rest of the world

Dataset: Main Science and Technology Indicators

MSTI Variables	Percentage of BERD financed by the rest of the world																			
Unit	Percentage																			
Year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Country																				
Canada	28.43	19.82	13.45	14.71	15.05	14.88	12.83	15.89	12.51	12.49	11.73	10.41	10.29	10.54	14.68	17.63	19.45	16.39	17.60	18.48
Israel	24.91	25.71	25.93	26.35	26.85	27.39	28.98	29.29	33.16	51.90	53.00	53.22	50.61	55.43	56.05	58.79	53.92	57.37		
United States										4.10	5.25	5.29	5.57	6.00	6.75	6.67	7.72	9.45	9.76	
China (People's Republic of)	3.98			2.61	1.51	1.01	1.96	1.55	1.42	1.62	1.60	1.59	1.13	1.04	0.92	0.87	0.76	0.75	0.39	
EU (28)	8.37	9.18	10.50	10.27	9.67	10.47	9.91	10.65	10.06	9.80	10.12	10.23	10.61	10.79	10.99	11.46	10.89	10.54		
OECD Total										5.62	6.14	6.22	6.46	6.74	7.18	7.44	7.96	8.60		
Top 5 countries	22.96	23.67	22.87	23.85	20.97	20.80	17.20	19.32	22.13	25.03	26.23	29.13	30.50	35.11	31.59	36.19	28.14	28.23	18.90	

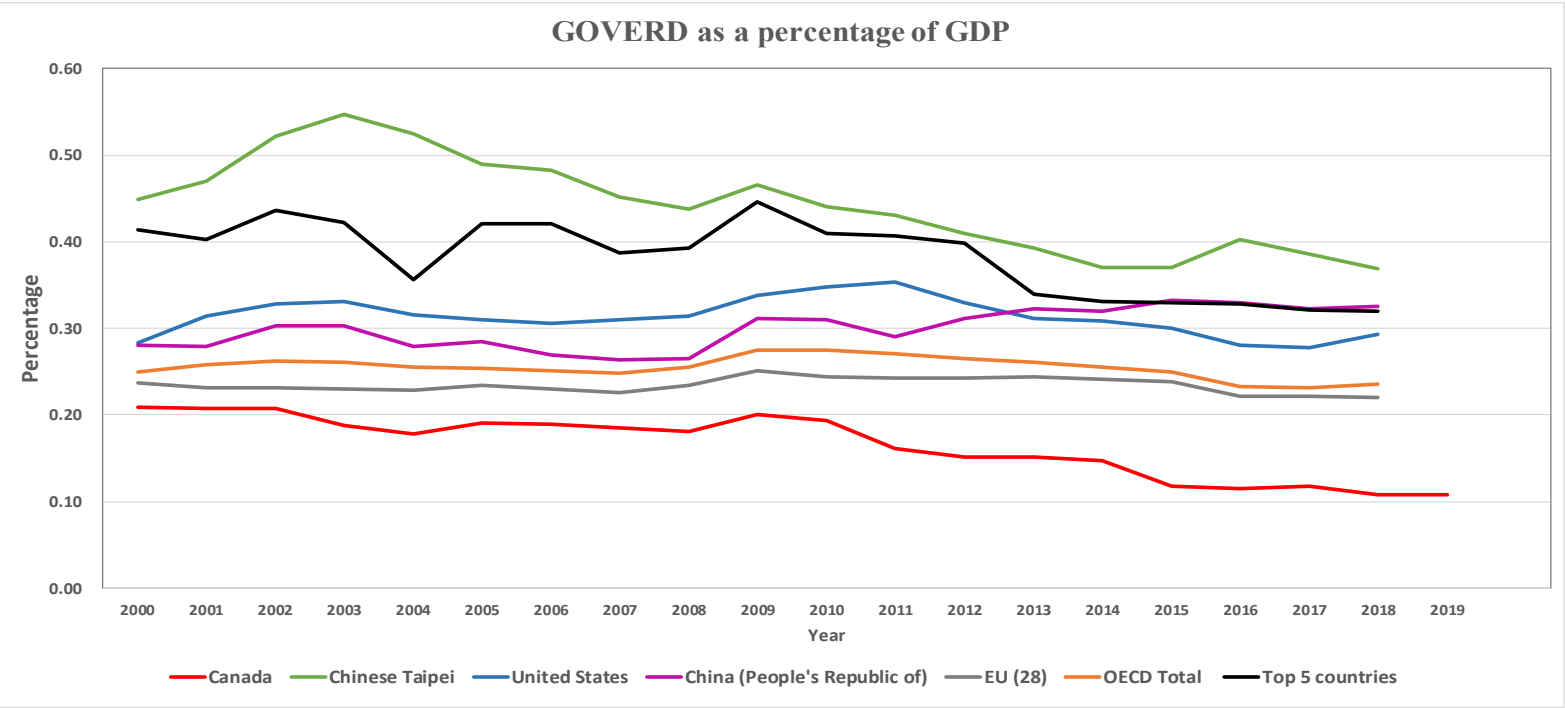


Source: *OECD Main Science and Technology Indicators* (https://stats.oecd.org/Index.aspx?DataSetCode=MSTI_PUB#)
Top 5 countries: Israel, Latvia, United Kingdom, Lithuania, Ireland. Note: Countries are excluded in the top 5 average if the county is missing entries for more than 5 years.
Excluded from the top 5 are Austria which is missing entries for 11 years and Iceland which is missing entries for 6 years.
NOTE: OECD uses totals for OECD, EU(28) as such these are excluded from the top 5
Data extracted on 04 Nov 2020 20:23 UTC (GMT) from OECD.Stat

Figure 12 GOVERD as a percentage of GDP

Dataset: Main Science and Technology Indicators

MSTI Variables	GOVERD as a percentage of GDP																			
Unit	Percentage																			
Year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Country																				
Canada	0.21	0.21	0.21	0.19	0.18	0.19	0.19	0.19	0.18	0.20	0.19	0.16	0.15	0.15	0.15	0.12	0.11	0.12	0.11	0.11
Chinese Taipei	0.45	0.47	0.52	0.55	0.52	0.49	0.48	0.45	0.44	0.47	0.44	0.43	0.41	0.39	0.37	0.37	0.40	0.39	0.37	
United States	0.28	0.31	0.33	0.33	0.32	0.31	0.31	0.31	0.31	0.34	0.35	0.35	0.33	0.31	0.31	0.30	0.28	0.28	0.29	
China (People's Republic of)	0.28	0.28	0.30	0.30	0.28	0.28	0.27	0.26	0.26	0.31	0.31	0.29	0.31	0.32	0.32	0.33	0.33	0.32	0.32	
EU (28)	0.24	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.25	0.24	0.24	0.24	0.24	0.24	0.24	0.22	0.22	0.22	
OECD Total	0.25	0.26	0.26	0.26	0.26	0.25	0.25	0.25	0.26	0.28	0.28	0.27	0.26	0.26	0.26	0.25	0.23	0.23	0.24	
Top 5 countries	0.41	0.40	0.44	0.42	0.36	0.42	0.42	0.39	0.39	0.45	0.41	0.41	0.40	0.34	0.33	0.33	0.33	0.32	0.32	

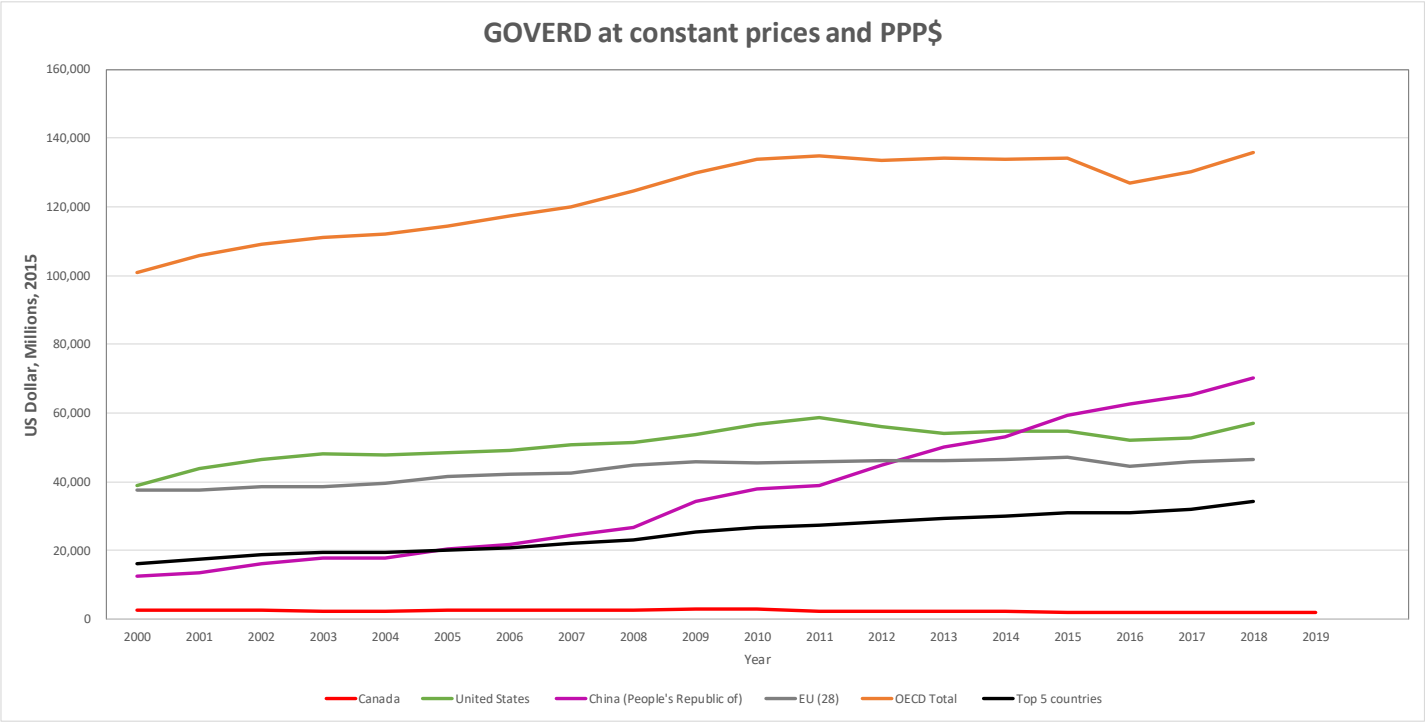


Source: *OECD Main Science and Technology Indicators* (https://stats.oecd.org/Index.aspx?DataSetCode=MSTI_PUB#)
Top 5 countries: Chinese Taipei, Iceland, Germany, Korea, Slovenia
NOTE: OECD uses totals for OECD, EU(28); as such these are excluded from the top 5
Data extracted on 03 Nov 2020 18:41 UTC (GMT) from OECD.Stat

Figure 13 GOVERD at constant prices and PPP\$

Dataset: Main Science and Technology Indicators

MSTI Variables	GOVERD at constant prices and PPP\$																				
Unit	US Dollar, Millions, 2015																				
Year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	
Country																					
<u>Canada</u>	2,490	2,523	2,589	2,395	2,332	2,588	2,626	2,629	2,595	2,786	2,774	2,378	2,287	2,334	2,338	1,879	1,851	1,961	1,827	1,869	
<u>United States</u>	38,997	43,711	46,440	48,115	47,703	48,367	49,130	50,614	51,334	53,856	56,788	58,671	55,858	53,897	54,669	54,666	51,963	52,583	57,153		
<u>China (People's Republic of)</u>	12,558	13,537	16,026	17,640	17,851	20,318	21,671	24,254	26,616	34,292	37,833	38,809	44,788	50,078	53,203	59,159	62,618	65,315	70,201		
<u>EU (28)</u>	37,643	37,626	38,399	38,636	39,633	41,415	42,133	42,615	44,653	45,776	45,551	45,948	46,003	46,229	46,514	47,246	44,508	45,814	46,552		
<u>OECD Total</u>	100,994	105,702	109,097	111,177	112,176	114,544	117,211	119,965	124,486	129,774	133,755	134,924	133,403	134,076	134,006	134,123	127,041	130,072	135,746		
<u>Top 5 countries</u>	16,052	17,386	18,629	19,432	19,469	20,029	20,817	21,968	22,985	25,394	26,685	27,220	28,274	29,248	30,022	31,050	31,101	32,044	34,164		



Source: *OECD Main Science and Technology Indicators* (https://stats.oecd.org/Index.aspx?DataSetCode=MSTI_PUB#)

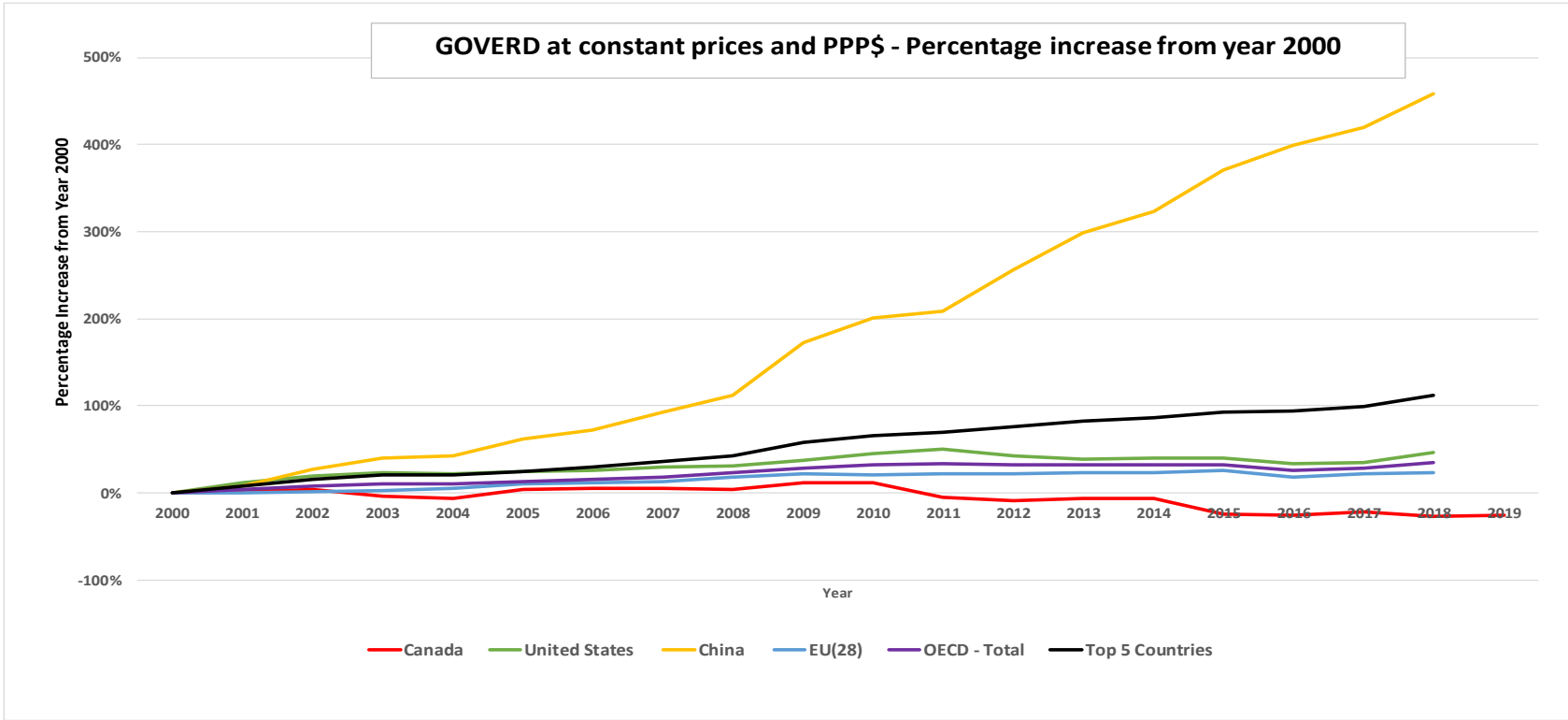
Top 5 countries: United States, China, Germany, Japan, Russia

NOTE: OECD uses totals for OECD, EU(28); as such these are excluded from the top 5

Data extracted on 06 Nov 2020 21:18 UTC (GMT) from OECD.Stat

Figure 14 GOVERD at constant prices and PPP\$ - Percentage increase from year 2000

Dataset: Main Science and Technology Indicators																					
MSTI Variables		GOVERD at constant prices and PPP\$ - Percentage increase from year 2000																			
Unit		Percentage increase from year 2000																			
Year		2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Country																					
Canada		0%	1%	4%	-4%	-6%	4%	5%	6%	4%	12%	11%	-5%	-8%	-6%	-6%	-25%	-26%	-21%	-27%	-25%
United States		0%	12%	19%	23%	22%	24%	26%	30%	32%	38%	46%	50%	43%	38%	40%	40%	33%	35%	47%	
China		0%	8%	28%	40%	42%	62%	73%	93%	112%	173%	201%	209%	257%	299%	324%	371%	399%	420%	459%	
EU(28)		0%	0%	2%	3%	5%	10%	12%	13%	19%	22%	21%	22%	22%	23%	24%	26%	18%	22%	24%	
OECD - Total		0%	5%	8%	10%	11%	13%	16%	19%	23%	28%	32%	34%	32%	33%	33%	33%	26%	29%	34%	
Top 5 Countries		0%	8%	16%	21%	21%	25%	30%	37%	43%	58%	66%	70%	76%	82%	87%	93%	94%	100%	113%	

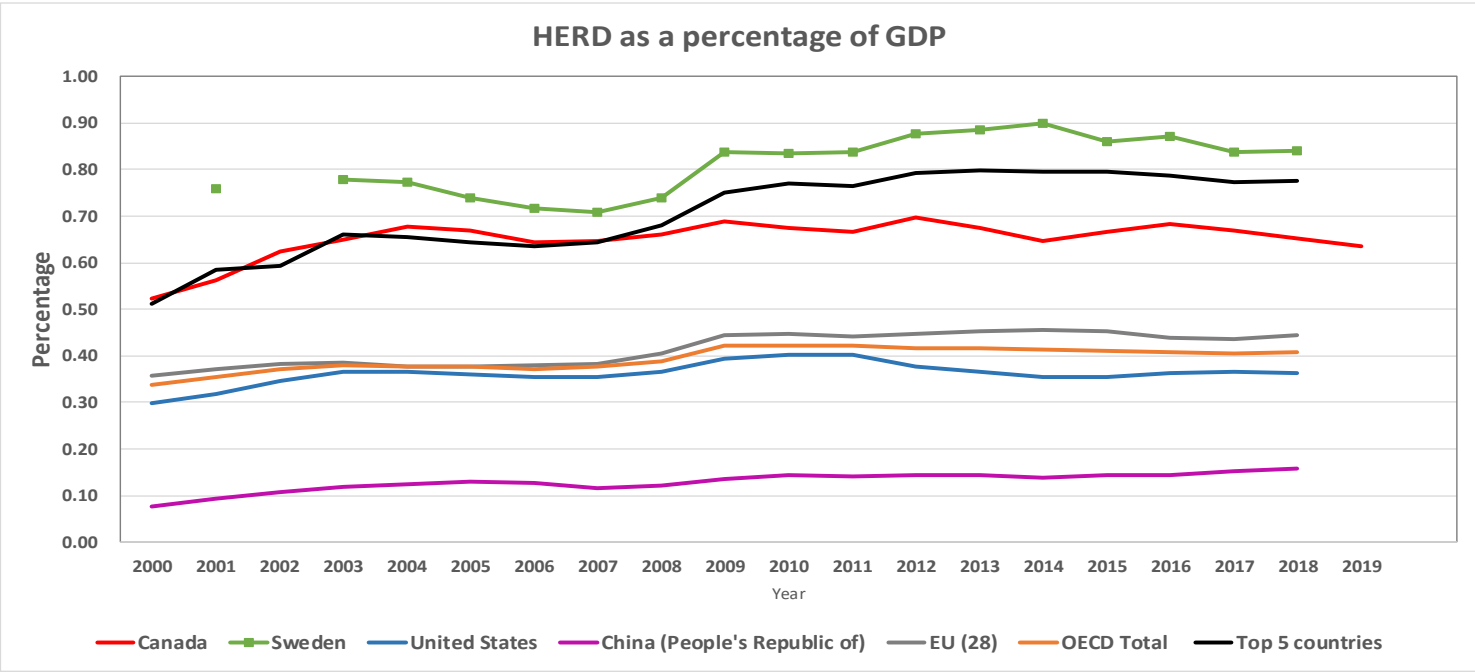


Source: *OECD Main Science and Technology Indicators* (https://stats.oecd.org/Index.aspx?DataSetCode=MSTI_PUB#)
Top 5 countries: United States, China, Germany, Japan, Russia
NOTE: OECD uses totals for OECD, EU(28); as such these are excluded from the top 5
Original data extracted on 06 Nov 2020 21:18 UTC (GMT) from OECD.Stat; percentage increases are author's calculations

Figure 15 HERD as a percentage of GDP

Dataset: Main Science and Technology Indicators

MSTI Variables	HERD as a percentage of GDP																			
Unit	Percentage																			
Year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Country																				
Canada	0.52	0.56	0.62	0.65	0.68	0.67	0.64	0.65	0.66	0.69	0.68	0.67	0.70	0.67	0.65	0.67	0.68	0.67	0.65	0.64
Sweden		0.76		0.78	0.77	0.74	0.72	0.71	0.74	0.84	0.83	0.84	0.88	0.89	0.90	0.86	0.87	0.84	0.84	
United States	0.30	0.32	0.35	0.37	0.37	0.36	0.35	0.35	0.37	0.39	0.40	0.40	0.38	0.37	0.36	0.35	0.36	0.37	0.36	
China (People's Republic of)	0.08	0.09	0.11	0.12	0.12	0.13	0.13	0.12	0.12	0.13	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.15	0.16	
EU (28)	0.36	0.37	0.38	0.39	0.38	0.38	0.38	0.38	0.41	0.44	0.45	0.44	0.45	0.45	0.46	0.45	0.44	0.44	0.44	
OECD Total	0.34	0.35	0.37	0.38	0.38	0.38	0.37	0.38	0.39	0.42	0.42	0.42	0.42	0.42	0.41	0.41	0.41	0.41	0.41	
Top 5 countries	0.51	0.58	0.59	0.66	0.65	0.64	0.64	0.64	0.68	0.75	0.77	0.76	0.79	0.80	0.79	0.80	0.79	0.77	0.78	



Source: OECD Main Science and Technology Indicators (https://stats.oecd.org/Index.aspx?DataSetCode=MSTI_PUB#)

Top 5 countries: Sweden, Denmark, Finland, Austria, Canada

Switzerland was excluded from the top 5 as it was missing entries for 10 years. Top 5 country average was not calculated for 2019 due to missing data for 3 countries.

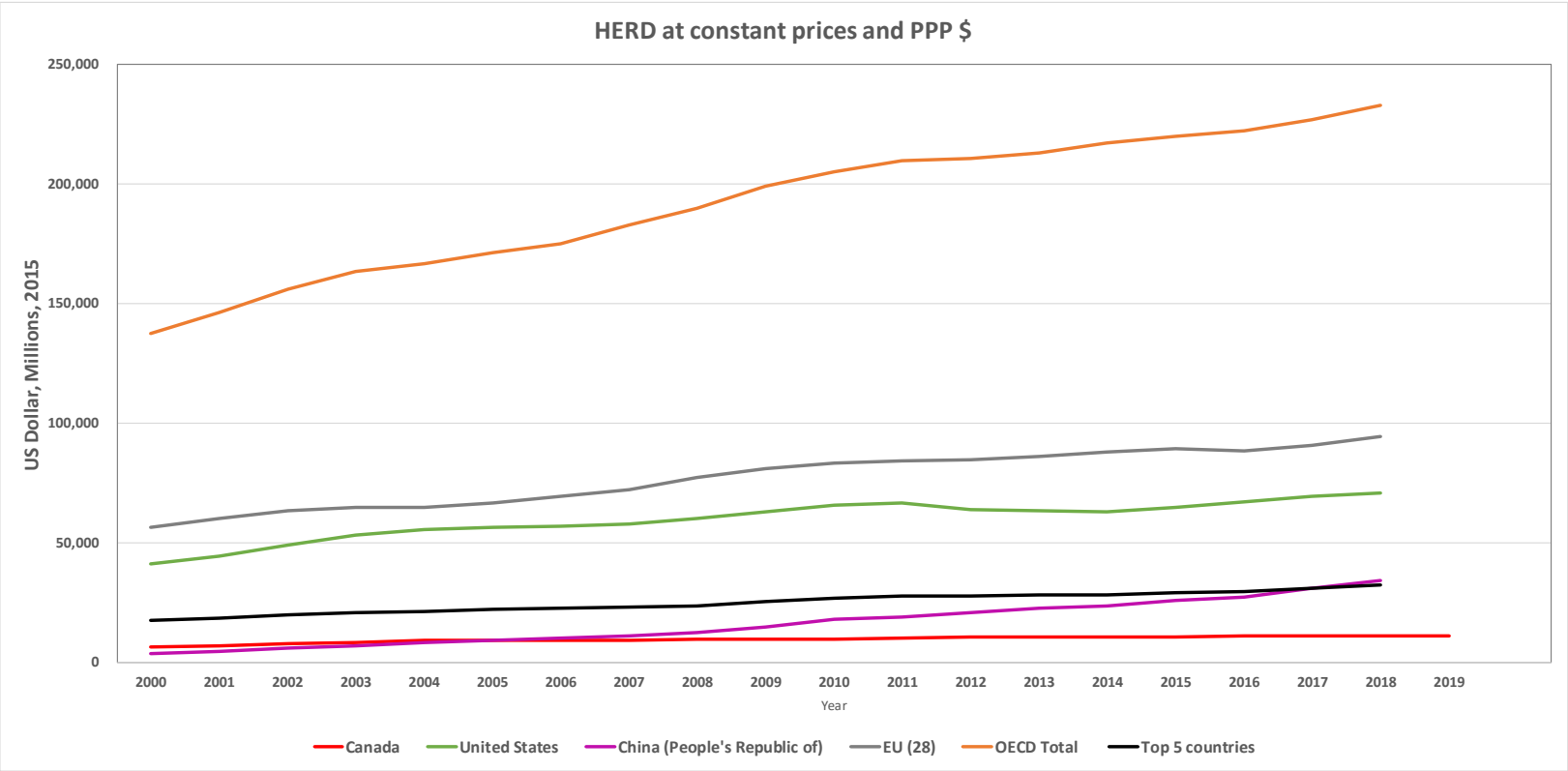
NOTE: OECD uses totals for OECD, EU(28); as such these are excluded from the top 5

Data extracted on 03 Nov 2020 14:54 UTC (GMT) from OECD.Stat

Figure 16 HERD at constant prices and PPP\$

Dataset: Main Science and Technology Indicators

MSTI Variables	HERD at constant prices and PPP \$																			
Unit	US Dollar, Millions, 2015																			
Year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Country																				
Canada	6,245	6,812	7,809	8,261	8,899	9,066	8,940	9,161	9,449	9,577	9,682	9,865	10,509	10,367	10,240	10,613	10,983	11,130	11,057	10,957
United States	41,165	44,254	48,950	53,221	55,313	56,306	56,914	57,913	59,883	62,797	65,780	66,634	63,768	63,339	62,998	64,623	67,105	69,217	70,863	
China (People's Republic of)	3,419	4,470	5,663	6,865	7,946	9,222	10,137	10,695	12,302	14,792	17,657	18,842	20,864	22,415	23,232	25,798	27,287	30,854	34,271	
EU (28)	56,483	60,078	63,462	64,812	64,822	66,462	69,279	72,229	77,343	80,890	83,233	83,928	84,805	85,811	88,007	89,350	88,304	90,450	94,150	
OECD Total	137,579	146,091	156,002	163,187	166,698	171,427	175,077	182,742	189,587	199,176	205,306	209,833	210,492	213,131	216,975	219,983	222,137	226,955	232,949	
Top 5 countries	17,180	18,276	19,519	20,665	21,176	21,927	22,353	22,856	23,637	25,246	26,613	27,433	27,430	27,963	28,199	28,879	29,630	30,988	32,166	



Source: OECD Main Science and Technology Indicators (https://stats.oecd.org/Index.aspx?DataSetCode=MSTI_PUB#)

Top 5 countries: United States, Japan, Germany, China, France.

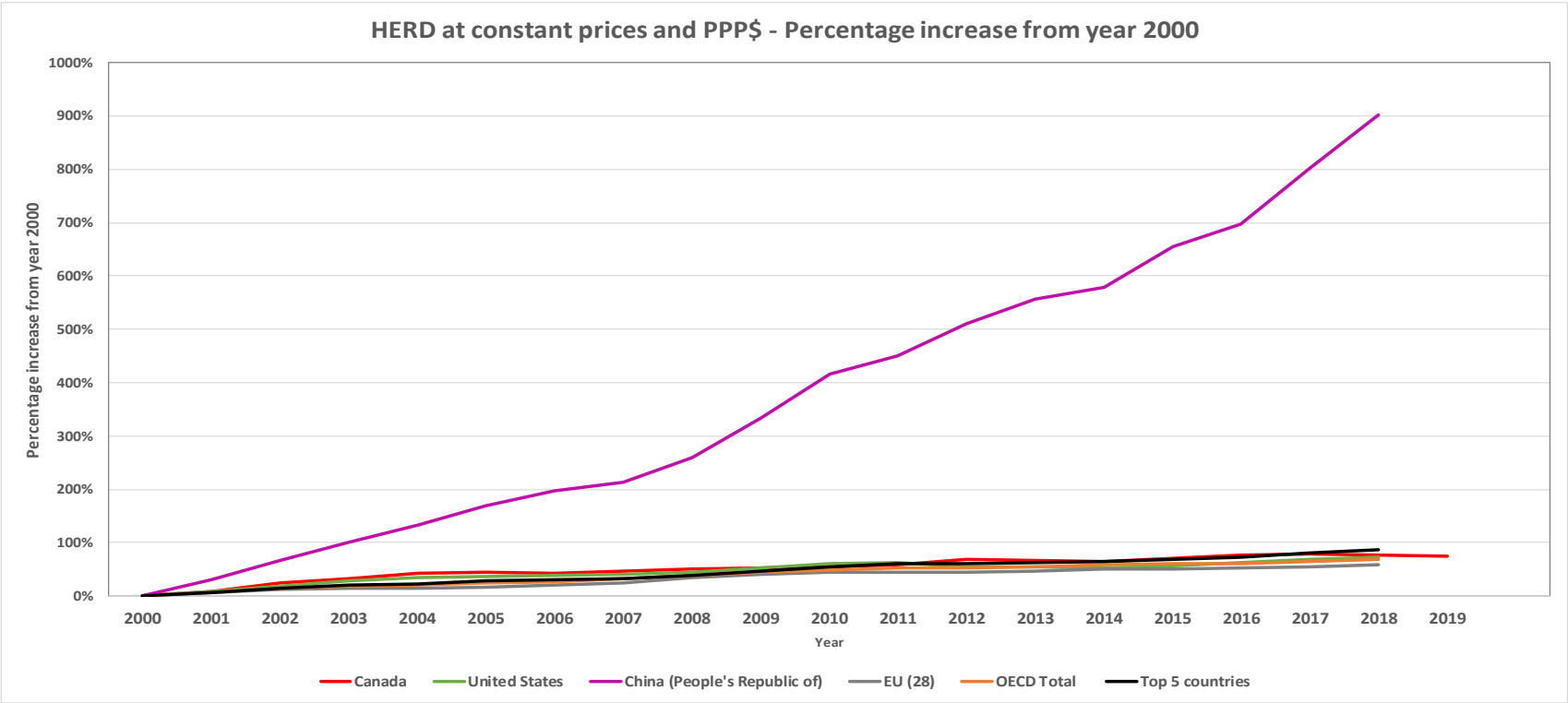
NOTE: OECD uses totals for OECD, EU(28); as such these are excluded from the top 5

Data extracted on 24 Dec 2020 22:21 UTC (GMT) from OECD.Stat

Figure 17 HERD at constant prices and PPP\$ - Percentage increase from year 2000

Dataset: Main Science and Technology Indicators

MSTI Variables		HERD at constant prices and PPP\$ - Percentage increase from year 2000																			
Unit		Percentage increase from year 2000																			
Country	Year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Canada		0%	9%	25%	32%	43%	45%	43%	47%	51%	53%	55%	58%	68%	66%	64%	70%	76%	78%	77%	75%
United States		0%	8%	19%	29%	34%	37%	38%	41%	45%	53%	60%	62%	55%	54%	53%	57%	63%	68%	72%	
China (People's Republic of)		0%	31%	66%	101%	132%	170%	197%	213%	260%	333%	416%	451%	510%	556%	580%	655%	698%	803%	902%	
EU (28)		0%	6%	12%	14%	14%	16%	21%	25%	34%	40%	44%	44%	44%	47%	50%	51%	52%	54%	58%	
OECD Total		0%	6%	13%	19%	21%	25%	27%	33%	38%	45%	49%	53%	53%	55%	58%	60%	61%	65%	69%	
Top 5 countries		0%	6%	14%	20%	23%	28%	30%	33%	38%	47%	55%	60%	60%	63%	64%	68%	72%	80%	87%	



Source: OECD Main Science and Technology Indicators (https://stats.oecd.org/Index.aspx?DataSetCode=MSTI_PUB#)

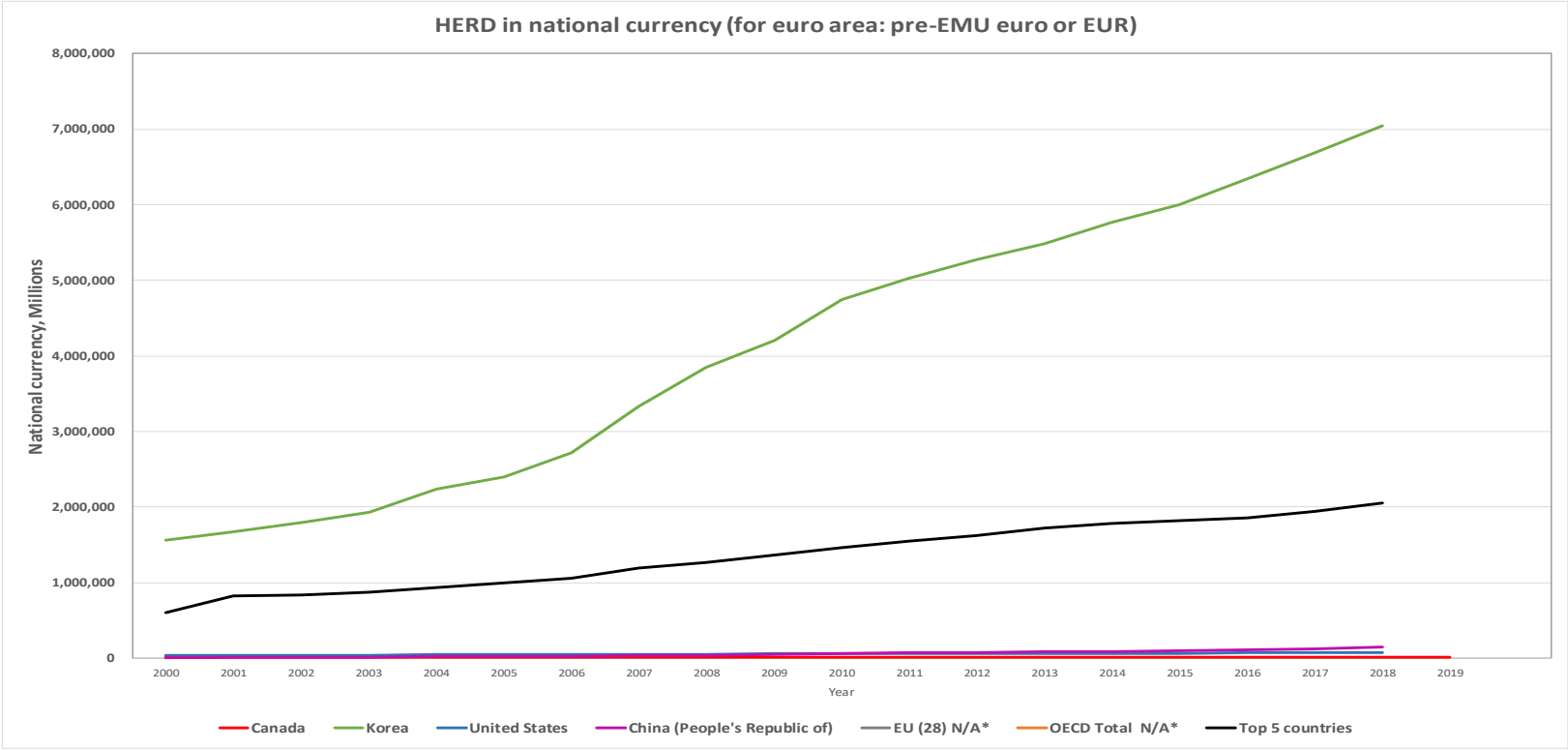
Top 5 countries: United States, Japan, Germany, China, France.

NOTE: OECD uses totals for OECD, EU(28); as such these are excluded from the top 5

Data extracted on 24 Dec 2020 22:21 UTC (GMT) from OECD.Stat

Figure 18 HERD in national currency (for euro area: pre-EMU euro or EUR)

Dataset: Main Science and Technology Indicators																				
MSTI Variables		HERD in national currency (for euro area: pre-EMU euro or EUR)																		
Unit		National currency, Millions																		
Year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Country																				
Canada	5,793	6,424	7,455	8,143	9,059	9,517	9,626	10,187	10,927	10,818	11,249	11,832	12,757	12,803	12,892	13,245	13,810	14,339	14,504	14,647
Korea	1,561,864	1,676,777	1,797,096	1,932,663	2,232,257	2,398,284	2,721,874	3,334,119	3,844,749	4,204,259	4,745,459	5,033,817	5,276,928	5,480,323	5,766,961	5,998,872	6,339,888	6,682,523	7,050,415	
United States	30,693	33,720	37,888	41,959	44,782	47,006	48,951	51,149	53,917	56,972	60,374	62,435	60,896	61,547	62,349	64,623	67,800	71,251	74,722	
China (People's Republic of)	7,674	10,238	13,050	16,231	20,094	24,230	27,681	31,469	39,016	46,817	59,730	68,885	78,056	85,671	89,815	99,859	107,224	126,596	145,788	
EU (28) N/A*																				
OECD Total N/A*																				
Top 5 countries	603,378	829,194	841,124	871,523	932,828	995,938	1,057,787	1,198,028	1,268,017	1,369,950	1,463,549	1,550,256	1,624,914	1,723,379	1,780,263	1,823,615	1,851,237	1,936,678	2,047,522	



Source: *OECD Main Science and Technology Indicators* (https://stats.oecd.org/Index.aspx?DataSetCode=MSTI_PUB#)

Top 5 countries: Korea, Japan, Colombia, China, Hungary. Chile is excluded from the top 5 - missing 7 data points not including 2019.

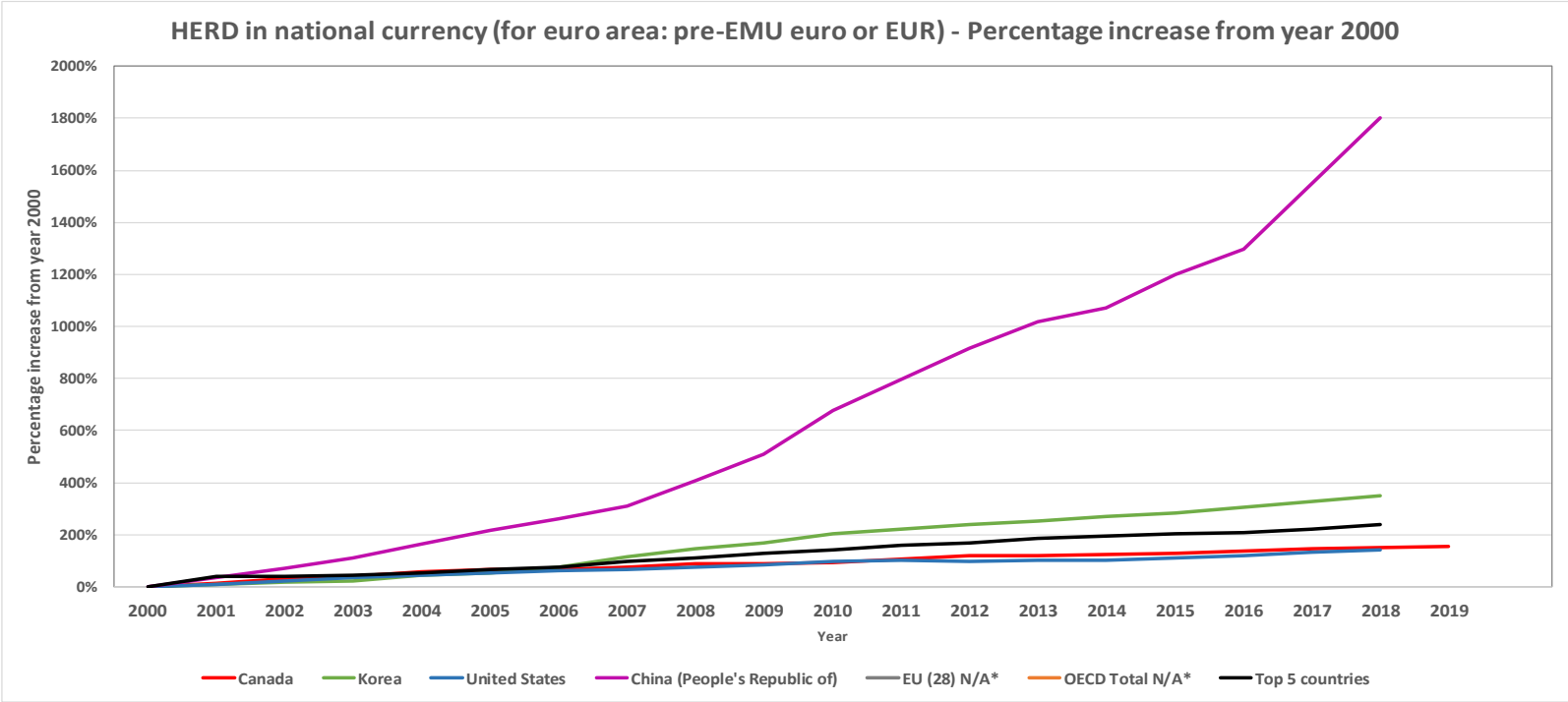
* NOTE: Given the indicator is HERD in national currency, OECD and EU(28) are not reported

Data extracted on 26 Dec 2020 14:42 UTC (GMT) from OECD.Stat

Figure 19 HERD in national currency (for euro area: pre-EMU euro or Eur) – Percentage increase from year 2000

Dataset: Main Science and Technology Indicators

MSTI Variables	HERD in national currency (for euro area: pre-EMU euro or EUR) - Percentage increase from year 2000																			
Unit	Percentage increase from year 2000																			
Year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Country																				
Canada	0%	11%	29%	41%	56%	64%	66%	76%	89%	87%	94%	104%	120%	121%	123%	129%	138%	148%	150%	153%
Korea	0%	7%	15%	24%	43%	54%	74%	113%	146%	169%	204%	222%	238%	251%	269%	284%	306%	328%	351%	
United States	0%	10%	23%	37%	46%	53%	59%	67%	76%	86%	97%	103%	98%	101%	103%	111%	121%	132%	143%	
China (People's Republic of)	0%	33%	70%	112%	162%	216%	261%	310%	408%	510%	678%	798%	917%	1016%	1070%	1201%	1297%	1550%	1800%	
EU (28) N/A*																				
OECD Total N/A*																				
Top 5 countries	0%	37%	39%	44%	55%	65%	75%	99%	110%	127%	143%	157%	169%	186%	195%	202%	207%	221%	239%	

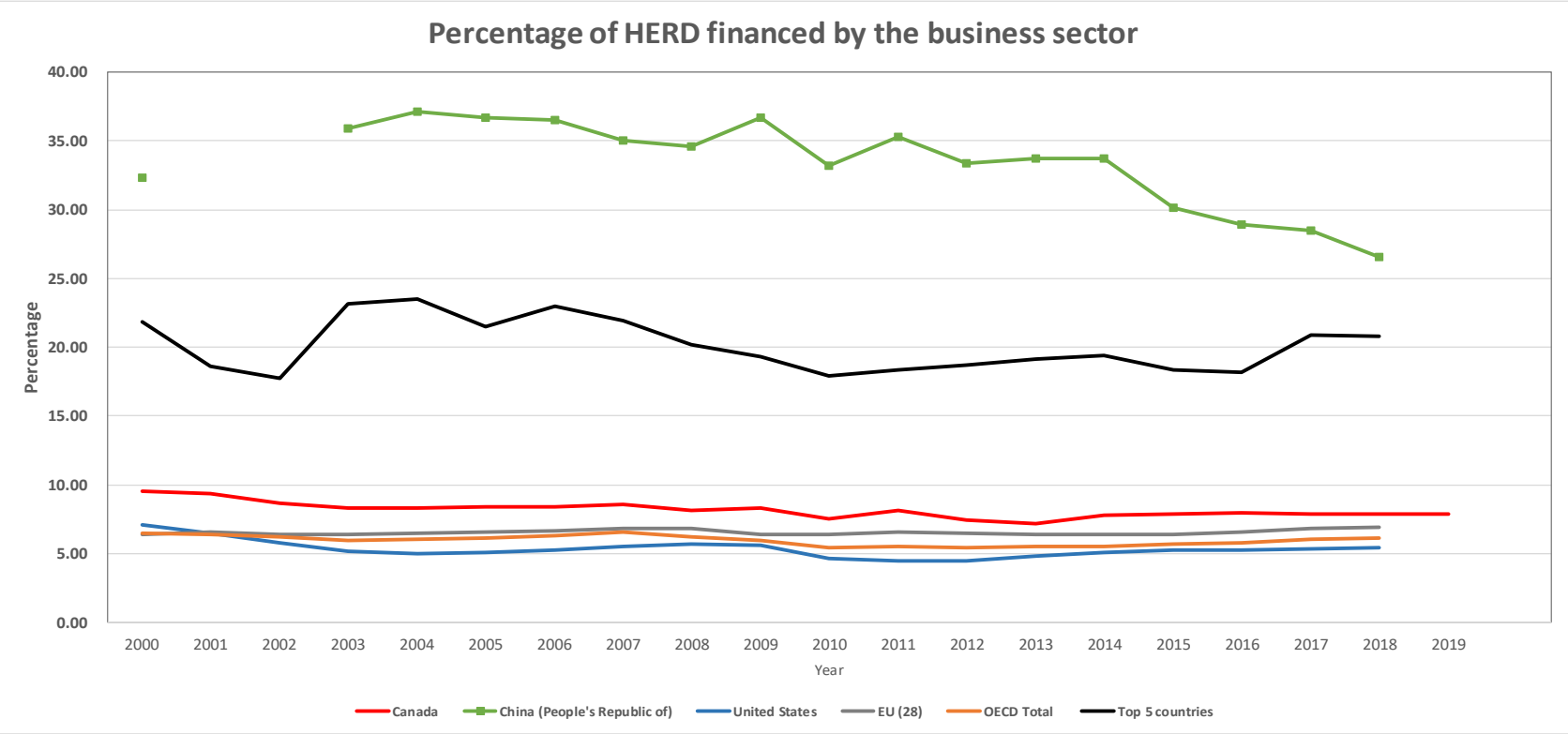


Source: OECD Main Science and Technology Indicators (https://stats.oecd.org/Index.aspx?DataSetCode=MSTI_PUB#)
Top 5 countries: Korea, Japan, Colombia, China, Hungary. Chile is excluded from the top 5 - missing 7 data points not including 2019.
* NOTE: Given the indicator is HERD in national currency, OECD and EU(28) are not reported
Data extracted on 26 Dec 2020 14:42 UTC (GMT) from OECD.Stat

Figure 20 Percentage of HERD financed by the business sector

Dataset: Main Science and Technology Indicators

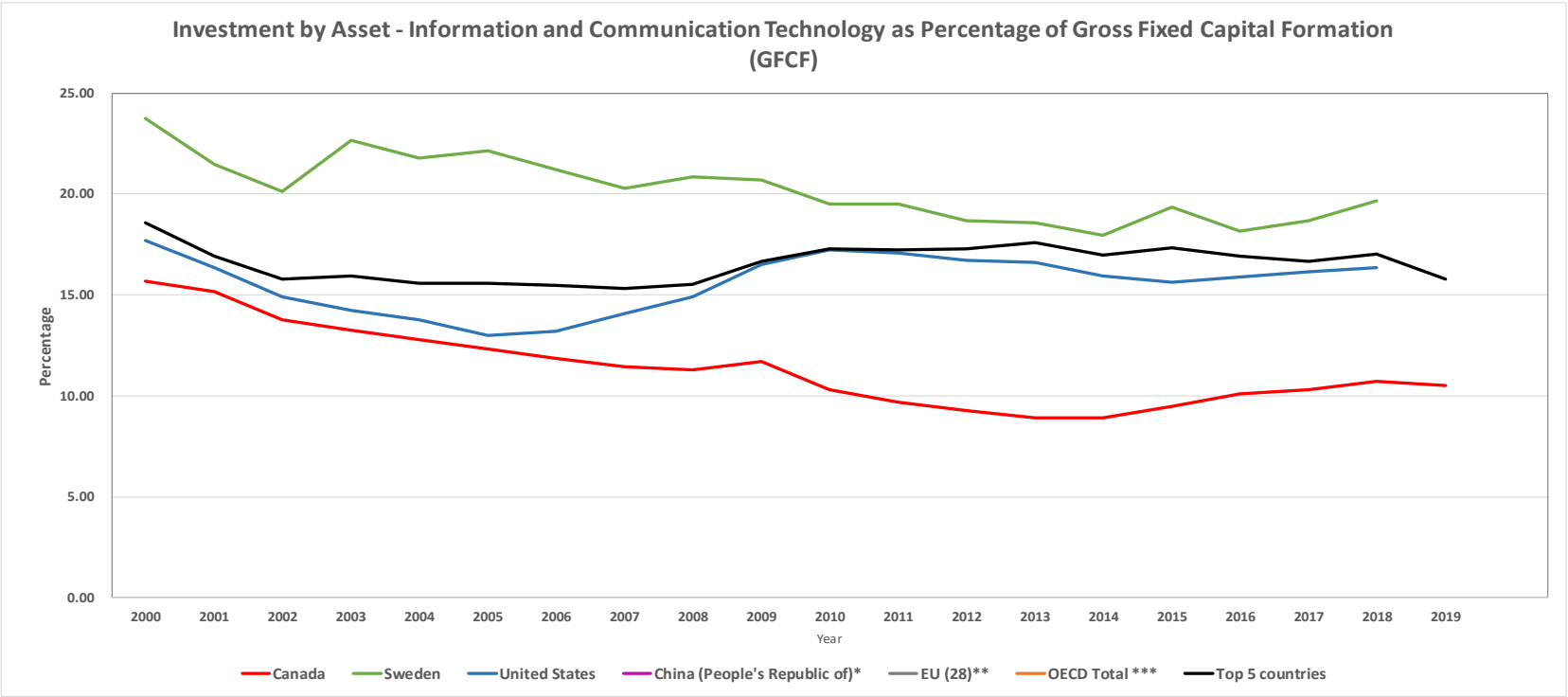
MSTI Variables	Percentage of HERD financed by the business sector																			
Unit	Percentage																			
Year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Country																				
Canada	9.55	9.39	8.63	8.34	8.33	8.44	8.39	8.54	8.16	8.28	7.49	8.16	7.46	7.14	7.74	7.86	7.92	7.85	7.85	7.84
China (People's Republic of)	32.36			35.89	37.10	36.70	36.57	35.05	34.57	36.67	33.23	35.26	33.37	33.77	33.70	30.19	28.96	28.47	26.56	
United States	7.08	6.49	5.75	5.16	4.98	5.04	5.24	5.48	5.69	5.60	4.67	4.49	4.47	4.84	5.11	5.25	5.25	5.30	5.42	
EU (28)	6.37	6.52	6.41	6.38	6.44	6.57	6.63	6.86	6.78	6.42	6.36	6.55	6.44	6.39	6.35	6.42	6.53	6.86	6.93	
OECD Total	6.49	6.36	6.18	5.94	6.06	6.13	6.28	6.53	6.19	5.94	5.43	5.47	5.41	5.51	5.55	5.67	5.79	6.01	6.16	
Top 5 countries	21.83	18.58	17.77	23.18	23.54	21.48	23.00	21.91	20.19	19.31	17.93	18.37	18.69	19.15	19.38	18.32	18.18	20.92	20.84	



Source: *OECD Main Science and Technology Indicators* (https://stats.oecd.org/Index.aspx?DataSetCode=MSTI_PUB#)
Top 5 countries: China, Russia, Germany, Korea, South Africa NOTE: OECD uses totals for OECD, EU(28); as such these are excluded from the top 5
Data extracted on 02 Nov 2020 21:17 UTC (GMT) from OECD.Stat

Figure 21 ICT investments, total, percentage of gross fixed capital formation (GFCF)

National Accounts	Investment by Asset - Information and Communication Technology as Percentage of Gross Fixed Capital Formation (GFCF)																			
Unit	Percentage																			
Year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Country																				
Canada	15.68	15.16	13.79	13.23	12.80	12.30	11.84	11.46	11.29	11.68	10.28	9.67	9.28	8.90	8.92	9.46	10.11	10.28	10.72	10.53
Sweden	23.75	21.49	20.10	22.65	21.77	22.15	21.21	20.30	20.86	20.67	19.52	19.48	18.68	18.56	17.96	19.35	18.14	18.67	19.68	
United States	17.68	16.33	14.88	14.21	13.76	12.97	13.20	14.06	14.90	16.51	17.22	17.05	16.71	16.63	15.93	15.62	15.90	16.14	16.33	
China (People's Republic of)*																				
EU (28)**																				
OECD Total ***																				
Top 5 countries	18.56	16.93	15.76	15.94	15.59	15.57	15.46	15.32	15.53	16.65	17.31	17.23	17.30	17.62	16.95	17.35	16.93	16.64	17.04	15.77

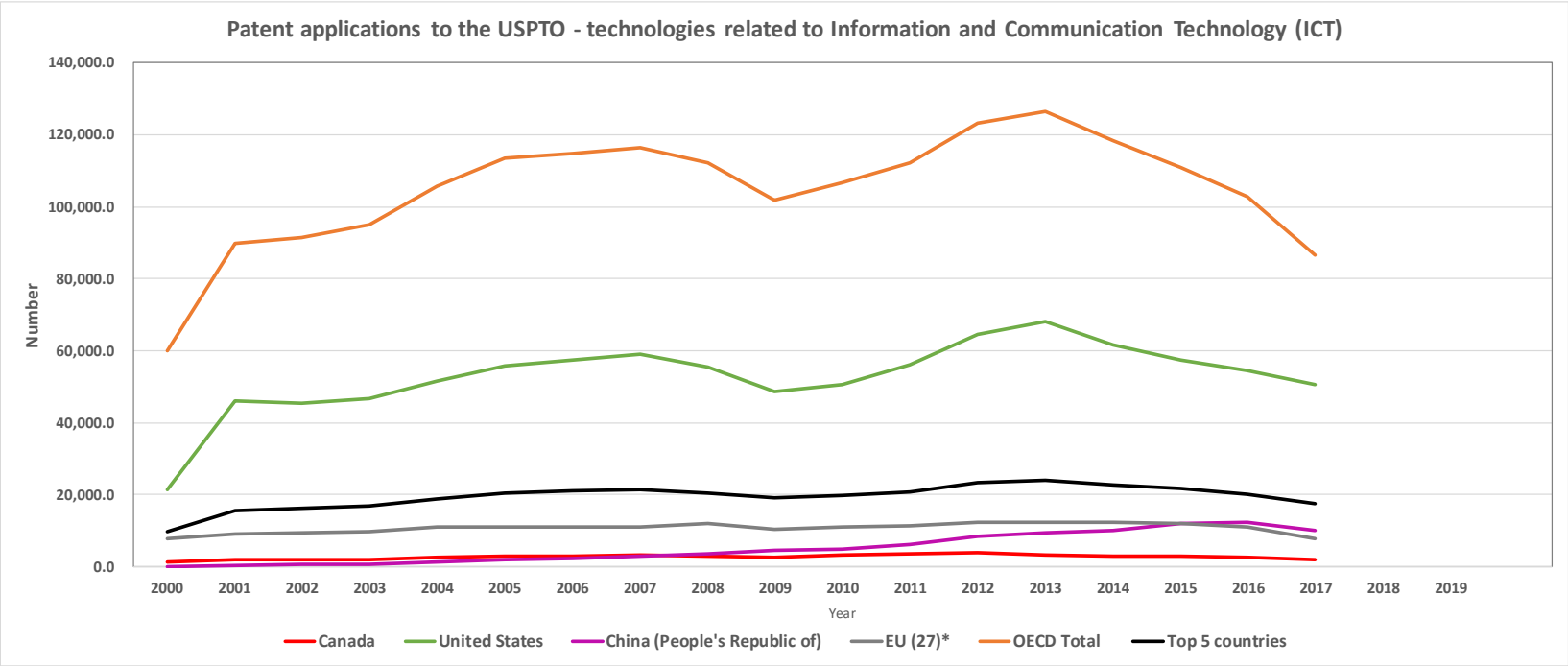


Source: *OECD Main Science and Technology Indicators* (https://stats.oecd.org/Index.aspx?DataSetCode=MSTI_PUB#)
Top 5 countries: Sweden, New Zealand, Netherlands, United States, United Kingdom
* No entries for China; **EU(28) not calculated; *** OECD not calculated; Entries do not appear for Germany, Korea, Japan
NOTE: OECD uses totals for OECD, EU(28); as such these are excluded from the top 5
OECD (2021), Investment by asset (indicator). doi: 10.1787/8e5d47e6-en ; Accessed on 03 January 2021

Figure 22 Patent applications to the USPTO - technologies related to Information and Communication Technology (ICT)

Dataset: Patents by Technology

Patents Office & Patents		Patent applications to the USPTO - technologies related to Information and Communication Technology (ICT)																			
Reference country	Inventor(s)'s country(ies) of residence																				
Reference Date	Priority date																				
Technology domains & IPC		ICT																			
Unit	Number, 2017																				
Year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	
Country																					
Canada	1,226.5	2,036.7	2,099.8	2,145.9	2,497.6	2,821.8	3,017.0	3,212.2	2,878.6	2,786.6	3,203.0	3,518.7	3,793.2	3,267.2	2,896.3	2,849.1	2,519.5	2,101.4			
United States	21,317.4	46,028.8	45,583.1	46,849.3	51,664.4	55,947.6	57,385.7	58,939.2	55,488.4	48,660.1	50,569.6	56,020.6	64,567.8	68,111.2	61,664.1	57,295.6	54,482.9	50,558.1			
China (People's Republic of)	155.3	294.7	580.0	812.4	1,224.1	2,110.4	2,447.2	3,120.6	3,641.1	4,423.4	4,879.9	6,152.2	8,527.8	9,329.5	10,131.9	12,167.6	12,221.0	9,988.1			
EU (27)*	7,715.2	9,198.3	9,418.0	9,839.1	10,995.7	11,137.2	11,090.5	11,200.3	11,879.3	10,526.3	11,024.9	11,460.2	12,446.2	12,473.2	12,418.3	11,889.3	11,074.3	7,705.2			
OECD Total	60,012.1	89,732.4	91,432.7	95,069.8	105,650.8	113,453.6	114,866.8	116,309.6	112,035.3	101,964.4	106,789.3	112,180.9	123,123.3	126,445.2	118,364.9	110,992.9	102,908.1	86,444.5			
Top 5 countries	9,688.6	15,490.1	16,110.2	16,964.9	18,988.4	20,581.0	20,969.7	21,334.5	20,513.8	19,034.7	19,857.7	20,926.8	23,306.3	24,176.3	22,687.7	21,672.6	20,300.8	17,606.3			



Source: *OECD Main Science and Technology Indicators* (https://stats.oecd.org/Index.aspx?DataSetCode=MSTI_PUB#)

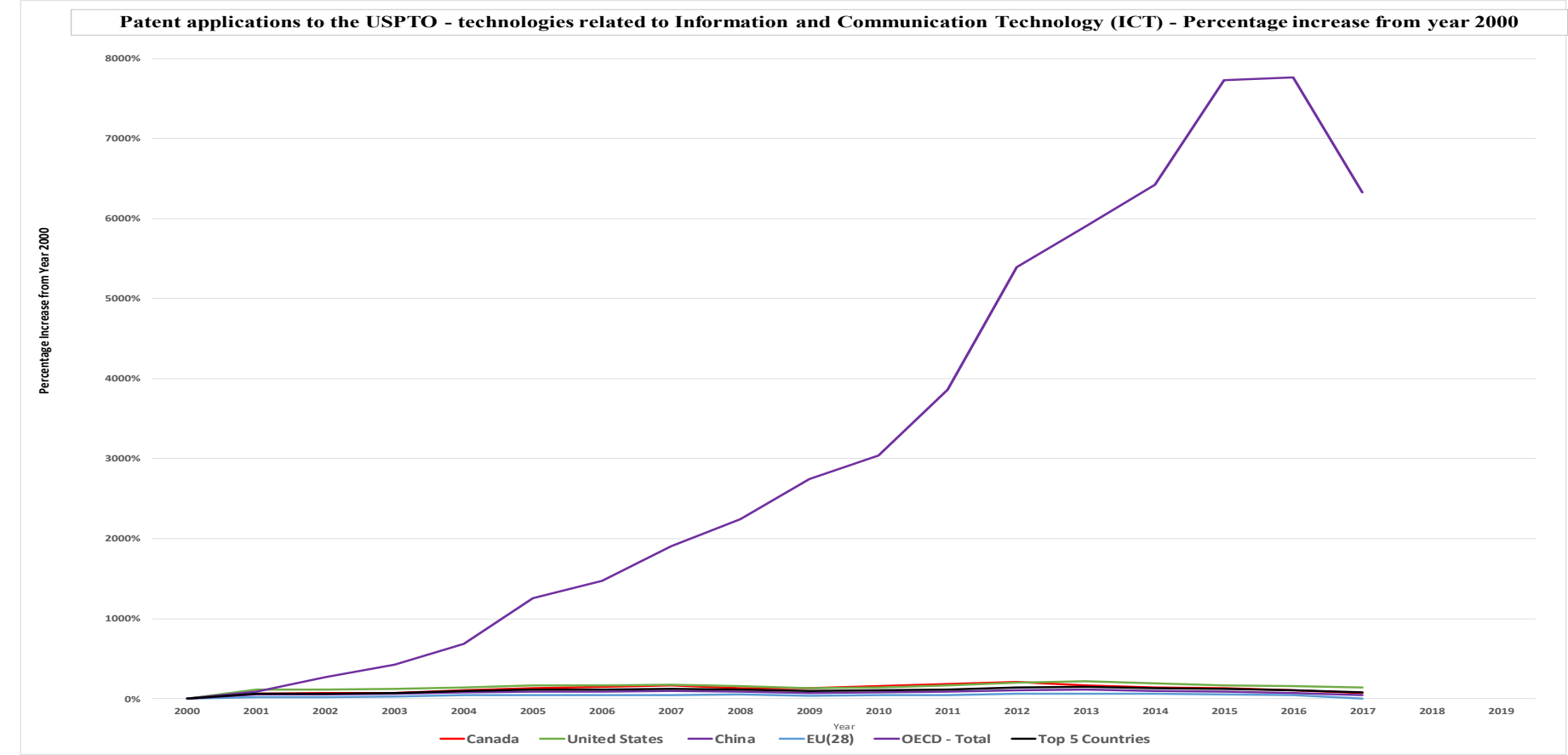
Top 5 countries: United States, Japan, Korea, Chinese Taipei, China

NOTE: OECD uses totals for OECD, EU(27); as such these are excluded from the top 5. *EU (27) is used in this OECD data.

Data extracted on 24 Dec 2020 15:34 UTC (GMT) from OECD.Stat

Figure 23A Patent applications to the USPTO - technologies related to Information and Communication Technology (ICT) - Percentage increase from year 2000

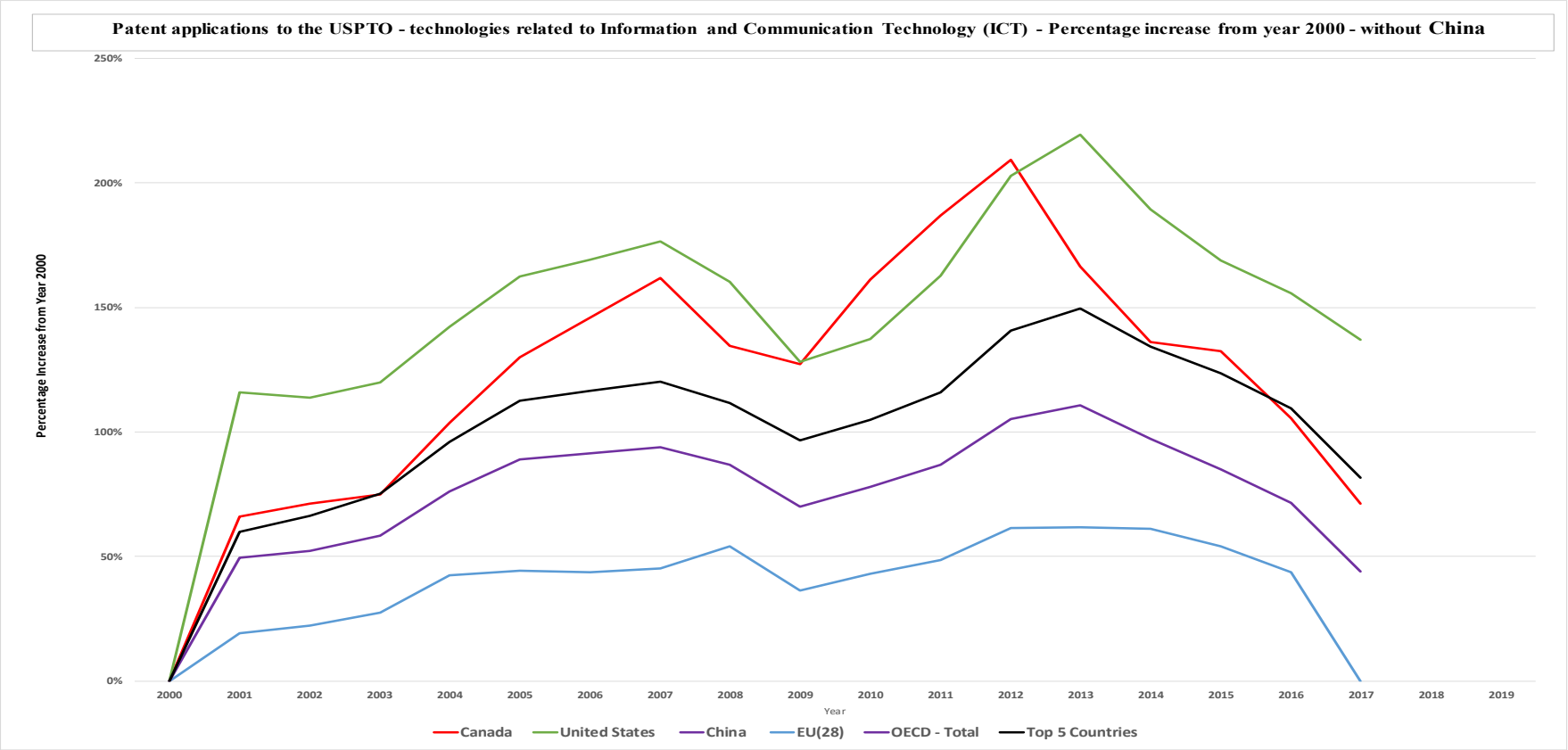
Reference country		Inventors(s)' country(ies) of residence																			
Reference Date		Priority date																			
Technology domains & IPC		Information and Communication Technology										Dataset: Patents by Technology									
Year		2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Country																					
Canada		0%	66%	71%	75%	104%	130%	146%	162%	135%	127%	161%	187%	209%	166%	136%	132%	105%	71%		
United States		0%	116%	114%	120%	142%	162%	169%	176%	160%	128%	137%	163%	203%	220%	189%	169%	156%	137%		
China		0%	90%	273%	423%	688%	1258%	1475%	1909%	2244%	2747%	3041%	3860%	5389%	5906%	6422%	7732%	7767%	6329%		
EU(28)		0%	19%	22%	28%	43%	44%	44%	45%	54%	36%	43%	49%	61%	62%	61%	54%	44%	0%		
OECD - Total		0%	50%	52%	58%	76%	89%	91%	94%	87%	70%	78%	87%	105%	111%	97%	85%	71%	44%		
Top 5 Countries		0%	60%	66%	75%	96%	112%	116%	120%	112%	96%	105%	116%	141%	150%	134%	124%	110%	82%		



Source: *OECD Main Science and Technology Indicators* (https://stats.oecd.org/Index.aspx?DataSetCode=MSTI_PUB#)
Top 5 countries: United States, Japan, Korea, Chinese Taipei, China
NOTE: OECD uses totals for OECD, EU(27); as such these are excluded from the top 5. *EU (27) is used in this OECD data.
Data extracted on 24 Dec 2020 15:34 UTC (GMT) from OECD.Stat

Figure 23B Patent applications to the USPTO - technologies related to Information and Communication Technology (ICT) – Percentage increase from year 2000 – without China

Patents Office & Patents Families			Patent applications to the USPTO - technologies related to Information and Communication Technology (ICT) - Percentage increase from year 2000																		
Reference country			Inventors(s)' country(ies) of residence																		
Reference Date			Priority date																		
Technology domains & IPC			Information and Communication Technology													Dataset: Patents by Technology					
Year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	
Country																					
Canada	0%	66%	71%	75%	104%	130%	146%	162%	135%	127%	161%	187%	209%	166%	136%	132%	105%	71%			
United States	0%	116%	114%	120%	142%	162%	169%	176%	160%	128%	137%	163%	203%	220%	189%	169%	156%	137%			
China																					
EU (28)	0%	19%	22%	28%	43%	44%	44%	45%	54%	36%	43%	49%	61%	62%	61%	54%	44%	0%			
OECD - Total	0%	50%	52%	58%	76%	89%	91%	94%	87%	70%	78%	87%	105%	111%	97%	85%	71%	44%			
Top 5 Countries	0%	60%	66%	75%	96%	112%	116%	120%	112%	96%	105%	116%	141%	150%	134%	124%	110%	82%			

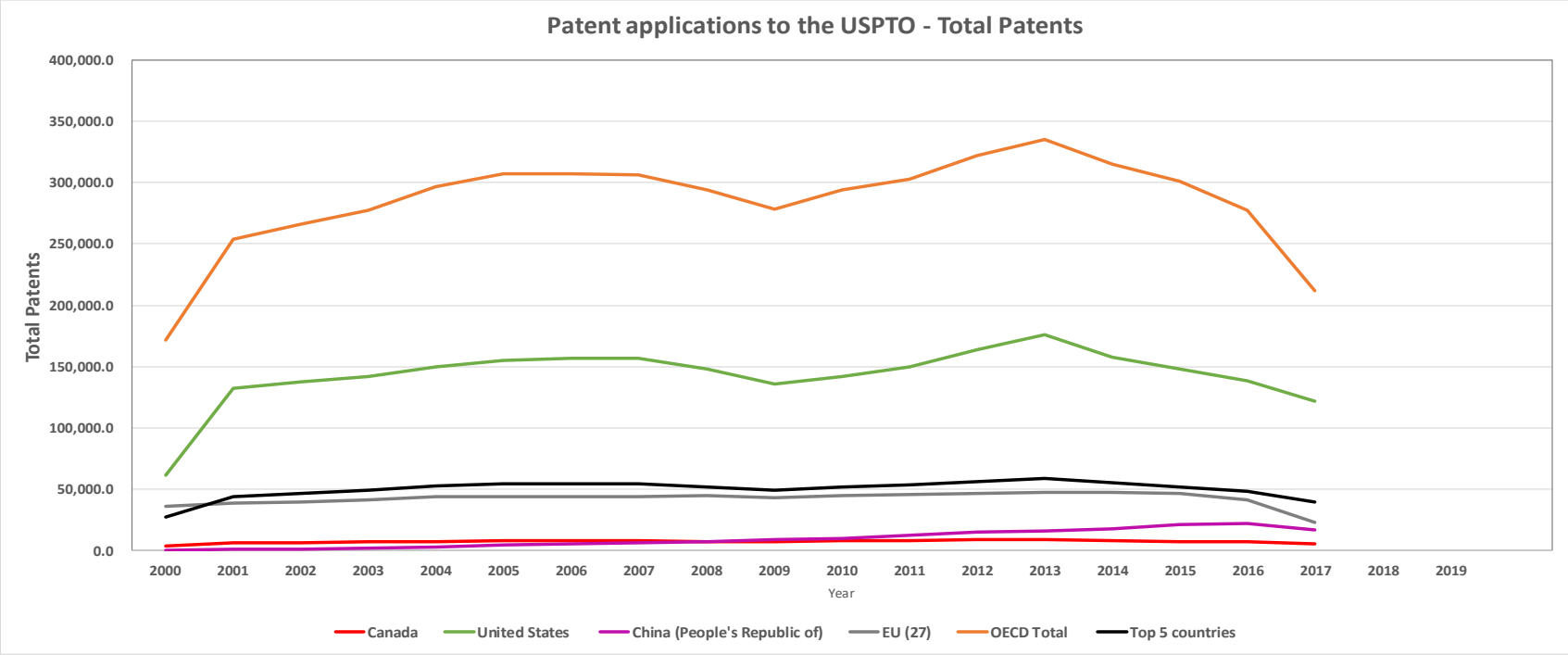


Source: *OECD Main Science and Technology Indicators* (https://stats.oecd.org/Index.aspx?DataSetCode=MSTI_PUB#)
Top 5 countries: United States, Japan, Korea, Chinese Taipei, China
NOTE: OECD uses totals for OECD, EU(27); as such these are excluded from the top 5. *EU (27) is used in this OECD data.
Data extracted on 24 Dec 2020 15:34 UTC (GMT) from OECD.Stat

Figure 24 Patent applications to the USPTO – Total Patents

Dataset: Patents by Technology

Patents Office and Patents Families		Patent applications to the USPTO - Total Patents																			
Reference country	Inventor(s)'s country(ies) of residence																				
Reference Date	Priority date																				
Technology domains & IPC		Total Patents																			
Year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	
Country																					
Canada	3,615.1	6,421.7	6,736.4	6,947.7	7,324.2	7,888.1	8,049.9	8,157.6	7,380.7	7,364.8	7,903.7	8,137.5	8,676.0	8,570.6	7,831.6	7,453.9	6,836.3	5,559.7			
United States	61,394.9	131,891.5	137,996.7	142,317.3	149,964.8	155,011.2	156,574.5	156,390.9	147,967.0	136,103.6	141,652.7	149,661.3	164,206.0	175,877.3	157,428.8	147,718.8	138,736.4	121,722.0			
China (People's Republic of)	507.7	920.2	1,466.7	2,086.9	2,712.9	4,390.8	5,028.6	6,273.9	7,317.7	8,798.2	10,063.1	12,108.4	14,932.4	16,170.9	17,824.6	20,818.0	21,756.3	17,041.2			
EU (27)	35,648.9	39,103.5	39,546.3	40,970.6	43,989.6	44,357.2	43,691.9	43,754.6	44,490.0	43,285.8	45,042.2	45,308.8	47,001.5	47,491.3	47,346.8	46,444.1	41,321.8	23,104.8			
OECD Total	171,423.9	254,009.8	265,827.4	277,903.9	297,159.8	307,478.9	307,342.1	306,821.0	293,726.0	278,317.1	294,268.1	302,831.3	321,817.5	335,129.5	315,553.5	301,038.4	277,261.0	212,312.9			
Top 5 countries	27,595.4	43,943.5	46,465.0	48,892.4	52,633.0	54,679.6	54,715.4	54,533.9	51,734.3	48,890.6	51,690.0	53,307.2	56,558.4	58,913.0	54,921.4	52,181.4	48,403.3	39,224.7			

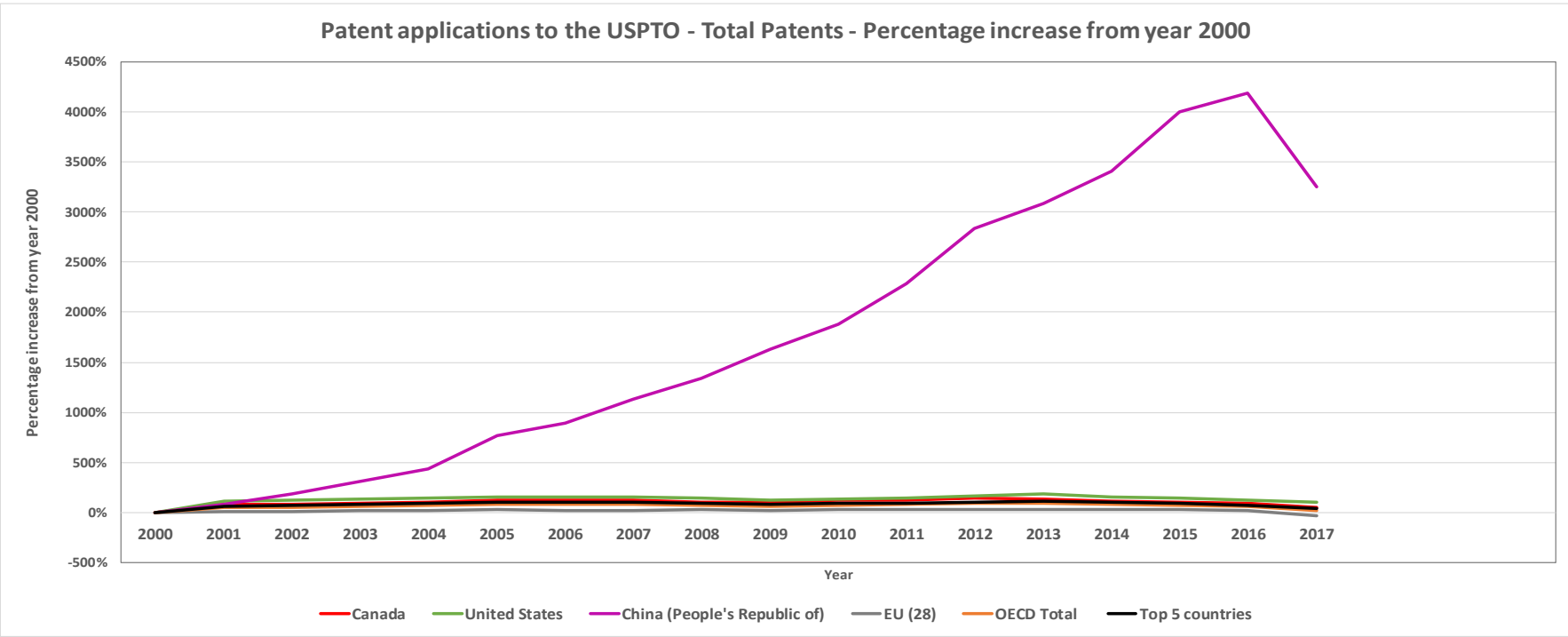


Source: *OECD Main Science and Technology Indicators* (https://stats.oecd.org/Index.aspx?DataSetCode=MSTI_PUB#)
Top 5 countries: United States, Japan, Germany, Korea, Chinese Taipei
NOTE: OECD uses totals for OECD, EU(27); as such these are excluded from the top 5. *EU(27) is used in this OECD data.
Data extracted on 15 Nov 2020 20:05 UTC (GMT) from OECD.Stat

Figure 25A Patent applications to the USPTO – Total Patents – Percentage increase from year 2000

Dataset: Patents by Technology

Patents Office and Patent Families	Patent applications to the USPTO - Total Patents - Percentage increase from year 2000																			
Reference Country	Inventor(s)'s country(ies) of residence																			
Reference Date	Priority date																			
Technology Domains & IPC	Total Patents																			
Year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Country																				
Canada	0%	78%	86%	92%	103%	118%	123%	126%	104%	104%	119%	125%	140%	137%	117%	106%	89%	54%		
United States	0%	115%	125%	132%	144%	152%	155%	155%	141%	122%	131%	144%	167%	186%	156%	141%	126%	98%		
China (People's Republic of)	0%	81%	189%	311%	434%	765%	890%	1136%	1341%	1633%	1882%	2285%	2841%	3085%	3411%	4000%	4185%	3256%		
EU (28)	0%	10%	11%	15%	23%	24%	23%	23%	25%	21%	26%	27%	32%	33%	33%	30%	16%	-35%		
OECD Total	0%	48%	55%	62%	73%	79%	79%	79%	71%	62%	72%	77%	88%	95%	84%	76%	62%	24%		
Top 5 countries	0%	59%	68%	77%	91%	98%	98%	98%	87%	77%	87%	93%	105%	113%	99%	89%	75%	42%		



Source: OECD Main Science and Technology Indicators (https://stats.oecd.org/Index.aspx?DataSetCode=MSTI_PUB#)

Top 5 countries: United States, Japan, Germany, Korea, Chinese Taipei

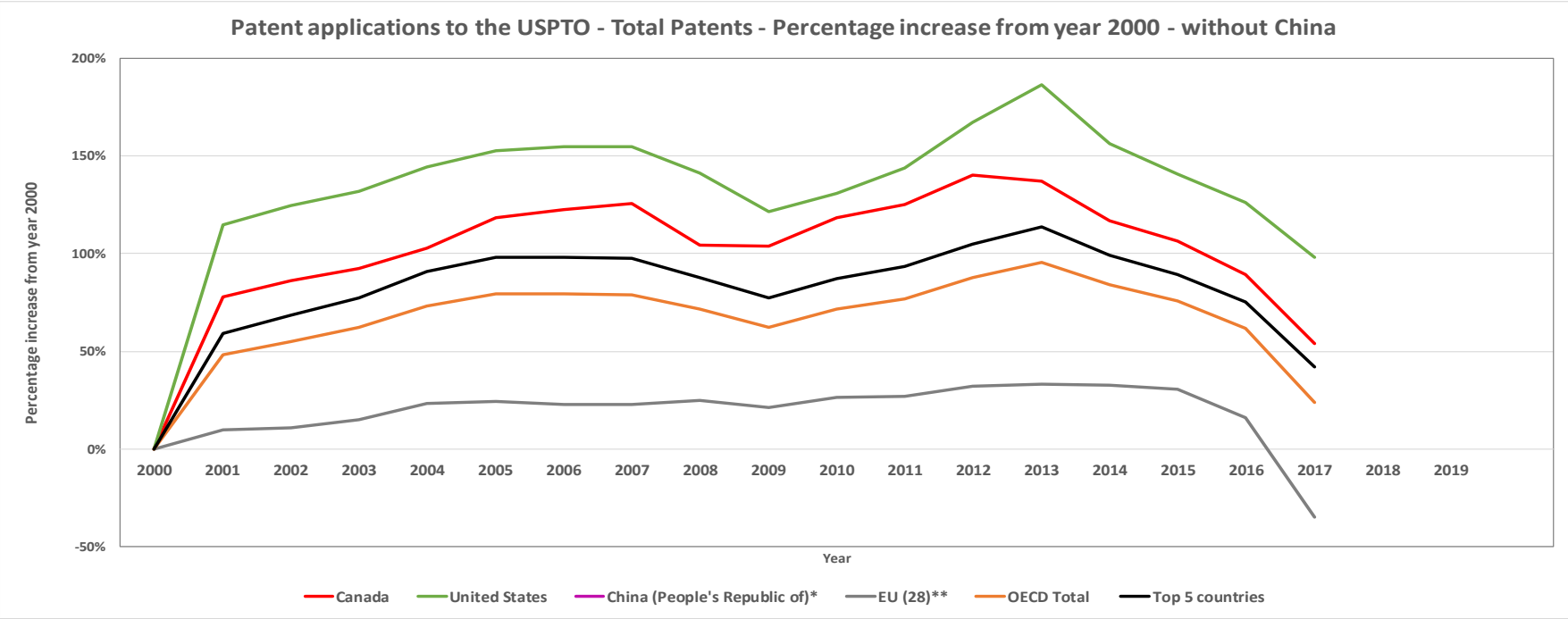
NOTE: OECD uses totals for OECD, EU(27); as such these are excluded from the top 5. *EU(27) is used in this OECD data.

Original data extracted on 15 Nov 2020 20:05 UTC (GMT) from OECD.Stat; percentage increases are author's calculations

Figure 25B Patent applications to the USPTO – Total Patents – Percentage increase from year 2000 – without China

Dataset: Patents by Technology

Patents Office and Patent Families	Patent applications to the USPTO - Total Patents - Percentage increase from year 2000 - without China																			
Reference Country	Inventor(s)'s country(ies) of residence																			
Reference Date	Priority date																			
Technology Domains & IPC	Total Patents																			
Year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Country																				
Canada	0%	78%	86%	92%	103%	118%	123%	126%	104%	104%	119%	125%	140%	137%	117%	106%	89%	54%		
United States	0%	115%	125%	132%	144%	152%	155%	155%	141%	122%	131%	144%	167%	186%	156%	141%	126%	98%		
China (People's Republic of)*																				
EU (28)**	0%	10%	11%	15%	23%	24%	23%	23%	25%	21%	26%	27%	32%	33%	33%	30%	16%	-35%		
OECD Total	0%	48%	55%	62%	73%	79%	79%	79%	71%	62%	72%	77%	88%	95%	84%	76%	62%	24%		
Top 5 countries	0%	59%	68%	77%	91%	98%	98%	98%	87%	77%	87%	93%	105%	113%	99%	89%	75%	42%		

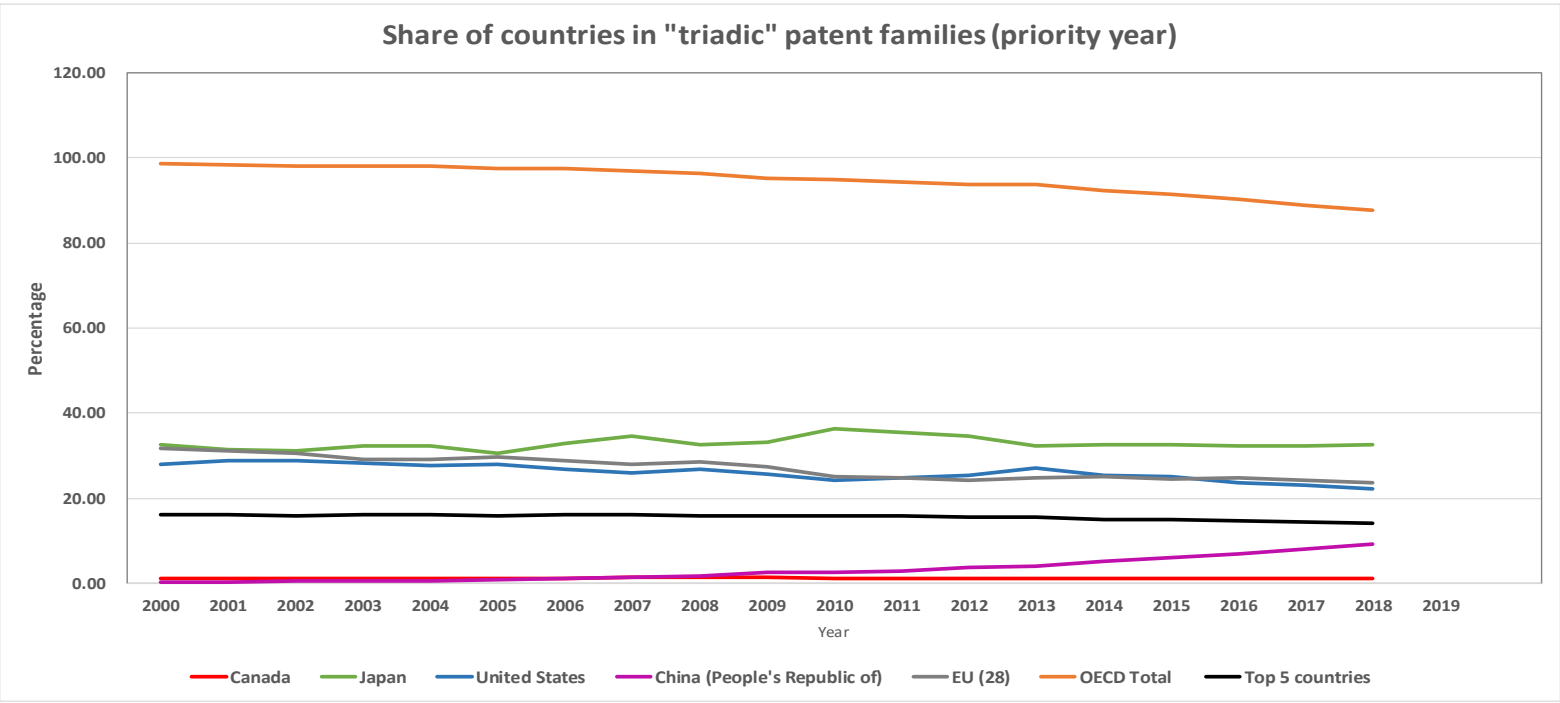


Source: OECD Main Science and Technology Indicators (https://stats.oecd.org/Index.aspx?DataSetCode=MSTI_PUB#)
Top 5 countries: United States, Japan, Germany, Korea, Chinese Taipei; Note China data is not presented in this graph
NOTE: OECD uses totals for OECD, EU(27); as such these are excluded from the top 5. *EU(27) is used in this OECD data.
Original data extracted on 15 Nov 2020 20:05 UTC (GMT) from OECD.Stat; percentage increases are author's calculations

Figure 26 Share of countries in “triadic” patent families (priority year)

Dataset: Main Science and Technology Indicators

MSTI Variables	Share of countries in "triadic" patent families (priority year)																			
Unit	Percentage																			
Year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Country																				
Canada	1.10	1.15	1.19	1.14	1.18	1.16	1.15	1.27	1.33	1.28	1.05	1.09	0.98	1.14	1.09	1.08	1.08	1.11	1.09	
Japan	32.62	31.49	31.24	32.16	32.30	30.54	32.87	34.56	32.54	33.13	36.41	35.56	34.54	32.23	32.51	32.47	32.28	32.19	32.58	
United States	27.91	28.73	28.87	28.23	27.65	28.02	26.75	25.80	26.77	25.68	24.07	24.74	25.46	27.05	25.21	24.98	23.76	23.12	22.28	
China (People's Republic of)	0.16	0.28	0.48	0.60	0.65	0.84	0.98	1.28	1.60	2.47	2.69	2.82	3.61	4.00	5.23	5.93	7.00	8.10	9.30	
EU (28)	31.64	31.21	30.44	29.22	29.09	29.71	28.86	28.08	28.50	27.47	24.94	24.91	24.26	24.75	25.18	24.47	24.67	24.32	23.67	
OECD Total	98.71	98.34	98.07	98.00	98.00	97.57	97.45	96.91	96.32	95.22	94.76	94.40	93.79	93.64	92.16	91.32	90.17	88.93	87.72	
Top 5 countries	16.20	16.09	15.96	16.02	16.02	15.89	15.99	16.00	15.81	15.71	15.86	15.72	15.53	15.46	15.00	14.86	14.56	14.30	14.12	



Source: *OECD Main Science and Technology Indicators* (https://stats.oecd.org/Index.aspx?DataSetCode=MSTI_PUB#)

Top 5 countries: Japan, United States, Germany, France Korea

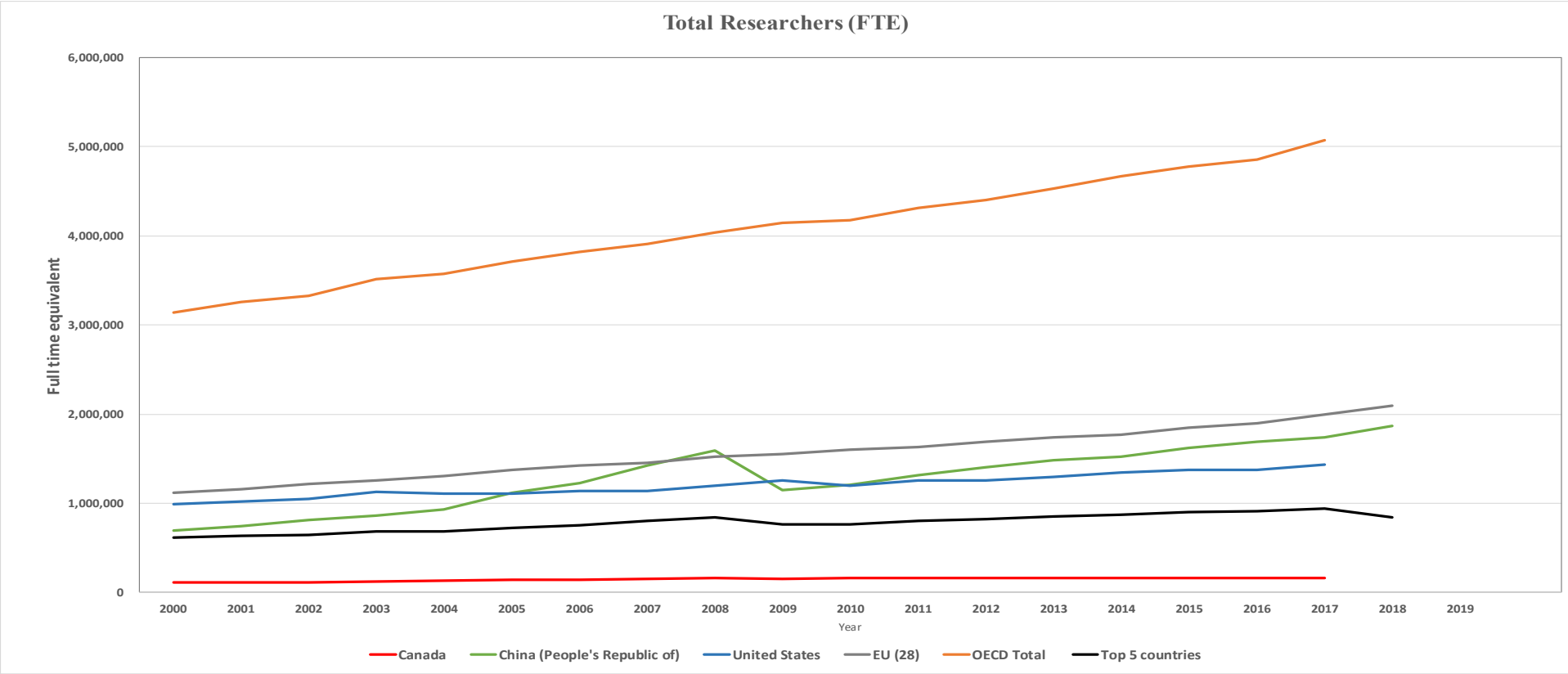
NOTE: OECD uses totals for OECD, EU(28); as such these are excluded from the top 5

Data extracted on 09 Nov 2020 14:15 UTC (GMT) from OECD.Stat

Figure 27 Total Researchers (FTE)

Dataset: Main Science and Technology Indicators

MSTI Variables	Total Researchers (FTE)																			
Unit	Full time equivalent																			
Year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Country																				
Canada	107,900	114,510	115,960	123,230	130,380	136,700	140,660	151,330	157,200	150,220	158,660	165,100	161,600	163,180	161,982	162,952	158,980	158,890		
China (People's Republic of)	695,062	742,726	810,525	862,108	926,252	1,118,698	1,223,756	1,423,381	1,592,420	1,152,311	1,210,841	1,318,086	1,404,017	1,484,040	1,524,280	1,619,028	1,692,176	1,740,442	1,866,109	
United States	984,965	1,015,318	1,049,197	1,128,803	1,107,758	1,104,019	1,133,369	1,136,653	1,194,367	1,252,882	1,200,535	1,254,786	1,253,231	1,294,358	1,340,103	1,369,457	1,372,091	1,434,415		
EU (28)	1,118,377	1,159,612	1,211,642	1,254,462	1,308,807	1,374,762	1,422,501	1,458,114	1,522,259	1,554,124	1,601,446	1,626,805	1,687,741	1,736,853	1,772,538	1,845,897	1,898,458	1,999,886	2,097,382	
OECD Total	3,140,958	3,260,384	3,330,127	3,517,972	3,575,228	3,708,122	3,819,951	3,910,555	4,034,008	4,143,450	4,177,081	4,315,962	4,404,895	4,529,992	4,670,047	4,780,628	4,855,797	5,075,075		
Top 5 countries	618,379	636,246	648,103	679,940	687,124	728,015	757,238	800,855	839,463	764,059	767,495	803,158	819,857	846,786	868,821	897,544	911,664	936,277	845,925	



Source: *OECD Main Science and Technology Indicators* (https://stats.oecd.org/Index.aspx?DataSetCode=MSTI_PUB#)

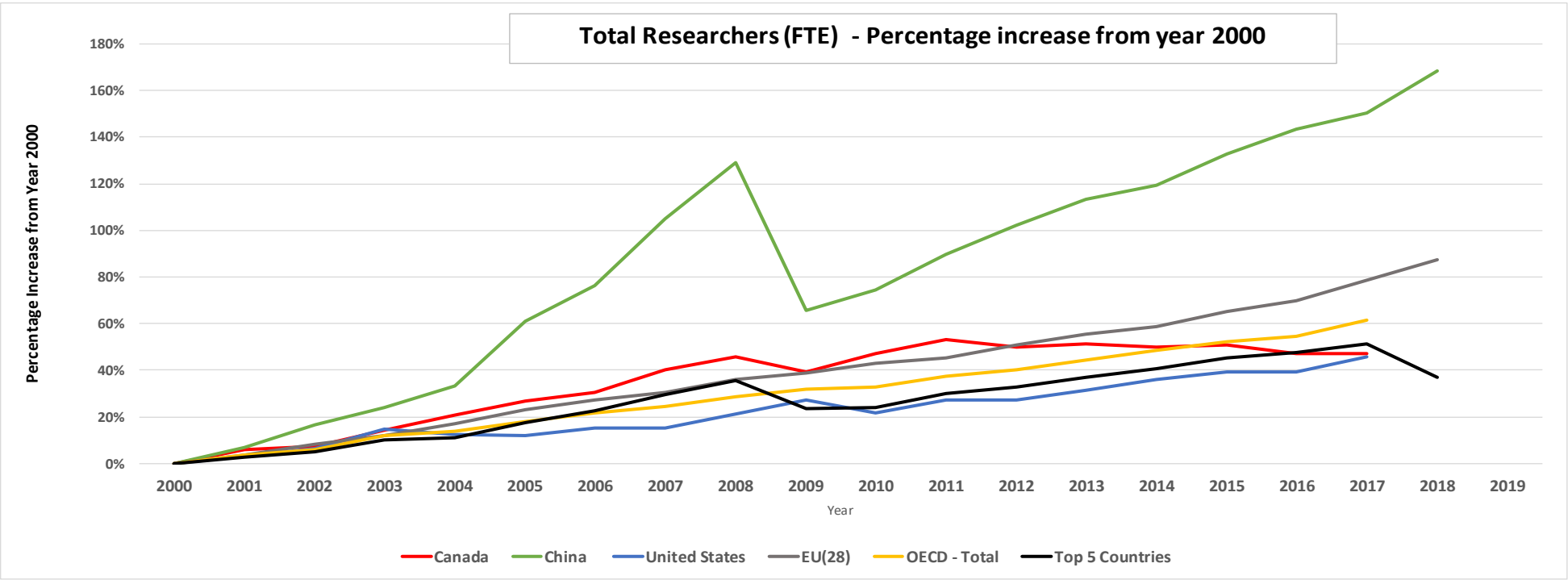
Top 5 countries: China, United States, Japan, Russia, Germany

NOTE: OECD uses totals for OECD, EU(28); as such these are excluded from the top 5

Data extracted on 06 Nov 2020 14:21 UTC (GMT) from OECD.Stat

Figure 28 Total Researchers (FTE) – Percentage increase from year 2000

Dataset: Main Science and Technology Indicators																				
MSTI Variables	Total Researchers (FTE) - Percentage increase from year 2000																			
Unit	Percentage increase from year 2000																			
Year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Country																				
Canada	0%	6%	7%	14%	21%	27%	30%	40%	46%	39%	47%	53%	50%	51%	50%	51%	47%	47%		
China	0%	7%	17%	24%	33%	61%	76%	105%	129%	66%	74%	90%	102%	114%	119%	133%	143%	150%	168%	
United States	0%	3%	7%	15%	12%	12%	15%	15%	21%	27%	22%	27%	27%	31%	36%	39%	39%	46%		
EU(28)	0%	4%	8%	12%	17%	23%	27%	30%	36%	39%	43%	45%	51%	55%	58%	65%	70%	79%	88%	
OECD - Total	0%	4%	6%	12%	14%	18%	22%	25%	28%	32%	33%	37%	40%	44%	49%	52%	55%	62%		
Top 5 Countries	0%	3%	5%	10%	11%	18%	22%	30%	36%	24%	24%	30%	33%	37%	40%	45%	47%	51%	37%	

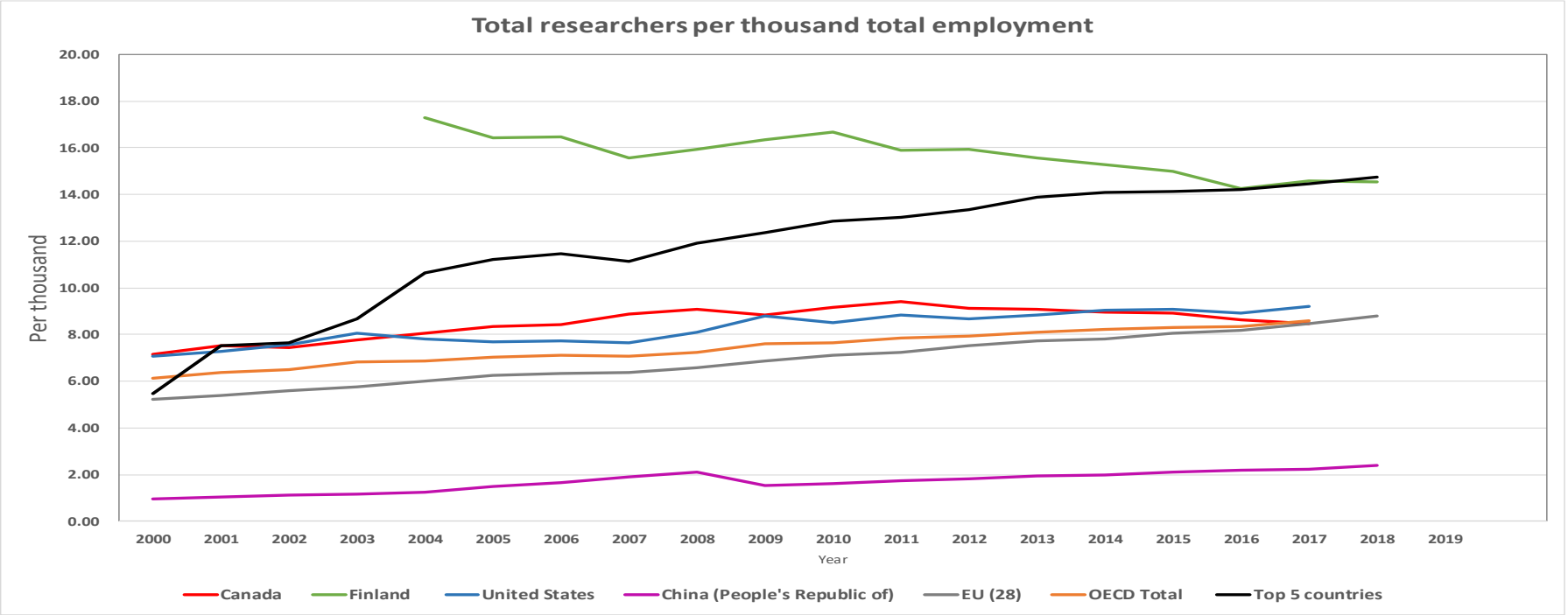


Source: OECD Main Science and Technology Indicators (https://stats.oecd.org/Index.aspx?DataSetCode=MSTI_PUB#)
Top 5 countries: China, United States, Japan, Russia, Germany
NOTE: OECD uses totals for OECD, EU(28); as such these are excluded from the top 5
Original data extracted on 06 Nov 2020 14:21 UTC (GMT) from OECD.Stat; percentage increases are author's calculations

Figure 29 Total researchers per thousand total employment

Dataset: Main Science and Technology Indicators

MSTI Variables	Total researchers per thousand total employment																			
Unit	Per thousand																			
Year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Country																				
Canada	7.17	7.54	7.45	7.75	8.07	8.33	8.44	8.89	9.10	8.85	9.18	9.40	9.10	9.07	8.95	8.92	8.62	8.45		
Finland					17.27	16.42	16.46	15.56	15.95	16.33	16.68	15.90	15.95	15.56	15.27	14.98	14.27	14.57	14.54	
United States	7.08	7.29	7.56	8.06	7.82	7.67	7.73	7.67	8.09	8.81	8.49	8.83	8.66	8.85	9.02	9.07	8.93	9.23		
China (People's Republic of)	0.96	1.02	1.11	1.17	1.25	1.50	1.63	1.89	2.11	1.52	1.59	1.72	1.83	1.93	1.97	2.09	2.18	2.24	2.41	
EU (28)	5.24	5.40	5.60	5.78	5.99	6.23	6.34	6.37	6.59	6.85	7.11	7.22	7.50	7.74	7.81	8.05	8.18	8.48	8.78	
OECD Total	6.14	6.36	6.48	6.82	6.86	7.02	7.10	7.08	7.25	7.60	7.65	7.83	7.92	8.10	8.24	8.32	8.33	8.58		
Top 5 countries	5.49	7.54	7.66	8.68	10.66	11.20	11.45	11.12	11.93	12.37	12.87	13.01	13.35	13.88	14.11	14.14	14.21	14.47	14.75	



Source: *OECD Main Science and Technology Indicators* (https://stats.oecd.org/Index.aspx?DataSetCode=MSTI_PUB#)
Top 5 countries: Finland, Denmark, Sweden, Chinese Taipei, Korea. Iceland is excluded from the top 5 as it is missing entries for 8 years.
NOTE: OECD uses totals for OECD, EU(28); as such these are excluded from the top 5
Data extracted on 06 Nov 2020 18:59 UTC (GMT) from OECD.Stat

PART II: FOUR LINES OF INQUIRY

Chapter 4

Government Priority-Setting: Policy Coherence, Continuity and Challenges

Introduction

This chapter directly attends to the question of consistency and coherence in Canadian federal innovation policy and priority-setting over the years from 2000 to 2020. More specifically, it addresses the first line of inquiry that we have laid out concerning the DNS framework¹ – namely from the period starting in 2000 is there sustained priority-setting around innovation imperatives and what can be characterized as policy “durability.”² The chapter centres around three dimensions. It first engages in some brief reflections regarding the DNS framework itself and the import of clearly operationalizing the framework with a focus on specific initiatives that have been taken over the years in Science and Technology and innovation writ large. Moreover, as earlier noted in Chapter One, the question of durability also needs to be accessed through the institutional means and administrative vectors so to speak through which policy is refracted and implemented.

Secondly, the chapter then follows these two dimensions – priorities and administrative capacity – through each of the different political administrations over this period, focusing on the early Liberal (2000-2006) years, the Tory years (2006-2015) that then followed and finally the later administration under the Liberals from 2015 onward.³ And in so doing, it particularly reveals the unique patterning of the Canadian case – the intense spikes of activity around Science

¹ See the Introduction and Chapter Two, “Four Domains of Research.”

² The term is employed by Patashnik (2003, 2008); also Lockwood (2013).

³ For specific dates of tenure for each of these administrations, see “Governments of Canada: Affiliation, Prime Minister and Term of Office” in Annex C – 2 in Chapter Two “Research Methodology.” It should be noted that while the focus is on the 2000 to 2020 period, as discussed below, in fact key developments around S&T also began to surface from the late nineties onward, including the Speech from the Throne of 1999 (SFT 199).

and Technology and innovation more generally, oftentimes overlaid with extremely ambitious objectives, followed by more dormant periods where other priorities prevailed.

Thirdly, the chapter moves on to introduce the results of the 54 in-depth thought leader interviews, initially noting the regional and sectoral breakdown of the participants as presented in a rolled-up manner that preserves anonymity of all interviewees. It then discusses the particular insights and perspectives garnered regarding the question of priority-setting. Concluding remarks follow.

DNS and Policy Durability

As has been earlier laid out in the theoretical discussion⁴ dealing with the challenges of applying the Developmental Network State framework in a comparative context, the concept of policy durability and coherence is an assumption in the framework more than one which has been conceptually surfaced and defined. As such two prongs of attack will be leveraged in the methodological approach to dealing with durability issues. Critically important will be a specific focus on the various priority-setting initiatives that the federal government has launched with respect to science, technology and innovation more widely – from 2000 onwards. All Throne Speeches, relevant Budget documents (for the emphasis on certain priorities and not resourcing *per se*) and strategic/framework visionary documents that federal administrations have issued over the last two decades will be reviewed. In undertaking such an exercise, the intent is to not only distill the priorities but also map the degree to which there have been patterns of continuity – or discontinuity -- in these efforts. Complementing this historical review will also be the

⁴ See Chapter One, “Innovation, Historical Institutionalism and the Developmental Network State: Mending the Gap.”

reflections and results from the in-depth thought leader interviews and perspectives on the consistency with which federal policy has been applied to innovation objectives.

Equally important, and channelling Skocpol and Finegold (1982), as well as the HI contributions of Pierson (2003; 2004) and Weir (1992a; 1992b), the intent is to assess the state's administrative capacity and "means" to sustain an innovation agenda. The analysis will examine the extent to which there was an institutional *base* for reform, particularly as articulated by specific government departments or agencies having both the institutional levers to deliver on an innovation agenda and being charged with the very task of reform. Quite simply, at issue is whether a federal "voice" for innovation can be discerned over this time frame and whether there was sustained directionality to S&T and innovation endeavours.

Coursing throughout this analysis then is a critical eye towards the "longue durée" (Pierson, especially 2003, 192) and whether this Canadian case study does display evidence of the policy consistency and tenacity that the DNS essentially assumes, and are supposedly essential ingredients for innovation success. It is an effort to move beyond time "snapshot[s]"⁵ – and the impediments that brings to seeing historical processes -- and observe the long arc of policy writ large.

Wrestling with Fundamentals

Setting Priorities: Pursuing "Excellence"

The period between 1999 and 2004 was characterized by a sober reckoning by the federal government of Canada's rather dismal performance on innovation among the "world's leading economies" (IC 2001a, 4). As a critical vision document at the time, *Achieving Excellence*:

⁵ Pierson (2004, 104). See also his reference to "snapshot accounts" (*Ibid.*, 134 and more generally his discussion 133-166 and 164-166).

Investing in People, Knowledge and Opportunity: Canada's Innovation Strategy bluntly indicated on the issue of Canada's "overall level of innovation" that Canada firmly stood "near the bottom" of the G7 list (*Ibid.*, 4).

To be sure, the Government of Canada prided itself on getting many of the "fundamentals" (*Ibid.*, 4) necessary to a strong fiscal environment and competitive tax regime right. There had been significant debt repayment, a return to budget surpluses by 2004 (Receiver General 2004), a continuing commitment to reduction in personal and corporate taxes and an ongoing focus on trade. However, on several key indicators, there was clear recognition that Canada was wanting on the innovation front. *Achieving Excellence* – the heart of the government's Innovation Strategy -- in its very fulsome report, did not mince words. Not only did Canada rank sixth among the G7 in terms of total R&D investment, but it similarly ranked fifth in term of BERD, fifth in terms of R&D personnel and fifth in terms of external patent applications (IC 2001b, 16). Moreover, innovation had a feedback loop to lagging productivity and what had been decreasing income levels. Likewise did the review of *Federal Science and Technology* conducted by the government in 2001 echo these concerns, cautioning that, given the extent of G7 investment in R&D, Canada was in fact "chasing a moving target" (IC 2001c, 11). It was clear the government and the "nation" had to meet the challenge head-on and Canada's stature as a country embracing the new Knowledge-based Economy (KBE) and positioning itself in the rapid flow of technological change had to be substantially raised.

Towards that end – and as a result of numerous expert studies and reports undertaken between the late nineties and early 2000s⁶ that urged the need for action -- Throne Speeches over

⁶ Most critically see IC (1996); also ACST (1999a; 1999b, 2000, 2001); CSTA (1999, 2000, 2001a, 2001b 2005). As well, in 2000, the Standing Committee on Industry issued a report demanding action and a commitment to raise Canada's R&D intensity above the G7 average (IC 2000, 14). Interestingly the government took a more muted response to the Report than federal pronouncements which were to follow.

the period between October 1999 and October 2004 laid out an extremely ambitious and seemingly targeted innovation agenda. The seminal document in this regard was the 2001 Speech from the Throne where the government boldly put out the challenge of Canada securing a rank among the top five countries for “research and development performance” by 2010 (SFT 2001). This was paired with a host of other critical challenges that would need to be met, including a commitment in the Throne Speech to “at least” doubling the “current federal investment in research and development” (*Ibid.*).

While the SFT laid out the key directions, the *Innovation Strategy* backing it was even more explicit in the goals and the “targets” that would need to be reached. By 2010, venture capital “investments per capita” were to be raised to US levels (IC 2001b, 51) and the performance of the private sector was to rise in international ranking – specifically to join “world leaders” in terms of the “share of private sector sales attributable to new innovations,” again within the decade (*Ibid.*, 51). Moreover, while not in the *Innovation Strategy* in its initial release, later announcements by the Minister of Industry, the Honourable Allan Rock, indicated that an equally important objective was to double Canada’s “share of North America-bound foreign direct investment” (HRDC/IC 2002, 71) – a goal that would of course pit Canada against the US in vying for FDI dollars. Even within the *Innovation Strategy* of 2001 Canada was to “substantially improve ...[its] ranking in international investment intention surveys” -- a somewhat moving target at best (IC 2001b, 70).

As for the issue of skills for the new Knowledge-based Economy, similarly over the decade the admissions of Master’s and PhD students was to increase by “an average of 5 per cent per year” (*Ibid.*, 60). Additionally, on a more compressed deadline – by 2004 -- Canada was to

significantly up its game with respect to an increase in “foreign talent” who could join the Canadian R&D community (*Ibid.*, 60).

Nor was that all. Equally daunting, by 2010 at minimum there were to be 10 “internationally recognized technology clusters” seeded across the country (*Ibid.*, 76). Furthermore, if there was to be an investment in post-secondary institutions on the part of the government, there needed to be a *quid pro quo*. Specifically, the challenge was laid out that performance indicators on commercialization should demonstrate a “tripling” (*Ibid.*, 86) by the end of the decade. Finally, on the part of the government itself, it committed to a “complete systematic review” of its regulatory and “stewardship” environment critical to attracting investment and enabling innovation (*Ibid.*, 70). Initially foreseen as an exercise to be completed by 2010, by 2002 at the urging of participants in the National Innovation Summit, this deadline was also moved up – to 2005 (IC, 2002b, 9).

Certainly, the agenda that the Government of Canada had laid out was sweeping, even breathtaking in its breadth, covering every dimension that would be required to place Canada among the world leaders. The skills a knowledge-based economy required, the infrastructure of information networks and knowledge critical to development, the need for a stable and “prudent” macroeconomic environment, as well as competitive Intellectual Policy and regulatory regimes and a focus on communities across Canada: all would need to be included in the path forward.

Throne Speeches which followed (2002, 2004a, 2004b) continued to sound these themes, providing more specificity to the targeted areas for R&D development. However, what was also critical in these early years was that all of this was bolstered by a massive engagement exercise undertaken in 2002 to consult the country around the priorities ahead. The consultations engaged some 10,000 Canadians, culminating in a National Innovation Summit of 500 “leaders”

in November of that year, in which many key recommendations were made. Figuring prominently among them were the need to strengthen “networks” and collaborative activity between universities and business (IC, 2002b, 3), develop a “pan-Canadian” skills strategy with provinces and territories (*Ibid.*, 4-5) and to ensure the engagement of local communities, not only to leverage the “growth of clusters” (*Ibid.*, 5) but to enable locally-situated innovation activities, and strategies. There was of course as well the requisite import of lowering or “eliminat[ing]” capital taxes (*Ibid.*, 3). As for the Scientific Research and Experimental Development Credit (SR&ED), it was to be both enhanced *and* its administrative processes streamlined (*Ibid.*, 3). Interestingly, there was a surprising degree of consensus around the Summit exercise, particularly given the far-flung nature of the whole consultation initiative. And it too generated a renewed wave of recommendations and priorities around the innovation agenda – although admittedly fiscal environment, collaboration and skills had been mainstays of the government’s original agenda. As for the government, it in turn responded vigorously to the recommendations, laying out a long list of “early actions and announcements” (*Ibid.*, 8-10) that could at once endorse and implement the recommendations.

Yet, despite the varied and intense activity around priority-setting in these early years, what was particularly marked about the government’s innovation agenda was the cross-cutting web of multiple R&D domains which emerged. Certainly, in 1999 the government had made the rather ambitious statement it would “encourage the development and adoption of new technologies in all [economic] sectors” (SFT 1999, 3). Over the subsequent years, Speeches from the Throne went on to identify twelve different areas for development. They included everything from biotechnology writ large to “new life forms,” as well as nanotechnology, information and communications technologies, natural resource management, ocean R&D,

advanced engineering and advanced materials.⁷ There were constants around life sciences -- particularly genomics -- as well as energy and environmental technologies and, as will be discussed in the following chapter on targeted resourcing, the means by which these initiatives were funded. But what is particularly striking about this highly ambitious priority-setting effort was the way in which areas for targeting multiplied, as well as the lack of a consistent evaluation and performance framework for the identification of these priorities. Even within the same Throne Speech of February 2004, inconsistencies are apparent, ICT figuring among the “path-breaking technologies” where Canada was to exert its international prowess, but inexplicably not figuring in the list of spheres where access to venture capital to become such “world leaders” was needed (SFT 2004, 13, 17).

Moreover, what is not evident in the SFTs, nor more importantly, in the variety of reports and studies which preceded and followed the goal setting of 2001, was an effort to tie these strategic areas to regional or community development or to the ten clusters worthy of “international” acclaim that were to be in place by the end of the decade. Cities and communities were to be bound to a process of innovation engagement – developing their own strategies for development -- but how this would fit within the larger lattice work of R&D domains was unclear.

Interestingly, all of this stands in sharp contrast to other areas where government was very much transfixed on objectives that would sustain the type of prosperity that they were seeking. There was, throughout these years, a primordial focus on the fiscal discipline and lower taxes needed to sustain an internationally competitive macroeconomic environment, both in terms of debt-to-GDP ratios and budgetary balances (SFT 1999, 2001, 2002, 2004a, 2004b). So

⁷ See Annex A – 4, “Identified R&D Priorities in Throne Speeches and Science, Technology and Innovation Frameworks or Strategies.”

too was the government dedicated to establishing a “smart” regulatory environment that could streamline unnecessary complexity all the while ensuring the precautionary efforts required for the protection of health and the environment (SFT 2002, 2004b). Indeed, an External Advisory Committee on Smart Regulation was established towards that end (SFT 2001, 2002, 2004a, 2004b). There was an ongoing commitment to the import of free trade and opening up new markets (SFT 1999, 2001, 2002, 2004a, 2004b) but also to mitigating the internal barriers that were seen to hamper capital and labour mobility within the Canadian federation (SFT 2004b). There was a clear focus on physical infrastructure to refurbish cities and communities and provide the arteries for economic development -- and new engagement with municipalities as the means to achieve this (SFT 1999, 2002, 2004a, 2004b).

As for the federal role with respect to developing innovation capacity so too were there areas where the goals were clear and a targeted implementation plan followed. Consistent over this period was the need for strengthened Intellectual Property policies (SFT 2001, 2002) and incentives that could reward researchers supported by federal funds and accelerate commercialization – an initiative that in fact culminated in an accord with universities and colleges in 2001. *The Framework of Agreed Principles*, penned by Industry Canada with the Association of Universities and Colleges of Canada, made a commitment to doubling the research output of post-secondary institutions and, true to the articulated goal in the *Innovation Strategy*, tripling the extent of commercialization (IC and HRDC 2002, 8). Additionally, the federal government took a highly activist role with respect to targeting the research infrastructure that could enable international collaborations to occur, most of which was – and to be -- under the auspices of the Canada Foundation for Innovation. And there was a consistent recognition of the importance of the granting councils, ensuring they could engage in highly competitive and

international research initiatives, attract the research talent they needed and launch the 21st century Chairs for Research Excellence (SFT 1999) that became a touchstone for their endeavours.

Nonetheless the lattice-like nature of the multiple domains to be targeted for investment and growth and the absence at the time of an overarching evaluation framework for plucking out these domains for recognition, speak to a policy coherence that is significantly fractured. Moreover, the massive scope needed to achieve all of these end-of-decade targets (if not earlier) would certainly strain institutional capacity as much as targeted resourcing. Thus, despite the grandeur of this era's focus on innovation – and clearly the political will to move forward not only on the part of the government but, as the National Summit demonstrated, others within the national innovation system -- the extensive number of innovation priorities do challenge the credibility of this exercise. As the years unfolded, it would be telling that not all of these ventures could be sustained at the pace that was anticipated; nor could they all contribute to resolving the innovation gap that OECD in fact had identified back in 1995 (IC, 2001b, 16).

Institutional Capacity

If the issue of policy coherence can be accessed through the priority-setting exercises that were occurring throughout this period, what is equally instructive to probe is the strength of the very institutional capacity needed to sustain these efforts. In that regard, Industry Canada was tasked with an important role steering through these initiatives. The Minister of Industry was responsible for chairing the Advisory Council on Science and Technology (ACST) which reported to the Prime Minister during these years and in turn his Secretary of State for Science, Research and Development was tasked with chairing the Council of Science and Technology Advisors (CSTA) (IC 2001c, 18) – tending to matters internal to federal S&T. Moreover, as the

following chapter will demonstrate, a significant proportion of direct R&D funding – with critical exceptions of indirect tax credits and particularly the SR&ED – flowed through the Department of Industry. To be sure, the Minister of Industry shared the mandate around innovation with Human Resources and Development Canada which was to shoulder the skills flank of the Strategy (HRDC 2002) but the preponderance of the initiatives to be undertaken were to funnel through IC. Moreover, Industry Canada and the Minister, together with HRDC, were instrumental in pulling together the extensive consultation exercise and Action Reports associated with the 2002 National Summit.

That said, however, what is readily apparent through these years is that there were several institutional loci of advice and activity. Specifically concerned that Canada lacked the robust “governance” systems and “institutions” around S&T to which other G7 countries could lay claim (IC 1996, 5), the government launched several such initiatives. The Prime Minister’s Advisory Council on Science and Technology was established in 1996 and charged with the dual role of reviewing federal S&T policy and providing foresight advice which could identify emerging issues on the S&T and KBE horizon. Seized with this mandate, the ACST undertook several critical expert studies, proffering this advice to the Prime Minister. Included were the lagging state of commercialization and the need to build in both incentives *and* performance targets with the post-secondary institutions to correct this (ACST 1999a). Reports on skills and learning (ACST 1999b); the need to significantly boost Canada’s engagement with international S&T and the infrastructure needed to support it (ACST 2000); the additional need to channel funding towards the indirect costs of research undertaken particularly by the three granting councils (ACST 2001): all followed thereafter. And quickly on the heels of these reports advice was transformed by the government into 2000-2001 budgetary decisions. Funding of \$500

million would flow to the Canada Foundation for Innovation, of which \$100 million would be designated for international research (Finance Canada 2000b, 11, 21); there would be a \$200 million investment for the indirect costs of federally-sponsored research (Finance Canada 2001, 134);⁸ and support to universities would be provided for their commercialization functions (*Ibid.*, 122).⁹ By 2002, the government had expanded the mandate of the ACST still further. Now charged with developing a “strategic framework” for “Canada’s research enterprises,” the government would look to the ACST for ongoing and general counsel on federal investment decisions and strategic targets pertaining to R&D (IC and HRDC, 2002, 9).

If the ACST was to focus on the larger economic issues associated with science and technology, the Council of Science and Technology Advisors (CSTA) created in 1998 was to target issues of S&T internal to the federal government. Although chaired by the Secretary of State for Science, Research and Development, the Council was to report directly into the Cabinet Committee on Economic Union (CSTA, 1999, 1). The Council also undertook several reports and expert studies but its principal contribution was around the principles that needed to inform government’s intramural S&T. Specifically, it was to “align” (*Ibid.*, 24) -- to run in its own lane leveraging the contributions of “others” where appropriate and sticking to its respective departmental stewardship mandates. It was to form “linkages” (*Ibid.*, 25) ensuring extensive horizontal collaboration – certainly interdepartmentally – but also with the other key players in the national innovation system: the private sector, universities and other levels of government. Finally, it was to achieve a level of “excellence” (*Ibid.*, 25 - 26) that would be assessed regularly via performance measures and would be the subject of regular reporting by the CSTA to the

⁸ See as well the additional \$75 million annual top up for the Canadian Institutes of Health Research in order to enable commercialization and the ensuing “economic benefits” (Finance Canada 2001, 115).

⁹ Also see the more general discussion in IC (2002b, 14-15).

responsible Cabinet Committee of the Economic Union. Moreover, shoring up this effort and ensuring implementation of the principles, were to be respective departmental external science advisory boards (SABs) monitoring ministries' action plans and progress forward (see IC, 2001; CSTA, 1999, 28; CSTA 2001). Indeed, a CSTA report in 2001, appropriately called *Reinforcing External Advice to Departments*, specifically called for an “enhanced” role for the science advisory boards – something to which respective departments, and Deputy Ministers, were in agreement (*Ibid.*, 4).

Nor was that all. A Canadian Biotechnology Advisory Committee was struck in 1999, specifically to advise the government on this sector's scientific, environmental, socio-economic and ethical implications (Canada, 2003, 10). Also functioning throughout this period was an interdepartmental Assistant Deputy Minister Committee on Science and Technology (IC 2001, 20-21), established to ensure the requisite interdepartmental coordination. Finally, by 2004 the position of National Science Advisor, ultimately to be located in the Privy Council Office, was created and additionally tasked with the mandate of expert scientific advice to the Government of Canada.

The First Innovation Policy Era: 1999 – 2004

All of this of course made for a crowded institutional landscape. It is worth noting that, following a review of S&T between 1994 and 1996, there had been a decision to purposely keep (at that time) the S&T exercise decentralized (IC, 2002a, 5) and to specifically nurture the horizontality that would be needed for a broadly-encompassing initiative. However, what becomes readily apparent in assessing this early period of federal innovation policy is that on several fronts it is lacking in the features which have been identified as critical – even imperative – for success. With respect to the institutional “capacity” argument of Skocpol and Finegold

(1982) as being fundamental to sustained policy and programmatic reform, in the Canadian case the administrative agencies were several – and they were simply layered alongside or over existing departmental and institutional structures as time unfolded. The mandate of a presumed “lead” department -- Industry Canada -- was shared with not only external advisory bodies, of which there were many (the Advisory Council on Science and Technology, the Council of Science and Technology Advisors, the Science Advisory Boards, and the National Science Advisor) but the various reporting lines went through to the PM or CCEU or individual department or the Privy Council Office respectively. Moreover, while these various advisory bodies were oftentimes chaired by Industry Canada (or in the case of the National Summit co-chaired with HRDC) these external agencies were not institutionalized or “embedded” within one particular structure. So too was the expertise riven among various institutional agencies making the task of “holistic” steering of the exercise and the attendant policy coherence more challenging.

It is of course important not to overstate this argument. Such an exercise as the Innovation Strategy demanded a high degree of horizontal flexibility and interdepartmental collaboration for success. Further, in terms of the national innovation system, there was a remarkable degree of consensus which emerged around what was needed, as particularly evidenced by the recommendations coming out of the Summit as well as the federal government response to the recommendations of the two councils. This was not an inconsiderable feat either of political will or national engagement. But as the Jenkins Report was later to reflect in assessing federal authorities, what was missing for innovation programming was one “voice” (Jenkins Report 2011, 8-4) acting on behalf of the federal government.

Furthermore, if our analysis is pursued à la Pierson¹⁰ along the dual dimension of the long-term functionality of institutional design for the task at hand, the plethora of agencies created ripened conditions for at least multiple effects if not also contending agendas – indeed a “geometric” increase in “unintended” consequences. All of this was less than optimal for policy success. That these external agencies would see a new break in continuity in the innovation phase that was to follow only added another dimension of complexity.

Caught between the pincers of the multiple priorities of a self-admitted “aggressive” policy agenda and numerous fora for dealing with the innovation project at hand, the Innovation Strategy was not situated on firm terrain for moving forward. Certainly, it was not well positioned to meet the demanding circumstances and sustained policy effort required for hitting all the 2010 and even 2005 targets.

A New Government: A New Agenda

“Mobilizing” Science and Technology

In the latter days of the Martin administration, things remained relatively dormant on the S&T front. As for the Conservatives, elected to a minority government in January of 2006, its first initiatives were focused on consumption-based tax cuts (lowering the GST by one per cent) and ushering in a new Federal Accountability Act and associated Action Plan that could renew citizenry “trust” in government institutions (SFT 2006). By 2007, however, S&T and issues of innovation had again emerged full-fledged on the federal agenda.

In contrast with the previous era, and the multiple (and multiplying) number of priorities, the period between 2007 and 2014 saw a more spartan presence around priority-setting on the

¹⁰ See Pierson (2004, 103-132 and especially 115 and 118; also 2003).

innovation file. There were some references to R&D domains traversing the Throne Speeches throughout this period. “High Arctic” research (and the accompanying infrastructure) (SFT 2007, 4; 2010, 9) as well as space technology (SFT 2010, 4) capable of monitoring that region was referenced, thus intersecting with the government’s Northern strategy and commitment to Northern sovereignty. Clean energy technology was frequently highlighted (SFT 2008, 10-11; 2010, 5; 2011, 4, 5; also IC Response 2007a, 3; IC 2007b, 63-64), particularly in the context of leveraging Canada’s rich resource “endowment.”

However, two other features more specifically characterized SFTs throughout this period. As the Great Recession of 2008-09 hit -- and lingered -- efforts both in terms of policy and funding were to be amplified to support traditional industrial sectors of the Canadian economy (SFT 2008, 7; 2009, 3; 2010, 5; 2013, 8, 9). Thus was the Technology Partnerships Program, previously dedicated to financing innovation in several key industrial sectors (https://ito.ic.gc.ca/eic/site/ito-oti.nsf/eng/h_00154.html),¹¹ to be revamped into a more directed funding instrument, the Strategic Aerospace and Defence Initiative (SFT 2013, 9; IC Response 2007a 6, 24; IC 2007b, 59-60). So too was the Automotive Innovation Fund reinvigorated with funding (SFT 2013, 9). And stalwart areas such as forestry and agriculture were to be enabled to “adapt,” compete and, most importantly, “innovate” (SFT 2013, 8; also 2010, 5; 2008, 7). Moreover, the administrative burden on small and medium-sized businesses was to be significantly reduced to ensure that their innovation capacity was fully released.

Equally critical, in 2007, as announced in that year’s SFT, the government’s efforts at R&D pivoted on a new S&T strategy and framework – *Mobilizing Science and Technology to*

¹¹ In fact the Program’s description refers to support for “pre-competitive projects across a wide spectrum of technology development including environmental technologies, life sciences, information, communications and technologies and advanced manufacturing” (*Ibid.*).

Canada's Advantage (IC 2007b). Oriented around three pillars of “entrepreneurial,” “research” and “people” “advantage,” the Strategy rested on broad recognition of the imperatives for kickstarting the government’s innovation agenda. Essential to this project was the macroeconomic environment necessary to sustain “healthy competition,” growth, and overall investment in R&D, particularly within the private sector. At the same time, evidence of a more defined and even disciplined approach to S&T and R&D more generally was apparent in the Strategy. Based on the country’s S&T strengths which had been previously identified by the Council of Canadian Academies, the “Mobilizing” Strategy put forward four key domains of research which could be leveraged to “advantage.” Specifically, “[e]nvironmental science and technology, [n]atural resources and energy, [h]ealth and related life science and technologies” and finally “[i]nformation and communications technologies:” these areas could be aligned with Canada’s economic strengths and function “strategically ... in the National Interest” (*Ibid.*, 63-64).

Institutional Machinery

Interestingly, not only was the S&T Strategy focused in the context of priority-setting but neither was the institutional machinery necessary to its implementation unduly diffuse or extensively diversified. Indeed, the administrative means was spelled out with a significant degree of clarity. On one front, the granting councils, NRC and CFI and other relevant partners were to form “a critical mass of expertise” (IC 2007b, 64) that could drill down on the four priorities. Moreover, stronger competitive processes were to be injected into these agencies’ decision-making, ensuring that research institutions could appropriately leverage world-class talent and expertise. On another, the Minister of Industry would be given responsibility for benchmarking progress against these initiatives and “renew[ing] priorities” (*Ibid.*, 64) as

required. Towards that end, there would be targeted consultations within the federal house as well as with agencies in other levels of government specifically tasked with an innovation mandate. Nor was that all. The Council of Canadian Academies would be further charged with undertaking the benchmarking and review process that could inform the Minister of Industry's evaluations, a mandate which by 2013 had been expanded to include an evaluation of the state of industrial R&D in the country as well (<https://www.ourcommons.ca/documentviewer/en/41-1/INDU/report-3/response-8512-411-200>). So too would specific metrics be established for evaluation of federally funded research institutes and agencies whereby results and "value for money" (IC 2007b, 66-68) could be assessed – a commitment that meshed with the government's larger concerns about federal accountability.

As for the granting councils, vested with a *direct* research mandate, here too dedicated institutional mechanisms were to be set in place that could enable success on the government's agenda.¹² The mandate of the councils was to be enhanced to include new business-driven Networks of Centres of Excellence, as well Centres focused on Commercialization and Research, that could strengthen public and private collaboration. And, in this context, the councils were to specifically establish a private-sector advisory body (IC 2007b, 58; IC Response 2007a, 21, 23) to inform those initiatives. The granting councils were to further ensure that their membership more appropriately represented those drawn from an expanded client base of industry and communities (IC 2007b, 67). As for the *indirect* infrastructure initiatives for public and non-profit research facilities, the strengths of the key actors here were to be also leveraged appropriately. The Canada Foundation for Innovation, CANARIE, the broadband network

¹² On the granting councils and these new NCE entities including their commercialization mandate and limited duration, see also Chapter Five, particularly "Constants – and Prowess." For the impacts for pharmaceuticals, see Chapter Nine, "Shifting Sands: Triadic Linkages and NCEs."

devised to link Canadian researchers domestically and internationally, the funding flowing through the Indirect Costs of Research (*Ibid.*, 65-66): all were to contribute to the “mobilization” of an innovation agenda.

Finally and in distinct juxtaposition to the era that had gone before, overarching all of was to be a more consolidated and “integrated” governance structure. The various contributions of the ACST, CSTA and Biotechnology Advisory Committee were duly credited but the time was deemed right to consolidate governance structures. The existing councils were to be disbanded and a new body formed -- the Science, Technology and Innovation Council to not only provide advice (IC 2007b, 86-88; STIC 2009) to the government on its S&T agenda but to also widely consult the network of innovation actors and, probably most critically, provide regular “state-of-the-nation” reports on how Canada was progressing in its goals. As the “Mobilizing” strategy succinctly put it: “A single external committee would be able to provide more integrated advice, with a stronger voice” (IC 2007b, 87). Tellingly, this too was to be orchestrated by the Minister of Industry, with the reporting line no longer running directly into the Prime Minister’s Office but rather to the Industry Minister himself.

The Second Innovation Policy Era: 2007 – 2013

In *toto*, on several fronts the agenda that was set out in 2007 and rather diligently pursued until 2013 was distinct from the earlier 1999 – 2004 period which had gone before. Tightened priorities and priority-setting; strengthened administrative means and reporting; targeted governance structures both for overarching concerns and specific needs relevant for business investment and collaboration: all evidenced a stronger institutional capacity for steering the ship of state in its pursuit of innovation goals. At least for a time it appeared that the institutional

capacity -- the institutional “foothold” -- central to reform momentum and policy durability appeared to be gaining ground.

To be sure, there were constants that resonated with the themes, and imperatives, of the earlier Liberal administrations. The emphasis on a solid fiscal framework and macroeconomic environment which could enable “healthy competition” and a robust “investment climate”¹³ remained front and centre. While Canada could take pride of place in their debt-to-GDP ratios, and its particularly low ranking among G7 countries, early into its mandate in 2006 the government committed to reducing that even further (Finance Canada 2006a, 29-31); and a year later it further accelerated the debt repayment schedule. Planning to hit a ratio of 25 per cent by 2012-13 (Finance Canada 2007, 18, 153-154), this would have been a drop of 10 percentage points. In fact, even as the government proceeded with its aggressive Economic Action Plan to weather the recession, Keynesian pump-priming while then needed¹⁴ was not to be sustained. The intent was to exit traditional public works measures as quickly as possible, returning to budgetary balance. So too was there the unequivocal commitment to low taxes,¹⁵ both on a corporate and personal income basis. Reductions in the GST had been introduced early in the administration’s tenure but by 2007 there was a more robust plan to undertake further cuts (Finance Canada 2007, 221-224) particularly with the goal of reaching the lowest level of business taxation in the G7, attracting foreign investment and being a “magnet” for global talent (IC, 2007b, 48-55; IC Response, 2007a, 2). Indeed, expanded capital cost allowances for machinery and equipment were introduced *prior* to 2008, to assist companies with remaining competitive.

¹³ This is probably most clearly articulated in the “Message from the Minister of Finance” (IC 2007b, 5).

¹⁴ See the comment “not balanced budgets “at any cost” (SFT 2008, 5; SFT 2010, 3).

¹⁵ See in particular SFT (2011) and the need for a “stable, predictable, low-tax environment;” also Finance Canada (2007, 221-224).

So too did there remain the continuing emphasis on “free[ing]” business from the “daunting maze” of red tape (SFT 2010, 4), with reviews of the regulatory environment and the weight of administrative burden to be undertaken (SFT 2007, 2008, 2010, 2013). Specifically, there was the intent to legislate a “One-for-One Rule” wherein every regulation introduced across the federal government would have to be balanced with reduction of one regulation as well (SFT 2013,10). Special emphasis was also placed on the streamlining needed for major resource projects, leveraging Canada’s resource “endowment” and creating one entry point for project approvals (SFT 2007;¹⁶ 2008, 2010, 2011). Even the work of the External Advisory Committee on Smart Regulation (Canada, External Advisory Committee, 2004) established under the previous administration was duly credited. As for the issue of physical infrastructure across the country for trade and for communities, this of course took on major proportions as the government ramped up from an emphasis on trade corridors and border crossing (SFT 2007) to a full-fledged public works program, spanning every region and type of infrastructure and intended to stimulate the economy. By 2010, 16,000 projects had been announced or were underway under the auspices of the *Economic Action Plan* of 2009 (Finance Canada 2010, 195.) Bringing up the final rank in this array of policy initiatives that did show remarkable continuity with the period that had gone before was the continuing focus on removing barriers to internal trade within the federation and ensuring an “open federalism” (SFT 2006, 8; also SFT 2007, 2008, 2013).¹⁷

If the big themes of macroeconomic environment, regulatory consolidation for large and small businesses and an investment context where “market forces [could] play out” (IC 2007b,

¹⁶ See SFT 2007, 11 on the “single window” that would be established for major project approvals – and indeed the Major Projects Management Office dealing with this issue was established that same year (<https://mpmo.gc.ca/8>).

¹⁷ See especially the comment “Despite the globalization of markets, Canada still has a long way to go to establish free trade among our provinces” (SFT 2007, 8).

51; Finance Canada 2007, 176) were the centrepiece of comparability with previous policy initiatives, however, even within the focus on R&D there were elements of priority continuity. For one thing, the emphasis on clean energy technologies remained a steadfast priority throughout all of these years. For another, and as will be especially seen in the next chapter on targeted resourcing, there was an ongoing commitment to indirect research costs, particularly associated with infrastructure. Thus (as earlier mentioned) were the Canada Foundation for Innovation, CANARIE and the program for Indirect Costs of Research – all introduced under the Liberal administrations – both maintained and injected with significant funding. If Canada's policy environment had difficulty maintaining a few key R&D priority areas over the *longue durée*, the research infrastructure required to support Canada's basic and applied R&D was not in this category.

Yet, what had particularly distinguished Canada's New Government (as it was then named) was both the tighter focus on R&D priority-setting and accompanying implementation machinery, even during a period of challenging economic crisis. However, this was not to be sustained. By 2013, the Speech from the Throne signalled coming changes with a new Science, Technology and (now) Innovation Strategy, as well as the launch of a new Advanced Manufacturing Fund geared specifically to the needs of Ontario (Finance Canada 2013, 6).

Moreover, by 2014 -- surprisingly given that Canada had now exited from the recession -- the original tight focus on four key priorities had begun to fray. The updated Science, Technology and Innovation Strategy which was crafted (IC 2014a), and consulted upon, cast a much wider net. It was not just that the four key priority areas originally articulated -- environmental science and technology, natural resources and energy, health and related life science and technologies and information and communications technologies -- were

understandably expanded to include agriculture with environment. Nor even that a new separate category of advanced manufacturing had been added, given the importance of this field in sustaining manufacturing with new enabling technologies. It was that, by the government's own reckoning, these now five priority areas spanned twenty-eight areas of "focus" (*Ibid.*, 20), ranging over a disparate array of categories. Topics as broad as climate change research and technology, health, energy and security of water, automation and robotics sat along side (albeit under different research priorities) specific areas such as additive manufacturing. If as Mazzucato (2018) has argued, innovation areas must ensure a diverse "portfolio" of measures to ensure the risk of success is balanced with that of failure, nevertheless this constituted a very wide-ranging array of priorities. And this time, in contrast with the quite honed CCA evaluation that had informed the original priority-setting exercise, priorities were linked more broadly to Canada's industrial sectors, a rather unique list including such categories as space and robotics, as well as the traditional domains of aerospace and automotive (*Ibid.*, 20-22). As it was, however, the impact this broad range of R&D priorities were to have on the country's rate of innovation was not allowed to play out. By 2015, a new government had been elected, and a new set of innovation priorities ushered in.

Another Beginning

An Innovation and Skills Plan: More Priorities

At first, following the election, another period of some dormancy ensued on the innovation front as the new administration found its footing and articulated new Throne Speech priorities (SFT 2015). To be sure, "clean" technology was referenced (SFT 2015, 5), although the traditional category of clean energy technologies had been jettisoned and now appeared to be encompassed under this broader rubric. But the main focus was on other factors than R&D or

innovation. Dealing with climate change, reconciling intractable issues around resource development, Indigenous rights and environment assessments; ensuring prosperity for the middle class; the benefits of “diversity” and gender equality; even democratic reform became the critical elements in the administration’s new agenda. As the government wrestled with these issues, however, strong growth and innovation came to the fore again. By 2016, the government was engaged in a consultation exercise around innovation, holding 28 roundtables and soliciting views from across the country (ISED 2019, 17). By 2017, the government had unwrapped its Skills and Innovation Plan (Finance Canada 2017, 43-112), announced through the Budget of that year. Extremely ambitious in the number of priorities it established, the targets it set, the breadth of issues to be tackled and the extent of institutional change, the Plan became the centrepiece of the administration’s strategic focus. As it evolved, it also became the North Star for ISED’s extensive institutional changes.

Aggressive in its reach and trained on the potential for strengthening Canadian economic growth and employment, the Innovation and Skills Plan laid out six key priority areas: agri-food, clean technology, digital industries, advanced manufacturing, health and bio-sciences and clean resources (Finance Canada 2017, 44). These areas were to be “target[ted]” not only for government action but equally were to be catalysts for enhancing (the enduring issue of) business investment in innovation (*Ibid.* 46), as well as initiatives to be undertaken by the academic and research communities. Aligned with growth and export potential, these priorities did not play to historic strengths or endowments as much as the capacity for penetrating rich global markets twinned with the international competitiveness they could buy for Canada. Towards this end, three areas in particular were singled out for action: clean technology, digital industries and agri-food (*Ibid.*, 95-108). Clean tech alone was deemed to have a global market of \$1 trillion per year

and similarly digital industries and global demand for “protein” and food were seen as being the waves of the future. Moreover, even within this framework, clean tech warranted special attention with a host of initiatives supporting the sector in the Budget.¹⁸ All told, in combination with initiatives that had already been taken in 2016, \$2.4 billion was being funnelled into this area over a four-year period (*Ibid.*, 96-97), including a special emphasis on access to capital. As for the sector itself, it was seen as a rather all-encompassing domain, including all of Canada natural resource industries (mining, energy, forestry) as well as agriculture and fisheries.

In addition, five innovation superclusters were to be launched, again with the intent of increasing the nation’s “global competitiveness” and strengthening -- and enabling -- Canada’s innovation ecosystem (see especially *Ibid.*, 79-80 and ISED 2019 on the latter). The specifics were yet to be designed, but the intent was “platform technologies” exemplified by the six priority areas that had already been identified *as well as* infrastructure and transportation (Finance Canada 2017, 80). Overlaid on this as well was a “mission”-driven Impact Canada Fund intended to deal with Canada’s grand “challenges” and specifically focusing on not just clean tech but also hyperlinked “smart” cities at the forefront of connectivity (*Ibid.*, 81). Economic Strategy Tables were also to be struck (falling under ISED but led by industry) aligning with the areas of clean tech, digital industries, agri-food, advanced manufacturing, health and bio-sciences, and clean resources. Bringing up a final flank in all of this was special attention to Artificial Intelligence (*Ibid.*, 104-105) where Canada already had some comparative advantage. In sum, in the Innovation and Skills Plan alone, *nine* key “priorities” were the subject of action in the government’s Innovation and Skills Plan – and ten if the focus on AI is equally included.

¹⁸ This will be discussed in greater detail in Chapter Five “Targeted” Resourcing: Budgets and Innovation.”

As events unfolded however, other initiatives were added to the list. The Superclusters that were selected did largely align with the already enunciated priorities in the Innovation and Skills Plan. Although situated around regional economies, the Superclusters did include digital industries in BC, a protein supercluster in the Prairies, advanced manufacturing in Ontario (later to be renamed Next Generation Manufacturing) and an AI initiative – SCALE AI -- in Québec (ISED 2018e; <https://www.ic.gc.ca/eic/site/093.nsf/eng/00008.html>). However, two things are of note here. Oceans were now added to the list for Atlantic and while the latter did encompass renewables (<https://www.ic.gc.ca/eic/site/093.nsf/eng/00013.html>), the traditional stalwart of energy R&D and technologies was not specifically among the clusters selected. Nor were health and bio-sciences plucked out for special action, although genomics was subsumed under the protein supercluster endeavours (<https://www.ic.gc.ca/eic/site/093.nsf/eng/00012.html>; <https://nrc.canada.ca/en/research-development/research-collaboration/programs/supporting-canadas-innovation-superclusters>). Moreover, additional priorities or areas of action followed. Through a new procurement vehicle the government launched to drive demand for innovative products and processes, more “challenges” were issued to the industry and research communities. All told by 2019, 14 participating departments had issued 42 “challenges” (ISED 2019, 49). As for the Economic Strategy Tables, even here additional consideration was being given to tourism and space, with a Tourism Industry Table eventually struck in Spring 2019.¹⁹ In sum, the priority-setting exercise of the Innovation and Skills Plan, as it gained momentum, further expanded. Certainly, gone was the rigour of the previous era where four and ultimately five innovation priorities were the locus of attention.

¹⁹ To date there has been no report by the Tourism Table. On the Table launch and tourism strategy, see <https://www.canada.ca/en/innovation-science-economic-development/news/2019/05/government-of-canadas-new-federal-tourism-strategy-empowers-communities-across-the-country-to-create-jobs-for-the-middle-class.html>.

If priorities had expanded significantly under the new administration, so too did the number, and breadth, of targets seen as required to turn the tide on disappointing innovation indicators and kickstart a “world-leading” innovation economy. Originally articulated in Budget 2017 in the Innovation and Skills Plan, the government had pronounced itself on four key goals (see *Ibid.*, 44), only two of which had explicit numeric objectives. Echoing the Plan’s emphasis on global growth trends, the intent was to “grow” the country’s goods and services exports by 30 per cent by 2025. So too by 2025 were “the number of high-growth companies” to be doubled from 14,000 to 28,000 firms. Clean technology’s contribution was to be equally expanded, although the document was silent on specifics, and job training that could support the Plan would be increased as well.

While clearly aggressive in their intent, the targets were extensively supplemented in the ISED documentation which followed. Indicating that targets were to be “bold and ambitious” (ISED 2019, 19), in fact a range of parameters, all deemed as essential to a healthy functioning innovation ecosystem, were to be pursued. Business investment in R&D was to increase by \$30 billion by 2025²⁰ in order to ride alongside the OECD BERD average – not an inconsequential objective given that Canada’s BERD would have had to essentially double from .87 per cent of GDP in 2017 to the OECD average of 1.65 per cent in the space of eight years.²¹ Moreover, it would come on the heels of almost two decades of decline in the Canadian BERD from a high of 1.25 per cent of GDP in 2001. ICT investment was to be similarly benchmarked against international targets, to increase to 3 per cent of GDP within the same time frame. Clean tech exports were also given an explicit objective, their exports to be doubled by 2025. Similarly,

²⁰ On this and the other targets below articulated in departmental documentation see https://www.ic.gc.ca/eic/site/062.nsf/eng/h_00083.html. On the OECD data see Figure 6 (BERD as a percentage of GDP) in Chapter Three.

²¹ On innovation indicator trends, see in particular Chapter Three, “The Health of the Canadian Innovation System: Taking the Pulse.”

collaboration between companies and post-secondary institutions was to double within that same period. As for the skills that would anchor this economy, here too the target was set high (departing quite radically from the more modest growth targets set in 2001 of augmenting graduate enrollment by 5 per cent per year). “[P]rofessional, science and tech-related jobs in the Canadian economy as share of total employment” was to increase to 40 per cent by 2025.

Further layered on top of this was a set of demanding objectives established by the Economic Strategy Tables. Having been mandated by the government to set “ambitious growth targets” (Finance Canada 2017, 77) their thinking equally spanned a wide range of aggressive goals. In their report, *The Innovation and Competitiveness Imperative: Seizing Opportunities for Growth* (EST 2018a) the list, premised on an aggressive time frame of 2030 was enumerated. Founded on the principle of “own[ing] the podium,” the number of “global-leading” Canadian firms was to double, from five to ten and, with the intent of catalyzing firm scale-up, medium-sized businesses were to grow at a rate of between 2 and 4 per cent per year.²² On the Bloomberg Innovation Index Canada was to leap forward from a rank of twenty-two to within the top ten. BERD was to grow to 2 per cent of GDP, a ranking it might be noted that was in fact slightly higher than even the OECD average in 2017, the equivalency that ISED had itself set. ICT was to be benchmarked in this case against the US, with an impetus to “close ... [the] gap,” the latter signifying a change of 20 percentage points. And a range of other complementary parameters were included: dispensing with regulatory burden and entering the top five of the World Bank Index for “Ease of Doing Business” and moving into the top ten performers on the World Economic Forum Human Capital Index. In *toto* by 2030, GDP was to have been given an

²² On this and the targets listed below, see EST 2018a, especially 6.

injection of \$318 billion, an increase in GDP growth – the document acknowledged -- of 15 per cent above 2017 (*Ibid.*, 6).

As for the aims and strategies of the separate Economic Strategy Tables, they too articulated their own objectives. Thus did Advanced Manufacturing focus on increasing exports by 50 per cent -- all by 2030 (EST 2018b, 3). The resource table was similarly aggressive, aiming to increase exports by 40 per cent by 2025 (EST 2018g, 4). Clean technology was to become one of Canada's "top five" exporting industries, an increase that translated into an annual amount of \$20 billion – by 2025 (EST 2018d, 3). By 2025 health and bio-sciences was targeting to have doubled the size of their sector *as well as* doubling the value of exports (EST 2018e, 2-3). And pivoting more on sectoral strength than exports per se, digital industries were aiming to double the number of firms to 26 with combined annual revenues of "over" \$1 billion (EST 2018f, 3). As for agri-food, it envisioned an increase of almost 32 per cent in exports -- again by 2025 (EST 2018c, 3).

This was then a much larger tableau that was being painted than even in 2001. And if one of the key elements of a developmental network state is consistent, coherent and viable strategies that set targets, maintain pathways to success and religiously winnow out failed efforts, this was a much grander -- and more crowded -- exercise. Moreover, not present in the documentation accompanying this visioning (from the Innovation and Skills Plan to departmental efforts to the work of the Tables) was an analysis of why similar efforts at target setting had failed in the early part of the century. Nor was there reflection on whether leaps of such magnitudes could be attained given the steadily decreasing trends that expenditures on

R&D – GERD and BERD alike, as well as ICT investment²³ – had experienced over the better part of two decades. Even plateauing trend lines evidenced in Higher Education R&D did not signal the base for a springboard that could catapult Canada into the top range of the Human Capital Index.

As for other priorities in terms of the macroeconomic context, this time in contrast with eras of previous Liberal and Conservative administrations, the emphasis was much more muted. To be sure, Canada still appeared to ride internationally on its reputation of macroeconomic “stability.” Both in 2016 and 2018, the OECD did not target the macroeconomic environment as one deserving of major concern. On the contrary, in 2016, the federal government was characterized as having a “strong fiscal position” (OECD 2016, 13). Two years later, the OECD did observe that macroeconomic policies could afford to be less stimulus-oriented (OECD 2018, 17 and 27-28). Nevertheless, the OECD was of the view that the federal debt-to-GDP ratio was “likely to decline” (*Ibid.*, 28) and attention was drawn more to global conditions and the instability of falling commodity prices.

However, beneath this somewhat rosy fiscal picture, there were incremental changes, signalling antithetical trends to eras of priority-setting that had gone before. For one thing, Throne Speeches under the Liberal administrations – both in 2015 and 2019 -- gave only passing reference to “pursuing a fiscal plan that is responsible, transparent and suited to challenging economic times” (SFT 2015, 3; 2019, 8),²⁴ in both cases garnering only a sentence in the Speeches. Moreover, the federal debt-to-GDP ratio, as the government pumped up stimulus spending, did show a temporary incline, moving from 31 per cent of GDP in 2014-15 (Finance

²³ On these trends, see Chapter Three.

²⁴ The statement in SFT (2019) is almost the same – “And the Government will pursue a responsible fiscal plan to keep the economy strong and growing.” (*Ibid.*, 8).

Canada 2016, 234) to 31.5 per cent by 2016-2017 (Finance Canada 2017, 251) before settling back down (pre-pandemic) to 30.8 per cent by 2018-2019 (Finance Canada 2019, 18) and an anticipated 31.2 per cent for 2019-2020, that is *prior* to COVID-19 spending (Finance Canada 2020, 104). The incline in debt-to-GDP was notable, however, given the surplus of \$1.9 billion (Public Accounts 2014-2015, Table 1) which the new Trudeau administration had inherited. Of course all of this has now paled as COVID spending has prevailed.²⁵

So too was there lessened emphasis on regulatory streamlining. Instead the approach articulated pivoted more on the balance between “protecting the environment” (SFT 2015, 5) and resource extraction -- and by 2019 the imperatives of dealing with climate change and the needs of Indigenous peoples (SFT 2019). While the Economic Strategy Tables (IC 2018, 4) did issue recommendations for going forward that included the need for a flexible and “agile” regulatory environment and while the government did indicate the need for an hospitable environment of small business start-ups (SFT 2019, 8), this was no by no means an overriding priority of the new administration as had marked previous eras. The exception to this seems to have been in the domain of IP strategy where the government wanted to create further incentives for commercialization by ensuring a competitive regime that could protect Canadian inventors.

Where continuity with past administrations did exist was with the emphasis on tax reductions, to ensure prosperity for the “middle class” (SFT 2015, 3; SFT 2019, 7-8; also Finance Canada, 2017). So too were major investments signalled for physical and social infrastructure (SFT 2015, 3) to ensure key fundamentals for economic growth were in place. Remaining a key concern as well was a reckoning with internal barriers to trade within the federation. In this case, the government promptly moved to action and, by July of 2017, a

²⁵ As the *Fall Economic Statement 2020* indicated, the debt ratio for 2020-2021 was foreseen at 50.7 per cent (Finance Canada 2020, 104), eventually coming in at 49.0 per cent of GDP (Finance Canada 2021, 47 and 328).

Canadian Free Trade Agreement with the provinces and territories (necessarily complete with some provincial exemptions) had been negotiated (<https://www.cfta-alec.ca/>).

One Voice: Institutional Change

If priorities and targets were similarly expansive, where change did occur was around the institutional mechanisms established to implement this agenda. Indeed, institutional coherence hardened considerably. For one thing, the renewed vigour being injected into the innovation agenda aligned well with ISED's traditional portfolio mandate. Spanning all dimensions of the innovation "continuum,"²⁶ the department was equipped with the levers to sustain a reform momentum. Via its granting councils as well as research infrastructure mechanisms for which the department held accountability (CFI, CANARIE, Indirect Costs for Research) ISED could leverage "fundamental" or basic science. Through such vehicles it could direct research priorities that stretched across the triadic linkages of business, academe and government. It had the capacity with the NRC to "reimagine" (ISED 2019, 40) the institution, not only to meet R&D priorities but to equally broker the networks engendering applied research and commercialization. As for the grander project of scale-up and what the ACEG had labelled "innovation marketplaces" (ACEG, 17), ISED was a lead actor in holding the competitive processes and brokering the deals that helped establish the five Superclusters (ISED 2018e; <http://www.ic.gc.ca/eic/site/093.nsf/eng/00014.html>; <http://www.ic.gc.ca/eic/site/093.nsf/eng/00016.html>). Spread across the five regions of the country and aligned with key priorities, these nodes of engagement were to be critical to a robust Canadian innovation "ecosystem."

With respect to the horizontal review of the labyrinth of innovation programs that had criss-crossed federal government departments, certainly it was Treasury Board (<https://>

²⁶ See in particular ISED 2019, 22-23.

www.canada.ca/en/treasury-board-secretariat/corporate/reports/inventory-federal-business-innovation-clean-technology-programs.html) which conducted this review, slashing the number of programs by two-thirds, from 92 to “about” 35 (ISED 2019, 64). Yet, many of these programs now rested under the auspices of Innovation Canada, again a central component of the ISED ministry. To be sure, a good number of these earlier efforts had been previously housed within ISED. But the ambit of the department²⁷ now stretched from new initiatives around direct programming where AI-powered algorithms could provide services to industry inquiries – in minutes, not days – to outliers such as Innovative Solutions Canada,²⁸ a key procurement vehicle for catalysing the innovation agenda at the pre-competitive stage. Traditionally such an instrument would have been situated within Public Services and Procurement Canada; following 2017, its capacity for demand-pull in the context of early stage development and prototyping rested within ISED. Similarly, a range of clean tech initiatives catalyzing growth “across the country” (ISED 2019, 59) and equally aimed at commercialization and scale-up were housed within ISED. And while one of these initiatives – the Clean Growth Hub – did fall under a Natural Resource Canada and ISED partnership, Sustainable Development Technology Canada, a foundation that had been dedicated since 2001 to clean technologies and recapitalized in the wake of Budget 2017, that too was now nested under Innovation Canada.²⁹

Equally compelling in terms of the institutional capacity developing was that a range of key programs and initiatives, oftentimes as well part of the historic Industry Canada portfolio but

²⁷ For extensive discussions of the department’s range of responsibilities, see ISED (2019); ISED DRR (2018 and 2020). On the issue of timelines see ISED (2019, 65-66) and the interactive web site <https://innovation.ised-isde.canada.ca/s/?language=en>.

²⁸ See ISED (2019, 23); also ISED DRR (2020, 4-5 and 23-24).

²⁹ On SDTC governance, see <https://www.sdte.ca/en/about/about-us/> and ISED (2019, 78).

now pivoted to innovation “scale-up” and global markets, were under ISED auspices.³⁰ Regional Economic Development agencies charged with targeting more localized innovation strategies; a Strategic Innovation Fund (<https://www.ic.gc.ca/eic/site/125.nsf/eng/00023.html>), also recapitalized, as a centrepiece of the government’s global growth strategy; the BDC’s venture capital initiatives (ISED 2019, 57-59; https://www.ic.gc.ca/eic/site/061.nsf/eng/h_03052.html; Finance Canada 2017, 83-84) expanding late stage capital as well as early development: all were within the ISED portfolio. Coming full circle within the innovation continuum even some of the skills imperatives around STEM training for youth and industry internships (traditionally what would be an Employment and Social Development Canada mandate) were located there (ISED 2019, 24-30, <https://www.ic.gc.ca/eic/site/121.nsf/eng/home>), as were of course the Canada Research Chairs responsibility of the tri-councils.

Certainly, in terms of the work of the Economic Strategy Tables, there were some disjunctures between the Tables and ISED, to whom they reported. Evident in their collective and respective reporting, the ESTs continued to articulate a robust critique of government programming that was too complex, unpredictable and “overwhelm[ing]” (EST 2018a, 16 and EST 2018b) in number: this, even as departmental authorities implemented the streamlined programming, new “hubs” of activity and “accelerated growth” services. And of course there were the usual observation on the density and unpredictability of government regulations (EST 2018a; 2018c; 2018d; 2018f; 2018g) as well as larger issues around competitive tax regimes (EST 2018a; 2018b; 2018e; 2018f; 2018g). However, the Tables had been specifically tasked with identifying not only strategies and opportunities but also “bottlenecks” that could hold back

³⁰ For extensive discussion and description of ISED’s range of innovation responsibilities, see ISED (2019); ISED DRR (2018 and 2020); <https://www.ic.gc.ca/eic/site/080.nsf/eng/home>; and https://www.ic.gc.ca/eic/site/131.nsf/eng/h_00000.html.

the innovation agenda. As such, these observations can not be considered a major institutional obstacle to the agenda that the department held before it and indeed the government as a whole promptly acted on some of the Tables' recommendations.

Finally, in this array of institutional levers (that the department held) it is worth noting that even in terms of political leadership (an element which Skocpol and Finegold (1982) also find compelling) Minister Bains had maintained his role throughout the 2015 - 2020 period, only stepping down in January of 2021.³¹ And while the Minister of Science position has been abolished under the 2019 administration, nevertheless responsibility for fundamental science as well as the Office and budget of the Chief Science Officer have remained squarely within ISED. All told then, this tableau does evidence a landscape where a significant degree of institutional cohesion and *capacity* had become apparent – where the earlier counsel of the Jenkins Report (2011) to speak with one institutional “voice” on innovation had been taken.

The Third Innovation Policy Era: 2017-2020

Thus, in reflecting on this third innovation era what particularly defines it is the bifurcated nature of the policy efforts around the innovation agenda. As has been evidenced, sharp differences emerged between the logic of priority-setting and the coherence of the institutional apparatus tasked with implementation. In the case of the latter, a definitive locus of activity and capacity emerged around the ISED portfolio and the Strategy Tables that operated within its orbit. As has been seen, key administrative mechanisms and fiscal instruments were assembled, recast or refined to deliver on the innovation agenda and made for a significant arsenal of implementation vehicles.

³¹ Minister Bains resigned as Minister of ISED in January of 2021 (<https://www.thestar.com/politics/federal/2021/01/12/prime-minister-justin-trudeau-shuffles-cabinet-after-navdeep-bains-says-he-plans-to-retire-from-politics.html>).

In juxtaposition, however – and creating an undercurrent of schism within this larger institutional coherence – were both the numerous priorities and the proliferating targets that characterized this period. Especially as the targets rolled out, rather unchecked, what was apparent was that these were not anchored to a realistic assessment of what had gone before; nor were they benchmarked against the goals that had marked the early part of the century; nor were they the subject of analysis as to why those earlier goals had failed.

Certainly, the combination of these two competing elements made for uneasy bedfellows. Moreover, with respect to the key question of policy durability implicit in the DNS framework, it poses the question of whether such a schism – or even tensions—between priorities and administrative apparatus can sustain reform momentum. This era illuminates in particular aspects of the policy durability conundrum that even the work of Skocpol and Finegold (1982), focused as they are on the capacity question and less on turbulence in priority-setting, do not consider. Definitely, it drives us to consider other critical pillars of the DNS argument, to which we will soon turn.

As a postscript to this analysis, it goes without saying of course that since March of 2020 and the onset of the COVID pandemic, the federal government’s agenda, similar to its global counterparts, has been thrown into disarray. In quick succession, the federal government undertook emergency fiscal measures; priorities became centred around personal protective equipment and vaccines and the federal deficit – and debt – subsequently ballooned. Certainly, the government’s innovation agenda was largely displaced with the immediate needs of an unsurpassed health crisis and the economic cratering that followed in its wake. Indeed, in broad strokes, the last several months of 2020 can only be seen as a radical disjuncture within the decade.

That said, however, it is worth noting that certain fundamentals of the government's agenda were retained – albeit now recast. In the Throne Speech of 23 September 2020 (SFT 2020) the government continued to focus on the middle class only now in terms of the rebuild that could kickstart the economy and “mend” the social safety net. So too would macroeconomic stability and budgetary balance be regained although the timeline for this was now moved forward until 2025-2026 (Finance Canada 2021, 47). Moreover, as Chapter Nine will discuss, even innovation became centred around domestic vaccine development and supply – this after many years in which (as will be seen) pharmaceutical manufacturing and R&D had languished as a government priority. However, while the last nine months of 2020 still resonate with the remnants of the government's priorities, these cannot be seen as a yardstick for measuring the integrity of the DNS framework in assessing the Canadian experience. Rather this period is a jarring and unique constellation of factors in the face of an unprecedented conjunctural crisis. If anything, it throws into relief the challenges around policy continuity in the Canadian context – and how ruptures in durability further widened the innovation gaps with which the country was faced.

In-Depth Interviews with Thought Leaders

As noted at the outset of this chapter, supplementing this historical review of federal policy have been extensive interviews with innovation thought leaders across the country.³² Given the import of the innovation issue, what this research centred on was taking the pulse of this situation with 54 key “thought leaders” across Canada who occupy or had occupied senior positions in their respective organizations. As has been earlier seen in Chapter Two, in-depth

³² A discussion of the methodology used is provided in Chapter Two.

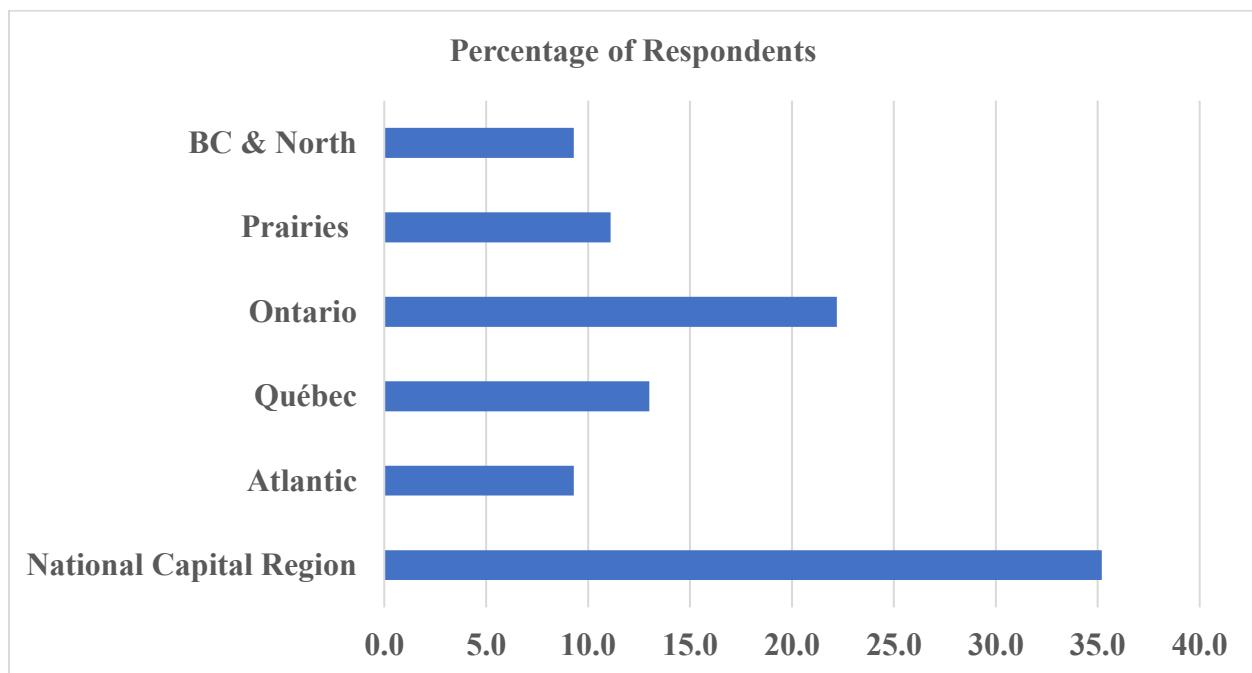
interviews of a “semi-structured” (Luton 2010, 23) nature were conducted during the period from April through to September 2020, with interviews lasting between 30 and 45 minutes and some running longer to the 50 and even 60 minute range. The interviews were conducted with senior officials within the federal government, scientists and engineers working in a federal capacity on R&D, as well as those representative of the political level of government at the federal level. In addition, the interviews included CEOs and senior executives within industry, leaders of networks, accelerators and institutions dedicated to incubating commercialization, leaders of professional associations, senior executives in universities and colleges, and policy experts associated with independent non-profit organizations.

Substantial efforts were made to have a representative sample of leaders within the Canadian innovation ecosystem, although it should not be noted from the outset this is not a statistically weighted “sample.” Rather it stands as a targeted effort to achieve a representative look at senior leaders within the Canadian innovation community. Moreover, information has been rolled up in aggregate form to protect the anonymity and confidentiality of the interviewees – one of the conditions of the interview.

In total, there was representation from various sectors of the Canadian economy, including not only legacy industries such as auto, energy, oil and gas, mining and agriculture but also the Information and Communications Technology sector, the life sciences, renewables and Artificial Intelligence as well as the Venture Capital community. Interviewees were also geographically dispersed, coming from all regions of the country or in one case from institutions that had a mandate dealing with that region (Figure 1). Lest it be thought that there was undue weighting on Ottawa as a bias towards national activity, in fact 65 per cent of those interviewed

came from areas of the country other than the National Capital Region.³³ Regional breakdown out of the total number of interviewees (and not including the NCR) broke along the following lines: BC and the North -- 9 per cent; the Prairies --11 per cent, Ontario -- 22 per cent, Quebec -- 13 per cent, and Atlantic -- 9 per cent. That breakdown was by design – encompassing as it did an effort to ensure that voices outside of central Canada were a strong part of the interviewee base and dialogue around innovation.

Figure 1 Regional Breakdown of Interviewees



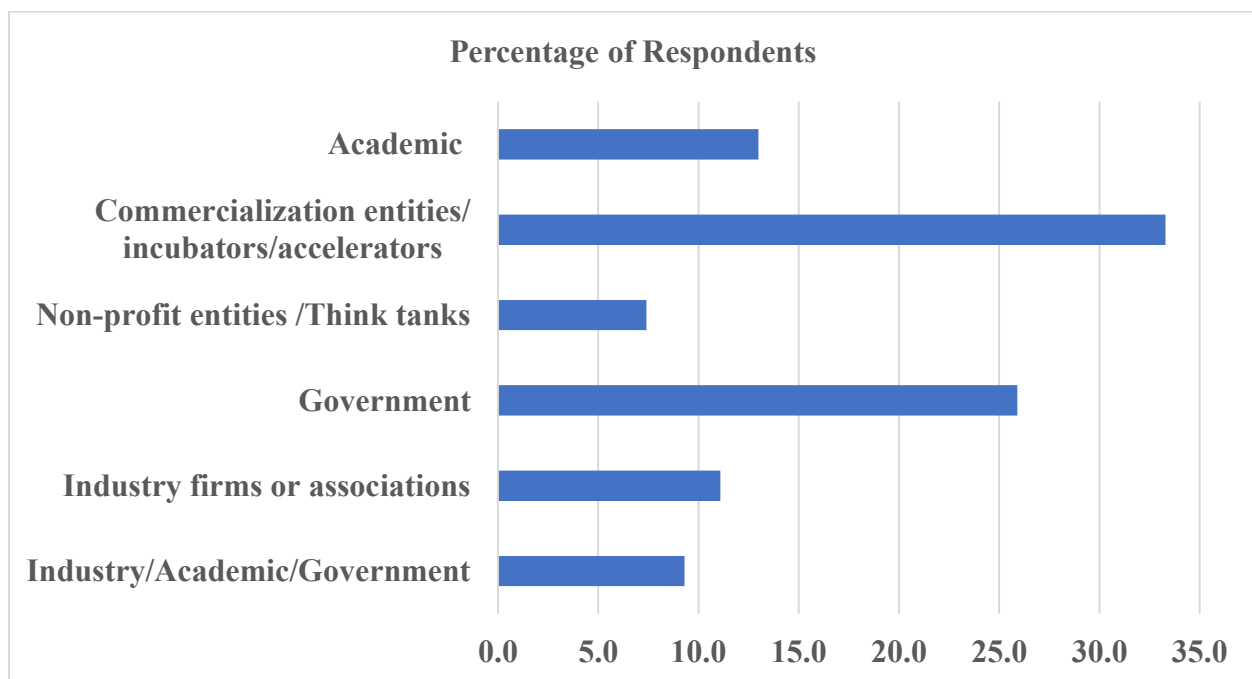
Further as Figure 2 indicates, representatives can be categorized along six different indices.³⁴ The largest group – 33 per cent were from centres and institutions which can be best categorized as focused on commercialization, incubating commercialization, accelerating start up

³³ The fact that government departments and agencies and national associations are often located in the National Capital Region did factor into the proportion of respondents from the NCR. It should be noted that percentages provided below on the regional breakdown are rounded for presentation purposes. The 65 per cent is based on calculation to the first decimal place – 64.9 per cent.

³⁴ Figure 2 does not add to 100 due to rounding.

or scale up activity or cluster activity of some kind. Another 26 per cent were from senior levels of government; 13 per cent were from the senior executive cadres within academe or highly specialized scientists; and 11 per cent were from industry, either firms or industry associations. Additionally, 7 per cent were associated with foundations – taken in its broadest sense or independent think tanks or non-profits centred around innovation. Finally, 9 per cent of the interviewees did not fall predominantly in one category but rather spanned government, academic or industry. While the industry representation through firms or associations may seem relatively small it should be noted that, together with those crosscutting industry from other fields, this component constituted 19 per cent of those interviewed. Moreover, it need be noted that 30 per cent of those interviewed had extensive experience in the innovation field and could draw on their historical knowledge in answering questions.

Figure 2 Sectoral Breakdown of Interviewees



Turning now to the first line of inquiry, to get at the issue of consistency in strategic priority-setting, the following question was posed to interviewees:

Another area that has merited debate is the need for federal policy to consistently target key priorities around R&D investment and innovation. Do you think federal policy has been sufficient in this regard?

The question was designed to open up a discussion of this issue and admittedly while the concept of “sufficient” might not be deemed a very high bar – in fact the vista of two decades of federal policy under the watch of different political administrations and with many ensuing economic and political challenges functioned as a reasonable benchmark for assessing this dimension. Indeed, at times the interviewer was met with “great question” before a response was provided.

As indicated, in all, 54 thought leader interviews were conducted. On this issue of consistency, however, in four cases either there was not sufficient time to address this issue or there was a conscious decision by the author to omit the question to provide greater opportunity for discussion of particularly important areas of specialization such as pharmaceutical manufacturing or venture capital. Of the 50 participants who did answer the question, in two cases, the answers that emerged at the end of question two on targeted resourcing or in final comments were leveraged as responses. In these instances, an organic continuity in the responses around federal efforts emerged and the ensuing discussion spoke directly to the issue of priority-setting and thus was included.

The responses elicited were notable on two fronts. Firstly, they tended to be very wide-ranging, oftentimes providing a much deeper reflection on the nature of policy and the policy process and its fundamental tenets – “la fondamentale” (I39) that needed to be guarded. At the same time, however, these enduring features needed to reckon with the differing political “platforms” of electoral cycles and the inevitable change (and the “back and forth” (I51)) that

the democratic process necessarily ushered into policy. Secondly – and interestingly rather dissimilar to the results for other answers – there was a much less pronounced tendency to binary responses, ie., yes /no or even yes/no of a “qualified” nature or even to a “split” perspective on the issue. In fact twenty per cent of those responding to this question answered in a fashion that could only be categorized as “other,” frequently challenging the very assumptions of the question itself.

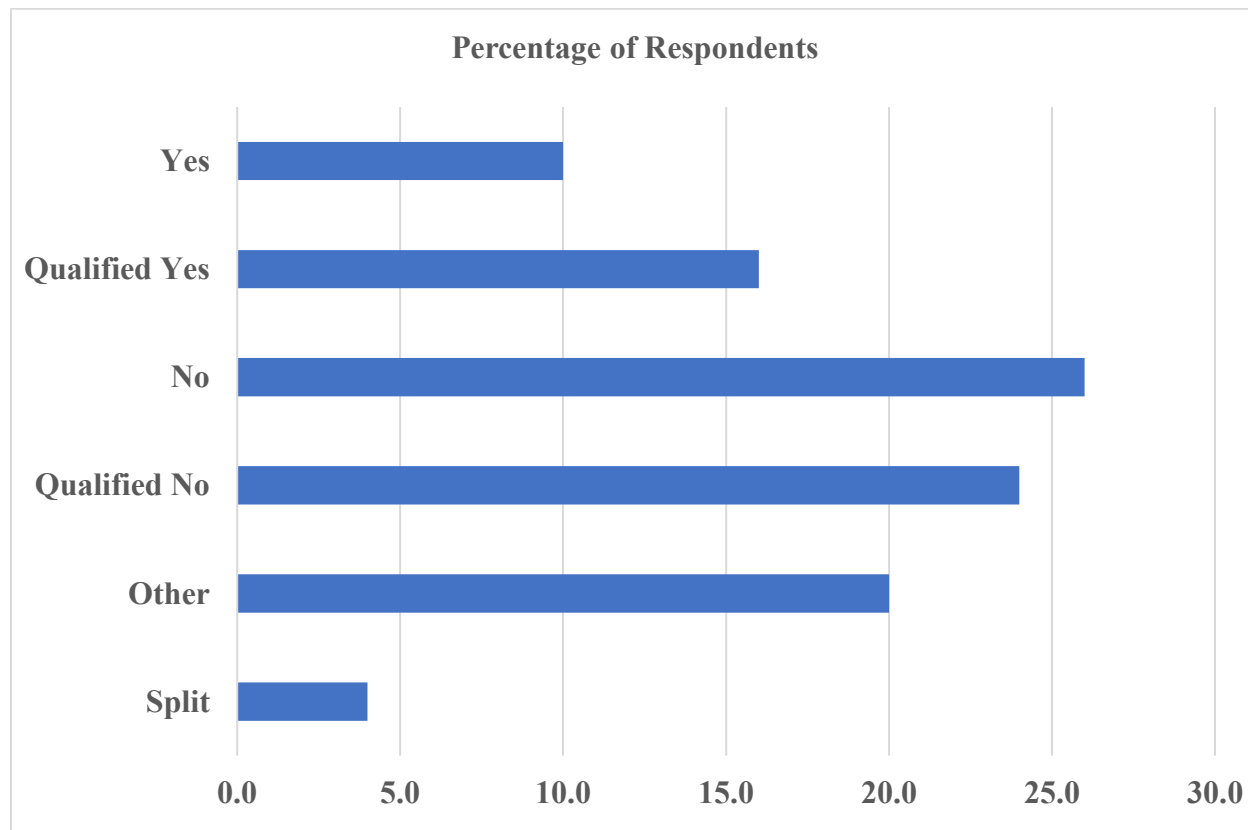
That said, of the 50 participants providing responses, the preponderance of comments was not particularly favourable towards the strategic consistency of federal policy (Figure 3). Specifically, 26 per cent provided a negative response to this question with another 24 per cent providing a qualified no – ie., with caveats. In total, then half of the interviewees did not see that the federal government was meeting the “sufficient” criteria on this dimension. In contrast, only 10 per cent of the respondents deemed the policy to be “sufficient” with another 16 per cent falling into the qualified yes category. And as noted, more surprisingly, another 20 per cent were deemed as other, with a further 4 per cent of respondents being evenly split on the issue.

Discussant Themes: Strategic Focus

With respect to the themes that emerged in these answers, one dimension was particularly pronounced -- that of the essential need for a “strategic focus,” clear “targets” and identified “mission” in innovation policy (Figure 4).³⁵ In fact, 58 per cent of respondents answering question three raised this issue. Nor were the comments oblique or shrouded in ambiguity. Rather the ground on which Canadian federal innovation policy rested was clearly stated.

³⁵ It should be noted that respondents could speak to different issues and were not confined to just one. Thus, the tally in Figure 4 refers to the percentage of respondents focused on that particular issue -- but it did not have to be exclusive.

Figure 3 Consistency in Federal Innovation Priority-Setting: Is It Sufficient?



For one thing, respondents commented on the multiplicity of policies and the way in which they tended to emerge around a unique or specific need – i.e., “next policy, different need: it [the policy] gets rolled out” (I5). Or as another commented about newly developing scientific domains that pique policy interest: “We actually go and write a policy for this area of science -- and here we go, have a policy” (I30). Moreover, in the words of another observing the number of “players” in the innovation domain, there was an overarching “impression from the outside that the policy suite ... has gotten quite sprawling over the years” (I22). Others at times were even more direct. Referencing specific projects where clarity on the way forward had

languished, Canadian innovation policy was characterized as a “littered landscape of disconnected things” (I20). So too did it make navigating this landscape quite challenging:

I’m being honest but again I don’t know what federal policy on innovation R&D is – what is it? ... Because you’ve probably got different policies related – you know by different departments... So it’s not policy, it’s policies. ... To me, there’s multiple policies that are disconnected between departments and it’s confusing or not totally relevant (I15).

Equally important for several respondents this had consequences particularly for industry, creating a lack of consistency and “predictability” that made long-term investments more “risky:”

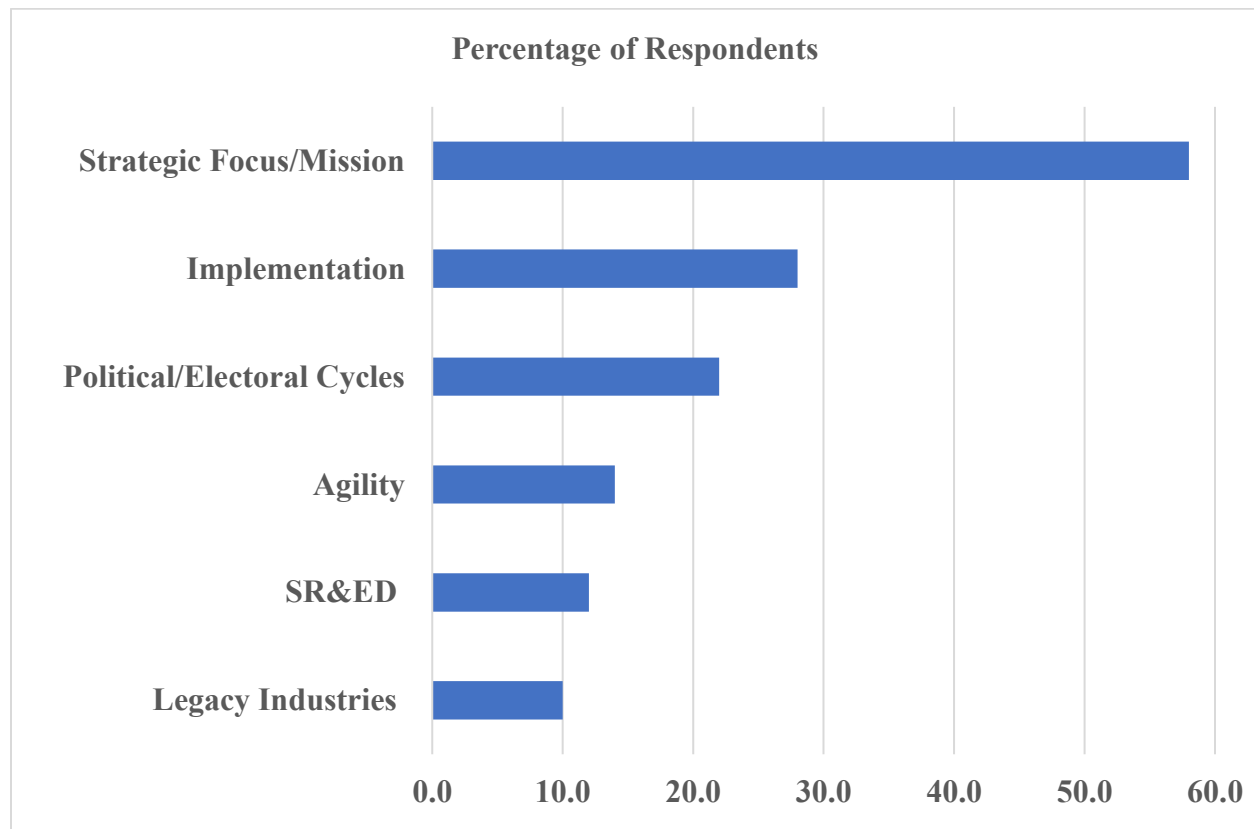
On the matter of consistency one thing is clear that ... you need to have sufficient – given the complexity of the economy, given the fact that the return on investment takes quite a bit of time, given the fact that predictability and, and certainty of consistent considerations often in the regulatory area in particular are highly relevant to major investment decisions by firms. If, if the government keeps changing them it is detrimental ... Firms are -- become more hesitant to invest if they don’t think it’s gonna be an enduring policy track (I19).

All of this required a sober step back from the pressures of policy-making and reflection on where Canada needed to position to be internationally competitive. Specifically at issue was the need for “government” to take a “long term strategic perspective” (I34) and “nail ... down” (I24) priorities. As one interviewee aptly captured:

If you’re going to set a strategic objective you have to know what is the market. Who are the competitors? What is my niche potential here – and ultimately that I think we have to define as a nation in a global context (I7).

Not that this meant drilling down in an overly detailed manner – certainly not plucking out specific areas – be it “la biologie moléculaire” (I46) or “optical technology” or choosing “company x over company y” (I43). Nor did it mean jettisoning the freedom and curiosity of fundamental science to discover and explore. Rather:

Figure 4 Consistency in Federal Priority-Setting: Themes Raised



C'est important d'avoir des programmes de subventions qui nous permettent de rêver parce que si tu laisses tomber le fondamental – le pipeline à un moment donné va être vide, tu ne seras plus capable de faire, de faire de l'innovation (I39).

What it meant instead, and what emerged from these discussions, was essentially threefold, indeed offering a systematic approach to developing a robust policy framework. It signalled the need to choose “societal objectives” (I43) engendering alignment with the innovation ecosystem and set meaningful “mission”-oriented policy and challenges which could address the innovation gap – not just chase the “target” of a “GERD to GDP ratio” (I6). It also meant articulating an approach that could adequately capture and identify such objectives, enabling the country to gain international recognition and profile (and as one participant

reflected move beyond Europe's perspective of Canada as just a "research hub" (I7)).

Specifically, there required a "methodology or clarity on how we determine where do we want to play and why apportion the money there – and really support those sectors that will enhance ... our longstanding national priority on the – the global stage" (I28). Finally, it meant taking a steely-eyed look at those innovation investments and identifying "what is the return on investment" (I21) and assessing "quel est l'impact sur l'économie canadienne – n'ont pas un petit but" (I49), and most critically taking appropriate action when these did not pan out.

Moreover, oftentimes discussion of these issues pointed to the quizzical nature of the quandary in which federal policy found itself, this despite the extensive "innovation assets" (I16) to which the country could lay claim and the natural resource wealth and citizenry talent which could be leveraged. And, for some, at least the answer distilled turned on the question of political will: there was a need to get on with the task at hand and just "do it" or as articulated in this eloquent portrayal of the issue:

I think where consistency to me is lacking and you know painfully and perhaps even tragically so is our inability to have a Cabinet level strategic policy that aims squarely at genuine sustainable development with Canadian context in mind ... We are unable to have that conversation and therefore innovation policies are lacking...

You need bravery and resolve – you need to be able to move past the short-termism and the rhetoric We have to be able to call out and declare where we stand as Canada and we have not been doing that and I think that related to that frankly ... we've not been able to state the ground and go big or go home (I44, emphasis added).

It is worth noting that while 58 per cent of respondents raised the issue of strategic focus (including those with answers that could be categorized as other or a qualified yes), this perspective was especially pronounced among those had who had answered with a no or qualified no to question three. Of those who responded to the consistency question with a no or

qualified no, 68 per cent of them identified the concerns around strategy and priority-setting as problematic.

Discussant Themes: Policy Implementation

Other issues also emerged in response to the question around priority-setting consistency. Raised by just over a quarter – 28 per cent – of the interviewees was that of policy implementation, with a number of points, and examples, surfacing in this regard. It was felt that “harmonization” between the federal and provincial levels around innovation projects and “awareness” could be strengthened (I51). However, it need be noted that several comments indicated that in smaller provinces where federal and provincial officials were located in the same environs the ability to work across levels of governments was more robust. So too could program “design” as constructed around larger parts of the country and particularly metropolises be more accommodating of regional difference. Referencing in particular programs such as the Superclusters, one participant noted:

I don’t think you can design something in Ottawa ... and hope it works in [name of a smaller city]. So it’s tough for, I’ll call it, remote provinces with remote communities to participate in those types of programs and maybe it’s – ok we’re going to design this Supercluster program but we’re also going to design kind of a rural, regional program to support innovation (I10).³⁶

Also highlighted, although specifically articulated within the context of a positive perspective on overarching policy goals, was the need to sharpen financial responsiveness for those undertaking R&D initiatives – namely:

Il y a peut-être à mon avis la façon dont les visions sont faites sont bonnes et elles sont assez larges pour accueillir l’innovation, mais la réactivité financière n’est pas bonne (I46).

³⁶ The city name has been removed to preserve confidentiality.

Further, projects even when policy was clearly stated and aimed at enabling industry to leverage federal “in-house science” (I3) could be sidelined by bureaucratic impediments – a tendency not just noted in the case of federal administration but with respect to tripartite partnerships involving industry could extend to academe as well.

Beyond such specific examples, however, the issue of “metrics” particularly stood as an area that could be strengthened. Just under half – 43 per cent -- of participants raising the implementation issue noted the need for a “scoreboard” on project performance. Nor was this seen as a type of one-off. As one interviewee aptly put it, government should experiment with innovation and “try[ing] things out:”

but then be very realistic about what’s working and what’s not working – collect the metrics; apply the metrics and things that work ramp them up and things that don’t work ramp them down which is something that ... governments generally are not very good at (I36).

And even for those who answered yes to the consistency question and where “the policies have been quite clear,” such metrics were deemed to be valuable in “measuring themselves against their mandate” (I50).

Finally (and on a related note), as for the categories that undergirded the implementation response, these by no means coalesced just around negative or qualified negative responses: in fact 43 per cent of the respondents raising the issue fell into the yes or qualified yes categories when responding to question three. Rather this dimension was noted as a consideration which could strengthen the policy cycle, providing for a more targeted approach and winnowing out gaps and poor performing areas as they emerged. It was not however intended to lend itself to more bureaucracy or keeping R&D projects on such a tight rope that space for experimentation could not be preserved.

Discussant Themes: Political Cycles

Also identified as a challenge by 22 per cent of respondents was the short-term nature of the electoral cycle and as the “180 degrees” (I33) turn in innovation priorities and programming which this could bring. To be sure, for participants the political process and the ideological construction of “political platforms” would necessarily entail change and definitively was seen as a necessary component of the democratic process. That, however, did not mitigate the obstacles posed for industry, for academe and for government researchers as well. Particularly illustrative was the “huge back and forth” (I51) between basic research and applied as this played out over different administration from Chrétien, to Harper, to Trudeau, making the longer term endeavours of biotechnology and biopharmaceutical R&D particularly challenging. It was recommended that policies in this domain simply “should be equally weighted that applied research gets 50 per cent of the funding and basic research – fundamental research should get 50 per cent” (I51), avoiding the undulations in approach. So too, did the straitened “time scales” of four-year election cycles impede research, with one interviewee noting “it’s hard to actually achieve anything because then you still haven’t completed the research you started when that policy was first put in place” (I23). Moreover, as for industry, faced with the “massive amount of changes” that transpired in innovation policy particularly again between the Harper and Trudeau eras, it was enough to engender substantial ennui:

You go from a Conservative government to a Liberal government. The policies change and they can change rapidly and drastically and that’s a big challenge and this is why in my view why very often you have industry putting their hands up and saying what’s the point – right? (I33).

Such insights however were not just grounded in a review of the impediments. For many, these circumstances need to be reckoned with, be it through articulating the overarching and deeper priorities that a “small country” should have on the global stage or by recognizing the

value of other comparative experiences such as Israel where a “long term vision ... strategy fairly consistent and independent of party” (I34) prevailed. In either case, approaches needed to be constructed that could balance off the change induced by political cycles with the longer-term needs and stability required for both breakthrough research and successful commercialization.

Discussant Themes: The Case for “Agility”

In contrast with these perspectives, however, equally of interest a smaller contingent of respondents – 14 per cent – challenged the very assumptions of consistency and stability implied by question three. For these participants, innovation policy would evolve and shift as circumstances and politics demanded and innovators themselves needed to be “agile” (I28, I33) and nimble accordingly. In fact a trajectory of consistency could work to the detriment of success. It could summarily “shut ... out” (I40) certain regions of the country (“because of the huge dominance of Ontario and Quebec in ... our industrial equation” (I40)) and engrain priorities that were ill-considered or ill-fitted to the issues at hand. As one interviewee put it:

I mean if you’re consistently wrong it’s not very good. The real – the real issue is less about does each government that comes in take a different tack and more about does each government that comes in or each new Minister that comes in focus on the right things (I19).

Indeed, the very notion of “remaining steadfast” in policy pursuits could be seen as a “very reckless statement” (I28). The upshot was that a kind of dual track approach needed to be maintained – with of course funding for priorities but also availability of “non-targeted” (I5) resourcing as new issues emerged, COVID being the prime example. Contingency efforts then needed to be safeguarded – with the accompanying recognition of being able to “plan for [the] unplanned” (I24).

Discussant Themes: Specific Policy Domains

Two specific policy domains also emerged during these conversations. The issue of natural resource legacy industries and their particularly treatment in the context of innovation policy was particularly referenced by 10 per cent of the interviewees – and overall comments did not have a very positive tone. There were concerns around inconsistencies between federal commitments to climate change, as for instance with the signing of the Paris Accord and yet a reluctance to acknowledge the innovation that carbon-reducing technologies in the oil and gas sector were bringing to the table. Or there was reluctance by government to engage with industry on these issues and the technology “roadmaps” that were being forged. Moreover, these concerns at times – and the policy shifts on such issues that could frequently occur – were not confined to federal experiences but could extend to provincial jurisdictions as well. And for some it seemed that it would simply be better to address these concerns front and centre and if the “future” did not include these “legacy resource industries,” then government should just articulate that – they should just “come out and say it” (I28).

The SR&ED tax credit also surfaced – again as a lesser theme -- in 12 per cent of the those responding to question three. And here the comments were evenly split, with half articulating the benefits and consistency industry drew from this tax credit and with half raising the unpredictability of changes in the credit over the years, particularly when businesses had already built it into their planning cycles. What was striking was how these comments resonated with the streamlining and predictability concerns that Jenkins had raised around the SR&ED over a decade earlier.

Interviews: An Overview

If this section on interview findings opened with a discussion of the negative responses to question around consistency in federal innovation priority-setting, it is the intent to close with some reflections on the 26 per cent of responded who responded to this issue in an affirmative manner. And in that regard – not surprisingly – the usual stalwart nature of federal endowments to Higher Education R&D surfaced strongly. As one respondent put it, “you know colleges and universities for instance have lots of opportunity to access R&D money ... in collaboration with industry ... (I29).” So too were the historical origins of these efforts illuminated, with participants noting the impetus towards funding of “university research” since the Chrétien and the “late nineties” (I4, I43 and similarly highlighting that innovation policy itself had benefited from a “pretty consistent and expansive commitment” (I4) from that era onwards. On an institutional front, ISED was also singled out as being “very clear” about their “mandates,” as well as communicating their “focus areas” and following up with the complementary programming (I50). Finally, in some instances, the Superclusters were referenced as moving in the “right direction” although the outcomes of those efforts were still not apparent (I27) – a perspective that also foreshadows the discussions to follow in Chapter Six.

That duly noted, it is worth reiterating from a methodological standpoint that the thought leader interviews were undertaken in this research as an additional line of empirical validation. The findings were to be used as a means of triangulating with policy and budget documents and statistical indicators, supplementing the traditional forms of historical inquiry with in-depth and personal perspectives. Towards that end, in fact what these interviews reveal – much more sharply than any assessment of Throne Speeches, strategy statements or annual performance reports can relay – are certain vulnerabilities in federal policy over the decades. Specifically,

what they portray is a highly pronounced tendency to change, at times “drastic” and with quite disquieting implications for the longer term endeavours and time lags inherent to research and development, as well for business planning and investment. And while the need for agility and capacity for adaptation was also referenced by the interviewees, as well as the realpolitik of electoral cycles, on this critical question of durability in priority-setting, federal innovation policy can be deemed to fall short. To be sure, there has been the stalwart exception around the longer term commitments and funding for higher education R&D -- and particularly so for fundamental science. But there has been nothing akin to the mission of a “moonshot” that has characterized American innovation success. Nor has there been the attachment to more enduring priorities found in other successful comparative experiences such as that of Israel where innovation objectives have rested on more “independent” footing, somewhat apart from the fluidity of politics.

Conclusion

In the end, then – and taking a holistic outlook on the various lines of evidence -- there are no simplistic conclusions that can be drawn from an assessment of two decades of innovation policy. Rather it throws into relief two distinctly different narratives that emerge – and abundantly illuminates the significant challenges around consistency on the policy, and reform, fronts. On the one hand, what is apparent is that there has been a gradual strengthening, in particular of the ISED portfolio, and the assembling of the agencies, programs and funding needed to move the innovation agenda forward. From the more institutionally diffuse efforts of the early Liberal administration, to the more spartan and focused initiatives of the Conservative period revolving around the Industry department, to the more recent approach assembling a broad range of institutional machinery under ISED auspices, the apparatus for developing and

delivering on innovation policy has continued to evolve – and harden. Akin to Pierson’s observations about the import of resisting “snapshot” (Pierson 2004, 104) perspectives of institutions and seeing the longer arc of “slow-moving processes” (*Ibid.*, 141) this evolution does speak to strengthening of state, and specifically departmental, means and capacity over the course of two decades.

Undoubtedly the ongoing counsel provided by the Advisory Council on Economic Growth, the Jenkins commission and studies by the CCA profoundly informed perspectives on governance over the course of these years. Focussing on the labyrinth of complexity that characterized innovation programming, as has been earlier seen, these studies had called for radical changes in how government formulated and delivered innovation support to business and academe. Moreover, industry be it through Economic Strategy Tables or larger National Innovation consultations reiterated these themes. In any case, the concerns around governance clearly resonated, culminating in a more strengthened -- and streamlined -- institutional coherence and machinery.

On the other hand, with respect to priorities, the picture that emerges is one of periods of significant rupture, with intermittent spikes of activity -- frequently resetting priorities anew. Over the course of these decades priorities were left to undulate more freely, each round of new administration oftentimes recasting science, technology and innovation in their own image or at least sculpting out large components of change. To be sure there were some key exceptions. Particularly of note, a large part of the Harper administration between 2007 and 2014 was characterized by an unusual restraint in priority-setting as well as attention to both Canada’s areas of expertise and processes for benchmarking progress. Moreover, in terms of specific domains throughout these two decades, clean energy and energy R&D, even as it rolled up under

clean tech and “resources for the future” has appeared as a relative constant, perhaps not surprisingly given the weight of this resource endowment within the Canadian economy. So too have health and bio-sciences dominated throughout the 2000-2020 period; aerospace and auto also figure relatively consistently at least at the level of strategic investment funding (be it through Technology Partnerships Canada or the Strategic Aerospace and Defence Initiative or the Strategic Investment Fund) and as they roll in under advanced or “next gen” manufacturing.

Despite such exceptions, however, there have been significant discontinuities. Thus do advanced engineering, advanced materials and nanotechnology all appear in the early part of the 2000s and then more recently seemingly recede from view. Even the focus on ICT disappears after the Harper administration and while, arguably this can be seen as a component of digital industries, the latter is intended to have much broader reach – turning as it does on “all industries, from manufacturing to agriculture to finance” (Finance Canada, 2017, 95). Or priorities appear and then reappear after many years, raising the question of consistency on the R&D front – the case of ocean technologies (2004 and then 2017) as well as space³⁷ being cases in point. That over the course of two decades, fully *twenty-one* (see Annex A - 4) priorities were articulated in Throne Speeches or key innovation Plans or Strategies only highlights this further. What is more, at least both within the context of the first and third innovation eras, these multiple priorities have been overlaid with extremely daunting and numerous “targets” that were supposedly to function as beacons for reaching innovation goals.

To be sure, the second innovation era does stand out as one more restrained in priority-setting and giving due consideration to the country’s then existing S&T strengths. So too do

³⁷ While space technology does not appear as one of the key priorities referenced in Budget 2017, it does appear as a significant area for investment (\$80.9 million), particularly enabling Canada to collaborate on NASA’s MARS mission – this after many years of relative dormancy on the space technology front (Finance Canada 2017, 90). So too has it been referenced as a possible area for Economic Strategy Tables focus.

macroeconomic concerns deemed as fundamental to innovation and growth – taxation regimes and the level of debt and deficit – figure prominently over both the early Liberal and Conservative administrations. Such continuities or strengths aside, however, all told the Canadian example differs sharply from the American case exemplified in the Developmental Network State literature. In the latter, operating under the cloak of national security, agencies such as DARPA were able to carve out an R&D agenda around communications technologies essentially from the Cold War onwards. Whether it was the development of mainframe computers or semiconductors or the silicon chip and the challenges of maintaining the increase in capacity predicated on Moore’s law – DARPA tenaciously tracked these priorities and nurtured breakthrough developments over the course of almost three-quarters of a century. In the Canadian case over a much shorter time span the issue of policy durability and priority-setting has seen much more contested terrain.

So too has this discontinuity resonated in the thought-leader interviews, with a majority of respondents highlighting the need for strategic focus and mission that could propel federal innovation policy forward. Moreover, there was a concomitant need to pursue such objectives with political will and “resolve,” gaining some degree of distance from the inevitable cycle of policy “fingerprints” and programmatic endeavours ushered in by new government. Present in these discussions was the exception of HERD funding of course. However, there was a pronounced view that Canada’s innovation capacity, commercialization potential and international stature had not been well served over the longer term.

All said, then, in the Canadian case, policy durability and coherence have been essentially vested with a dual nature, on the one front with respect to priority-setting proving to be a much more fleeting endeavour and on another, in terms of administrative capacity, revealing a more

enduring nature. Certainly, it does not fit the DNS framework in any paradigmatic way. And, at least in the Canadian case, it raises sobering questions around the significance of policy durability over larger swaths of time for innovation success. Faced with this issue, and faced with the schism on the durability question, it is particularly important to pursue the other dimensions of the DNS thesis and whether resourcing, brokering and capitalization can create complementary pillars that might compensate for the shallower nature of the durability component.

Annex A – 4: Government Priorities

Table 1 Identified R&D Priorities in Throne Speeches and Science, Technology and Innovation Frameworks or Strategies

1) Advanced Engineering	SFT 1999
2) Advanced Materials	SFT 2004b
3) Advanced Manufacturing/ Next Generation Manufacturing Supercluster	EST 2018b; IC 2014a; ISSED 2019; Fin 2017; SFT 2013
4) *Aerospace	IC, 2007b; SFT 2013
5) Agriculture, Agri-food/ Protein Industries Supercluster	EST 2018c; Fin 2017; IC 2014a; ISSED 2019; SFT 1999, 2004a, 2008; 2013
6) *Automotive	SFT 2013
7) Biotechnology	SFT 2002, 2004a, 2004b
i. Genomics	SFT 1999
ii. New Life Forms	SFT 2002
8) Clean Technology	SFT 2015; Fin 2017; ISSED 2019; EST 2018d
9) Digital Industries/Digital Technology Supercluster	EST 2018e; Fin 2017; ISSED 2019
10) Environment/Environmental Science and Technologies	IC 2007b; IC 2014a; SFT 2001
i. Environmental Science Research	SFT 1999
ii. Environmental Technologies	SFT 1999, 2004b
11) Energy R&D/Clean Energy Technologies/ Clean Resources/Resources of the Future	EST 2018g; Fin 2017; IC 2007b; IC 2014; ISSED 2019; SFT 2002, 2004b; 2008; 2010; 2011
i. Climate Change	SFT 1999
ii. Green Technologies	SFT 2004a
12) Forestry	SFT 2008, 2010, 2013

13) Health/Health Sciences/ Health and Life Sciences Health and Bio-sciences	EST 2018g; Fin 2017; IC 2007b; IC 2014a; ISED 2019; SFT 2001, 2002, 2004b
i. Health Research	SFT 2004b
ii. Health Technologies	SFT 2004a
14) Information & Communications Technologies	IC 2007b; IC 2014a; SFT 2004a, 2004b
15) High Arctic Research	SFT 2007, 2010
16) Nanotechnology	SFT 2004
17) Natural Resources/Natural Resource Management	IC 2007b; IC 2014a; SFT 1999, 2001
i. Natural Resource Advanced Technologies	SFT 2004a
ii. Natural Resources and Energy	IC 2007b; IC 2014a
iii. Mining	SFT 2008; 2013
18) Oceans Research/Ocean Technology Ocean Supercluster	SFT 2001; 2004b; ISED 2019;
19) SCALE AI Supercluster	ISED 2019
20) Space R&D /Space Technology	IC 2007b; Fin 2017; SFT 2010, 2013
21) Water Quality	SFT 2001

* SFT 2008 specifically references the automotive and aerospace sectors but in the context of providing “further support” (*Ibid.*, 7) during a period of recession. As there is no specific reference to innovation or R&D in this context, this SFT has not been included in these cases.

Chapter 5

Targeted Resourcing: Budgets and Innovation

Introduction

As previously laid out in the theoretical chapter, one of the central elements of the DNS framework is the use by the state of “targeted resourcing” (Block 2008, 172) The focus in resourcing on critical “technological challenges” (*Ibid.*, 172, 175 and the twinning with rigorous objectives *and* benchmarks are essential in the DNS framework for innovation. Indeed, the process is sublimated to a strict regime of tight timelines, clear benchmarks, competitiveness and an early proclivity to withdraw funding when success does not emerge. Epitomized in the Defence Advanced Research Program Agency and the Small Business Innovation Research Program, these are the foundations on which “targeted resourcing”¹ rests. And while Mazzucato and Semieniuk (2017) do reference the extensive historical funding of the National Institutes of Health and nanotechnology more in the context of mission-oriented ventures than strictly resourcing, the issue and import of the public purse directed at clear goals remains.

Thus, this chapter directly addresses the second research domain in the dissertation -- namely, is federal priority-setting accompanied by “targeted resourcing” focused on priorities and Science and Technology areas that show the potential for success? Towards that end, the chapter undertakes several cuts into the issue of “targeted” funding of innovation in the Canadian context. Admittedly the lens is broadened somewhat from the original framework’s laser focus on programmatic initiatives. Nevertheless, it is undertaken with the intent to pursue this issue

¹ As has been earlier noted, the term is employed by Block (2008).

from various angles and provide a rich portrait of resourcing in the Canadian case – and particularly in the context of federal public policy and budgeting.

Firstly, an aggregate rollup is presented of the resources dedicated to R&D in Canada – specifically in terms of OECD data on Government Budget Allocations for R&D or GBARD – as well Stats Can numbers for federal Science and Technology expenditures. Secondly the issue of targeted funding is tackled head on via the balance between “indirect” and “direct” government R&D expenditures, including subsequent federal efforts taken to recalibrate on this front. Thirdly (and complementing the political priorities highlighted in Chapter Four) the budgetary priorities that dominated in successive political regimes are illuminated, as is the patterning they depict. Fourth it is the intent to take a deeper dive on the nature of directed expenditures and the extent to which this aligns with upstream science activities or downstream commercialization efforts. And while the research here may not be equipped with all the necessary data on this front, it is believed it is sufficient to draw out the main lines of evidence and wed that back to the undulations seen in priorities by successive (Liberal, Tory, Liberal) administrations. Fifth, in an effort to provide qualitative insight and nuance on this issue, the findings from the 54 thought leader interviews are reviewed.

Thus, the chapter examines each of these areas in turn and concludes with reflections not only on the extent to which Canada and federal policy fit the DNS framework but the strengths and vulnerabilities that are perceived. Further it makes an effort to highlight the anomalies that, to be sure, make the Canadian case distinct but also contribute to persistent challenges which the country has had with innovation.

Aggregate Spending on R&D

With respect to aggregate resourcing as measured by Government Budget Allocations for R&D – GBARD – before reviewing the data, there are several dimensions that need to be clarified. Most critically, this measure is not the same as the intramural government expenditures on R&D captured by GOVERD. Rather, it is of much broader scope, encompassing “all spending allocations met from sources of government revenue foreseen within the budget,” including “taxation” (OECD 15, 323). Thus, budgetary allocations dedicated to business, higher education and private non-profits as well as “government-financed” R&D all come within its compass (*Ibid.*, 325).² And theoretically at least (and assuming deadline compliance by reporting countries) it does measure “final” budget allocations (*Ibid.*, 331) such as in the Canadian case supplementary appropriations.

Admittedly, however, this measure lacks precision in zeroing in on just federal investments – at least from a definitional standpoint. The OECD *Frascati Manual* indicates GBARD includes not only the “central government” but also subnational units, although this is very much country dependent, and particularly so if the data has not been collected by the time of submission (OECD 2015, 322-323). That said, however, GBARD covers a broad swath of categories from “defence,” “economic,” “health and environment,” “education and society,” to “non-oriented research” and “general university funds” – (OECD https://www.oecd.org/sti/inno/MSTI_documentation_e.pdf). Further, it provides a comparative reading, especially in terms of annual growth rates on Canada’s performance.

Certainly, what the GBARD numbers demonstrate (Figure 1 based on national currency)³ is that Canada has had a consistent pattern of significant investments with the country logging in

² See generally the discussion in the OECD *Frascati Manual* (2015, 321-342).

³ Unless otherwise specified, Figures references in this chapter are located in Annex A - 5.

at a grand total of CAD \$160 billion for the years reported between 2000 to 2017. Moreover, what is especially interesting is how the annual growth successively mounts, peaking at the height of the Great Recession with increases over the base year of 80 per cent and 84 per cent in 2009 and 2010 respectively and, despite a moderate slowdown in the years following, then cresting at 96 per cent in the herald budget of 2017 (Figure 2).

Even more intriguing when the lens moves to GBARD in constant US 2015 dollars (Figure 3), these trends while more muted still generally hold, with successive increases up to 2009 (at 48 per cent) and still comparable (at 47 per cent) the year following (Figure 4). In this instance, numbers again do drop off and, in fact, when controlled for national currency the impact of the 2017 budget is also more moderate, logging in well below (at 41 per cent) the increase (of 96 per cent) seen in Figure 2. That noted, however, overall Canada performs more strongly than the top five countries in this category (the latter including the US, Japan, Germany, France and Korea – with certainly four of these five being innovation powerhouses) and after 2010 consistently outpacing the US. In fact, at two discrete points in this time series – 2013 and 2015 -- Canada doubles or almost doubles the American growth (Figure 4). In all, then, it cannot be said that Canada, or the federal government, has scrimped on injecting resourcing into R&D and indeed the growth rate has kept pace with comparator nations, or has outpaced them at times.

So too do federal S&T actual expenditures for the period from 1999-2000 to 2019-2020 show similar patterns. While labelled Science and Technology, as can be seen from Figure 5, it contains both investments in Research and Development as well as Related Science Activities. It should be noted that years 2018-2019 and 2019-2020 in Figure 5 are based on preliminary estimates and intentions. As seen in Figure 6 what is very much evident is a broadly similar pattern to GBARD in national currency (Figure 2) with progressive percentage increases over the

base year similarly cresting during the recession (at 86 per cent both for 2009-10 and 2010-11), with growth then moderately decelerating until 2016-2017. 2017-2018 also shows a similarly high percentage growth over the base year, although slightly lower than GBARD. Interestingly, when the R&D component is separated out growth is amplified from 2019-2010 onward, logging in at 99 per cent for 2017 and continuing in this general realm. Figure 7 overlays the two indicators to illuminate the trend lines. Despite all the caveats referenced in Figure 7 -- what this graph demonstrates are broadly similar patterns -- but with amplified tendencies induced by the *Economic Action Plan* through the recession, downward trends as deficit-tightening occurs and then steeper movement upward with the Trudeau administration.

Thus, this aggregate data is significant on several counts. It suggests the investments registered in GBARD are not unduly inflated by the provincial and territorial components and both offer a valuable and comparable perspective on aggregate investments in R&D. And while GBARD measures budgetary years as opposed to Statistics Canada data measuring fiscal periods, in fact the average growth over the base year for GBARD (in national currency) comes in similarly as well -- 58 per cent for GBARD and 55 per cent for Federal Expenditures on S&T (as calculated until 2016-2017). Even the total amounts for the two measures are not radically dissimilar with GBARD (national currency) at \$160 billion and Total Federal S&T Expenditures registering (until 2016-2017) at \$174 billion.⁴ If Canada is consistently challenged by the innovation gap, it would not appear to be catalyzed by a lack of federal funding or major jolts associated with economic cycling.

⁴ This number rises to \$211 billion if the preliminary estimates for 2018-19 and 2019-20 are included (Figure 5).

Indirect Federal Expenditures on R&D

The issue of indirect versus direct government support to R&D is not one that has seemingly drawn the attention of DNS contributors, presumably because the preponderance of support in the American case has traditionally been directed at programmatic endeavours⁵ or Intellectual Property initiatives that could catalyze innovation. It has not been seized with the less discriminating or at least less targeted forms of government support in the way of R&D taxation. In contrast, however, the issue has been one of relatively longstanding interest and substantive concern in the Canadian context, at least through a major portion of the years under consideration in this research.

Certainly, the issue first caught the OECD's attention in their 2006 "country survey" of Canada, wherein the organization noted that Canada was "one of the most generous" nations "by OECD standards" (OECD 2006, 13) in their dependence on R&D taxation incentives of stimulating innovation. Moreover, while the OECD was not prepared to weigh in on the contrasting bodies of evidence as to whether fiscal R&D credits were actually effective in achieving their objectives, they were prepared to opine on the design of the Canadian taxation instruments, specifically the federal Scientific Research and Experimental Development Investment Tax Credit. Arguing that the SR&ED manifested a proclivity – indeed "bias" towards small firms, it was recommended that the credit be resculpted to focus on "new firms,"⁶ although the survey did add the caveat of the need for further empirical study (OECD 2006, 87-89).

⁵ See the discussion below and the STIC data.

⁶ The OECD also suggested that the reliance of the credit on R&D expenditures was also a less discerning way of getting at improvements and reduce costs (*Ibid.*, 89)

By 2008, the issue was joined by the Science, Technology and Innovation Council (STIC 2009),⁷ they in turn noting two critical points. For one thing, Canada's government support for R&D was in direct contrast to the American experience, with Canada providing 90 per cent of that support in "indirect" measures and the US in fact structuring 80 per cent of their funding into direct forms of incentivization. For another, as of 2005, Canada ranked first among the 13 OECD nations (with accessible data on this issue) in terms of overall government largesse for R&D (as a percentage of GDP), even edging out our American counterpart – this all the while business investment languished and innovation challenges remained (*Ibid.*, 6-7 and 21).⁸ And while STIC did not submit any recommendations on this issue, they did pointedly note that direct government funding of R&D was a hallmark of successful countries in the innovation domain – i.e. such as "Finland, the U.S. and Korea" (*Ibid.*, 6-7).

Moreover, by 2011 the Jenkins Report (2011) had weighed in on the matter, casting a much more discerning eye on the imbalance evidenced in direct and indirect federal funding of R&D and the linkage to the rather lopsided nature of federal government programming. The critique was both expansive in scope and detailed in terms of the changes needed. As the Jenkins Panel highlighted, fully 70 per cent of all federal programming planned for in 2010-11 was singularly accounted for by SR&ED: this among an array of sixty federal programs that were in the planned expenditures.⁹ The Panel raised several concerns about the diffuse nature of this instrument, including: the blanket manner in which it was spread across all sectors and the disincentives it harboured for growing profitable firms, mainly due to the 35 percent fully

⁷ While each of the STIC reports for 2008, 2010, 2012 and 2014 – and advice being offered to the government -- were focused on the "State of the Nation" for those respective years, formal publication dates were a year later.

⁸ STIC makes reference to OECD data but does not provide the reference. A review of OECD documentation by the author shows that the *OECD Science, Technology and Industry Outlook* (2008, 26-28) provides the relevant data.

⁹ Jenkins (2011), 3-3 – 3-4). For their general analysis and recommendations on tax instruments and SR&ED see 3-1 – 3-13 and especially 6-10 – 6-14.

refundable tax credit that was dependent on a \$1 million expenditure threshold rather than a firm's taxable income. Even access to the instrument was not timely or "predictable" for firms. Nor was SR&ED "targeted" either on a sectoral basis or on its ability to support start-up firms with high growth potential (what the OECD had called "gazelles"). For start-ups this issue was particularly acute given the more shallow seed and angel capital available in Canada. Together with the high costs of compliance by smaller firms for accessing the credit, that being approximately three times higher than for larger firms,¹⁰ the unpredictability of the tax regime in actually acquiring the credit, and the time lags in CRA decision-making, these factors led the Panel to recommend that the system needed to be substantially revamped. Specifically, there needed to be a tighter focus on high-growth, R&D-intensive firms, with tax breaks that could reward profitability of Canadian-controlled Private Corporations (CCCP)¹¹ and a more rigorous accountability for SR&ED credits and the ensuing public benefits. Most importantly, the savings on a more streamlined and predictable SR&ED were to be directed towards "direct" programming efforts focused on high-growth SMEs which could facilitate financing, commercialization efforts and the ability of these firms to develop into anchor firms.¹²

For its part, the government of the day – the administration under Prime Minister Harper – began to respond to the concerns levelled. Budget 2013 evidenced a retooling of the SR&ED – with proposals to streamline the credit, broaden access, strengthen "predictability" for investment decisions and enhance its "accountability" (Finance Canada 2013, 201-202). Further

¹⁰ *Ibid.*, 6-11. The Panel found that costs were 14 per cent for small firms as opposed to 5 per cent for large, largely due to the complexity of calculating non-labour costs (overhead, capital) and for which the Jenkins Report recommended change, specifically streamlining to labour costs only.

¹¹ Basically the Jenkins Report recommended that the refundable portion for CCPCs be reduced over time so a "portion of the benefit would be claimed only if the company is profitable". The new basis for calculating access to the credit based on labour costs however was to be extended to larger firms (2011, 6-10).

¹² See especially *Ibid.*, their Recommendation 2, 6-10 to 6-14.

as will be seen in the following section, from 2010 onwards the Harper administration began to inject more direct funding into the innovation ecosystem – primarily focused on commercialization initiatives. Nevertheless, this was no wholesale revamp – the emphasis on small firms still remained and even the recalibration towards direct funding was still relatively modest at best. By 2014 STIC, although acknowledging some of the recent “effort[s],” reiterated their concerns about the dependence on indirect instruments and was now openly calling for a rebalancing of government R&D support towards much more “high-risk, high reward” R&D ventures (STIC 2015, 16-17 and 42).

This history is amply borne out in Figure 8 which provides a survey of OECD data on indirect government support through R&D tax incentives as a percentage of BERD or business enterprise R&D over the 2000-2017 period. As is immediately evident, Canada has followed only Hungary and Colombia in terms of appearing at the top of this for indirect support and the Canadian performance pales in comparison to the extremely lean annual percentages registered for the US, as well as the yearly OECD totals. At Canada’s peak for indirect support in 2012, the reliance on this instrument was almost six times greater than that of our American counterparts. Certainly, it is in stark contrast as well to Germany which does not employ indirect taxation in its fiscal arsenal.¹³ As for the recalibration of dependence on indirect taxation and the SR&ED in particular, Figure 8 evidences some turnaround starting in 2013, and especially from 2014 onwards in the 14 per cent and 15 per cent range. Nevertheless, this has not been a dramatic reform and the change from 2014 onwards actually brings the country 2.4 percentage points lower in 2018 than at the beginning of the time series in 2000. Moreover, while percentages reflect one dimension of this issue, a review of the actual Canadian dollars annually invested in

¹³ The table for indirect government support through R&D tax incentives as a percentage of BERD indicates “0” throughout the years in question.

indirect taxation comes to no small amount – all told \$53.849 billion

([https://stats.oecd.org/Index.aspx?DataSetCode=MSTI_PUB&_ga=2.200379628.330107463.](https://stats.oecd.org/Index.aspx?DataSetCode=MSTI_PUB&_ga=2.200379628.330107463.1621010277-207428999.1594908456)

1621010277-207428999.1594908456)¹⁴ over the years in question. As for any potential pivot to high growth “new firms” a report by the CCA in 2018 found that there had been some slight recalibration towards smaller companies but here too the concern with the preponderance of indirect tax incentives remained (CCA 2018, 154).

All told, then, if “targeted resourcing” is a necessary or even sufficient condition for catalyzing innovation, the portrait painted by this measure of indirect support indicates that Canada has essentially languished on this front. Rather there has been a relatively “sticky” trajectory around dependence on this fiscal instrumentation. What is more, efforts to turn the ship around – and particularly target the “unicorn” type firms with high-growth potential or even recalibrate to more directed programming – have had only modest results. Certainly, this factor has not registered changes in the Canadian innovation ecosystem or visibly changed the more general innovation indicators for the 2000s reviewed in Chapter Three.

Twenty Years: Patterns and Priorities

The issue of competing budgetary priorities appearing throughout the decades of the twenty-first century must be subtly approached. This is not a narrative of deep disjunctures affecting innovation policy initiatives and the attendant budgetary expenditures for which those policies claimed. Rather it is a narrative of less-than-stellar consistency – one where the shape of innovation priorities and investments is contoured and policy durability is more subtly compromised. That noted, it is possible to discern three distinct periods in these years – that of

¹⁴ Note this data was accessed on the OECD website on 14 May 2021. The MSTI variable was “Indirect government support through R&D tax incentives – Totals and Subnational.” The measure was in national currency – millions of Canadian dollars.

the Chrétien/Martin years with a special focus on research and higher education as the path to innovation; that of the Harper era with an industry-led focus and an effort to reshape institutional mandates and resourcing towards that goal. Finally, there has been the more bifurcated agenda pursued by the Trudeau administration, straddling science and commercialization in an effort to find the sweet spot for innovation – and indeed bifurcated much before the shocks of COVID-19 and the priorities that have arisen in its wake. The upshot however has been a more disjointed budgetary history – one that resonates as well with the challenges around policy priorities and political agendas seen in Chapter Four.

Investing in World Class Research

As the Chrétien government emerged successfully from deficits by 1997-98 and saw a diminishing debt-to-GDP ratio, the focus shifted. Now in its sights both by the PM and the Finance Minister was not only the lagging productivity gap with the United States but the need to embrace the “knowledge economy” of a new globalized world. By Budget 1999,¹⁵ it was clear that the government was intent on pulling Canada into the new century. Premised on a policy framework keyed not only to macroeconomic stability but also investment in “knowledge and innovation” (Finance Canada 1999, 107-108), the government undertook a series of bold and targeted moves – largely with the intent of massively refurbishing Canada’s research capabilities and infrastructure. As Budget 2000 succinctly put it, while a government could “provide the right economic, social and regulatory framework” this on its own was not sufficient. Instead a “nation’s potential for innovation [wa]s strongly linked to its research capacity” (Finance Canada 2000, 106) – and the latter was inclusive involving post-secondary institutions, research hospitals as well as government labs and third-party entities. To be sure, the country’s potential needed to

¹⁵ See also the discussion in IC DPR (2000, 1-6).

be linked to entrepreneurship and the “private sector” but what was highly visible throughout the Chrétien and Martin years, both in rhetoric and in dollars, was the import of an aggressive research “excellence” agenda.

Certainly, as early as Budget 1997, the Canada Foundation for Innovation was established with an initial endowment of \$800 million. Intended to “modernize” and create a “world class” Canadian research infrastructure it was followed only two years later with another infusion of funding – topping the endowment up to \$1 billion. Tri-council funding as well as the NRC also benefited from investments in Budget 1999 and the Canadian Space Agency was finally put on a permanent A-base set at \$300 million per year.¹⁶ By 2000, as the federal government remained in the black, investments in research continued to flow – to the sum of \$1.9 billion and covering out the period to 2002-2003.¹⁷ The CFI received another \$900 million. \$900 million was to be dedicated to 2000 Canada Research Chairs creating a “critical mass of world-class researchers.”¹⁸ And a new foundation – Genome Canada – to focus on the genetic codes that could unlock the potential of biotechnology was created with an initial investment of \$160 million. A year later, the government now proclaiming a surplus of \$17.1 billion for fiscal 2000-2001 (Finance Canada 2001 11, 53), undertook more of the same – with substantive increases for the granting councils, NRC (an additional \$110 million for regional innovation) and new funding (of \$200 million) for the “indirect costs” of research funded by federal money.¹⁹ Key strategic technologies such as Artificial Intelligence and nanotechnology also received a

¹⁶ On the specifics of Budget 1999 and the references to the CFI creation, see Finance Canada (1999, 110-114).

¹⁷ On the specifics of Budget 2000, see Finance Canada (2000, especially Table 5.1, 122; also 106-113).

¹⁸ This funding was to flow through the three granting councils.

¹⁹ On the specifics of Budget 2001, see Finance Canada (2001, 115; 121-124). The scaling for the Council funding was not the same, with CIHR receiving a top up of \$75 million to their annual budget, NSERC \$36.5 million and SSHRC \$9.5 million.

boost, with \$25 million to be dedicated to their primary scientific vehicle – the Canadian Institute for Advanced Research.

By 2003 as the Budget tallied the total allocations for “research and innovation” from 1998-1999 out to 2004-05, the government estimated that \$11.073 billion of new money had been or would be expended. And while clearly this did include items such as Industry Canada’s financing instrument of Technology Partnerships Canada, a review of that resourcing indicates \$8.1 billion or 73.2 per cent was specifically devoted to research or research-oriented activities.²⁰ The usual stable of initiatives (CFI, Genome Canada, the councils, NRC, CSA, Canada Research Chairs) continued to be the beneficiaries (Finance Canada 2003, 122-129 and especially Table 5.1) as well now as some newcomers in the form of Northern Science and the Rick Hansen Foundation for spinal cord injuries. To be sure, Budget 2004 did somewhat break with this pattern with \$100 million for commercialization efforts and technology transfer capacity at universities and research hospitals and with an injection of \$270 million for venture capital. As well it targeted stimulating commercialization efforts by federal labs (Finance Canada 2004, 132-139). But by Budget 2005 the research focus remained. Once again indicating that “recognized excellence in science is crucial to ensuring Canada’s strong innovation performance and ongoing competitiveness in the global economy” (Finance Canada 2003, 120) the government maintained the scientific largesse with additional funding of \$810 million to be allocated over the next half-decade out to 2009-10 (Finance Canada 2005, 128 and 133). What is more the standing that Canada had now garnered in terms of Higher Education R&D expenditures (HERD) was not lost on the administration. As the Budget indicated, there was

²⁰ The author has excluded the Atlantic Innovation Fund, Government On-Line, Technology Partnerships Canada and internet “Connectedness” from the research components. See Finance Canada (2003, Table, 5.1, 124).

now pride of place in Canada being within the top five cohort for OECD HERD spending and “rank[ing] first among G-7 nations” (*Ibid.*, 128) on that same indicator.

Moreover, while government budgets – and budget announcements – depict a pattern of research priority-setting, still this does generally speak to intentions. And while not wishing to belabour the point, it is worthwhile to track actual expenditures among the key research initiatives that Budgets throughout these years targeted. As Figure 9 demonstrates on this score as well the findings are reinforced. In fact, eleven categories have been identified (including Northern Science under Polar Knowledge and TRIUMF involving nuclear and particle physics) as the stalwarts essentially for research funding during the period from 1997-1998 to 2005-2006.²¹ These include of course CFI and associated “indirect costs” of research, CIFAR (for AI) Genome Canada, the granting councils and NRC. While total expenditures are not always annually increasing, with peaks being registered in 2001-2002 and 2005-2006 at \$3.77 billion and \$3.72 billion respectively, what is truly remarkable about the graph is the overall portrait of extensive funding during this era. In all, \$26.1 billion was, according to Public Accounts figures, actually expended during these years, constituting a testament to the targeted efforts to catalyze research as a “bridge to the future” and a vector for innovation.

It is of course important to note that there were other efforts through these years, even aside from Budget 2004, that were cast in the vein of technology transfer or commercialization. An exemplar are the “indirect costs” for research which did include a dimension relating to commercialization. So too do the NRC figures embody IRAP initiatives to assist small and medium-sized companies to access expertise and resources and ultimately scale. Still overall it speaks to policy, backed up by dedicated funding, that pushed at the forefront of research

²¹ Northern Science figured in Budget 2003 (Finance Canada 2003, 126) and TRIUMF in Budget 2005 (Finance Canada 2005, 130).

initiatives – targeting post-secondary institutions, research scientists and knowledge workers as well as “world-class” infrastructure -- and that positioned Canada in this domain on a global scale.

“Mobilizing” Commercialization

Though elected in February of 2006, it was in fact by Budget 2007 that the “New Government” of Prime Minister Harper began to put its stamp on R&D and, more broadly, their innovation agenda. True by Budget 2007 (19 March) the “Mobilizing Science and Technology” strategy had not yet been released but the Budget, and its Minister, clearly signalled a definitive change in direction – and in priorities. Specifically,²² there was to be a new emphasis on commercialization and industry “led” initiatives. Building on the Networks of Centres of Excellence forged back in 1989 and focused on working partnerships among business, academe and government, the government introduced the new Centres of Excellence in Commercialization and Research. To be injected with \$350 million, and already leveraging seven key existing networks, the Centres were to be focused on concrete priorities where Canada had the “potential to be a world leader” – namely, in areas such as energy, environmental technologies and health sciences (Finance Canada 2007, 193, 199-200). Further, and although the recipient of a lesser allocation of \$11 million, five new Business-led Centres of Excellence were to be established. With governance attuned to the private sector and a mandate to “truly meet the need of businesses” this initiative was to additionally strengthen not only commercialization but direct engagement and leadership by industry (*Ibid.*, 205).

²² On the “Knowledge Advantage” initiatives introduced at the time and discussed below, see Finance Canada (2007, 192-209 and Table 5.6, 219).

Other initiatives completed the package. Industrial R&D internships were to be launched at a cost of \$4.5 million, thus creating “exposure” to hands on challenges in the private sector. (*Ibid.*, 205). The College and Community Innovation Program (CCIP) was to receive a permanent envelope of \$48 million for ventures between colleges, polytechnics and local firms – again to deal with “real-life market needs and opportunities” (*Ibid.*, 204). Even a federal lab (CANMET) was to be transferred and nested within a Hamiltonian manufacturing “Innovation” centre. Moreover, the three federal granting councils of CIHR, NSERC and SSHRC, were to be recast – a theme that would become even more prominent as the years of the Harper administration continued. The councils would receive an infusion of \$85 million per annum but they were to refocus on a “more strategic approach” – one that could deliver results and “impact” and could enable “global leadership” (*Ibid.*, 202-203).

To be sure, Budget 2007 did build on the stable of usual infrastructure initiatives: more funding for the Canada Foundation of Innovation (\$510 million of which \$350 would flow in the first three years); Genome Canada (\$100 million) and the Canadian Institute for Advanced Research (\$10 million) (*Ibid.*, 200-201 and 203). Moreover, all of these endeavours were cast within the government’s emphasis on macroeconomic stability – low taxes, reduction of net federal debt, as well righting what was termed the “fiscal balance” with provinces and territories, including a transfer of \$800 million for post-secondary education (*Ibid.*, 207). However, the new imprints on “knowledge transfer” and commercialization were clear. If a tally is done of the \$904 million dedicated to “Science and Technology Leadership” initiatives in Budget 2007, fully 41.4 per cent of that budget could be designated as falling under commercialization efforts or industry “needs.”²³ If granting council reorientation is added to the mix, this in fact ups the ante

²³ Author’s calculations. See Table 5.6, Finance Canada (2007, 219). Included in the author’s calculations are Centres of Excellence in Commercialization and Research, transfer of federal labs, tech support for firms and

to 60.2 per cent. Clearly, in marked difference to the focus on science associated with the previous Liberal regime, priorities – and prioritization – were shifting.

Budget 2008 certainly continued these themes – instructing the granting councils to “help accelerate the translation of knowledge into practical applications “– while upping their funding (Finance Canada 2008, 119-120) and in a rather prescient move given what was to come creating an Automotive Innovation Fund with an injection of \$250 million (*Ibid.*, 122-123). A year later, however the government was wrestling with the extensive impacts of the Great Recession and the sectoral craters that created in manufacturing and auto in particular. And, somewhat surprisingly given its fiscal conservative orientation, it turned to traditional Keynesian tools to arrest the economic hemorrhaging – specifically stimulus spending and particularly public works. In all, in 2009 through the government’s *Economic Action Plan* close to \$12 billion was to be invested in almost every type of Canadian infrastructure (Finance Canada 2009, 140-160). Moreover much of this Stimulus funding engaged some sort of matching provisions from the provinces and territories²⁴ and at times the private sector, thus leveraging further injection of funds. And all of this had actually come on the pre-recession heels of Budget 2007 where \$33 billion had been pumped into the system through the *Building Canada Plan* (to be spread out over seven years (*Ibid.*, 142)).

Needless to say Knowledge Infrastructure, consistent with the government’s overall S&T Strategy, figured prominently among these investments. A new \$2 billion Knowledge Infrastructure Program (KIP) was launched to support “repair” and “expan[sion]” at universities

colleges or CCIP, Business-led Networks of Centres of Excellence and Industrial R&D internships. It should be noted that it appears the section on “linking research to business needs” should be \$19 million and not \$18 million (i.e., 3 plus 11 plus 5). However the author has used the numbers designated in the Budget.

²⁴ The Gas Tax Fund was clearly an exception to the matching provision.

and colleges (Finance Canada 2009, 138). \$750 million was provided to the Canada Foundation for Innovation and additional funding was provided for Arctic research, upgrades to federal labs, and Quantum Computing facilities in Waterloo (*Ibid.*, 138-139 and 148-153). In all \$3.137 billion was allocated to knowledge infrastructure – at least for bricks and mortar so to speak.²⁵ If broadband infrastructure and health digitization are included, the figure tallied to \$3.862 billion.

A year later signs of renewal were evident, with Canada pulling more quickly out of the recession than other G7 nations, and the government once again found its footing with its commercialization agenda.²⁶ In fact, 2010 was a banner year with doubled funding for the College and Community Innovation Program, funding to the NRC for “technology clusters” across the country, a new government procurement program to simulate innovation by SME and even a new tone of commercialization with the Canadian Space Agency – to work closely with the private sector on “advanced radar remote sensing satellites.” Even TRIUMF, the internationally respected nuclear and particle physics institute, was to forge partnerships with industry in this particular domain. As for the granting councils, the commercialization theme was sounded again with increased funding and in particular with NSERC receiving \$5 million specifically for academic/industry “collaboration.” In all, \$284 million supported the thrust to commercialization and if the granting councils are included this tallies to \$348 million – 56.8 per cent of the \$613 million innovation budget for that year.²⁷

It is not the intent to detail every innovation and “knowledge transfer” initiative over the period of the Harper administration but a few key areas stand out in the years that followed 2010.

²⁵ See Finance Canada 2009, 138-139. Author’s calculations for sums for this and the succeeding sentence. It should be noted that the total sums listed here are based on the description in *Ibid.*, 138-139 and should be distinguished from *Ibid.*, Table 3.7, 160 where only \$50 million is included for CFI, given the shorter time lines.

²⁶ On the specifics of Budget 2010 noted below see Finance Canada (2010).

²⁷ Author’s calculations. See Finance Canada (2010, Table 3.3.1, 120-121) and the category “Creating Economic Growth and Jobs Through Innovation” which sums to \$613 million.. The \$284 million includes all the line items listed under “Knowledge transfer and commercialization” in Table 3.3.1.

For one thing, there was a concerted effort to propel innovation among small and medium-sized enterprises, primarily through the “cornerstone” of NRC’s Industrial Research Assistance Program (IRAP). In quick succession, \$80 million was devoted to in Budget 2011 to enabling information and communication technologies in SMEs (Finance Canada 2011, 145, 150); an additional \$110 million in Budget 2012 to double IRAP capacity for services to small businesses and help them navigate the plethora of federal funding programs (Finance Canada 2012, 61); and finally in Budget 2013 \$20 million for IRAP to equip SMEs with “credit notes” that would let them buy R&D services from post-secondary institutions and other research organizations (Finance Canada 2013, 199-200). Paralleling this (and in the wake of the Jenkins report) so too was NRC itself to undergo change. With an allocation of \$188 million in funding over 2012-2013 out to 2014-2015) it was to “refocus” on industry challenges and specifically “demand-driven business-oriented research” (Finance Canada 2012, 59).²⁸

On another front, also in the context of Jenkins recommendations, there was to be a retooling of SR&ED – this time not only excising the unwieldy capital expenditures from calculation of eligibility for the tax credit but also streamlining and enhancing stability and “predictability” for investment purposes.²⁹ And while the funding for a battery of scientific endeavours continued – i.e., granting councils (experiencing annual increases from Budget 2011 onward), TRIUMF, space research, the net around commercialization for these activities remained clearly in place.³⁰ Even Genome Canada was to launch an “applied research”

²⁸ The first tranche of funding of \$67 million towards this endeavour was allocated in Budget 2012 (Finance Canada 2012, 68 and 82) and followed in Budget 2013 with \$121 million (Finance Canada 2013, 199 and 210); see also Budget 2015 (Finance Canada 2015, 108-109) on the need for “Business-driven Research and Development” and an additional injection of \$119.2 million.

²⁹ See specifics in Finance Canada (2012, 68-71).

³⁰ On the Councils, see Finance Canada (2011, 154); (2012, 73-74); (2013, 193-194); (2014, 116-117); (2015, 100); on TRIUMF, Finance Canada 2014, 120 on its commercialization efforts and industry collaboration; on the Canadian Space Agency, Finance Canada (2014, 106-108).

competition for health services (Finance Canada 2012, 74). So too did the specific Networks of Centres of Excellence centred on commercialization goals which were launched back in 2007 continue, with the Business-led Centres of Excellence being refurbished with an additional annual \$12 million in Budget 2012 (Finance Canada 2012, 65). Finally, sectoral industries impacted heavily by the recession – auto, aerospace, defence – were targeted for enhanced innovation funding.³¹

All told, by the government's own accounting, by 2014-2015 there had been over \$13 billion invested in Science, Technology and Innovation, in areas of research, infrastructure, "talent" development and deployment and "business innovation" since the administration had come to power in 2006 (Finance Canada 2015, 91). And with respect to the latter of these categories, the business innovation or commercialization initiatives within this (including venture capital and sectoral funding) made up the bulk of the commitments constituting close to half – 44.9 per cent ³² of the \$13 billion. Arguably as well, if the new casting of the councils towards industry needs is included -- at \$2.8 billion of new monies -- the number rises to 66.5 per cent of the full S&T and innovation funding allotment.³³ Indeed, even focussing just on the NRC and other dedicated programming for industry access to and leverage of post-secondary R&D, approximately \$1.72 billion was committed towards such commercialization efforts – i.e., 13.2 per cent of the total. Thus, even aside from the mandate language around the purposes of new funding, in raw aggregate numbers (and the concomitant percentages) the government's commitment to the "mobilizing" knowledge agenda was clear.

³¹ On auto, see Finance Canada 2013, 117 and 2014, 124; on aerospace and defence, Finance Canada (2013, 111-116) and Finance Canada (2014, 125).

³² Percentages here are based on the author's calculations. See the "Business Innovation" category in *Ibid.*, 91.

³³ There needs to be a distinction made here. Programming such as the Commercialization and Business-led Centres of Excellence was delivered via the granting councils. However, the councils also had their more general funding (of \$2.8 billion) as well, although as has been seen this too was given a business thrust.

It is worth noting as well, what is remarkable about this period is the ongoing increases into the innovation agenda even during the recession and emergence afterwards. At its peak in 2009-10 and 2010-2011 federal expenditures on S&T rose by 86 per cent respectively over the base year (Figure 6). Moreover, as Figure 10 portrays, expenditures in key federal investments in this domain increased by close to one billion – specifically \$833 million -- to \$4.6 billion over the 2006-2007 to 2014-2015 period.

In sum, however, what this portrait presents is a very discernible shift in direction. If the Liberal administration had pursued science as a main pathway to innovation, the Conservative regime veered much more distinctly from this trajectory, toward innovation centred on pragmatic industry challenges and “needs.”

Straddling Priorities: Science and Scale-up

In contrast with the Chrétien/Martin years and those of the Harper government, it is in fact hard to decipher a sustained focus or pattern with the most recent Liberal administration. To be sure (and as seen in Chapter Four), the Trudeau government has advanced its Innovation and Skills agenda but the implementation – at least in terms of targeted resourcing – might be best captured as bifurcated. Budgetary commitments, and expenditures, have manoeuvred between fundamental science and commercialization and back again.

Certainly, Budget 2016 set the tone for what was to come. Nested within a broader framework of “growth and prosperity for the middle class” and including lower taxes, “life-long learning” and a more inclusive and equitable society, the government announced it was embarking on a “new vision” (Finance Canada, 2017, 109) for the country. Canada would stand as a beacon – a “centre of global innovation” -- characterized by “entrepreneur[ship],” world-class science, technology and infrastructure, internationally “competitive” firms and an environs

based on “commercialization and growth” (*Ibid.*, 109). To be sure, the Innovation Agenda as it was then called was not yet fully developed, engaged as it would be in national consultations across the country with respect to purpose and priorities but it would soon come. Despite the vision, however, Budget 2016 was a more stalwart affair, largely focused on the usual staples of infrastructure, granting councils and the stable of respected research institutes that housed breakthrough endeavours in recognized areas of Canadian scientific strength.

Specifically, the government would dedicate \$1.75 billion to a new Strategic Infrastructure Investments at Post-Secondary Institutions fund -- one which would exist alongside the CFI – and would be used to refurbish aging research facilities.³⁴ The tri-councils would receive \$190 million and Genome Canada, the Brain Canada Foundation, the Stem Cell Network, the Perimeter Institute for Theoretical Physics and the Canadian Space Agency would all receive additional funding. So too would the Centre for Drug Research and Development which, while receiving funding since its creation in 2007, had been left relatively unattended over the intervening years but which now was highlighted as central to “commercializing” in the domain of pharmaceutical R&D. \$800 million was set aside in the fiscal framework for an innovation “clusters” initiative to come, but for the present there would be the traditional funding for IRAP (with an allocation of \$50 million) and renewal of \$4 million in funding for the Canadian Technology Accelerator Initiative, designed to position Canadian firms with markets abroad. Monies were also set aside for some other commercial endeavours such as in photonics. All told, however, Budget 2016 was quite light on the commercial orientation. In fact of the \$2.6 billion dedicated to both science and “Business Growth and Innovation” in the Budget, almost 87 per cent -- 86.5 -- of this was on the side of “Strengthening Science and Research”³⁵ (Figure 12).

³⁴ On the specifics of Budget 2016 see 109-126; in particular see the funding breakdown in Table 2.2 130-131.

³⁵ Author’s calculations. See Finance Canada (2016, Table 2.2, 130-131); also Methodology Notes in Annex A - 5.

By Budget 2017, however, the government launched its Innovation and Skills Plan. Certainly it included initiatives around industry-based “learning” and digital and STEM skills, as well as a Strategy to pull into Canada the best international “talent.” But, acknowledging the continuing challenges around business investment, one of the key pillars of the Plan was to specifically “bridge the commercialization gap” (Finance Canada 2017, 46) focusing especially on six key areas of advanced manufacturing, agri-food, clean technology, digital technology, health/biosciences and clean resources (*Ibid.*, 77, 79). And key to this in turn would be the Superclusters. To be provided with \$950 million over five years and to serve as “engines of growth,” these entities were to form a “dense” cluster ecosystem, complete with large corporate players or “anchor” firms, small and medium-sized businesses, universities and colleges, “specialized talent,” as well the research infrastructure that would accompany this (*Ibid.*, 79-80). A centrepiece of the Innovation and Skills Plan, the Superclusters were to enable Canadian research to break through the commercialization barrier, enabling firms to scale up and become internationally competitive.

As seen in Chapter Four, a number of other key initiatives complemented the Superclusters. A new Strategic Innovation Fund (SIF) of \$1.26 billion was to be struck.³⁶ To consolidate a welter of sector-specific innovation funds existing in auto, strategic aerospace and defence, and technology demonstration, SIF drew a billion of its funding from existing sources and found \$200 million of new monies in the fiscal framework. Mandated to simplify access to company financing and leverage R&D into recognized Canadian “economic strengths,” SIF was intended to enhance both innovation and growth. So too was there to be a radical streamlining of the numerous innovation programs existing across the federal government, now

³⁶ On SIF and the other initiatives listed below, see Finance Canada (2017, 76- 82, 85-90 and Table 1.3, 110).

to be housed under Innovation Canada in ISED. As well, \$50 million would be injected into a federal procurement effort called Innovation Solutions Canada (ISC). Likened to the American Small Business Innovation Research program, this Canadian entity was to provide a ready market for companies developing and validating new products or services. And while there was funding for third-party research -- i.e., CIFAR, the Stem Cell Network, the Institute for Quantum Computing, the Canadian Space Agency, even Social Innovation -- and while a new Chief Science Advisor would be created, still Budget 2017 was predominantly keyed to entrepreneurship, firm scale-up and generating the sweet spot where commercialization could occur.

Indeed, fully 97 per cent of the items listed in the Budget under “A Nation of Innovators” and “Canada’s Innovation Economy” were geared to stretching the R&D continuum into commercialization and deployment – and positioning businesses for markets and growth³⁷ (Figure 12). In this context it is also worth noting (and not totally unlike Budget 2011 of the Harper administration) even the mandates of scientific endeavours were brushed with a new tone. Stem cells, space, quantum science: these were positioned as capable of “transform[ing] markets” and moving “research into ... commercial products” (*Ibid.*, 90). And while Budget 2017 at times was unnecessarily complex -- particularly with clean tech being identified not only in the six priority areas and in a special Impact Canada Fund but also provided with a separate tranche of \$1.08 billion (*Ibid.*, 96-101, Table 1.3, 111) – nonetheless the broad strokes of Budget 2017’s emphasis on innovation and commercialization were clear. Clearly defined to transcend Canada’s traditional stickiness around the innovation valley of death, targeted resourcing in this agenda was to propel real change.

³⁷ Author’s calculation. See Finance Canada (2017, Table 1.3, 110-111); also Methodology Notes in Annex A - 5.

Nevertheless a year later, the government did a hard pivot. In the wake of the Naylor report and the review of “fundamental science” that had been undertaken, Budget 2018 undertook major investments in the domain of research. Designed to be an “historic” investment addressing gaps in “funding per researcher,” building a more inclusive and forward-looking research environs and enabling world-class “discovery science,” the government allocated almost \$4 billion – specifically \$3.86 billion³⁸ – to Canada’s premier research organizations. Of this fully \$1.41 billion was destined for the granting councils, including provisions for more Canada Research Chairs as well as a funding stream dedicated to “higher-risk” scientific endeavours (Finance Canada 2018, 88-89).³⁹ Another \$1.08 billion was to flow to research infrastructure (including federal labs) and if the new focus on digital infrastructure around “open data” is included that number tallies to \$1.65B.

Even the business focus in Budget 2018 was now relabelled to a “More Client-Focused Federal Partner for Business” although it did contain the usual array of IRAP funding (\$700 million to service firms up to a new \$10 million dollar threshold), regional funding agencies and regulatory streamlining.⁴⁰ And, reflecting the government’s commitment to equity, so too were there funding streams for supporting female leadership and diversity more generally within the business community. In all, then, government resourcing in 2018 reflected a substantial recalibration from the year previous. Fully 60 per cent ⁴¹ of the \$6.435 billion profiled under the Budget’s rubric of “Progress” was now dedicated to the scientific domain (Figure 12).

³⁸ On the specifics of Budget 2018 and the nature and purpose of these investments, see Finance Canada (2018 84-102, especially 87) and for funding totals and breakdowns see Table 2, 122-123.

³⁹ The \$1.41 billion for Councils and the \$1.08 billion noted below for research infrastructure are the author’s calculations based on *Ibid.*, Table 2, 122.

⁴⁰ On these specific items, see *Ibid.* (100-121 and especially the totals Table 2, 122-123). Included as well in the Budget was a new thrust for the NRC on collaboration which is discussed in Chapter Six.

⁴¹ Author’s calculation. See *Ibid.* (Table 2, 122-123); also Methodology Notes in Annex A - 5.

Finally – and briefly -- as for Budget 2019 (the last pre-pandemic effort), it too illustrated the duelling nature of these resource priorities, once again recentring the respective weights for science and industry-focused initiatives. Only this time, the tables were turned again with 29 per cent of the total funding⁴² allocated profiled for a research agenda and the remainder dedicated to innovation largely through sectoral and regional efforts in oil and gas, forestry, tourism and the West (Figure 12). Additionally, there was a broadening of the SR&ED tax credit for small and medium-sized enterprises.

What this rather detailed recounting of the years of the Trudeau administration reveals then is “targeted resourcing” seemingly caught on the twin shoals of science and industry-oriented commercialization. Successive Budgets speak to the ongoing endeavours to find the right formula that could create the sought-after economic growth and global competitive edge for the country. But in contrast with the two earlier regimes respectively building a lasting legacy of research prowess and infrastructure or a commercialization thrust aimed at unlocking potential and propelling the economy through the recession, the agenda of the most recent administration has been more bifurcated. In toto, it has been a more uncertain path, trying to straddle both world class science and globally competitive industry “scale-up.”

As for the larger arc of history herein, as noted at the outset, what the decades of the 2000s illuminate are certainly a less than consistent approach to resourcing. Instead, different administrations have forged their own paths, leading to a more kaleidoscopic edge in terms of policy durability. And on this dimension, it speaks to a DNS framework where longer term

⁴² Author’s calculation. See Finance Canada (2019, 125-126); also Methodology Notes in Annex A - 5.

endurance is not present. There is however a significant exception to this pattern -- and it is to that which we now turn.

Constants -- and Prowess

In sharp counterpoint to the triadic patterning and discontinuities of budgetary priorities throughout these years, there have in fact been certain funding constants, particularly of a research nature. For one thing, and mirroring the more general emphasis on national infrastructure witnessed in our earlier review of policy priorities, has been a dedicated and continuing effort to infuse research infrastructure with capital – for bricks and mortar to be sure but also for the needed equipment for leading-edge science. Seen in Figure 14, this funding has been primarily channeled through four mechanisms. Specifically, the Canadian Foundation for Innovation has been focused on “modernizing” the infrastructure of universities, colleges and research hospitals. Indirect costs of research – i.e., administrative costs associated with tri-council research grants – have been subsidized. Further, there has been the Knowledge Infrastructure Program enacted through the Economic Action Plan, also focused on maintenance and expansion of infrastructure at “post-secondary institutions” (Finance Canada 2010, 78, 242; Finance Canada 2011, 248). And finally, and more recently, the Strategic Infrastructure Investments at Post-Secondary Institutions has been struck, it too focused on research facilities. Nor have the sums here been insignificant. CFI alone has accounted for \$5.6 billion of funding since its genesis in 1997-1998 and in total research infrastructure has logged in at \$14 billion (\$14.19B to be more exact) over the years in question (Figure 14).

So too has funding been pronounced in genomics research and associated technologies, straddling innovation in the fields of environment, health and natural resources (Finance Canada 2010, 80; also IC 2020). Moreover, it has been complemented, albeit of a more intermittent or

recent nature – by the science of regenerative medicine, particularly stem cell and spinal cord injuries, as well research related to the brain (see Figure 2 in Chapter Nine). And, while these sums pale in comparison with research infrastructure, nevertheless \$1.3 billion has been vested in genomics (through Genome Canada) over the last two decades and, taken with the other components, there has been \$1.5 billion expended in these fields.⁴³

So too have theoretical physics as well as particle physics (and the particle accelerator) associated with the Perimeter Institute and TRIUMF respectively have been historical constants, with funding first appearing as early as 1994-1995 (Figure 15). Space too has complemented these investments, the Canadian Space Agency being established in 1990 and receiving \$7.7 billion over these years (Figure 16). Moreover, while initially at least one of the least expansive investments, federal funding of Artificial Intelligence has been a mainstay since as early as 1987-1988. And while the Canadian Institute for Advanced Research or CIFAR which led the charge in this field in fact only received \$130.3 million over the years since the first federal investments (Figure 1, Chapter Eight),⁴⁴ AI has been amplified of late, bringing the total dollars to \$739.4 million as of 2019-2020.⁴⁵ Taken together – and with a standardized starting point of 1997-1998 when the first major infusions of funding began to flow -- key federal investments in research have tallied up to \$92.8 billion (Figure 16). Admittedly not measured in constant dollars, nevertheless it stands as a testament to the funding that has kept Canada in, or close to, the top five countries in HERD R&D investments -- clearly no small endeavour.

⁴³ The \$1.5 billion includes funding for the Canada Brain Research Fund, the Rick Hansen Foundation, the Stem Cell Network, as well as Genome Canada. See Figure 2, Chapter Nine.

⁴⁴ Figure 16 in this chapter references a sum of \$105.48 million. Note that this sum covers the period from 1997-1998 until 2019-2020.

⁴⁵ Chapter Eight, Figure 1 which includes all AI federal investments from 1987-1988.

It is course tempting to conclude that these investments simply centre around upstream advanced scientific research. And, to be sure, the research component of these areas is, and was, dominant. However, both in the case of genomics and the technology “platforms” it generates as well as the way in which Artificial Intelligence (as will be seen in Chapter Eight) has particularly flourished across the innovation spectrum, that would be too narrow a perspective. Yet two points about the federal infusions of cash into these domains must be made. The patterning here was consistent and it was not usurped or whipsawed by competing political priorities or structural economic needs or different political administrations. Indeed, in the case of the Knowledge Infrastructure Program, the Program was complementary, leveraging and amplifying the effects of traditional Keynesians instruments (and essentially public works) through the Great Recession. Secondly, and equally important, a clear association can be drawn between these strategic federal investments and Canada’s acknowledged scientific prowess in these domains.

True, as noted in Chapter Three on the health of the Canadian innovation system, there has been what may be termed some scientific ailing in particular fields – including Regenerative Medicine, Clinical Medicine, Physics and Astronomy -- even to a certain extent in AI. Still these have been traditionally been Canadian scientific strongholds, with Canada punching very much above its globally-positioned weight and in the case of Artificial Intelligence functioning as a North Star for international breakthroughs.⁴⁶ So too in stem cell research have Canadian scientists numbered among “the world’s leading stem cell biologists.” And if Naylor in particular warns against complacency (2017, 40-43) that is not say these federal investments over the years were ill-considered or short-sighted or devoid of economic and social value.

⁴⁶ See the discussion in Chapter Eight.

Moreover, these exceptions stand out in contrast with targeted endeavours placed on commercialization. The Centres of Excellence for Commercialization and Research Program, the Business-led Networks of Centres of Excellence Program, the Centres of Excellence Knowledge Mobilization Initiative -- all launched in 2007 had been deemed to “bridge... the challenging gap between innovation and commercialization” (https://www.nce-rce.gc.ca/Programs-Programmes/CECR-CECR/Index_eng.asp) or address particular “real-world challenges” (https://www.nce-rce.gc.ca/Programs-Programmes/BLNCE-RCEE/Index_eng.asp within industry). Yet not only are these initiatives now winding down with some activities already having ended by 2020 and programmatic efforts -- at least in the current form – not extending beyond 2024. But the budgetary allocation in these endeavours has been rather small and certainly not commensurate with some of the other research investments. All told \$399.3 million will have been expended by 2024.⁴⁷ If these centres were to be crucial to “bridg[ing]” the valley of death between invention and commercialization -- in critical domains from refined manufacturing to “antibodies and biologics” their life span has been both short and, in terms of expenditure, rather limited. This point of course should not be overstated. There have been other ongoing commercialization efforts, as associated with the NRC’s Industrial Research Assistance Program. But the commercialization centres particularly highlight the problem with budgetary continuity on issues – even those as central to the old, and ongoing, policy “chestnut” of straddling invention to market.

Thus, the question we are left with is not why the jigsaw nature of budgetary priorities or shortened cycles for commercialization ventures. Akin to the undulation of priorities also

⁴⁷ This sum is based on funding allotted to all the initiatives for the Centres of Excellence for Commercialization and Research (\$286.8 million), Business-Led Networks of Centres of Excellence (\$99.3 million) and Knowledge Mobilization Initiative Networks (\$13.2 million) as described on the Networks of Centres of Excellence Government of Canada website (https://www.nce-rce.gc.ca/NetworksCentres-CentresReseaux/Index_eng.asp).

evidenced in Chapter Four, this more disjointed pattern would appear to be the default “go-to” in the Canadian case. The question is why the break in the patterning and the segmentation between the overall funding arc of these decades and these more particularistic investment endeavours around areas that have become central to Canadian scientific expertise – and prowess. In part, of course it may be due to certain historical legacies. Certainly, with respect to infrastructure, this has been a mainstay in this country (rail, the Seaway, the Trans-Canada) carving through rock and waterways since colonial days and has been particularly present in government priority-setting throughout the 2000s. Research infrastructure is no exception to this longstanding legacy. But in part it may also be (à la Pierson) the play of a self-reinforcing and successful feedback loop. Certainly successive evaluations by government have spoken to the successful payoff and performance of these investments – in terms of genomics, AI, particle physics or indeed research infrastructure.⁴⁸

That aside, however, what can be drawn from this budgetary history – and histories -- of the 2000s is that the big picture does not largely conform to the consistency and mission-driven efforts hypothesized, and in fact envisioned, by the DNS. Nor does it conform to the durable nature of American programmatic efforts in the innovation domain. Segmented areas – even niches – have thrived in the Canadian case but they have been the exception. In all, the portrait that emerges over two decades is one of rather fragmented patterning in federal expenditures and the more shallow nature of policy durability – thus giving further justification to the DNS lens in capturing the challenged nature of Canada’s innovation ecosystem.

⁴⁸ See in turn government evaluations of: Genome Canada particularly with respect to the positive impacts on “breadth of knowledge” (ISED 2020, ii)); CIFAR for AI (IC 2013; also IC (2009, 28), Finance Canada (2017, 90) and as discussed in Chapter Eight); the CFI’s capacity to “build upon its successes” (IC 2015, i), as well as TRIUMF and its “world-class efforts” in “all” their research areas (IC 2019, 4).

In-Depth Interviews with Thought Leaders

As noted at the outset, the final piece in this review of targeted resourcing endeavours over the last two decades is the in-depth thought leader interviews. Not surprisingly, here too the results – at least in broad strokes -- tend to validate the other findings that have surfaced in this chapter – i.e., that federal budgetary efforts to “target” innovation have been less than optimal over the years. Specifically, interviewees were asked a question that turned on the nature of government programming and the degree to which it was or was not fragmented – namely:

One of the areas that reports throughout the 2000s – specifically, the Science, Technology and Innovation Council, the Jenkins Report, the Advisory Committee on Economic Growth – have focused on has been the relatively fragmented nature of government programs and federal programming and the need to invest strategically.

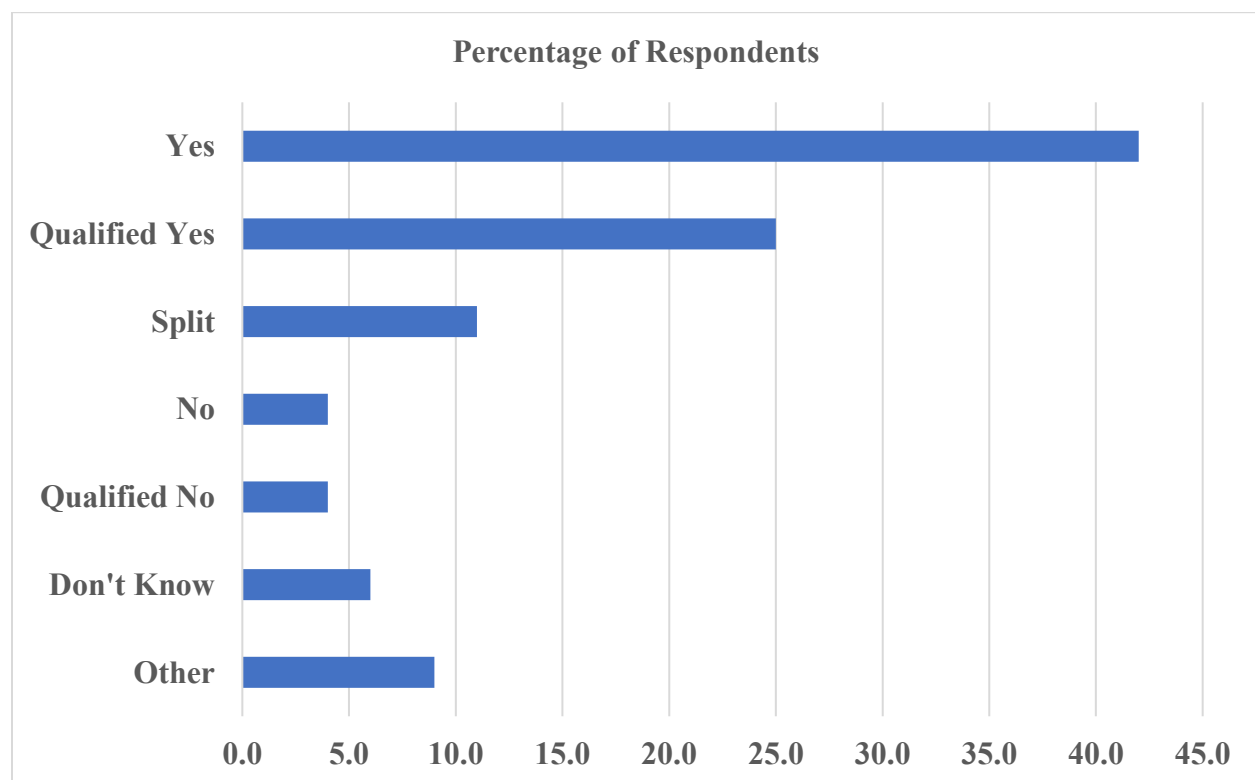
Do you think these concerns are a fair appraisal of the challenges Canada has had with innovation policy?

Responses were then captured and collated according to whether the person indicated agreement with the statement – i.e., yes; agreed but with certain caveats – qualified yes; articulated a split perspective on the issue; definitely disagreed – ie., no; or disagreed with certain qualifiers – qualified no. In addition, there were categories for those who indicated “don’t know” as well as “other” that essentially challenged the assumptions of the question. As has been previously noted in Chapter Four, 54 interviews were conducted. However, one interviewee was not asked this question, as it was the intent to take a deeper dive with this individual on other issues and thus time would not have allowed. As such, percentages noted in Figures 17 and 18 are based on the 53 interviewees who answered the resourcing question.

The data itself is quite arresting and broke in number of ways. For one thing, as evidenced in Figure 17, fully 42 per cent of these thought leaders concurred with the statement and viewed this as a fair appraisal, with another quarter – 25 per cent – agreeing but in a more nuanced or limited manner. Another 11 per cent were essentially split on the issue, balancing off

the various factors weighing into their decision. A much smaller group of four per cent indicated that they did not share this perspective, with another four per cent indicating a negative answer although not as strong. Six per cent felt that they did not have sufficient expertise to answer the question definitively, although interestingly they still offered very in-depth opinions and nine per cent approached the issue from a totally different perspective and fell into the “other” grouping. In all, then two-thirds of the interviewees⁴⁹ agreed with the premise of the question, finding federal programmatic activity to be “fragmented.”

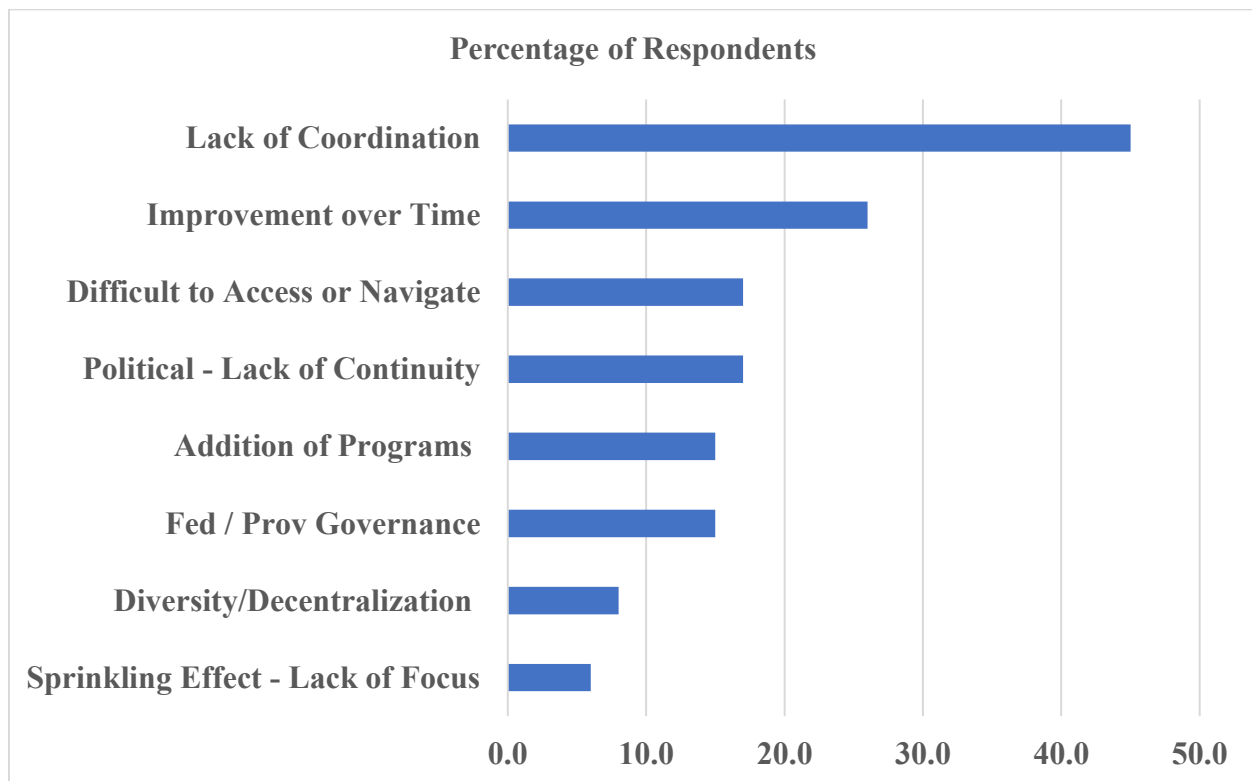
Figure 17 Fragmentation in Federal Innovation Programming: A Fair Appraisal?



⁴⁹ For purposes of presentation, percentages have been rounded. In the case of Yes answers the actual percentage is 41.5 per cent and for Qualified Yes it is 24.5 per cent - thus 66 per cent. Due to rounding it will appear that the number is 67 per cent.

More interesting still are the reasons that surfaced behind these positions, with answers basically falling into eight different categories (Figure 18).⁵⁰ Certainly what emerged most clearly was the “lack of strategic coordination” (I26) among federal programs and agencies, and the concomitant need to move to a “coherent multi-aspect approach” (I22). Indeed, 45 per cent of participants raised the lack of coordination as an important consideration in responding to this question. There were the usual kinds of bureaucratic impediments that were raised – a respondent having to provide the same extensive information to two separate departments, or a participant applying to a program only to find two other similar initiatives roll out shortly afterwards, or a specialized lab being closed only to be reopened in another research institution. But more critically, the themes around this issue broke along both vertical and horizontal lines.

Figure 18 Fragmentation: Themes Raised



⁵⁰ It should be noted that interviewees could give more than one answer so the tally in Figure 18 in fact refers to the percentage of respondents focused on that particular issue.

On the one hand there was concern that within the federal family there was not sufficient engagement and communication among departments and agencies. As one interviewee noted, “some of the programs could do a better job of communicating with their federal counterparts” (I50) or as another put it more bluntly – they “need to talk with each other” (I53). This in turn engendered a proclivity for “insular[ity]” (I1)⁵¹ or “silos” or agencies “who seem to be doing their own thing” (I34). And a view certainly was apparent that programs tended to create their own “balliwick[s]” (I16) with corresponding sets of rules and processes. But overlaid on this was also the need to more thoughtfully align regional economic development initiatives with national policy. Not that the regional agencies did not fulfill a critical role but rather they could be leveraged to work in a more holistic manner and synced up with national innovation policy. One comment particularly captures both the challenges and the way forward. Speaking of the development agencies, the critical nature of their mandate and the expertise they house, the respondent notes:

They’re great regionally but when you want to collaborate nationally on an initiative ... especially when it’s proven to work, then you can be kind of hooped (I29).

The interviewee goes to conclude: “... so I think there’s a way of actually elevating and lifting up all regions because you know innovation is not regionally exclusive” (I29). Also emerging however was an opportunity to strengthen the connections between scientific experts and the program “decision-makers.” Interestingly, this element led to reflections on how government labs were “underutilized” and, akin to the American model associated with DARPA or Department of Energy labs, could play a more valuable role as “interlocutor” between “basic research and innovation” (I6).

⁵¹ The exact word used was “insular.”

In addition, and while articulated separately from the coordination issue, another six per cent of respondents raised the issue of trying to do too much with too little, leading to a “sprinkling” effect – a theme that resonates more strongly as well in the next chapter dealing with “Collaborative Networks.” As one respondent noted: “... and so we do the great Canadian strategy which is to give a little bit to everybody and then everybody’s happy but you really can’t move the needle” (I35). Thus, in all, over half of the respondents – 51 per cent – indicated there needed to be reckoning with specific “disconnects” within federal programming initiatives.

While not equal in importance, nevertheless, another 17 per cent of the participants also raised the issue of access to innovation programming. Deemed to be overly complex, each program vested with its “own particular target audience and set of restrictions,” (I16) the process of application bore significant “opportunity costs” for those businesses trying to “navigate” them. Particularly challenging for SMEs, as one respondent indicated, “la complexité – c’est absolument incroyable” (I49). Or as another explained:

There’s still opportunity costs even if the program is free to the company. There’s still opportunity costs for them to actually go through the work – go through the energy. I know a lot of people in industry who just don’t bother with government grants or government programs because it eats up so much of their time – so there are opportunity costs there.

And if they don’t need it, if they don’t see the value in it – if they think there’s other ways that could actually improve their bottom lines, then they’re not going to invest in that innovation (I36).

Nor did this just apply to direct support programming. Even with SR&ED, companies oftentimes needed to engage consultants to draw down on this indirect tax credit. Moreover, while challenges lay for industry, there was also a regional dimension, with programs in “some cases” at least not sufficiently scoped to respond to the needs and realities of “smaller jurisdictions” – likened to “at times trying to fit a round peg in a square hole” (I10).

Finally, and still on the problem side of the ledger, 15 per cent of the respondents commented on the “proliferation” and “multiplicity” of programs. Specifically, there was a proclivity for rolling out new programming with fresh “announcements” rather than taking a “step back” (I2) and engaging in a more holistic review of whether such initiatives continued to serve their purposes and needed to be retained:

You – you know – create something and you just don’t want to shut it down.
You don’t want to reorganize it. It’s kind of working so let’s leave it as it is (I2).

As one respondent noted, “nothing disappears” (I22). And this too fed into challenges around strategic focus and targeting and leveraging the full impacts which “integration” (I5) in innovation programming could have.

To be sure, these concerns were not the only picture that was painted. A significant proportion of those commenting – 26 per cent - indicated that “consolidation” and streamlining of programming had improved over the last half-decade or so. Interestingly the Clean Growth Hub focused on clean technology in ISED was singled out by several as a model that was working well. Having integrated programs, the Hub served as a useful access point for industry and it further “reflect[ed] a partnership across several departments” (I13). Indeed, it was referenced as an example of how “government recognizes an issue” (I34). So too was the IRAP concierge program dedicated to helping SMEs navigate federal programming as well as “consolidation” efforts undertaken by NSERC referenced as moves in the right direction. Surfacing as well among members of this group was an acknowledgement that the Superclusters in terms of selecting strategic areas to focus that buil[t] on Canadian expertise” (I27) highlighted a move forward. As one respondent commented:

I would say that ... there’s been an evolution .. you know if – you’re asking about federal policy – there’s been an evolution in federal policy towards more targeted goals – more targeted outcomes.... I think the Supercluster

investment approach was an attempt to – not necessarily pick winners but to focus the investment in areas that mattered to the country and we can discuss already about how ...it's implemented but I know I think from a strategy perspective – I think that is in the right direction (I32).

Similarly, eight per cent of those interviewed were not convinced that centralization and tight coordination were necessarily a good thing. Rather it had the potential to create an Ontario or Quebec-centric approach and fail to recognize the diversity of the federation or as one commented: “.. we saw value in difference and diversity so we could respond more directly to our programming...” (I40). It enabled targeting of critical areas as for example of Indigenous economic development and it relieved the system from becoming just “too clunky” (I24). So too could an overemphasis on centralization squeeze out the space for funding of curiosity-driven research and the “breakthroughs” that engendered and which could not be “predicte[d]” (I18). In fact, as the No answers to the fragmentation question indicated, some questioned the very assumptions built into the question, arguing that programs such as the Networks of Centres of Excellence had engaged academics as “advocates” of innovation and had similarly fostered collaboration with their provincial counterparts – an approach that had particularly paid off in the area of “medical research,” at least in terms of research, if not commercialization (I4).

To be sure, underpinning these various responses were those that spoke to the larger structural issues associated with federal programming. Specifically, 15 per cent of the interviewees referenced the challenges of aligning governance and direction in a federated union, and the “patchwork” of programming that could engender, even when the proponents were committed to an innovation agenda. Moreover, another 17 per cent of respondents noted the toll political cycles took on program “continuity,” with each new administration ushering in a new set of priorities and announcements and programming. Indeed, the challenge of having these

bifurcated agendas as well as the need to move to a greater degree of policy and political, coherence was captured well in the following comment:

... my point is that instead of having a Canadian approach we had a Mulroney approach; we had a Chrétien approach; we had a Harper approach – there’s no single coherent policy which lasts over time which sweeps everybody into it and becomes a national undertaking (I47).

Interviews: An Overview

In the end, then, what these thought leader findings speak to are the persistent trends and challenges around targeted resourcing in innovation programming. Admittedly some of this was beyond easy fixes – federated governance or the cycle of electoral agendas -- and admittedly, there was a reckoning with improvements that had occurred. But equally some of this could be strengthened through deepened engagement and “communication” within the federal family, as well as with industry and academe, and continuing efforts towards programmatic streamlining and forging easier paths to funding accessibility. Moreover, for the DNS thesis – at least in broad brush terms – these findings equally underline the significant gaps in programming that mitigate against more effective targeted resourcing and the benefits of a more holistic “ecosystem” (I6) orientation.

Conclusion

As indicated at the outset, this chapter set out to examine whether federal innovation initiatives over the 2000s featured elements that aligned with the second pillar of the DNS framework – that of targeted resourcing. And it undertook this analysis based on five grounds, extending some way beyond just a focus on a few specific programmatic targets. Examined in turn was the extent of aggregate spending on R&D; the directed nature of government programming, and the nature of priorities and priority-setting -- and particularly whether this

depicted patterning of durability or rather ebb and flow. The analysis also cast its lens on constant features of government largesse that could be discerned. Finally, and fifthly, it turned to the perspectives of the thought leader interviews – those on the front lines of innovation so to speak, integrating their experiences and insights into the overall evaluation. Moreover, as with the other lines of inquiry in this dissertation this font of knowledge was employed as an additional source of validation in the findings and conclusions drawn.

That duly noted, the results are telling. If the Developmental Network State framework posits targeted resourcing as a condition for innovation success, what is revealed in this review is that the Canadian context and specifically federal initiatives in that regard are wanting on several fronts. Certainly, as the GBARD (national currency) on R&D and Stats Canada data on federal S&T expenditures attest, federal initiatives had not been deprived of adequate funding. Logging in respectively at \$160 billion for GBARD and \$174 billion for federal expenditures (up until 2016-2017), there has been surprising continuity in funding, largely increasing growth rates on these indicators – even when controlling for constant dollars and even during a major recessionary downcycle. Nor, interestingly, did this issue emerge as one of significant concern in the thought leader interviews.

So too has there been a particularly robust investment over the years in basic research and its associated infrastructure. Genomics research; regenerative medicine; neuroscience; theoretical and particle physics; space robotics and Artificial Intelligence writ large: areas where Canada has had relatively enduring international scientific prowess have been bequeathed with long-standing and, in many cases, significant investments. The final figure for key federal investments in these domains during the period from 1997-1998 (when first early initiatives were launched) until 2019-2020 rolls in at \$93 (\$92.8) billion in total.

Nonetheless, other key claims for targeted resourcing have much less currency. There has been a definitive overreliance on the more diffuse instrument of indirect tax credits and specifically SR&ED as an instrument for innovation stimulus, particularly compared to Canada's OECD competitors. Moreover, despite some efforts to recalibrate toward more directed program expenditures as well orient SR&ED more effectively to R&D activities, as has been seen this situation has largely remained, Canada's position on this not changing that significantly over the time period in question. In fact, indirect government support as a percentage of BERD was two percentage points lower in 2000.

Further – and among the most critical factors -- the cycle of different political regimes has displayed strong differentiation rather than patterns of durability in resourcing. Be it “world class research” or “mobilizing” knowledge into market product or pursuing twin efforts at science and innovation -- federal resourcing has been consistently punctuated with distinctiveness – in focus albeit not in actual funding largesse. As has been amply evidenced, governments of different political persuasions – Liberal, Conservative and Liberal again -- have undulated between investments in research, then commercialization and finally a more bifurcated agenda of latter years that has attempted to straddle both science and business growth. To be sure, these patterns should not be viewed as totalizing: as witnessed, there were more muted competing currents within each administration. But overall, in terms of shaping institutional mandates – and particularly those of the tri-councils and the NRC – as well as actual targeted funding, oscillation between research and commercialization obtains, even within the Trudeau years under the auspices of the same administration.

Moreover, this patterning has served to challenge and, at times even fundamentally so, experimentation that requires longer-term horizons in which to bear fruit. The best exemplar is

of course those Centres of Excellence dedicated specifically to commercialization or “business-led” efforts and “bridging” the innovation gap. Particularly exposed to prevailing political imprints, these have shown to be relatively short-lived entities, with their funds similarly limited compared to other initiatives. Overlaid on this, of course, has been the challenge this type of whipsaw effect has on both researchers and industry partners – and the type of sharp turns which that necessitates.

Finally, the perspectives that emerged in the thought leader interviews tend to reinforce these findings. Concerns with the need for strengthened “coordination” in federal programming together with enhanced accessibility and a keener eye on “integration” rather than “addition” (I5) clearly emerged in these discussions. And notwithstanding the import of the space necessary to carry on fundamental research, or reach out to particular Canadian sectors or populations, or the significant improvements that have been made to date, these interviews do suggest the need for a more substantive reboot – one that can winnow out stale programming, establish both clear mandates and benchmarks and provide focus – in a word targeted resourcing.

All in all then, federal budgetary initiatives have displayed a rather checkered pattern, arguably contributing to Canada’s poor showing on innovation indicators witnessed in Chapter Three. Indeed, there is an interesting duality to this pattern that throws into relief the ongoing challenges of the Canadian situation – and of federal resourcing policy. On the one hand the country’s enviable international record on Higher Education R&D is the result of a consistent flow of substantial investments over the period in question and reflects a historical trajectory and legacy signalling stability and durability. In contrast, budgetary instruments over the “longue durée” remain caught in the “back and forth”⁵² represented by differentiated political priorities

⁵² The phrase is actually from one of the insights provided in the interviews, specifically:
“I think part of ... the reason behind fragmented is changing governments all the time

and the concomitant fragmentation within government programming that may instill. In sum, if consistency and strategic precision are the objective benchmarks of success for targeted resourcing, it is not untoward to suggest that federal innovation resourcing has by no means fully measured up to that bar.

-- priorities and focuses and so, and so then these programs swing back and forth between different industries, or technologies or clusters or whatever and so then you don't get the long term view of things" (I31).

Annex A – 5: Investment Indicators

Figure 1 Total GBARD in national currency

Dataset: Main Science and Technology Indicators																						
MSTI Variables		Total GBARD in national currency (for euro area: pre-EMU euro or EUR)																				
Unit		National currency, Millions																				
Country	Year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Canada		5,634.00	6,519.00	6,843.00	7,237.00	7,603.00	8,225.00	8,316.00	9,145.00	9,793.00	10,120.00	10,356.00	9,593.00	9,641.00	10,027.00	9,766.00	9,918.00	10,200.00	11,046.00			
Korea		3,749,497.00	4,485,315.60	5,158,300.00	5,576,800.00	6,099,500.00	7,799,638.90	8,909,571.20	9,762,911.45	11,078,368.50	12,705,917.00	13,701,369.25	14,890,190.21	16,024,423.00	17,147,140.00	17,779,261.00	18,890,025.94	19,149,201.00	19,501,845.75	19,748,269.00	20,853,200.00	
United States		72,681.00	78,538.00	88,665.00	98,767.00	106,246.00	111,332.00	114,442.00	117,691.00	116,710.00	136,599.00	119,382.00	113,386.00	116,796.00	109,608.00	112,502.00	115,220.00	126,093.00	127,306.00	144,459.00	149,971.00	164,453.00
China *(People's Republic of)																						
EU(27)*																						
OECD - Total*																						
Top 5 Countries**		1,432,404.43	1,625,154.14	1,797,421.12	1,899,802.06	2,017,422.06	2,346,077.51	2,583,214.31	2,761,482.82	3,057,461.49	3,415,269.79	3,621,703.57	3,870,099.58	4,107,816.33	4,384,440.83	4,527,236.29	4,742,774.72	4,781,123.17	4,869,443.73	4,991,094.77	5,325,945.18	

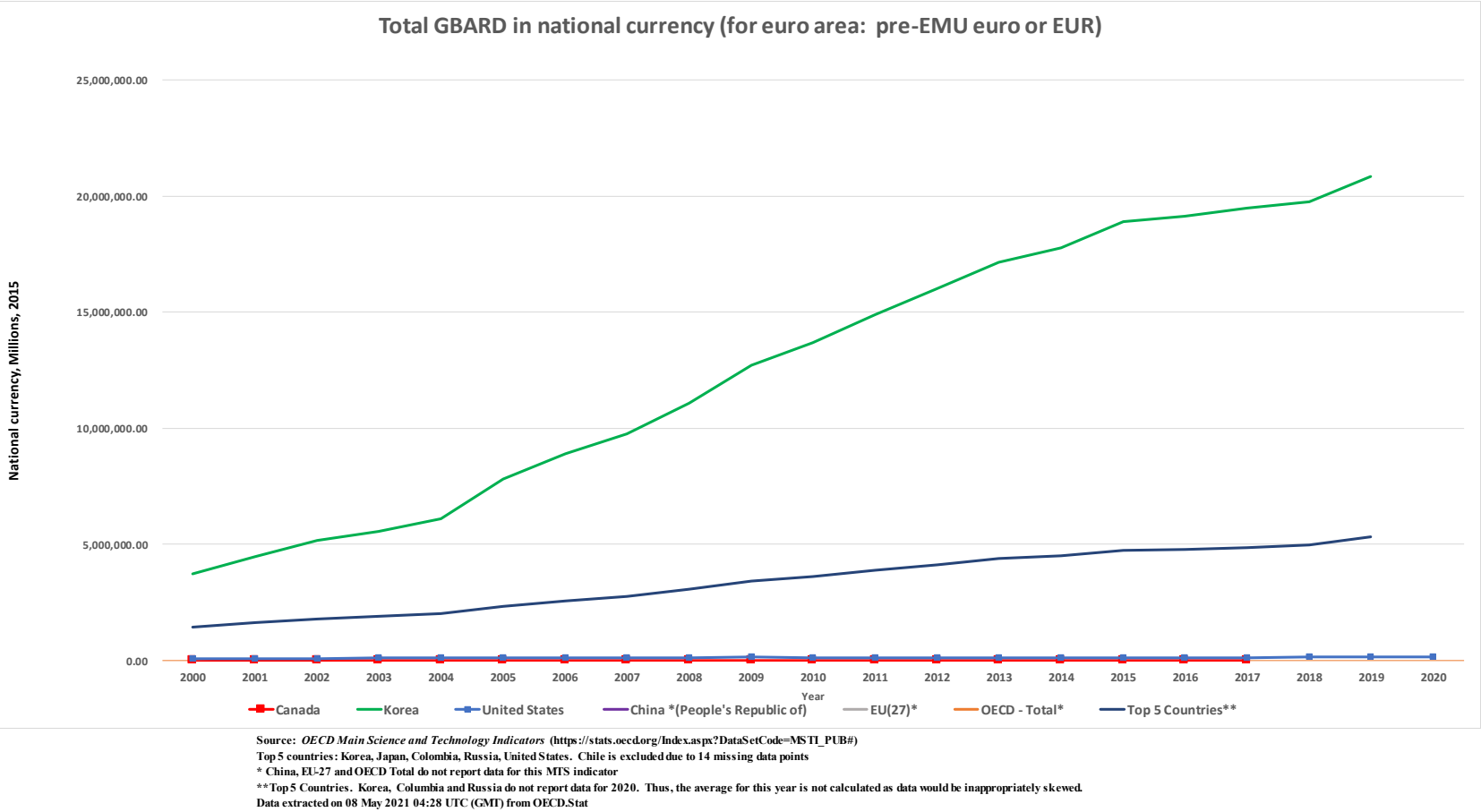
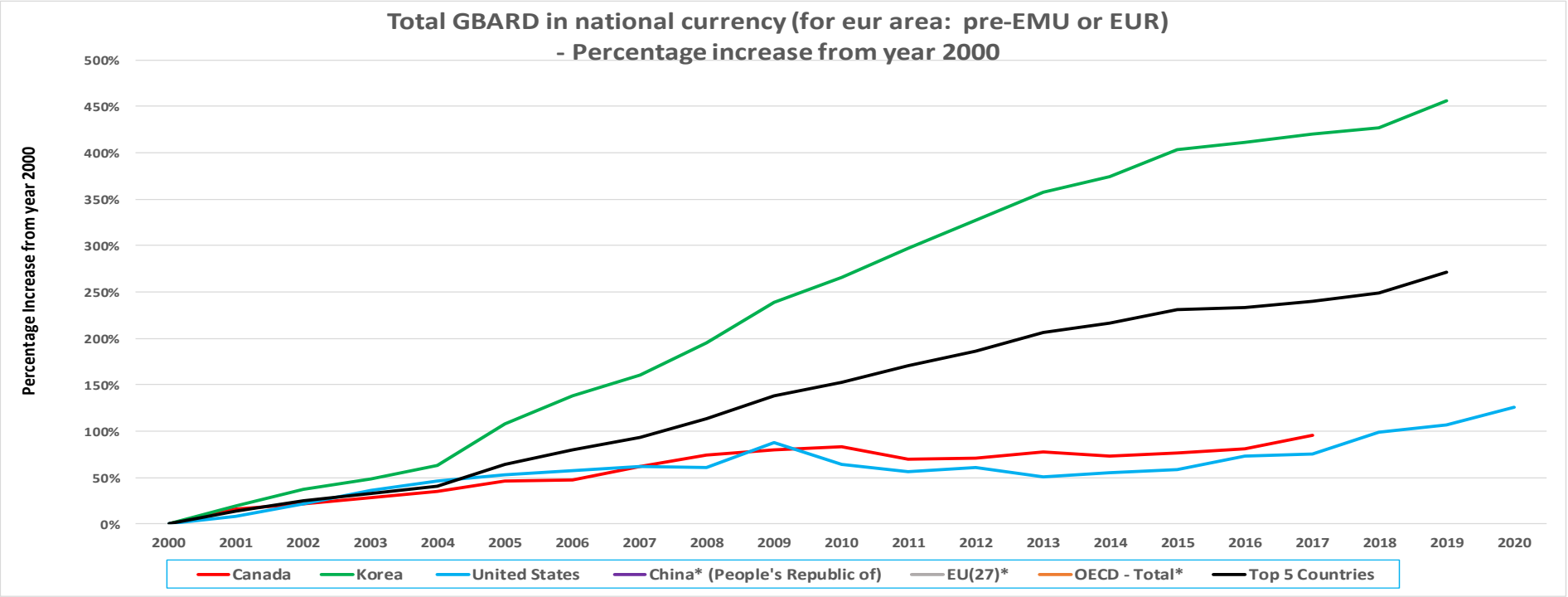


Figure 2 Total GBARD in national currency – Percentage increase from year 2000

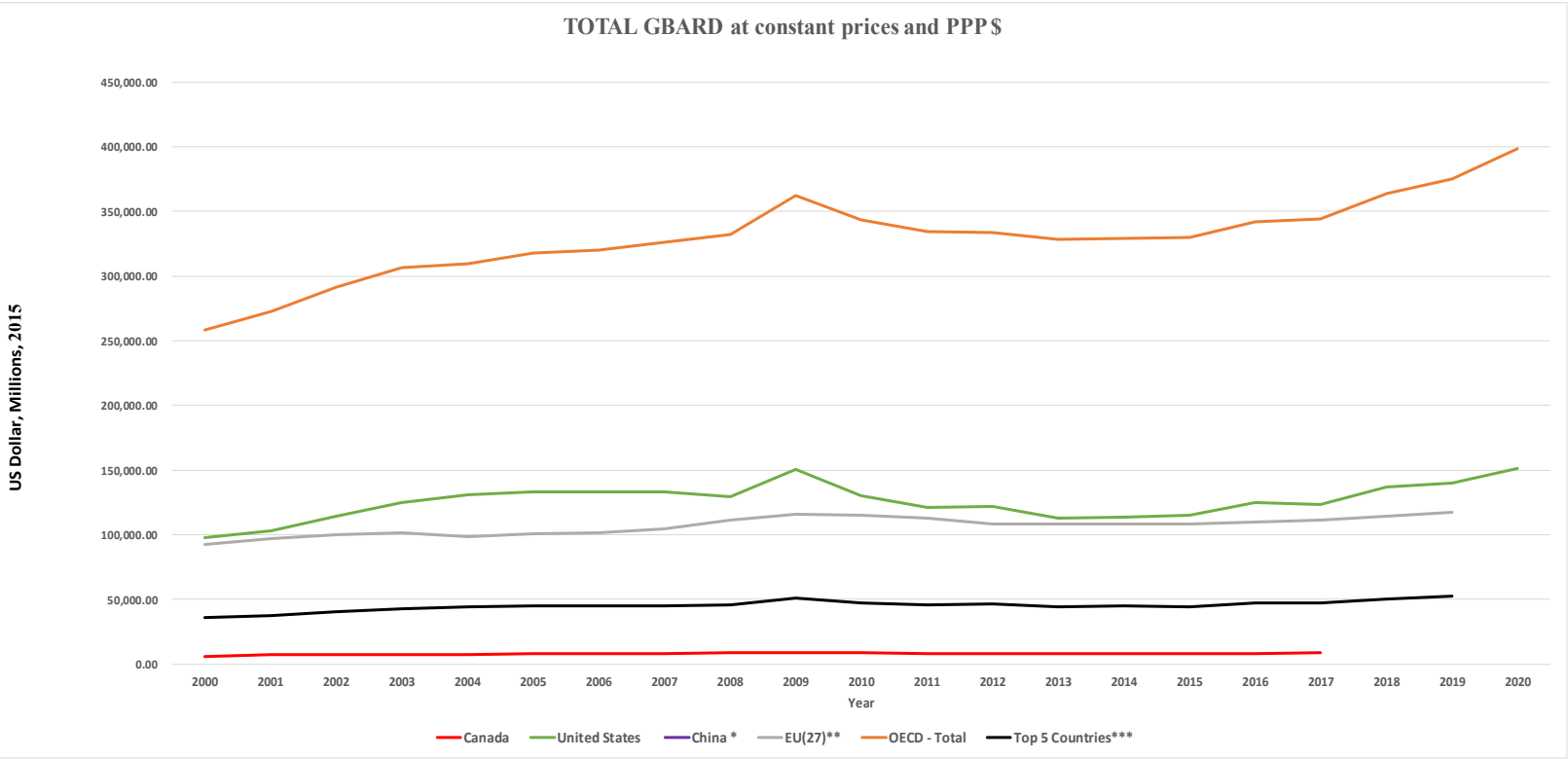
		Dataset: Main Science and Technology Indicators																				
MSTI Variables		Total GBARD in national currency (for euro area: pre-EMU euro or EUR) - Percentage increase from year 2000																				
Unit		Percentage increase from year 2000																				
Year		2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Country																						
Canada		0%	16%	21%	28%	35%	46%	48%	62%	74%	80%	84%	70%	71%	78%	73%	76%	81%	96%			
Korea		0%	20%	38%	49%	63%	108%	138%	160%	195%	239%	265%	297%	327%	357%	374%	404%	411%	420%	427%	456%	
United States		0%	8%	22%	36%	46%	53%	57%	62%	61%	88%	64%	56%	61%	51%	55%	59%	73%	75%	99%	106%	126%
China* (People's Republic of)																						
EU(27)*																						
OECD - Total*																						
Top 5 Countries		0%	13%	25%	33%	41%	64%	80%	93%	113%	138%	153%	170%	187%	206%	216%	231%	234%	240%	248%	272%	



Source: OECD Main Science and Technology Indicators (https://stats.oecd.org/Index.aspx?DataSetCode=MSTI_PUB#)
Top 5 countries: Korea, Japan, Colombia, Russia, United States. Chile is excluded due to 14 missing data point.
* China, EU-27 and OECD Total do not report data for this MTS indicator
** Top 5 Countries. Korea, Columbia and Russia do not report data for 2020. Thus, the average for this year is not calculated as data would be inappropriately skewed.
Original data extracted on 08 May 2021 04:28 UTC (GMT) from OECD.Stat; percentage increases are author's calculations

Figure 3 Total GBARD at constant prices and PPP\$

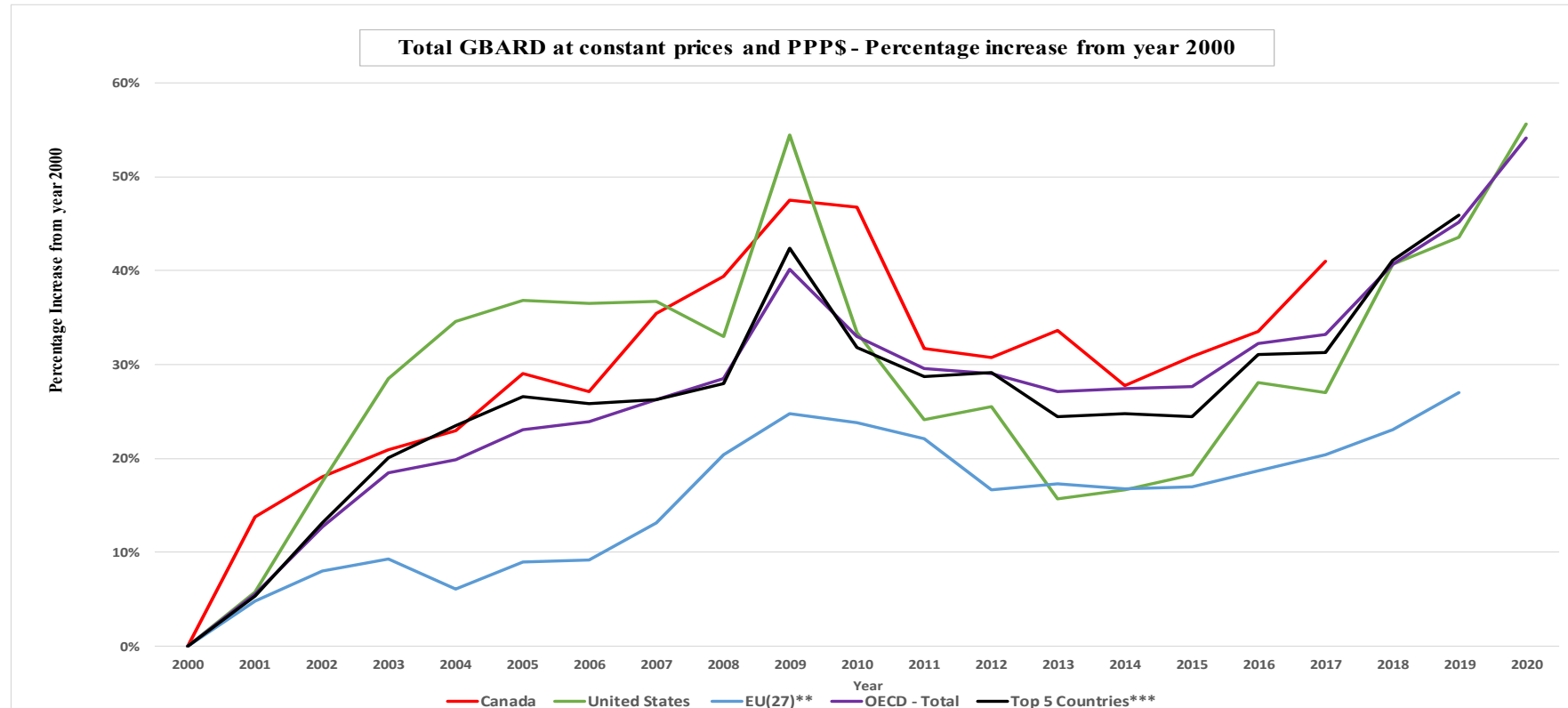
Dataset: Main Science and Technology Indicators																						
MSTI Variables		Total GBARD at constant prices and PPP \$																				
Unit		US Dollar, Millions, 2015																				
Year		2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Country																						
Canada		6,073.61	6,913.01	7,167.79	7,341.56	7,468.88	7,835.17	7,723.02	8,223.48	8,468.52	8,958.60	8,913.52	7,998.03	7,941.72	8,118.61	7,756.45	7,946.85	8,111.62	8,564.74			
United States		97,393.03	102,982.62	114,451.27	125,166.72	131,114.92	133,241.06	132,940.03	133,137.70	129,508.84	150,432.13	129,957.27	120,904.53	122,197.10	112,698.91	113,573.01	115,220.00	124,783.72	123,659.24	137,030.80	139,764.35	151,518.30
China *																						
EU(27)**		92,637.25	97,099.02	100,058.92	101,217.04	98,283.77	100,910.32	101,136.26	104,775.74	111,567.48	115,597.59	114,713.03	113,071.27	108,054.18	108,648.87	108,134.30	108,329.71	109,900.12	111,531.31	114,046.31	117,673.47	
OECD - Total		258,449.10	272,809.82	291,363.76	306,250.37	309,832.76	318,060.36	320,199.59	326,367.45	332,065.07	362,214.80	343,624.16	334,762.63	333,361.54	328,448.60	329,271.99	329,937.88	341,663.42	344,314.90	363,665.79	375,149.95	398,300.41
Top 5 Countries***		35,743.57	37,654.72	40,456.99	42,918.74	44,153.01	45,249.30	44,977.78	45,116.49	45,739.73	50,879.37	47,106.30	46,026.77	46,146.68	44,490.93	44,589.67	44,496.98	46,859.36	46,906.01	50,431.99	52,136.03	



Source: OECD Main Science and Technology Indicators (https://stats.oecd.org/Index.aspx?DataSetCode=MSTI_PUB#)
Top 5 countries: United States, Japan, Germany, France, Korea - Averages for OECD and EU(27) are not included in the top 5
* China does not report data for this MSTI indicator
** EU(27) - 27 countries from 01/02/2020
*** Top 5 Countries - France and Korea do not report data for 2020. Thus the average for 2020 is not calculated as data would be inappropriately skewed.
Data extracted on 07 May 2021 21:48 UTC (GMT) from OECD.Stat

Figure 4 Total GBARD at constant prices and PPP\$ - Percentage increase from year 2000

Dataset: Main Science and Technology Indicators																					
MSTI Variables	Total GBARD at constant prices and PPP\$ - Percentage increase from year 2000																				
Unit	Percentage increase from year 2000																				
Year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Country																					
Canada	0%	14%	18%	21%	23%	29%	27%	35%	39%	48%	47%	32%	31%	34%	28%	31%	34%	41%			
United States	0%	6%	18%	29%	35%	37%	36%	37%	33%	54%	33%	24%	25%	16%	17%	18%	28%	27%	41%	44%	56%
China (People's Republic of)**																					
EU(27)**	0%	5%	8%	9%	6%	9%	9%	13%	20%	25%	24%	22%	17%	17%	17%	17%	19%	20%	23%	27%	
OECD - Total	0%	6%	13%	18%	20%	23%	24%	26%	28%	40%	33%	30%	29%	27%	27%	28%	32%	33%	41%	45%	54%
Top 5 Countries***	0%	5%	13%	20%	24%	27%	26%	26%	28%	42%	32%	29%	29%	24%	25%	24%	31%	31%	41%	46%	



Source: OECD Main Science and Technology Indicators (https://stats.oecd.org/Index.aspx?DataSetCode=MSTI_PUB#)

Top 5 countries: United States, Japan, Germany, France, Korea - Averages for OECD and EU(27) are not included in the top 5

* China does not report data for this MSTI indicator

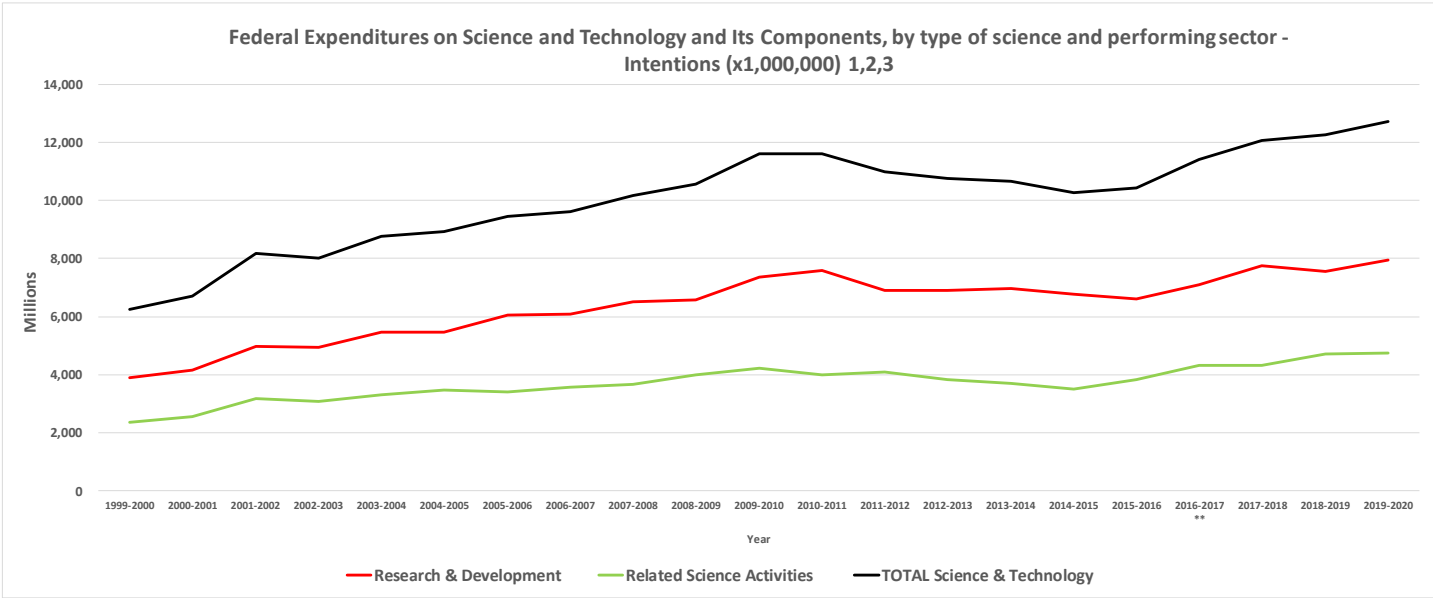
** EU(27) - 27 countries from 01/02/2020

*** Top 5 Countries - France and Korea do not report data for 2020. Thus the average for 2020 is not calculated as data would be inappropriately skewed.

Original data extracted on 07 May 2021 21:48 UTC (GMT) from OECD.Stat; percentage increases are author's calculations

Figure 5 Federal Expenditures on Science and Technology

Measure	Federal Expenditures on Science and Technology and Its Components, by type of science and performing sector - Intentions (x1,000,000) ^{1,2,3}																					
Unit	Millions																					
Year	1999-2000	2000-2001	2001-2002	2002-2003	2003-2004	2004-2005	2005-2006	2006-2007	2007-2008	2008-2009	2009-2010	2010-2011	2011-2012	2012-2013	2013-2014	2014-2015	2015-2016	2016-2017	2017-2018	2018-2019	2019-2020	TOTAL *
Research & Development	3,890	4,150	4,989	4,927	5,462	5,454	6,042	6,073	6,521	6,573	7,374	7,601	6,901	6,911	6,978	6,758	6,620	7,092	7,742	7,554	7,947	133,559
Related Science Activities	2,362	2,557	3,180	3,087	3,303	3,480	3,407	3,560	3,655	4,000	4,239	3,997	4,091	3,843	3,692	3,506	3,821	4,335	4,312	4,705	4,762	77,894
TOTAL Science & Technology	6,252	6,707	8,169	8,014	8,765	8,934	9,449	9,633	10,176	10,573	11,614	11,598	10,993	10,754	10,670	10,265	10,441	11,427	12,054	12,259	12,709	211,456



TOTAL* Totals are not in the original Stats Can table - calculated by author. **2016-2017 NOTE: Total for 1999-2000 until 2016-2017 is \$174,434,000,000

Federal expenditures on science and technology and its components, by type of science and performing sector - Intentions (x 1,000,000) 1 2 3

Table: 27-10-0006-01 (formerly CANSIM 358-0143) - Frequency: Annual; Geography: Canada

Science refers to Natural Sciences and Engineering as well as Social Sciences, Humanities and the Arts.

1. Due to rounding, components may not add to the totals.

2 Conceptual changes were implemented for the 2016/2017 survey cycle to account for non-program costs (indirect costs).

The value of services provided without charge to the responding department by other federal departments will not be added. Revisions were applied to data on intramural expenditures and related activities back to 2010/2011.

These revisions affect expenditure totals by type of science, science and technology, research and development, and related scientific activity.

As a result, data for 2010/2011 onward are not comparable with data for previous years.

3 The last two years of data in this table represent preliminary estimates and intentions, reported at the time of data collection.

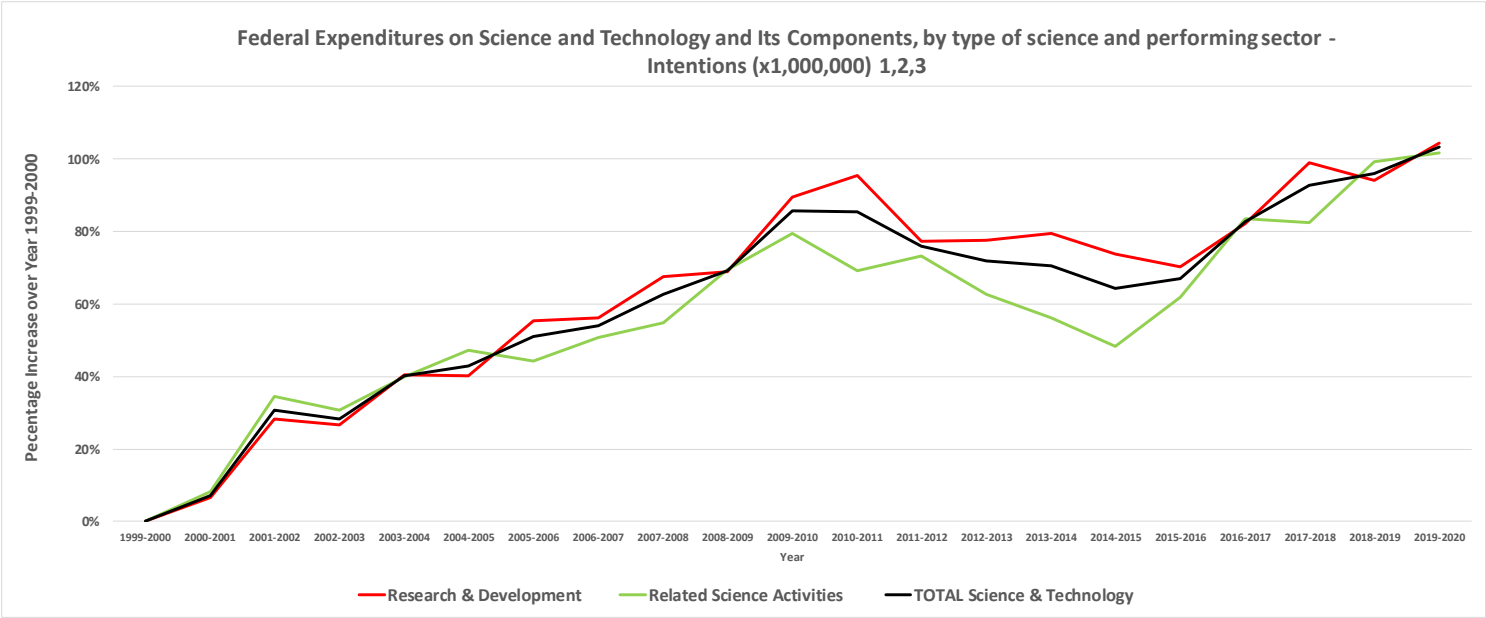
Source: Statistics Canada. Table 27-10-0006-01 Federal expenditures on science and technology and its components, by type of science and performing sector - Intentions (x 1,000,000)

<https://www150.statcan.gc.ca/t1/tbl1/en/tv.action?pid=2710000601>

DOI: <https://doi.org/10.25318/2710000601-eng>

Figure 6 Federal Expenditures on Science & Technology -Percentage increase over base year

Measure	Federal Expenditures on Science and Technology and Its Components, by type of science and performing sector - Intentions (x1,000,000) ^{1,2,3}																					
Unit	Percentage Increase over Year 1999-2000																					
Year	1999-2000	2000-2001	2001-2002	2002-2003	2003-2004	2004-2005	2005-2006	2006-2007	2007-2008	2008-2009	2009-2010	2010-2011	2011-2012	2012-2013	2013-2014	2014-2015	2015-2016	2016-2017	2017-2018	2018-2019	2019-2020	
Research & Development	0%	7%	28%	27%	40%	40%	55%	56%	68%	69%	90%	95%	77%	78%	79%	74%	70%	82%	99%	94%	104%	
Related Science Activities	0%	8%	35%	31%	40%	47%	44%	51%	55%	69%	79%	69%	73%	63%	56%	48%	62%	84%	83%	99%	102%	
TOTAL Science & Technology	0%	7%	31%	28%	40%	43%	51%	54%	63%	69%	86%	86%	76%	72%	71%	64%	67%	83%	93%	96%	103%	



TOTAL* Totals are not in the original Stats Can table - calculated by author.

Federal expenditures on science and technology and its components, by type of science and performing sector - Intentions (x 1,000,000) 1 2 3

Table: 27-10-0006-01 (formerly CANSIM 358-0143) - Frequency: Annual; Geography: Canada

Science refers to Natural Sciences and Engineering as well as Social Sciences, Humanities and the Arts.

1. Due to rounding, components may not add to the totals.

2 Conceptual changes were implemented for the 2016/2017 survey cycle to account for non-program costs (indirect costs). The value of services provided without charge to the responding department by other federal departments will not be added. Revisions were applied to data on intramural expenditures and related activities back to 2010/2011. These revisions affect expenditure totals by type of science, science and technology, research and development, and related scientific activity. As a result, data for 2010/2011 onward are not comparable with data for previous years.

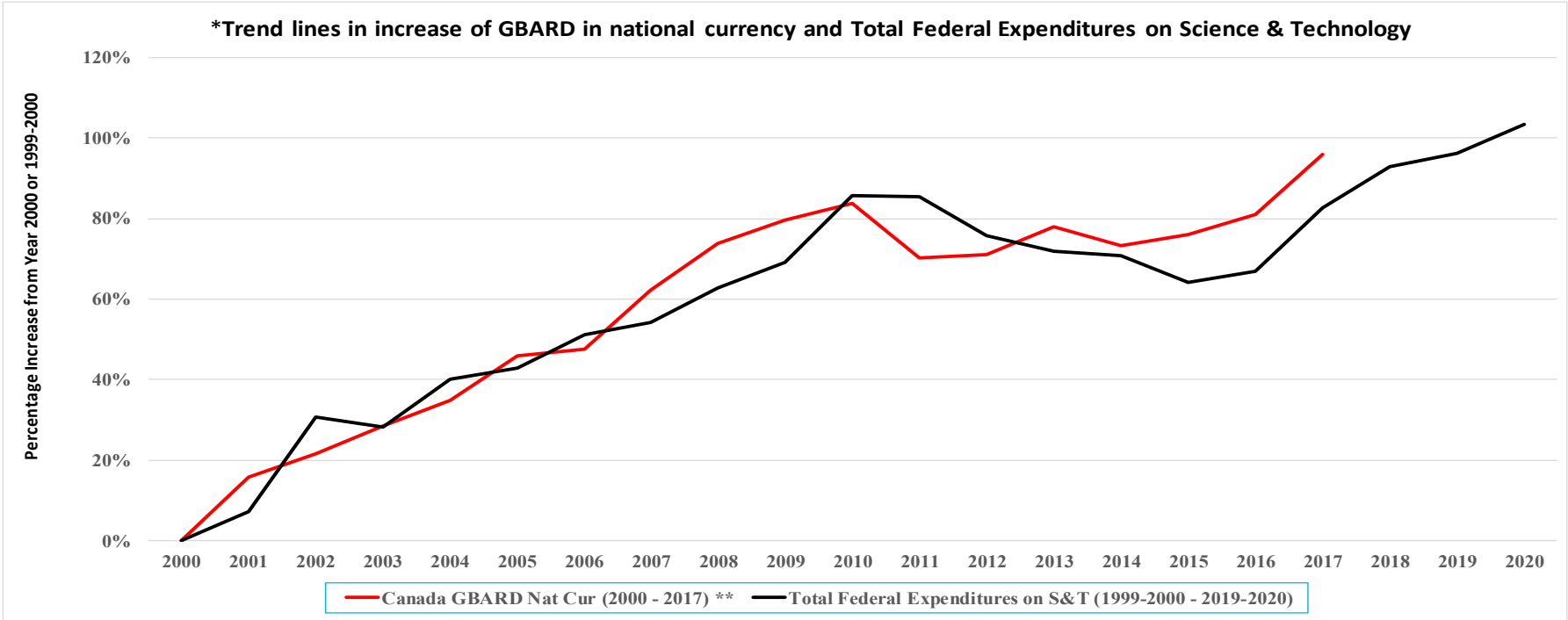
3 The last two years of data in this table represent preliminary estimates and intentions, reported at the time of data collection.

Source: Statistics Canada. Table 27-10-0006-01 Federal expenditures on science and technology and its components, by type of science and performing sector - Intentions (x 1,000,000)

<https://www150.statcan.gc.ca/t1/tbl1/en/tv.action?pid=2710000601> DOI: <https://doi.org/10.25318/2710000601-eng>

Figure 7 Trend Lines in increase of GBARD in national currency and Total Federal Expenditures on S&T– Percentage increase over base year

Measure	* Trend lines in increase of GBARD in national currency and Total Federal Expenditures on Science and Technology																					
Unit	Percentage increase over base year																					
Year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	*** Average
Canada GBARD Nat Cur (2000 - 2017) **	0%	16%	21%	28%	35%	46%	48%	62%	74%	80%	84%	70%	71%	78%	73%	76%	81%	96%				58%
Total Federal Expenditures on S&T (1999-2000 - 2019-2020)	0%	7%	31%	28%	40%	43%	51%	54%	63%	69%	86%	86%	76%	72%	71%	64%	67%	83%	93%	96%	103%	55%



* NOTE: This is not a direct comparison as Canada GBARD National Currency allocations run from 2000-2017 while Total Federal Expenditures on S&T run from 1999-2000 until 2019-2020.

**GBARD Nat Cur (2000-2017) : Total GBARD in National Currency (for eur area: pre-Emu euro or EUR)

GBARD constitutes budgetary allocations, not expenditures. For Total Federal Expenditures on S&T year 2019-2020 represents preliminary estimates and intentions.

As well methodological definitions of R&D and S&T may differ.

This graph is to be used solely for generally comparing trends lines.

Sources: GBARD OECD MSTI - See Figure 1 in this chapter for full reference.

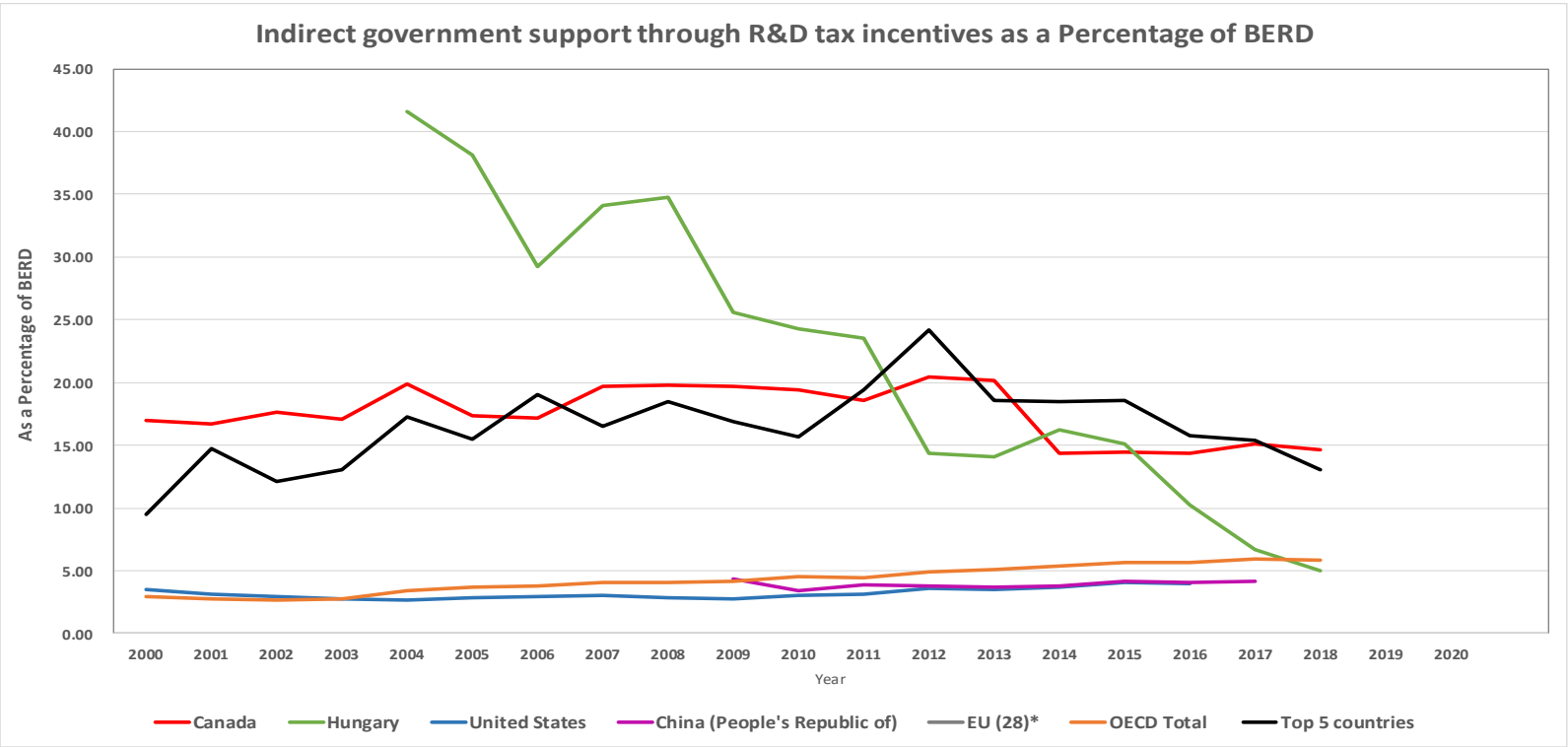
Total Federal Expenditures on S&T, and its components, by type of science and performing sector - Intentions. Statistics Canada. See Figure 5 in this chapter for full reference.

*** Average - Author's calculation from 2000 to 2017 or 1999-2000 to 2016-2017

Figure 8 Indirect government support through R&D tax incentives as a percentage of BERD

Dataset: R&D tax expenditure and direct government funding of BERD

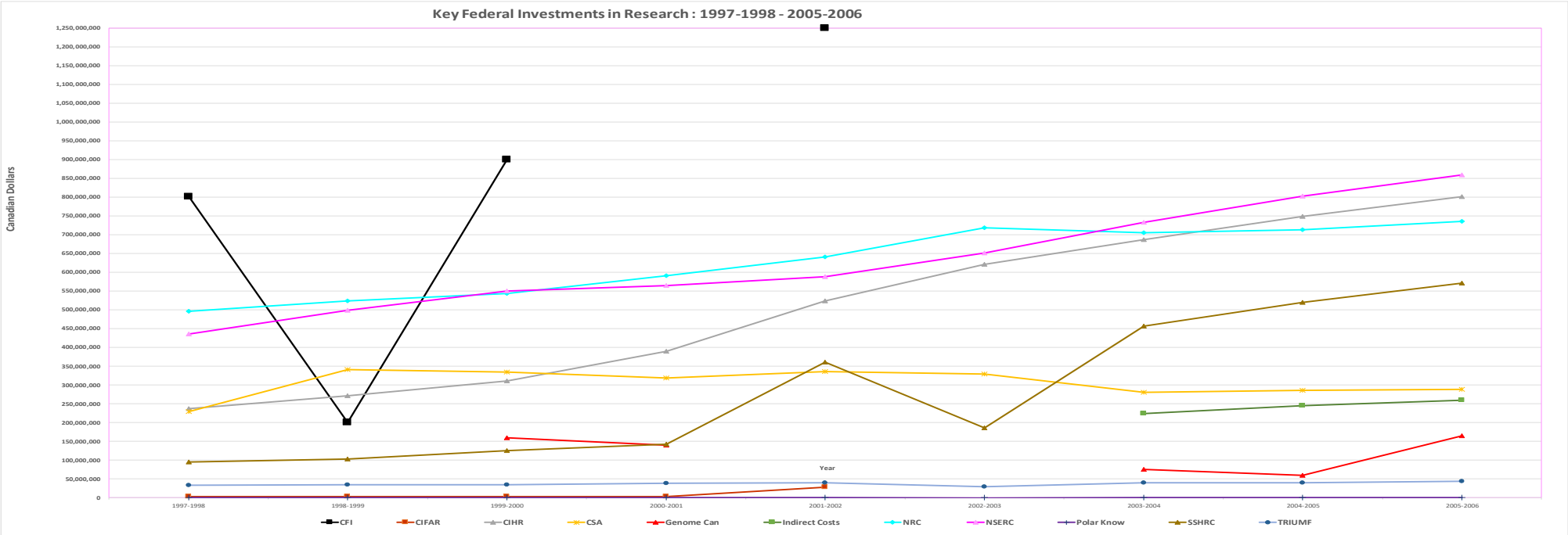
MSTI Variables	Indirect government support through R&D tax incentives as a Percentage of BERD																				
Measure	As a Percentage of BERD																				
Year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Country																					
Canada	16.99	16.71	17.67	17.03	19.87	17.39	17.15	19.72	19.77	19.67	19.40	18.59	20.42	20.12	14.34	14.48	14.34	15.09	14.64		
Hungary					41.62	38.14	29.25	34.11	34.78	25.61	24.27	23.50	14.34	14.08	16.23	15.07	10.26	6.73	5.04		
United States	3.54	3.15	2.92	2.73	2.67	2.81	2.95	3.07	2.86	2.75	3.05	3.14	3.59	3.50	3.69	4.03	3.97				
China (People's Republic of)										4.36	3.44	3.84	3.81	3.68	3.77	4.13	4.03	4.17			
EU (28)*																					
OECD Total	2.91	2.76	2.70	2.72	3.40	3.66	3.80	4.03	4.03	4.18	4.50	4.45	4.87	5.11	5.37	5.68	5.69	5.97	5.84		
Top 5 countries	9.49	14.77	12.08	13.08	17.28	15.48	19.03	16.55	18.51	16.89	15.70	19.42	24.17	18.58	18.44	18.61	15.76	15.37	13.02		



Source: OECD Main Science and Technology Indicators (https://stats.oecd.org/Index.aspx?DataSetCode=MSTI_PUB#)
Top 5 countries: Hungary, Colombia, Canada, Portugal, France. Russia is excluded from the top 5 as it is missing 10 data points.
Data extracted on 14 May 2021 17:24 UTC (GMT) from OECD.Stat

Figure 9 Key Federal Investments in Research: 1997-1998 - 2005-2006

Measure	Key Federal Investments in Research : 1997-1998 - 2005-2006									
Unit	Canadian Dollars									
Year	1997-1998	1998-1999	1999-2000	2000-2001	2001-2002	2002-2003	2003-2004	2004-2005	2005-2006	TOTAL
CFI	800,964,384	200,000,000	900,000,000		1,250,000,000					3,150,964,384
CIFAR	3,500,000	3,500,000	3,500,000	3,490,000	28,490,000					42,480,000
CIHR	237,325,430	271,367,123	310,504,413	390,035,089	524,146,861	621,424,625	686,217,269	747,972,258	800,875,508	4,589,868,576
CSA	228,963,883	341,289,855	334,593,606	318,790,525	336,131,887	328,910,429	280,652,664	286,046,633	288,024,944	2,743,404,426
Genome Can			160,000,000	140,000,000			75,000,000	60,000,000	165,000,000	600,000,000
Indirect Costs							224,182,351	244,518,326	259,046,938	727,747,615
NRC	495,598,424	523,992,442	543,520,583	591,177,394	641,247,699	718,876,736	705,485,131	712,637,634	734,862,632	5,667,398,675
NSERC	435,448,221	498,492,255	549,848,434	564,952,867	587,559,453	651,293,221	732,579,465	803,049,577	859,423,209	5,682,646,702
Polar Know	968,262	1,020,325	956,347	980,080	992,315	931,999	971,854	977,041	955,194	8,753,417
SSHRC	94,719,041	102,497,255	125,824,863	143,039,265	360,021,221	186,212,605	457,112,093	519,409,937	571,323,242	2,560,159,522
TRIUMF	32,954,000	35,000,000	34,318,000	39,000,000	40,000,000	29,000,000	40,000,000	40,000,000	44,000,000	334,272,000
TOTALS	2,330,441,645	1,977,159,255	2,963,066,246	2,191,465,220	3,768,589,436	2,536,649,615	3,202,200,827	3,414,611,406	3,723,511,667	26,107,695,317

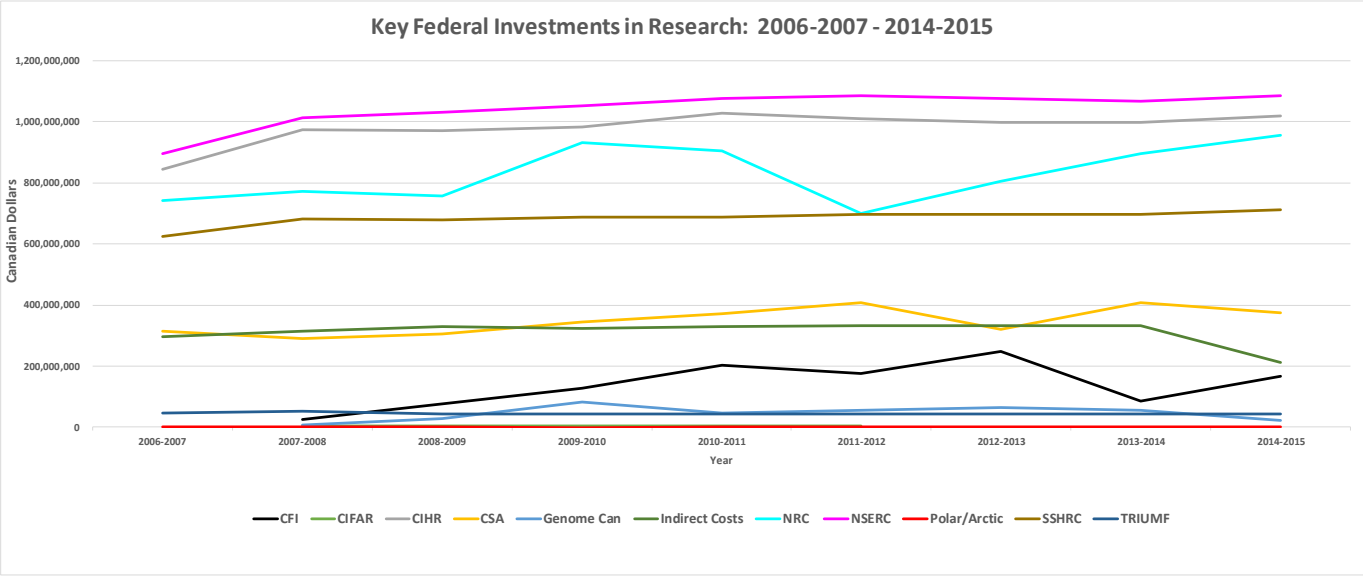


CFI
CIFAR
CIHR
CSA
Genome Can
Indirect Costs
NSERC
Polar/Arctic*
SSHRC
TRIUMF
* Polar Arctic.
Source:

Canada Foundation for Innovation
Canadian Institute for Advanced Research
Canadian Institutes of Health Research
Canadian Space Agency
Genome Canada
Indirect Costs of Research
National Science and Engineering Research Council
Canadian High Arctic Research Station - since 2015-2016; previously known as the Canadian Polar Commission
Social Sciences and Humanities Research Council
Canada's Particle Accelerator Centre
In 2015-2016 the Canadian Polar Commission was transferred to the Canadian High Arctic Research Station. The number provided for that is the line for the High Arctic Research Station, Public Accounts 2015-2016, 11-14.
Public Accounts 1997-1998 - 2019-2020

Figure 10 Key Federal Investments in Research: 2006-2007 - 2014-2015

Measure	Key Federal Investments in Research: 2006-2007 - 2014-2015									
Unit	Canadian Dollars									
Year	2006-2007	2007-2008	2008-2009	2009-2010	2010-2011	2011-2012	2012-2013	2013-2014	2014-2015	TOTAL
CFI		26,700,000	77,700,000	128,600,000	203,000,000	177,000,000	249,000,000	85,300,000	168,200,000	1,115,500,000
CIFAR		5,000,000	5,000,000	5,000,000	5,000,000	5,000,000		5,000,000		30,000,000
CIHR	843,269,265	974,070,783	969,415,324	983,733,066	1,026,871,276	1,009,091,392	997,052,742	997,971,988	1,017,279,382	8,818,755,218
CSA	314,415,704	291,660,915	305,979,432	344,573,326	372,835,809	409,135,515	320,245,415	408,715,240	376,090,938	3,143,652,294
Genome Can		6,700,000	29,500,000	82,900,000	46,900,000	55,100,000	64,000,000	56,900,000	22,700,000	364,700,000
Indirect Costs	297,847,037	313,260,437	328,251,990	324,608,188	329,330,000	331,674,642	331,638,911	331,624,374	212,403,000	2,800,638,579
NRC	742,083,857	771,150,040	757,929,665	931,013,760	903,298,393	698,503,582	804,804,912	894,418,206	955,704,916	7,458,907,331
NSERC	895,422,774	1,012,459,934	1,029,809,172	1,051,247,282	1,075,943,914	1,085,737,592	1,075,981,272	1,066,679,030	1,085,445,456	9,378,726,426
Polar/Arctic	1,003,996	980,345	996,614	955,688	1,016,646	1,263,210	1,317,735	2,355,267	2,355,267	12,244,768
SSHRC	625,248,530	681,046,571	679,546,796	686,433,454	689,095,926	697,853,661	696,432,583	695,719,438	712,926,648	6,164,303,607
TRIUMF	45,500,000	51,500,000	43,500,000	44,000,000	45,000,000	44,000,000	44,000,000	44,300,000	45,000,000	406,800,000
TOTAL	3,764,791,163	4,134,529,025	4,227,628,993	4,583,064,764	4,698,291,964	4,514,359,594	4,584,473,570	4,588,983,543	4,598,105,607	39,694,228,223



CFI

CIFAR

CIHR

CSA

Genome Can

Indirect Costs

NSERC

Polar/Arctic*

SSHRC

TRIUMF

* Polar Arctic.

Source:

Canada Foundation for Innovation

Canadian Institute for Advanced Research

Canadian Institutes of Health Research

Canadian Space Agency

Genome Canada

Indirect Costs of Research

National Science and Engineering Research Council

Canadian High Arctic Research Station - since 2015-2016; previously known as the Canadian Polar Commission

Social Sciences and Humanities Research Council

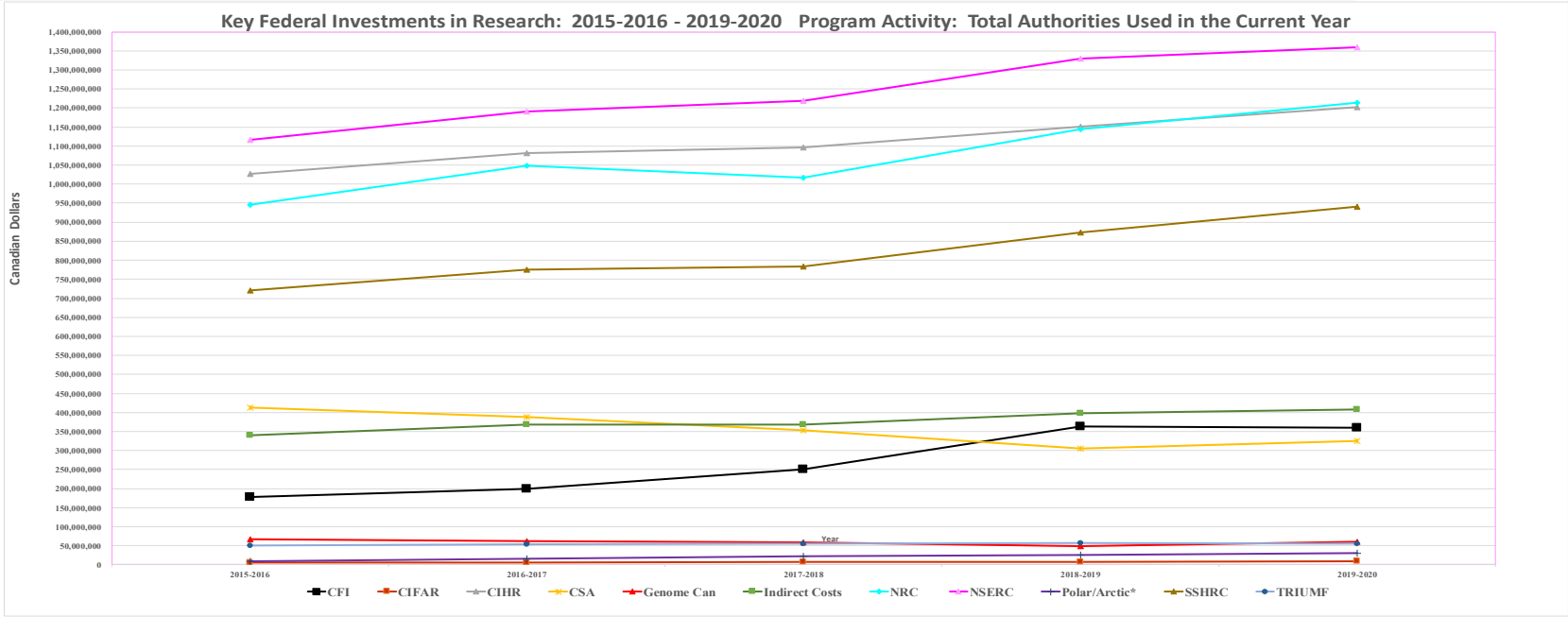
Canada's Particle Accelerator Centre

In 2015-2016 the Canadian Polar Commission was transferred to the Canadian High Arctic Research Station. The number provided for that is the line for the High Arctic Research Station, Public Accounts 2015-2016, 11-14.

Public Accounts 1997-1998 - 2019-2020

Figure 11 Key Federal Investments in Research: 2014-2015 - 2019-2020

Measure	Key Federal Investments in Research: 2015-2016 - 2019-2020 Program Activity: Total Authorities Used in the Current Year					
Unit	Canadian Dollars					
Year	2015-2016	2016-2017	2017-2018	2018-2019	2019-2020	TOTAL
CFI	177,100,000	198,550,000	250,900,000	362,700,000	359,300,000	1,348,550,000
CIFAR	5,000,000	5,000,000	7,500,000	7,000,000	8,500,000	33,000,000
CIHR	1,026,378,153	1,081,330,344	1,097,161,185	1,150,927,127	1,202,050,854	5,557,847,663
CSA	412,799,058	388,298,278	353,457,987	305,745,600	324,436,091	1,784,737,014
Genome Can	67,400,000	61,900,000	59,100,000	48,400,000	60,400,000	297,200,000
Indirect Costs	340,666,298	368,679,893	368,706,690	397,648,742	407,067,651	1,882,769,274
NSERC	945,077,595	1,048,740,465	1,016,523,437	1,145,203,852	1,214,601,865	5,370,147,214
NSERC	1,115,653,194	1,191,260,893	1,219,141,888	1,330,149,905	1,359,365,352	6,215,571,232
Polar/Arctic*	8,286,711	15,866,478	21,528,127	24,656,671	30,577,492	100,915,479
SSHRC	720,292,139	775,954,047	783,979,328	873,129,828	940,757,288	4,094,112,630
TRIUMF	50,832,800	53,672,800	54,572,800	57,280,490	55,162,800	271,521,690
TOTALS	4,869,485,948	5,189,253,198	5,232,571,442	5,702,842,215	5,962,219,393	26,956,372,196

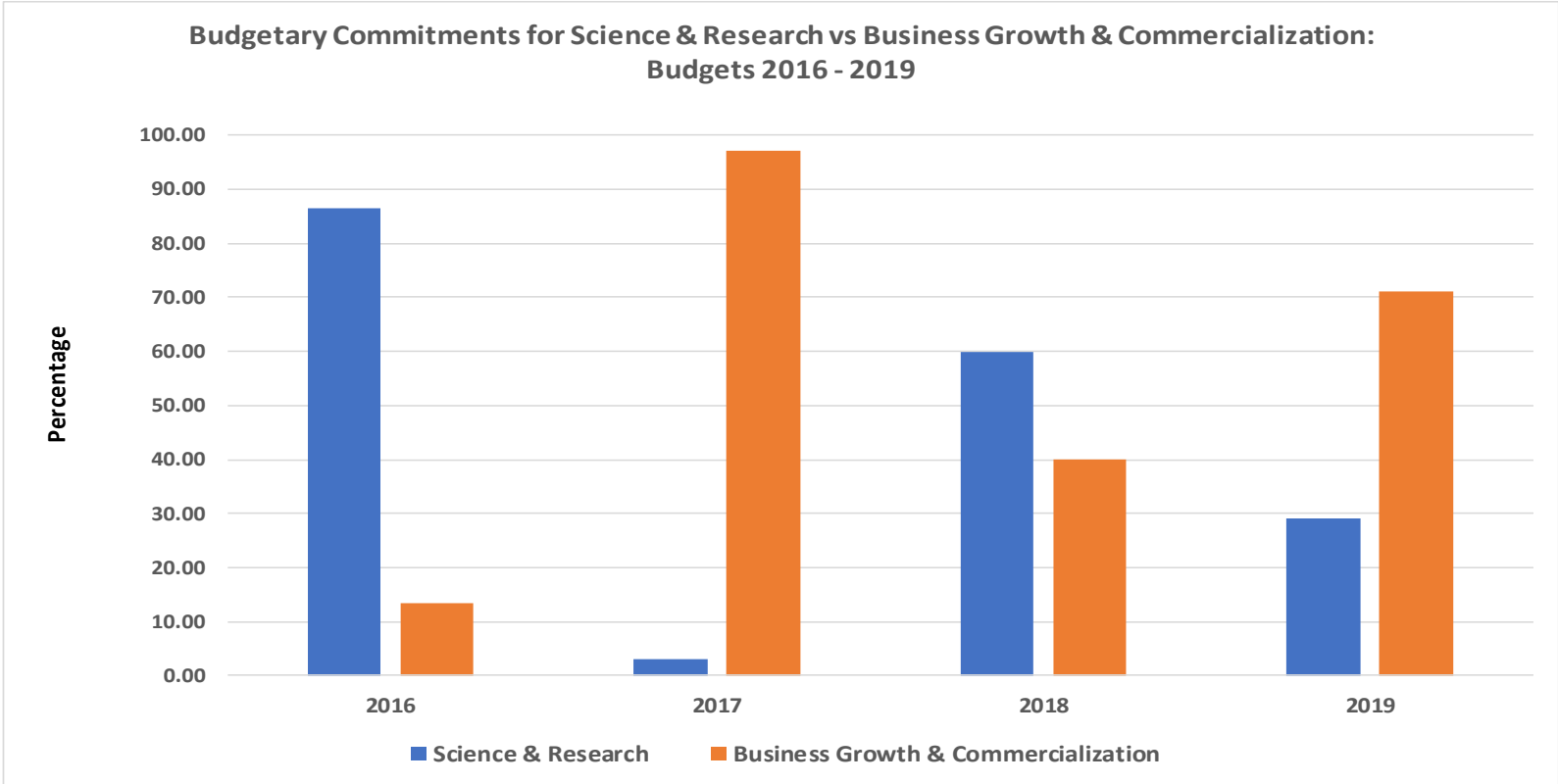


CFI
CIFAR
CIHR
CSA
Genome Can
Indirect Costs
NSERC
Polar/Arctic*
SSHRC
TRIUMF
* Polar/ Arctic
Source:

Canada Foundation for Innovation
Canadian Institute for Advanced Research
Canadian Institutes of Health Research
Canadian Space Agency
Genome Canada
Indirect Costs of Research
National Science and Engineering Research Council
Canadian High Arctic Research Station - since 2015-2016; previously known as the Canadian Polar Commission
Social Sciences and Humanities Research Council
Canada's Particle Accelerator Centre
In 2015-2016 the Canadian Polar Commission was transferred to the Canadian High Arctic Research Station.
The number provided for that is the line for the High Arctic Research Station, Public Accounts 2015-2016, 11-14.
Public Accounts 2015-2016 - 2019-2020

Figure 12 Budgetary Commitments for Science & Research vs Business Growth & Commercialization: Budgets 2016 - 2019 - Percentage

Measure	Budgetary Commitments for Science and Research vs Business Growth & Commercialization: Budgets 2016 - 2019				
Unit	Percentage*				
	Budget Year	2016	2017	2018	2019
	Science & Research	86.51	2.98	60.00	29.01
	Business Growth & Commercialization	13.49	97.02	40.00	70.99



* Percentage - Author's calculations

Source: Finance Canada 2016, Table 2.2, 130-131

Finance Canada 2017, Table 1.3, 110-111

Finance Canada 2018a, Table 2.1 - 2.3, 122-123

Finance Canada 2019, Parts 5 & 6, 125-126

For methodology used, see Methodology Notes - Annex A-5. See Figure 13 for aggregate funding in millions of dollars.

Figure 13 Budgetary Commitments for Science & Research vs Business Growth & Commercialization: Budget 2016 – 2019 - Millions

Measure	Budgetary Commitments for Science & Research vs Business Growth & Commercialization: Budgets 2016 - 2019				
Unit	millions of dollars *				
	Budget Year	2016	2017	2018	2019
	Science & Research	2,245	89	3,861	459
	Business Growth & Commercialization	350	2,899	2,574	1,123
	Total	2,595	2,988	6,435	1,582

* Author's calculations of the breakdowns

Source: Finance Canada 2016, Table 2.2, 130-131

Finance Canada 2017, Table 1.3, 110-111

Finance Canada 2018a, Table 2.1 - 2.3, 122-123

Finance Canada 2019, Parts 5 & 6, 125-126

For methodology used, see Methodology Notes, Annex A-5.

Methodology Notes

Budgetary Commitments for Science and Research vs Business Growth and Commercialization: Budgets 2016 – 2019 – Figures 12 and 13

Budget 2016

See Finance Canada 2016, Table 2.2, 130-131.

The category of Science and Research includes the initiatives listed in *Ibid.*, Table 2.2 under “Strengthening Science and Research” with the exception noted below.

Note that the total for Science and Research -- and thus the 86.51 per cent in Figure 12 -- is based on excluding the \$16 million for the Centre for Drug Research and Development which, although appearing on the science side of the Budget ledger, is profiled as “Commercializing Canada’s World-Class Health Discoveries.”

The category of Business Growth and Commercialization includes the initiatives in *Ibid.*, Table 2.2 under “Supporting Business Growth and Innovation” plus the exception noted above.

Budget 2017

See Finance Canada 2017, Table 1.3, 110-111.

The category of Science and Research includes the initiatives in *Ibid.*, Table 1.3 under “A Nation of Innovators” – specifically for Stem Cell Research, Space Exploration, Quantum Information, Social Innovation, International Research Collaborations and Strengthening Science in Government, all of which total \$89 million.

The category of Business Growth and Commercialization includes the initiatives listed in *Ibid.*, Table 1.3 under “A Nation of Innovators” as well as “Canada’s Innovation Economy: Clean Technology, Digital Industries and Agri-Food” – with the exclusion of the initiatives noted above.

Budget 2018

See Finance Canada 2018a, Table 2.1 – 2.3, 122-123.

The category of Science and Research includes both the total initiatives for “Investing in Canadian Scientists and Researchers” found in *Ibid.*, Table 2.1 as well as the total for “A Stronger and More Collaborative Federal Science” listed in Table 2.2.

The category of Business Growth and Commercialization includes the initiatives listed under “Innovation and Skills Plan – A More Client-Focused Federal Partner for Business” found in *Ibid.*, Table 2.3.

Budget 2019

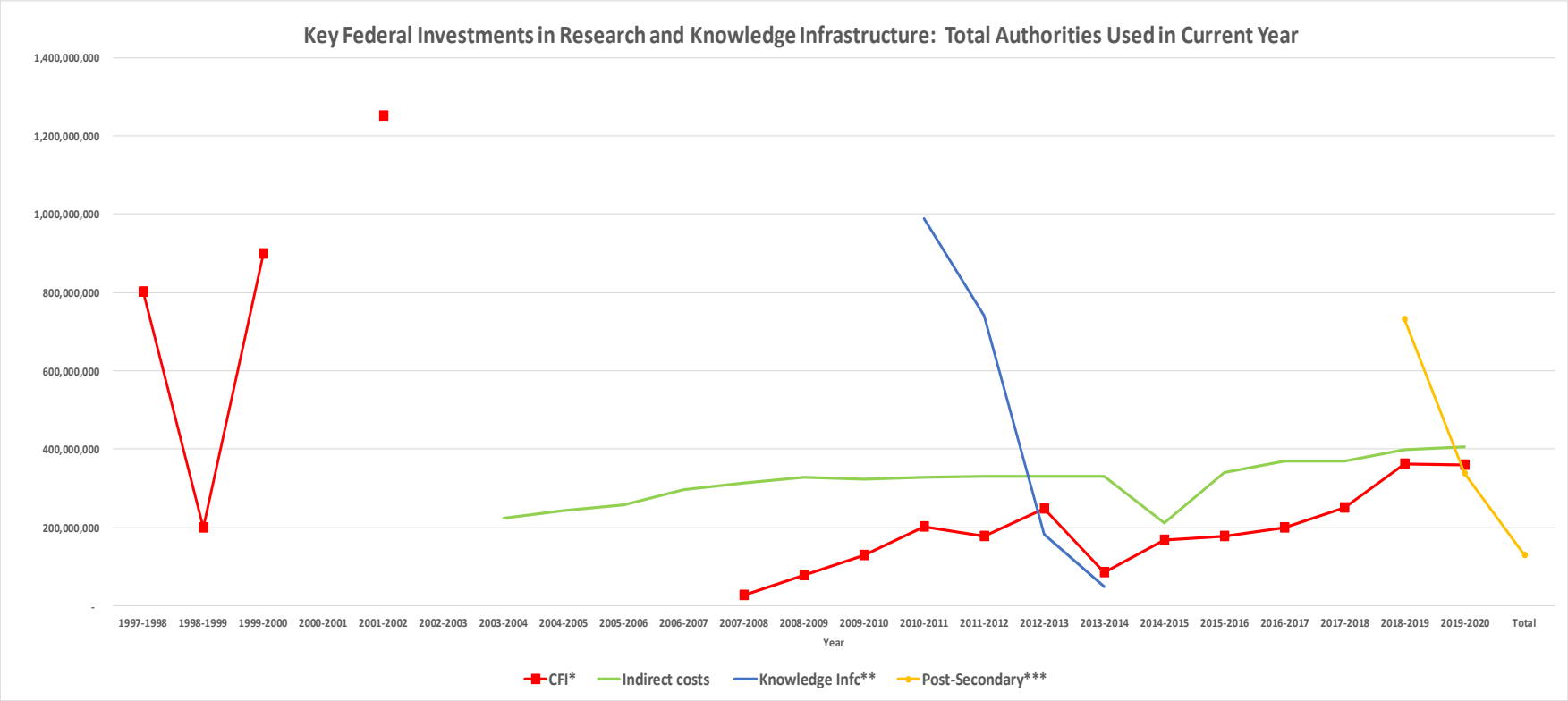
See Finance Canada 2019, Parts 5 and 6, 125-126.

The category of Science and Research includes the initiatives listed in *Ibid.*, Part 6 under “Building Research Excellence in Canada.”

The category of Business Growth and Commercialization includes the initiatives listed in *Ibid.*, Part 5 under “Building a Nation of Innovators.”

Figure 14 Key Federal Investments in Research and Knowledge Infrastructure

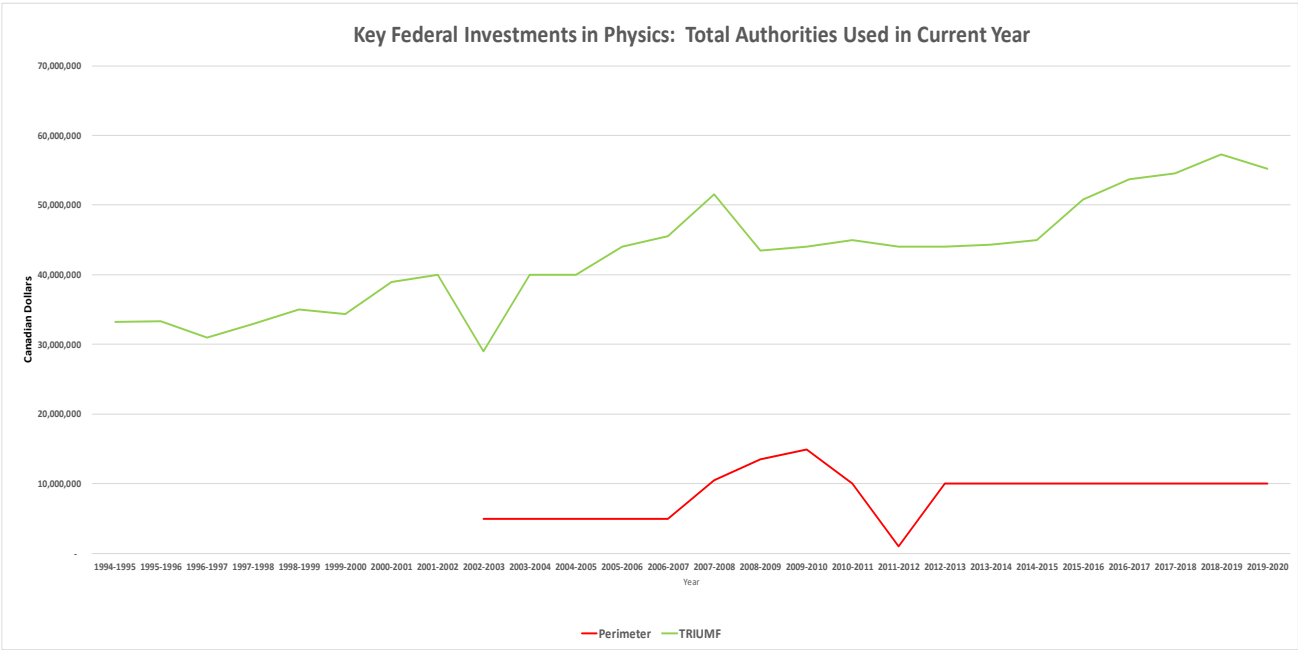
Measure	Key Federal Investments in Research and Knowledge Infrastructure: Total Authorities Used in Current Year																							
Unit	In Canadian Dollars																							
Year	1997-1998	1998-1999	1999-2000	2000-2001	2001-2002	2002-2003	2003-2004	2004-2005	2005-2006	2006-2007	2007-2008	2008-2009	2009-2010	2010-2011	2011-2012	2012-2013	2013-2014	2014-2015	2015-2016	2016-2017	2017-2018	2018-2019	2019-2020	Total
CFI*	800,964,384	200,000,000	900,000,000		1,250,000,000						26,700,000	77,700,000	128,600,000	203,000,000	177,000,000	249,000,000	85,300,000	168,200,000	177,100,000	198,550,000	250,900,000	362,700,000	359,300,000	5,615,014,384
Indirect costs							224,182,351	244,518,326	259,046,938	297,847,037	313,260,437	328,251,990	324,608,188	329,330,000	331,674,642	331,638,911	331,624,374	212,403,000	340,666,298	368,679,893	368,706,690	397,648,742	407,067,651	5,411,155,468
Knowledge Inf**													987,900,000	741,651,948	182,771,499	49,912,858								1,962,236,305
Post-Secondary***																					731,759,904	337870606	128,216,653	1,197,847,163
TOTAL	800,964,384	200,000,000	900,000,000	-	1,250,000,000	-	224,182,351	244,518,326	259,046,938	297,847,037	339,960,437	405,951,990	1,441,108,188	1,273,981,948	691,446,141	630,551,769	416,924,374	380,603,000	517,766,298	567,229,893	1,351,366,594	1,098,219,348	894,584,304	14,186,253,320



CFI: Canada Foundation for Innovation*
Indirect Costs: Indirect Costs of Research
Knowledge Inf: Knowledge Infrastructure Program**
Post-Secondary : Post-Secondary Institutions Strategic Investment Fund ***
Source: Public Accounts: 1997-1998 - 2019 - 2020

Figure 15 Key Federal Investments in Physics

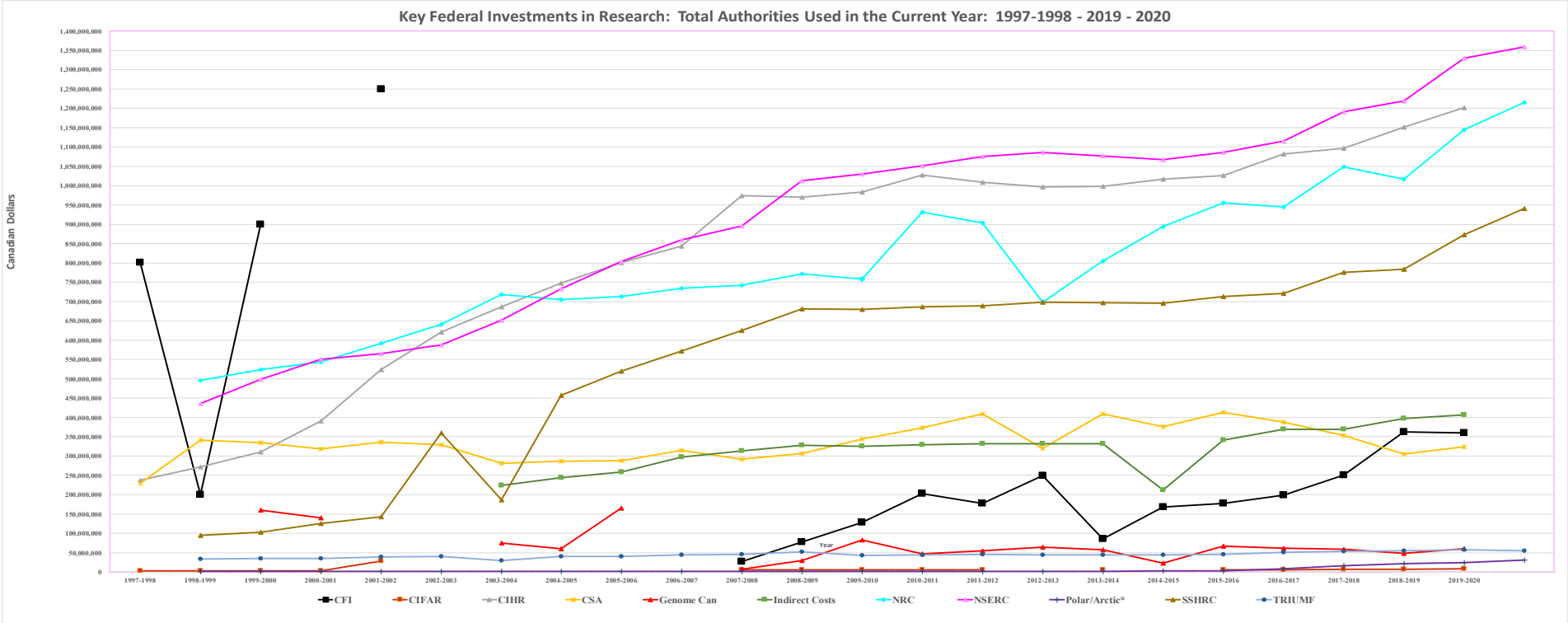
Measure	Key Federal Investments in Physics : Total Authorities Used in Current Year																										
Unit	In Canadian Dollars																										
Year	1994-1995	1995-1996	1996-1997	1997-1998	1998-1999	1999-2000	2000-2001	2001-2002	2002-2003	2003-2004	2004-2005	2005-2006	2006-2007	2007-2008	2008-2009	2009-2010	2010-2011	2011-2012	2012-2013	2013-2014	2014-2015	2015-2016	2016-2017	2017-2018	2018-2019	2019-2020	Total
Perimeter									5,000,000	5,000,000	5,000,000	5,000,000	5,000,000	10,543,000	13,495,600	14,951,000	10,000,000	1,010,400	10,000,000	10,000,000	10,000,000	10,000,000	10,000,000	10,000,000	10,000,000	10,000,000	155,000,000
TRIUMF	33,250,000	33,318,000	31,000,000	32,954,000	35,000,000	34,318,000	39,000,000	40,000,000	29,000,000	40,000,000	40,000,000	44,000,000	45,500,000	51,500,000	43,500,000	44,000,000	45,000,000	44,000,000	44,000,000	44,300,000	45,000,000	50,832,800	53,672,800	54,572,800	57,280,490	55,162,800	1,110,161,690
TOTAL	33,250,000	33,318,000	31,000,000	32,954,000	35,000,000	34,318,000	39,000,000	40,000,000	34,000,000	45,000,000	45,000,000	49,000,000	50,500,000	62,043,000	56,995,600	58,951,000	55,000,000	45,010,400	54,000,000	54,300,000	55,000,000	60,832,800	63,672,800	64,572,800	67,280,490	65,162,800	1,265,161,690



Perimeter Perimeter Institute for Theoretical Physics
TRIUMF 1994-1995 - 2010 - 2011 University of Alberta, University of British Columbia, Simon Fraser University and University of Victoria in support of the TRIUMF project
TRIUMF 2011-2012 - 2019-2020 Canada's National Laboratory for Particle and Nuclear Physics
Source: Public Accounts 1994-1995 - 2019- 2020

Figure 16 Key Federal Investments in Research: 1997-1998 – 2019-2020

Measure Unit	Key Federal Investments in Research: Total Authorities Used in the Current Year: 1997-1998 - 2019 - 2020																							
	Canadian Dollars																							
Year	1997-1998	1998-1999	1999-2000	2000-2001	2001-2002	2002-2003	2003-2004	2004-2005	2005-2006	2006-2007	2007-2008	2008-2009	2009-2010	2010-2011	2011-2012	2012-2013	2013-2014	2014-2015	2015-2016	2016-2017	2017-2018	2018-2019	2019-2020	TOTAL
CFI	800,964,384	200,000,000	900,000,000		1,250,000,000						26,700,000	77,700,000	128,600,000	203,000,000	177,000,000	249,000,000	85,300,000	168,200,000	177,100,000	198,550,000	250,900,000	362,700,000	359,300,000	5,615,014,384
CIFAR	3,500,000	3,500,000	3,500,000	3,400,000	28,490,000						5,000,000	5,000,000	5,000,000	5,000,000	5,000,000	5,000,000	5,000,000	5,000,000	5,000,000	7,500,000	7,000,000	8,500,000	105,400,000	
CIHR	237,325,430	271,367,133	310,594,413	390,035,000	524,146,861	621,424,625	686,217,269	747,972,258	800,875,508	843,269,265	974,070,763	969,415,524	983,733,066	1,026,871,276	1,000,001,392	997,052,742	997,971,988	1,017,279,382	1,026,378,153	1,081,330,344	1,097,161,185	1,150,921,127	1,203,050,854	18,966,471,457
CSA	228,063,883	341,289,855	334,593,606	318,790,525	336,131,887	328,910,429	280,652,664	286,046,633	288,024,944	314,415,704	291,660,915	305,979,432	344,573,326	372,835,809	409,135,515	320,245,415	408,715,240	376,090,938	412,799,058	388,298,278	353,457,987	305,745,600	324,436,091	7,671,793,734
Genome Can			160,000,000	140,000,000			75,000,000	60,000,000	165,000,000	6,000,000	6,000,000	29,500,000	82,900,000	46,900,000	55,100,000	64,000,000	56,900,000	22,700,000	67,400,000	61,900,000	59,100,000	48,400,000	60,400,000	1,261,900,000
Indirect Costs						224,182,351	244,518,326	239,046,938	297,847,037	313,200,437	328,251,190	324,608,188	329,330,000	331,674,642	331,638,911	331,624,374	212,403,000	340,666,298	368,679,893	368,706,690	397,648,742	407,967,651	5,411,155,648	
NRC	495,598,424	523,992,442	543,520,583	591,177,394	641,247,699	718,876,736	705,485,131	712,637,634	734,862,632	742,083,857	771,150,640	757,929,665	931,013,760	903,298,393	698,503,582	804,804,912	894,418,206	955,704,916	945,077,595	1,048,740,465	1,016,523,437	1,145,203,852	1,214,601,865	18,496,453,220
NSERC	435,448,221	498,492,255	549,848,434	564,952,867	587,559,453	651,293,221	732,579,465	803,049,577	859,423,209	895,422,774	1,012,459,934	1,029,809,172	1,051,247,282	1,075,943,914	1,085,737,592	1,075,981,272	1,066,679,030	1,085,445,456	1,115,653,194	1,191,260,893	1,219,141,888	1,330,149,905	1,359,365,352	21,276,944,360
Polar/Arctic*	968,262	956,247	1,620,325	980,000	992,315	931,999	971,854	977,041	955,194	1,003,396	980,345	996,614	955,688	1,016,646	1,263,210	1,317,725	2,355,267	2,355,267	8,286,711	15,866,478	21,528,127	24,656,671	30,577,492	121,913,664
SSHRC	947,119,044	102,497,255	125,854,063	143,039,265	360,021,221	186,212,605	457,112,093	519,409,937	571,323,542	625,285,539	681,046,571	679,546,796	686,423,454	689,005,926	697,853,661	696,432,583	695,719,438	712,926,648	720,292,139	775,594,047	783,979,328	873,329,828	940,757,280	12,818,575,759
TRIUMF	32,954,000	35,000,000	34,318,000	39,000,000	40,000,000	29,000,000	40,000,000	40,000,000	45,000,000	51,500,000	43,500,000	44,000,000	45,000,000	44,000,000	44,000,000	44,000,000	44,000,000	45,000,000	50,832,800	53,672,800	57,280,490	55,162,800	1,012,593,690	
TOTALS	2,330,441,645	1,977,095,277	2,963,130,224	2,191,465,220	3,768,589,436	2,536,649,615	3,202,200,827	3,414,611,406	3,723,511,667	3,764,791,163	4,134,529,025	4,227,628,993	4,583,064,764	4,698,291,964	4,514,359,594	4,584,473,570	4,588,983,543	4,598,105,607	4,869,485,948	5,189,253,198	5,232,571,442	5,702,842,215	5,962,219,393	92,758,295,736



CFI Canada Foundation for Innovation
CIFAR Canadian Institute for Advanced Research
CIHR Canadian Institutes of Health Research
CSA Canadian Space Agency
Genome Can Genome Canada
Indirect Costs Indirect Costs of Research
NSERC National Science and Engineering Research Council
Polar/Arctic* Canadian High Arctic Research Station - since 2015-2016; previously known as the Canadian Polar Commission
SSHRC Social Sciences and Humanities Research Council
TRIUMF Canada's Particle Accelerator Centre
* Polar Arctic. In 2015-2016 the Canadian Polar Commission was transferred to the Canadian High Arctic Research Station.
The number provided for that year is the line item for the Research Station, Public Accounts, 2015-2016, 11-14.
Source: Public Accounts 1997-1998 - 2019-2020

Chapter 6

Collaborative Networks: Thickening the “Triple Helix” of Innovation

Introduction

Central to the Developmental Network State Framework is the brokering role the state may play in enabling the strategic linkages and alliances that can span the “triple helix”¹ of industry, government and academe. Indeed, this is the critical third pillar -- policy durability, targeted resourcing and venture capital being the other key components – which rests at the heart of this research inquiry. Testing the comparative leverage of DNS in this regard, this chapter centres on the catalyzing impact federal policy and actions may have, and had, on the Canadian innovation ecosystem and the capacity to shape not just (à la Block (2011, 22) a “public space” advantageous to triadic linkages)² but a deepened and “thickened” set of networks that propels and breeds success. As such this chapter turns on the question laid out at the beginning of this endeavour: “To what extent are federal policy initiatives focused on thickening clusters of innovation activity across, industry, academe and government, including government laboratories, strengthening linkages that can incubate ideas and lead to commercialization?”

The chapter initially unfolds with some reflections on the theoretical prowess of the DNS on this collaboration issue. It then moves to take four methodological slices into this issue. First, it lays out the degree to which the federal government has established such collaboration, not just as rhetorical mantra but clear and consistent priorities that have been perpetuated over the last two decades – in other words, to what extent have priorities around network thickening also been subject to policy durability? Secondly, it traces the extent to which federal actions

¹ The term is employed by Etzkowitz (1998, 2003).

² Block indicates he is drawing from Lester and Piore (2004) on this. The specific reference is to “public spaces.”

have transcended agenda-setting and moved to implementation – specifically by funding network initiatives over the 2000-2001 to 2017-18 period. In this regard, the tools and organizational entities that have been the vectors for that implementation will be laid out.

Thirdly, the chapter takes a long hard look at the richness (or lack thereof) of statistical indicators of collaboration in Canada, drawing on both international and domestic data and laying bare the answers provided and questions left. In this context, an array of metrics will be used as noted in the Research Methodology chapter, including patents, bibliometrics, joint projects and cooperation, import of partner to the innovation process and joint funding initiatives. Fourthly, in an effort to not only round out existing sources of data but fill some of the important gaps, the research reports on the 54 in-depth interviews that were conducted with innovation leaders across the country, assessing in turn questions of critical mass, the Superclusters and greatest challenges for Canadian innovation. These interviews are particularly enlightening as they speak to the range of factors influencing network collaboration in Canada, including federal initiatives to be sure but structural and even cultural aspects of the country's innovation ecosystem as well. The chapter concludes with reflections on the alignment between federal policy intent and impact, the adequacy of the federal measures taken to date and the comparative leverage DNS offers in this regard.

DNS: Theorizing Networks

Certainly, the DNS Framework offers important conceptual tools at a meso-level of analysis for dealing with innovation. As has been noted, the Framework centres on the dynamics of the innovation vortex and how an inclusive and densely compacted network of institutional actors – economic, academic and governmental -- may incubate and transform research into new products and processes that are market-ready. So too does it focus on the manner in which these

networks can accelerate key disruptive and transformational technologies – i.e., semiconductors, genomics, nanotechnologies and of course Artificial Intelligence. Characterized by flexibility, “experimentation” and essentially a “decentralized” web of collaborative relations,³ these networks can concentrate resources, integrate local knowledge, accelerate technological development and respond rapidly to the intensifying pace of global product and process innovation cycles. And, most critical to this schema is the capacity of the state – of government initiatives -- to enable and support these nodes of innovation, linking different groups and negotiating alliances among them.

Yet, as the theoretical chapter had intimated, the concept of state as broker is still rather thinly developed in DNS for our purposes – and is so on two fronts. It needs to be enriched with the notion of state policy aimed at definitively thickening networks of entrepreneurs, scientists, engineers and government researchers that synergize innovation; it needs to be enriched not only with brokering but purposefully nurturing networks into fulsome entities that integrate the various actors in the ecosystem and deepen their collaboration. Moreover, it needs to be consistently tested, pursuing whether such policy actions have demonstrable change. As such, the level of density or shallowness in collaboration that exists in the Canadian case – across a range of consistent metrics and calibrated over time -- are important tools by which to gauge such developments. So too must the subjective perceptions of senior innovation leaders across the country be taken into account. Armed then with these instruments, the comparative suasion of the Developmental Network State Framework can be more fully examined, assessed and understood.

³ See in particular Block (2011, 15-25); also on this Whitford and Schrank (2011).

Networks and Priorities

Collaborating for “Excellence”

Percolating throughout senior policy circles at the federal level in the late nineties and early 2000s was of course Porter’s work on competitiveness and clusters (1990), as well as the OECD (1999) engagement with a cluster approach. And while, among some in those circles, there was a critical eye to the notion of clusters as an all or nothing solution (I47),⁴ nevertheless the Chrétien administration whole-heartedly did embrace the innovation agenda and collaboration and “internationally competitive clusters” became significant elements among the priorities being established. Thus, as the government indicated in their primary roadmap for innovation, *Achieving Excellence* (IC, 2001b), it was not just a matter of exhortation for all components of the national innovation system to increase investment in R&D – industry, academe and government alike – given Canada’s “weak performance” (*Ibid.*, 19) but also the need for these entities to work across this system in a more integrated way.

True, the government viewed the innovation agenda primarily through the lens of “knowledge performance,” “skills” and a stable, healthy “innovation environment.” True, as well, on the partnership front, Canada was leading against its main international competitors in terms of industry funding of Higher Educational investment in R&D (HERD) (*Ibid.*, 41) -- a trend that has remained remarkably consistent for the country over the years, even if Canada has not always led in OECD terms. Nonetheless, collaboration resonated strongly at the time throughout GOC priorities and the actions that were to be taken.

For its part, the private sector needed to form “strategic alliances” (*Ibid.*, 48; also 19) that went well beyond traditional collaborations in the arena of sales and marketing and forge the

⁴ To preserve anonymity, the nomenclature used to refer to the in-depth interviews conducted with innovation leaders is I followed by the number that has been assigned to that participant’s interview.

partnerships across the full spectrum of commercialization and technology development (*Ibid.*, 48-49).⁵ Universities were to up their game both with respect to linkages with industry and with respect to commercialization. Further, reckoning with the understanding that “innovation thrives in clusters” (*Ibid.*, 21), Canada was to set its sights on establishing ten “internationally recognized technology clusters” (*Ibid.*, 72-77). And, interestingly, in contrast with the later Supercluster initiative that would come with Budget 2017, these initiatives were to reach out beyond the traditional metropolises – “large urban centres” – and penetrate into smaller communities where innovation also thrived. The issue of unequal access to infrastructure – bricks and mortar as well as telecommunications and broadband -- was also to be duly leveraged to enable that growth and development (Finance Canada 2001). All of this was to be further cemented through the consultations and dialogue with provinces and territories that the federal government held in 2001 as well as through the larger Innovation Summit that both Industry Canada and Human Resources Development Canada were charged with leading. For the federal government the National Research Council was to especially lead the charge on the cluster front – engaging in numerous cluster initiatives to further catalyze change (*Ibid.*, 46; also <https://nrc.canada.ca/en/stories/arthur-carty-nrcs-entrepreneurial-scientist-balanced-cluster-development-commercialization>). Critical as well, as indicated in Budget 1999, the Canadian Institutes of Health Research (CIHR) were to be launched, further contributing to networking in key health research areas and “embody[ing] an innovative and integrative approach” (Finance 2001, 115). By Budget 2001, the CIHR was to encompass a commercialization component as well (*Ibid.*, 115).

⁵ Interestingly, this plea has remained relatively unheeded through the last two decades as Statistics Canada data discussed later in this chapter has indicated. International collaboration among firms – with their parent, and subsidiaries, as well as suppliers and clients as opposed to universities or government labs – has remained paramount. See below “Collaboration: A Patchy Landscape and Troubling Trends.”

There were gaps to be sure in this agenda. There appeared to some comfort in the idea that large firms were collaborating fairly ably (based on a Conference Board report) and the problem principally lay with small and medium-sized enterprises. Moreover, as was seen in Chapter Four on “Government Priority-Setting,” here too the number of priorities for clusters mushroomed quite extensively. Clusters were to include twelve different areas from bio-pharmaceuticals, to nanotechnology to fuel cell technology” (IC 2001b, 76),⁶ the weight of this falling primarily on NRC to shoulder. So too was the agenda of the federal S&T departments and agencies to remain relatively narrow, focusing on a “multistakeholder” model but confined to expertise in areas of “high public policy relevance” (IC 2002b, 8-11) rather than a broader sweep at national innovation system capacity. Even here, however, there was an important exception. Spurred on the by wake of 9/11 events, the Chemical, Biological, Radiological and Nuclear Research and Technology Initiative was established, binding federal labs together with first responders to work on issues of capacity, technology and need – a collaboration that beyond the assessment in government documents was deemed to have worked quite effectively (I3, also IC 2002b, 8-9). Yet, despite such discrepancies and the concomitant tendency to load the activity with too many specific clusters, the effort to focus on collaboration within the broader national innovation community clearly surfaces as a priority at the time. Further, in contrast with latter-day activities, it surfaces as one with breadth across smaller communities in Canada and recognition of the infrastructure that was needed to support such development.

⁶ The list included the following: bio-pharmaceuticals, photonics, nano-technology, network security, high-speed computing, medical diagnostic technologies, nutraceuticals, fuel cell technology, functional genomics, proteomics and ocean and marine technologies.

Collaborating for “Knowledge Mobilization”

As has been earlier indicated in Chapter Four, the years of the Harper administration placed a strong emphasis on creating a sound fiscal environment conducive to market forces⁷ sharpening Canada’s global innovation competitiveness. Indeed, “creat[ing] an investment climate that encourage[d] the private sector to compete against the world on the basis of its innovative, products, services, and technologies” was underlined by the Minister of Finance in the administration’s key agenda-setting document *Mobilizing Science and Technology to Canada’s Advantage* (IC 2007b). Low taxes, low debt, streamlining of the Scientific Research and Experimental Development tax credit, a similarly aligned regulatory regime, access to venture capital: all were to create the “enabling environment” for successful innovation. Despite the fiscal orientation, however, here too collaboration and partnership and a thickening of the innovation ecosystem (albeit in the latter case not called as such) were essential elements in the path forward. “Encouraging partnerships” was to be one of the four key “principles” of the government’s S&T Framework (*Ibid.*, 11) and its import was put in unabashed terms:

Partnerships involving the business, academic, and public sectors at home and abroad are essential to lever Canadian efforts into world-class successes and to accelerate the pace of discovery and commercialization in Canada. The cost, complexity, and pace of scientific achievement today ...demand the creation of smart partnerships (IC 2007b, 46).

Supporting this vision were to be a series of initiatives aimed at strengthening networks and specifically “knowledge mobilization” and commercialization.⁸ The Networks of Centres of Excellence, focused as they were on industrial research, were to be expanded on two fronts. There would be new business-led research networks strengthening the ties among government

⁷ See in particular the need for “letting market forces play out” although not in a way that enabled monopolistic practices (IC 2007b, 51).

⁸ For the initiatives which follow see the discussion in *Ibid.* (56-60 and 94-95).

industry and academe. Additionally, new Centres of Commercialization and Research drawing in business, universities, provinces/territories and the federal government would be launched, the objective of which was to concentrate a “critical mass of capacity in strategic areas of ... competitive advantage” (IC 2007b, 94). And not that dissimilar to the Chrétien administration, so too would there be a new emphasis (and programmatic ventures) enabling collaboration at the local level – particularly in this case between community colleges and their surrounding firms. Technology transfer from universities to industry would also be subject to review, finding mechanisms to enhance the technology pull from lab bench to “factory floor,” including a substantial review of the Intellectual Property regime and the impediments it might harbour. Finally, the key funding agencies would be given a strong industry focus be it private sector advisory councils for the tri-councils or pivoting the National Research Council (NRC), the Natural Sciences and Engineering Research Council (NSERC) and the Business Development Bank of Canada (BDC) to a sharpened commercialization focus. And all of this was backed up by funding in Budget 2007 (Finance Canada 2007).

Surprisingly, there were also elements of continuity with some of the initiatives that continued to be pursued – and heralded. The NRC would continue its Technology Cluster initiatives and the Chemical, Biological, Radiological and Nuclear Research and Technology Initiative would maintain its network status and leadership at the forefront of hazards containment and national security.

The government’s 2014 update – *Seizing Canada’s Moment* (IC 2014a) -- only reinforced this priority setting, adding measures for Industrial Research Chairs in colleges to strengthen linkages. Once again the NRC was spotlighted for further networking efforts, the Council being named to enhance the special Concierge service enabling business to navigate and use

government programs and resources. Akin to the German Fraunhofer Institute, the NRC would also wed research more closely to industrial needs, being “responsive to industry demand” and propelling “business-driven” innovation (*Ibid.*, 48 and 43 respectively).

All told, then, throughout these years of the Harper administration, there continued to be an emphasis placed on networks and national ecosystems. While fiscal discipline and a competitive investment regime reigned large (at least prior to the Keynesian pump-priming of the Great Recession), there is little if any evidence that collaboration was treated with a nonchalant eye on its import for the dynamics of innovation.

Collaboration: “Building a Nation of Innovators”

The arrival of the Trudeau administration on the political scene in November of 2015 did reinvigorate the Innovation Agenda as it was first called – and collaborative efforts within that. The priority given to this was initially evidenced in the Budget of 2016 which sounded all the right themes, even if took a somewhat more muted, and less ambitious, form than later evolved. There was to be “strengthening of innovation networks and clusters” (Finance Canada 2016, 120), and in an unwitting homage to Lundvall (1988, 1992) a focus on the compacted linkages between “producers and users.” Although light on details, the agenda would be leavened by significant funding (\$800 million over four years)⁹ (*Ibid.*, 120) and would also provide for a new “cluster mapping” portal. To be developed in conjunction with provinces and territories, the portal was designed to address sourcing of government funding for business, provide mechanisms for finding both clients and partnerships and provide the information needed to attract global investors as well.

⁹ See also the discussion in Chapter Five, “Straddling Priorities: Science and Scale-up.”

By Budget 2017 the new administration had begun to articulate its *Innovation and Skills Plan* (Finance 2017), with Canada to become a “nation of innovators” (*Ibid.*, 75). Central to this perspective would be five Superclusters with a not insignificant investment allocation of \$950 million over five years and with monies starting to flow to 2017-2018. To be selected through a competitive process, the Superclusters would focus on areas of strategic importance to the country such as advanced manufacturing, agri-food, clean technology and resources, digital industries and the bio-sciences (*Ibid.*, 75-80). Modelled on the cluster approach evident in Silicon Valley or even Waterloo-Toronto, the Superclusters were to provide the means and infrastructure to rally together large anchor firms, SMEs and start-ups, academic researchers, colleges and polytechnics – all of which would be facilitated by government. There collaboration and linkage were to congeal, creating “dense areas of business activity,” “energiz[ing] economies and act[ing] as engines of growth” (*Ibid.*, 79). Interestingly, absent from this Budget document in its assessment of the innovation challenges Canada was facing is the issue of collaboration and Canada’s historic poor showings in that regard. Nevertheless, the Budget document does turn to the indicators of success for an innovation agenda, noting the “greater collaboration” and partnerships to be forged, the enhanced linkages among “creative thinkers” and the commercialization and economic growth that would presumably flow (*Ibid.*, 76). Budget 2017 also signalled an intent to undertake two major reviews – of innovation programs across government and that of fundamental science.

From this more prosaic rendering in earlier Budget documents, by 2018 and 2019 the government had fashioned a much more fulsome agenda and indeed vision. Certainly, it was to be bold – none other than “redefining” Canada’s “innovation ecosystem” (ISED 2019, iii). The Superclusters remained a centrepiece of this strategy, focused as they were on “new innovation

ecosystems” capable of spanning the “gaps” from lab to market – from “science to commercialization” (*Ibid.*, 43-45). And the partnerships and linkages borne in these crucibles were to produce efficiencies across the innovation spectrum, scaleup of smaller firms and ultimately growth. Moreover, by this time, the Superclusters had significantly evolved. Five specific areas with a regional overlay had been selected, specifically digital industries in BC, protein industries in the Prairies, advanced manufacturing in Ontario, Artificial Intelligence and associated scaleup in Quebec and oceans and related technology and industries in the Atlantic.

Following on the heels of the Naylor Report, the Supercluster initiative was also to be complemented by a significant refurbishing of fundamental science – both through investments in attracting and keeping world class talent and in maintaining the necessary infrastructure for cutting-edge tools and facilities (Finance 2018, 85-99; ISED 2019 38-41). So too was the NRC to be once more “reimagined” pulling together “large-scale national teams” from across the triad of industry, academe and government and addressing Canada’s major innovation challenges (ISED 2019, 40; Finance 2018). Indeed, both in the mandate letter of the NRC President at the time and the Budget 2018 documentation was the Council to be inspired by the American model of the Defense Advanced Research Projects Agency – DARPA (Finance Canada 2018, 97; <https://nrc.canada.ca/en/corporate/about-nrc/mandate-letter-mr-iain-stewart-september-6-2018>). IP strategy was also to be the subject of review and a rethink.

Despite all this, the Innovation and Skills Plan is more an echo than replica of the way in which the necessity of triple helix networks coursed through priority-setting of early administrations, be it the “Achieving Excellence” roadmap with its intent for international clusters or the essential principle of collaboration housed in the “Mobilizing” framework. For one thing, the funding of science within the Trudeau Plan – while clearly pushing knowledge

“frontiers” and making up for the regress in basic researcher-driven science -- is not specifically linked with industrial research or even commercialization in the manner of earlier initiatives. So too is funding for the granting councils focused on their internal linkages. Moreover, planned priorities and investment around Canada Research Chairs are situated as a fully academic activity and remain severed from industrial research. Further, there is a nuts and bolts feel in this Plan, as it focused on the necessary but operational needs to streamline Government of Canada innovation programming, establishing a consolidated Strategic Innovation Fund (from the welter of programming that previously existed) or establish new procurement initiatives.¹⁰

That said, however, this observation should not be overstated. Quite clearly the priority-setting and efforts around that agenda of the Trudeau administration do have in their line of sight the need to address the collaboration issue and reckon with priorities that can propel both networks and innovation. And in that sense, what distinguishes this dimension of priority-setting of the last twenty years from the discussions in Chapter Four is the surprising degree of continuity – even tenacity -- around prioritizing the ecosystem issue. In terms of agenda-setting and calculated priorities, Canadian federal administrations of different political stripes and eras have respectively turned their attention to thickening those networks and attempting to wrestle the challenges to the ground. It might well be expected then that this intent would translate into results – a subject to which the latter part of this chapter will turn.

Targeted Resourcing of Innovation Networks

Critical Federal Players

One of the clearest ways to probe the extent to which federal policy actually made good on its promises to strengthen the Canadian innovation ecosystem is through funding or in DNS

¹⁰ On the range of specific initiatives laid out in the Innovation and Skills Plan, see Finance Canada (2018, 81-123).

terms ‘targeted resourcing’ of those networks. The data on this issue is not that easily assembled – and interestingly DNS literature tends to access the historical funding through measures like the Small Business Innovation Research program (Block and Keller 2011b) or contract services provided by federal laboratories (Keller, Block and Negoita (2017) or funding of specific initiatives over the post-war period such as with semi-conductors (Mazzucato 2015b, 105-106 or nanonetworks (*Ibid.*, 90-92)¹¹. What is less evident in that case is an aggregate overview of state efforts to fund networks specifically. It has been argued that in the case of the National Nanotechnology Initiative (NNI) for example, launched under the Clinton administration, the whole effort has been shrouded in a degree of secrecy, precisely to limit the perception that it was a “top-down” state-run effort. As such, attempts to track specific lines of NNI funding and to whom, with what specific results have proved particularly daunting. As Newfield, engaged in such an exercise concludes: “The level of non-specificity omits the stakes, the value, the financial sources, and the potential implications of possibly ground-breaking work.” (Newfield 2011, 292). While a read on total dollars for the NNI (\$1.8 billion annually) is referenced by Mazzucato (2015b, 92), nevertheless the larger point here rings true. Threading together this tapestry of network funding by the state is not a task easily accomplished. Not surprisingly, then, careful attention must be paid to the challenges when slicing into the Canadian context on this issue.

It might be argued that the OECD measure of Government Expenditures on Research and Development could possibly be considered for use as an aggregate indicator in this context. And indeed, what the GOVERD shows is a continuing decline from 0.21 per cent of GDP in 2000 to approximately half that at 0.11 per cent by 2018 and 2019 as well, in contrast with a more robust

¹¹ Also see Mazzucato’s reference to Motoyama, Appelbaum and Parker (2011) on the US government’s role in the National Nanotechnology Initiative.

performance by the United States, EU and OECD more generally (Figure 1).¹² Trends aside, however, while useful for tracking overall government funding, GOVERD is much too blunt an instrument to be of much use here. Rather, a more refined scalpel will be used with the focus on five specific components, all with mandates that include a focus on building networks and helix integration. As such funding will track: the Department primarily responsible for the federal innovation mandate – Innovation, Science and Economic Development (previously Industry Canada), the National Research Council Canada, the preeminent federal research facility and the three tri-council agencies – the Canadian Institutes of Health Research, the Natural Sciences and Engineering Research Council of Canada and the Social Sciences and Humanities Research Council of Canada.

With respect to IC/ISED, the Department finds its legislative roots in the Department of Industry Act (S.C. 1995, c.1) which clearly provides a mandate (among other elements) for “industry and technology in Canada,” as well as “science” and “investment” writ large. The Act also encompasses a litany of objectives related to economic growth, although given the 1995 crafting, not innovation per se. Specifically included, however, are enhancing international competitiveness, “encourage[ing] the fullest and most efficient and effective development and use of science and technology” (*Ibid.* s 5(d)) and “foster[ing] and promoting science and technology in Canada” (*Ibid.*, s,5(e)). So too are functions of the legislation broad in scope, including “promot[ing]” and “assist[ing]” “investment in, Canadian industry, goods, services, science and technology” (*Ibid.*, s.6 (c)) and of course collaboration with provincial government and non-governmental agencies. More critically, as the innovation agenda gained ground in the late nineties, evident in departmental performance reports reaching across the last two decades is

¹² Unless otherwise specified, Figures and Tables referenced in this chapter are located in Annex A - 6.

a clear focus on innovation or innovation capacity as a strategic objective or outcome for the federal government.

As such, this analysis of departmental funding dedicated to networking tracks the specific program activity over the 1999-2000 to 2019-2020 period which has been dedicated to enhancing “science, technology and innovation capacity,” and particularly intensified or “accelerated” commercialization of research and development across Canada’s innovation ecosystem. Funding appears in Figure 2 where various program elements are rolled up under the heading of “innovation capacity.” (Specifics of the metrics employed are detailed in Table 1.) It should be noted that innovation financing has been carved out under a separate heading and includes dedicated innovation funding for various critical sectors such as auto, aerospace and defence, the stereotypical example here being the Technology Partnerships Program and later similar entities (see Table 1). Importantly, these program activities relate only to line departmental activities and do not include the NRC or tri-council agencies which fall more generally under the ISED’s portfolio.

Aside from the Department, principal as well in the government’s arsenal for enhancing more robust network activity has of course been the National Research Council Canada. Clearly laid out in its governing legislation, the agency’s mandate is crafted to “undertake, assist or promote scientific and industrial research” (National Research Council Act R.S.C., 1985, c.N-15, s.5(c)) and without restricting its activities then gives a number of exemplars from natural resources to “technical processes” employed by Canadian “industries” to more esoteric matters such as the “fundamental properties of matter” (*Ibid.*, s 5(c), (i),(ii)(iv)). So too does the information on the corporation’s website speak to the deep collaborative efforts in which the NRC is to engage in “all” of its endeavours, be it research excellence, respecting the “expertise”

of others or “harnessing” the “creativity” essential for breakthroughs in research and technology, as well as in “new collaborations” (<https://nrc.canada.ca/en/corporate/about-nrc>).

True, as Doern and Levesque (2002) document, it was not always such. In the early post-war period and into the sixties NRC functioned as more of a stand-alone entity, rather isolated from business and interacting with universities primarily (at that time) as a provider of grants. However, since then the agency has become a key actor in forging collaboration, particularly with industry but with academe and other stakeholders as well. Starting with the leadership of President Perron in the eighties and the embrace of a “hard competitiveness” agenda (Doern and Levesque 2002, 153) that mirrored the Conservative government’s efforts at the time, NRC pivoted strongly towards engagement with and support for industry. Moreover subsequently under the decade-long leadership of President Carty (from 1994 to 2004), NRC underwent significant transformation to align with the Chrétien government innovation agenda, particularly focussing on integration into pan-Canadian and “local-regional innovation systems” (*Ibid*, 153; also 57-74 and 150-163;) and in fact undertaking a “cluster strategy” of engagement (<https://nrc.canada.ca/en/stories/arthur-carty-nrcs-entrepreneurial-scientist-balanced-cluster-development-commercialization>). Indeed, by 2002, Doern and Levesque reflect on the fact that the NRC while having a network before it became “fashionable” (Doern and Levesque 2002, 151 and 153) was “more intricately networked now than it ever was in the past” (*Ibid.*, 8).

Interim years have reinforced these trends. A sampling of the Council’s Departmental Performance Reports (which were publicly available) from the mid 2000s onward illuminates the heavy emphasis on enabling business and brokering the capacity for industrial research. And while a lesser focus is placed on academe and other private research facilities nevertheless partnering does definitively stretch across the innovation ecosystem (NRC DPR 2007, 2008,

2008-09, 2009-10, 2010-11, 2012-13, 2016, DRR 2017, 2018b, 2020c, 2020d). Be it the focus on numerous technology clusters under the Harper administration (NRC DPR 2009-2010, 5) or partnership efforts to strengthen commercialization (NRC DPR 2012-2013, 2) or, under the Trudeau administration, a “national footprint” enabling “38 large-scale, collaborative R&D initiatives” (NRC DPR 2016, 2), NRC has kept its sight trained on leavening and strengthening the Canadian innovation ecosystem. Critical to this as well has been the lead role played by the Industrial Research Assistance Program in helping small and medium-sized enterprises traverse the “valley of death,” making their way from “ideas to market” (<https://nrc.canada.ca/en/support-technology-innovation/about-nrc-industrial-research-assistance-program>). And while recent efforts to situate the Council as a key “collaboration partner with business, academia, and government”¹³ are deemed to be transformational and likened even to the American DARPA, this argument could be easily contested. The current approach articulated by NRC is not as much a pivot as a reinforcement of trends already evidenced and levers already wielded from the late nineties onwards and even the decade before.

That said, it is of note that the oscillation in priority-setting evidenced among governments – and as particularly seen in Chapter Four on “Policy Coherence, Continuity and Challenges” as well as in Chapter Five on “Targeted Resourcing” -- did play out organizationally within the NRC as well. To that point, the Harper years, characterized as they were towards commercialization imperatives and “market drivers” (Spears 20 March 2011)¹⁴ did see a substantive focus on industry needs. As the Council’s *Departmental Performance Report 2012-2013* messaged, NRC would be directed to a “renewed focus and commitment to helping

¹³ In this regard, see in particular the mandate letter for the NRC President dated September 6, 2018 (<https://nrc.canada.ca/en/corporate/about-nrc/mandate-letter-mr-iain-stewart-september-6-2018>).

¹⁴ The quotation is by the NRC President at the time, John McDougall; also see McKenna (5 August 2011) and Taylor-Valsey (8 May 2013).

Canadian industry remain on a productive, profitable and sustainable growth path” (NRC, DPR 2012-2013, 1). This did entail significant organizational restructuring¹⁵ and as the Minister of State for Science and Technology indicated at the time a shift to “industrial research, new growth and business development” (Spears 8 May 2013).

With the onset of the Trudeau administration, however, there was another sharp turn to align with new priorities and particularly a rethinking of the Council’s role. As such a comprehensive NRC “dialogue” was initiated with employees as well as with outside experts, followed by a new *Strategic Plan* (NRC 2020a; also 2020b, 2020c, 2020d and 2020e)¹⁶ and a restructuring of the Council organizationally. A return to “fundamental science” was a critical component of this new focus, complete with an Ideation Fund for enabling basic science and “self-directed research” (NRC 2020a 21, 41.) Even the Vision statement was recalibrated to state: “Our Vision is a better Canada and world through excellence in research and innovation” (NRC 2018b, 10; also NRC 2018a). Nevertheless, the collaboration components – both with industry and academe – as well as support for “business innovation” (NRC 2020a, 2) and the Supercluster initiatives have remained central elements of the new *Strategic Plan* going forward.

Aside from the NRC, finally are the tri-council funding agencies and their roles in all of this. Paramount among them has been the Natural Sciences and Engineering Research Council of Canada (NSERC). Established in 1987, NSERC was legislated to “promote and assist research in the natural sciences and engineering, other than the health sciences ...” (Natural Sciences and Engineering Research Council Act R.S., 1985, c. N-21, s.4(1)(a)). This more

¹⁵ This organizational dimension was brought to the author’s attention during a confidential discussion. With respect to the concerns restructuring precipitated among NRC staff as well as outside scientific observers, see especially media reports at the time: McKenna (5 August 2011); McKenna and Semeniuk (7 May 2013); Spears (8 May 2013). For a discussion of these various transformations and the “change fatigue” they have at times wrought, see NRC (2020e, 14).

¹⁶ On the transition within the NRC and on new leadership under President Iain Stewart, see Semeniuk (28 July 2016); also (Spears (9 March 2018).

prosaic rendering by the governing legislation, however, belies the active role that the Council has played over the years in efforts to thicken the Canadian innovation system. Articulated in bold terms on its website, the Council presents its mandate as “fund[ing] visionaries, explorers and innovators who are searching for the scientific and technical breakthroughs that will benefit our country” (https://www.nserc-crsng.gc.ca/nserc-crsng/index_eng.asp?wbdisable=true).

Similarly, NSERC’s 2017-2018 Departmental Performance Report captures well their role as broker and enabler:

... NSERC acts a convener of discovery and innovation partners with a goal of maximizing the value of public investments in science and engineering research

In today’s highly competitive global economy, NSERC plays a central role in supporting Canada’s innovation ecosystem. By connecting ... innovative research to industry through its partnerships initiatives, NSERC also makes it easier for the private sector to collaborate with academia and access the wealth of resources Canada’s first-rate academic system has to offer (NSERC, DPR, 2018).

Nor is this just a current undertaking. DPRs throughout the years – or at least from 2000-2001 onwards where this research picks up the story -- clearly depict a mandate focussed on “partnerships” and a directed linking of academe and business in the service of “new knowledge” and strengthening the country’s “capacity for innovation” (NSERC DPR 2004, 2; 2007, 4). The historic funding data speak to cultivation of linkages across the triple helix as well, the Council noting in 2001 that to date their programs had leveraged \$700 million from industry for funding of academic research (NSERC DPR 2001, i). As of 2017-2018, a comparable figure stood at \$250 million for that year alone (NSERC, DPR 2018, 3, 21).

Moreover, until very recently, a centrepiece of the agency’s activities was the Networks of Centres of Excellence. Designed precisely to finance “partnerships between universities, industry, government and not-for profit organizations to create large-scale research networks,”

(https://www.ic.gc.ca/eic/site/063.nsf/eng/h_68597F8D.html), the NCEs at peak involved 38 centres across all sectors of the economy and a broad array of specialized research (see in particular https://www.nce-rce.gc.ca/NetworksCentres-CentresReseaux/Index_eng.asp). Moreover, these entities spanned not only the traditional focus on R&D but also those actively dedicated to commercialization. Rather inexplicably, there have been recent decisions to wind up these programs, first in Budget 2018 rolling up the Centres of Excellence for Commercialization and Research and the Business-Led Networks of Centres of Excellence into a broader fund (the Strategic Innovation Fund) within ISED (NSERC, DRR, 2019, 12). Also, as of December of 2018, the original Networks of Centres of Excellence are to be wound down by 2023-2024, being gradually transferred to a new fund for the tri-council agencies housed at the Social Sciences and Research Council (NSERC, DRR 2019, 12). Nonetheless for the period under study in this research, the engagement of the Natural Sciences and Engineering Council on the innovation file – and as a key funder and broker of collaboration – is very present.

As for its sister council, the Canadian Institutes of Health Research, so too is harnessing research collaboration central to its mandate. Clearly, in this case, the pursuit of knowledge and discovery are primordial – and achieving the “highest standards of [research] excellence” (Canadian Institutes of Health Research Act S.C. 2000, c. 6 Preamble). However, critical as well is the import of mobilizing the knowledge – “enabl[ing] its translation” in the service of Canadian citizens and the country’s health care system, as well as innovation more generally (<https://cihr-irsc.gc.ca/e/37792.html>). Certainly, the import of this “translation” function and its links specifically to commercialization are very much profiled in the agency’s reporting and results performance over the years, to the extent that the exact same wording or wording to that effect appears under the CIHR’s mandate and “responsibilities” or Ministerial message

consistently in Departmental Performance Reports publicly available from 2006-2007 onward. Specifically, the Council notes the import of “focusing on knowledge translation that facilitates the application of the results of research and its transformation into new policies, practices, procedures, products and services” (CIHR DPR 2011, 2; 2012, 3; 2013, 3; 2014, 5; 2015, 3; 2016, 7; DRR 2017,5; 2018, 5).¹⁷ Here too, then, the CIHR functions not only in the pursuit of breakthrough science but also as a key player and enabler in the Canadian health innovation ecosystem.

Making up the third component of the council triumvirate is the Social Sciences and Humanities Research Council. Tasked with “promot[ing]” and nurturing research in the social sciences and humanities (Social Sciences and Humanities Research Act, R.S.C., 1985,c. S-12), it too pronounces its mandate as one of “driving” forward innovation (https://www.sshrc-crsh.gc.ca/about-au_sujet/mandate-mandat-eng.aspx). Equally important, it sustains a vision and programmatic effort that fosters the “co-creation” and “multisectoral partnerships” that can deepen networks, advance research and address issues of major socio-economic import to the country (see in particular SSHRC, DRR 2018,19).

All told then these five entities – IC/ISED, NRC and the tri-councils – serve as important indicators of the targeted resourcing the federal government has allocated to network initiatives. It is of course an entirely separate issue whether these efforts, pronounced as they have been or driven by innovation agendas or a thickened integration of the ecosystem, have had the actual impact intended – an issue to which we will turn in the latter part of the chapter.

¹⁷ CIHR DPR (2010, 2) has one word change – promoting knowledge translation. See also DPR (2007, 6); (2008,4) where the wording does vary but intent is the same.

Federal Network Initiatives: Total Funding Authorized

With respect to the issue of IC/ISED innovation capacity and financing, the sum at the end of fiscal 2019-2020 has not been insignificant, weighing in at almost \$10B (\$9.9B) for innovation capacity, \$6.1B for financing and \$16.0B in total (Figure 2.)¹⁸ The trek has been quite jerky – for capacity peaking at \$1.4B at or near the apex of the Great Recession (2009-2010, 2010-2011), dropping quite precipitously and¹⁹ then climbing again to almost earlier levels at \$1.3B in 2017-2018, as Budget 17 monies flowed. Allocations then recede for the last two fiscal years in the decade. Innovation financing on the other hand, while more muted has been more consistent, in fact pushing the overall funding to a higher level of \$1.7B in 2017-18 than even the 2009-10 peak (\$1.6B) (Figure 2). As for the tri-council agencies, CIHR, NSERC, and SSHRC here too trend lines are much more consistent and generally show a gradual but fairly persistent incline (Figure 4). The NRC sustained a financial hit in 2011-12 but it too has been back on track and seen increasing levels of financial support, coming in at \$1.2B at the end of the decade (Figure 4). Overall, federal Program Activity around Networks (using a conservative number that does not actually include innovation financing) rolls in at \$78.8B over the full time period from 1999-2000 to 2019-2020 (Figure 4).

While clearly there has been no perfect trajectory – with year-over-year steadily ascending dollar amounts – nonetheless the financial picture has been rather solid. Surprisingly even during the recession years when the biggest hits would be expected, funding was sustained and, in the case of IC and the councils, it actually increased. So too it should be noted that the

¹⁸ For the specific methodology employed in undertaking this assessment, see Table 1; also Annex A-6, the “Methodological Notes for Network Charts.”

¹⁹ For a specific breakdown of all program initiatives and associated funding included in capacity, see Figure 3 in Annex A-6.

network funding initiatives actually run counter to GOVERD at constant prices (and PPP\$),²⁰ the latter in the Canadian case (and in contrast to Canadian comparators) registering a decline from \$2.5B to \$1.9B over the 2000-2019 period (Figure 5). Thus, there is very little to suggest that federal policy has starved networks of funding. Nor is it evident that those state agencies enabling collaboration across industry, academe and government have sustained such financial body blows as to make federal policy around ecosystems meaningless. As we shall see, this is not an insignificant point when it comes to assessing the actual collaborative capacity of Canada's innovation ecosystem. If not robbed of funding – and if it is not operating at full thrust so to speak -- it begs the question of the factors and perhaps oppositional elements contributing to the shallowness of those ecosystem linkages.

Collaboration: Signs of Success

At first blush, Canada's degree of collaboration, at least in terms of research and traditional bibliometric indicators, would seem to be caught in the country's traditional middling territory. OECD data (2017 *Scoreboard*, 124) shows that in 2015 Canada ranked 20th of 41 countries in terms of “international scientific collaboration as a percentage of domestically authored documents.” This included both domestic-led collaboration as well as collaboration with a foreign-lead. Moreover, this was a relatively modest increase over where Canada stood a decade earlier.²¹ So too, did other OECD data on the period between 2012 and 2016 display Canada as being in the “low collaboration, high quality” (*Ibid.*, 125) quadrant when it came to the import of scientific publications and international cooperation.

²⁰ PPPs refers to Purchasing Power Parities. The OECD defines the term as “the rates of currency conversion that equalize the purchasing power of different currencies by eliminating the differences in price levels between countries... The indicator is measured in terms of national currency per US dollar” (<https://data.oecd.org/conversion/purchasing-power-parities-ppp.htm>).

²¹ Unfortunately, the *Scoreboard* has not allowed access to the actual raw numbers.

These indicators are not borne out however whenever other slices of time into this issue are taken **and** when citation impacts are normalized for country size. Specifically, the CCA found that Canada actually increased its international cooperation on scientific publications from 41 per cent in 2003-2008 to 46 per cent in 2004-2014, garnering the country an international ranking of seventh in this regard (CCA 2018, 41-42). More critically, when country size is accounted for, Canada clearly punched above its bibliometric weight, ranking seventh out of the top 20 countries. Rolled up under what the CCA called the Collaboration Index, Canada had a score of 1.26 for the 2009-2014, meaning “Canadian researchers collaborated 26 per cent more than might be expected based on the total number of Canada publications for the period” (*Ibid.*, 42).

All of this is not particularly surprising, given Canada’s generally stellar performance on bibliometric indicators²² and the research front more widely, as well as the fact that smaller countries generally are more outreach oriented on publication collaboration. (The top three countries on the noted CI index are Switzerland, the United Kingdom and Sweden (*Ibid.*, 42) respectively.) Moreover, this still operates within the research community – rather than a sweep across all of the elements of the triple helix – academe, industry and government. On this latter front, there is a much more sobering portrait.

Finally, it is worth noting that with respect to international cooperation, Canada has done well. As Figure 6 shows, in fact, the country has experienced an almost eight percentage point increase between 2000 and 2016 and, as of 2016, almost one-third of its applications to the United States Patent and Trademark Office (USPTO) registered foreign co-invention. Yet what is interesting here is that countries with typically strong innovation indicators such as Israel,

²² This data is laid out in the earlier chapter “The Health of the Canadian Innovation System: Taking the Pulse;” see “Knowledge Creation.”

Japan, South Korea, United States or even Germany are definitively not among the top five nations. Further, Canada is tracking well above the OECD average.

While OECD treats this cooperation in patents as a type of collaboration indicator, however, this has a double-edge sword. In fact, the data on cooperation may well represent eroding indicators of domestic innovation. Certainly, as was seen in Chapter Three on the “Health of the Canadian Innovation System: Taking the Pulse,” in terms of Canada’s percentage or “share” of triadic patent families (US, EU and Japan) Canada is operating far below the leading nations – Japan and the US and the top five generally (Figure 29, Chapter 3). Indeed, it registered an astonishing 31.5 percentage point spread between Canada and Japan, the leader, as of 2018. China too, while starting at a lower baseline, has been outpacing Canada particularly over the last decade. Thus, a significant amount of caution must be exercised in interpreting patents as a proxy for collaboration; in any case, it does speak to international cooperation and not domestic considerations.

Collaboration: A Patchy Landscape and Troubling Trends

There does seem to be a relatively robust degree of collaboration across the Canadian innovation ecosystem at least for higher education-industry interactions when it comes to the issue of business financing of Higher Education R&D – ie., HERD. As Figure 7 portrays, the percentage of HERD financed by the business sector has been relatively stable over the last 19 years, showing only a slight decline from 9.6 per cent in 2000 to 7.8 per cent in 2019. Moreover, when these trends are compared to the EU, OECD and the Americans, Canada is clearly outperforming its competitors on this front. Of course, all of this stands in stark contrast to China and even the top five countries, although interestingly China presents a noticeable downward trend.

This aside, however, with respect to other indicators of a thickened innovation ecosystem, the data is much less compelling. It should be noted at the outset that a clear and consistent picture of Canada’s performance on collaboration is significantly hampered by a less than robust ongoing review of the status and extent of those practices within Canadian innovation networks. Statistics Canada has undertaken at least six surveys on this issue since 1999 (and seven since 1997) with the latest being released in 2021. But the surveys employed over the years form somewhat of a patchwork of indices, with in fact significant gaps between 2005 and 2014 and frequently differing indicators and populations bases from which the data is drawn. Following the *Survey of Innovation* produced respectively in 1997, 1999, 2003 and 2005, there is not a similarly-focused data collection until the *Survey of Advanced Technology* in 2014. Even then the data collected in 2014 is cut somewhat differently than the *Survey of Innovation and Business Strategy* undertaken in 2015-2017 and again in 2017-2019 – although the methodologies employed are, in large part, similar. Moreover, even despite modified versions of questions around collaboration, earlier surveys tended to focus on particular industry sectors, so a national read on collaboration across all key sectors of the North American Industry Classification System over a longer time series is missing.

That said, what is indicated by the various queries into Canadian patterns of firm cooperation by firms does not display a particularly robust “triple helix” of engagement and cooperation. 1999 data²³ (Statistics Canada, 31 January 2000) indicated that, of the innovators in manufacturing, only 8.5 per cent had used universities and colleges as a “source of information ...contribut[ing] to innovation” and only 8.7 per cent had engaged federal government agencies and research laboratories including the NRC (*Ibid.*, Aggregate Data Files, Table 8.1) (in this text,

²³ This data is not on-line. The source for these tables indicates that these are preliminary estimates.

see Table 2, Annex A-6). Indeed, the bulk of collaboration was undertaken with internal sources of information, and particularly marketing staff. Interestingly the 1999 *Survey of Innovation* – which included not only the manufacturing sector but “selected” natural resource industries as part of their target population -- did take a deeper dive. What surfaced was that firms which were “world class innovators” were “twice as likely” (Industry Canada 2001, 56) to indicate collaboration with public research entities (ie., federal labs, provincial labs and universities) than firms who were “first in Canada” or “first to firm.” Unfortunately, this question and its import for collaboration and innovation success does not appear to be replicated in later studies however.

Similarly, the 2003 *Survey of Innovation* (Statistics Canada, 31 March 2004) – this time focused only on ICT innovators – registers 8.5 per cent of those firms collaborating with federal government research institutes with another 4.4 per cent collaborating with provincial/territorial entities (see Table 3, Annex A-6). And while universities and “other higher education institutes” fared better with 29.3 per cent of businesses collaborating with these entities, nevertheless it is telling that the major interface was with “clients or customers,” with almost 90 per cent (88.2 per cent) involved in “collaborative arrangements” with these groups. Moreover, this trend is crystallized even more distinctly as it relates to the “high” importance of these entities to “business units” as “sources of information” enabling the development of innovation during the 2001-2003 period²⁴ (Table 4, Annex A-6). Specifically on this critical dimension, universities or other higher education institutes and federal government research labs garnered an astonishingly low level of **1.6 per cent and 0.5 per cent** respectively (*Ibid.*, Table 22A.2.), in contrast with

²⁴ The exact table reference is “Percentage of business units using sources of information needed for suggesting or contributing to the development of innovation during the period 2001 – 2003” (Statistics Canada 31 March 2004) for ICT service industries.

over one-third of firms (37.1 per cent) relying on their own internal resources of “research and development staff.”

As for 2005 (Statistics Canada, 2 June 2006) -- now focused on manufacturing and logging – it in fact changes the question slightly to access cooperative “arrangements” among the innovators, this time with results of a high 39.7 per cent for universities and 21.6 per cent with federal government labs²⁵ (Table 5, Annex A-6). Similar to 2003, however, these trends drop precipitously when the criticality of the cooperation partner to innovation is once again probed. As Table 6, Annex A-6 shows, on the dimension of the “most valuable type of cooperation partner,” only 8.3 per cent of innovative plants in this Survey had cooperative arrangements with universities or other higher education institutes and only 3.2 per cent with federal government laboratories.

While these surveys focus on the innovators however which it might be assumed skew towards higher levels of collaboration, the *Survey of Advanced Technology 2014* (Statistics Canada, 11 December 2015) cuts a swath across all NAICS categories. And it is here that a measure of the shallowness of Canadian collaborative “practices” particularly surfaces. Only **5.2** per cent of firms were characterized by collaboration or “strategic alliances” with universities, polytechnics or colleges; only 3.0 per cent with government research institutes and only 14.1 per cent even with other companies (Table 7, Annex A-6). Most surprising **81.6 per cent of firms in the 2014 exercise showed no collaboration in these three categories (academe, government, other firms) at all.**

²⁵ There is somewhat of an anomaly in the title of this table. The table references the innovation, logging and manufacturing industries which were sampled for the *Statistics Canada Survey of Innovation 2005*. However, the data in the table specifically refers to Information and Communication Technology (ICT) Manufacturing Industries. That the data is drawing down only on ICT manufacturing may explain the higher numbers.

A somewhat later snapshot of this issue by the *Survey of Innovation and Business Strategy* 2015-2017 (Statistics Canada, 26 March 2019) indicates slightly stronger trends, coming in at 17.4 per cent overall, with 18.6 per cent for universities and colleges and 13.1 per cent for government, public or private research institutes (Table 8, Annex A-6). Here again, however, a slice into this issue by “most critical co-operation partner for the business’s innovation activities” actually registers much lower numbers – **2.9 per cent for universities and colleges and 1.9 per cent for government, public or private research institutes** (Table 9, Annex A-6).

Particularly interesting however, especially given the variety of network initiatives undertaken over the intervening years, two years later, the *Survey of Innovation and Business Strategy* 2017 – 2019 (Statistics Canada, 26 April 2021) actually shows certain decelerating trends with respect to collaborative practices (Tables 10 and 11, Annex A-6). True, overall for all surveyed industries, co-operation on innovation activities registers a very small degree higher – at 17.8 per cent. However, co-operation of the firm with the parent, affiliated or subsidiary businesses increases to 43.0 per cent (from 36.9); that with post-secondary institutions falls to 15.6 per cent and that with government or private research institutes to 10.2 per cent. As for practices related to the most “critical” partner there are some extremely modest increases (to 3.5 per cent for universities and colleges and 2.1 per cent for government and private research facilities) but generally speaking the extent of engagement when innovation is most at stake continues to display the lowest level of collaboration. Thus, on the whole -- despite the complex nature of tracking this through various Statistics Canada instruments -- a picture does not emerge of clearly rising trends in collaboration or a manifestly “thickened” innovation ecosystem. If

anything, steep declines in co-operative practices are most pronounced when the criticality of that partner to the innovation process is most important.

It should be added that turning to OECD data on this matter unfortunately does not shed much more light on this picture – at least in terms of developments over the course of the last 20 years. The OECD *STI Scoreboard* 2007 (also STIC 2009) indicates that Canada had a less than stellar international ranking of 24th (out of 27 countries) in the percentage of firms “collaborating with public research organizations in innovative activities, by size for the period between 2002 and 2004.” However later *Scoreboards* do not appear to track Canadian data on this indicator, founded as they are on the Eurostat survey instruments.

On the other hand, the World Economic Forum has tracked this issue with generally consistent indicators on industry/university collaboration in R&D or more recently multi-stakeholder collaboration. To be sure the country’s rankings here are out of a much larger proportion of counties, specifically between 125 and 141 over the time period between 2006-2007 and 2019. Yet what is quite visible – and sobering -- as Table 12, Annex A - 6 indicates, is that Canada’s ranking on this index has largely been deteriorating, having registered at a ranking of 24th for 2018 (and in that “sticky” range back to 2016-2017) from earlier highs and indeed a peak of 7th in 2010-2011.²⁶ While 2019 did see a rebound to 15th position, this can still be characterized as a somewhat modest recovery.

All said, then, two dimensions are important here. For one thing, HERD financing by business over the last 20 years stands out as an important but isolated case of strategic alliance across the “triple helix”. Secondly, given the rather patchy evidence for collaboration in Canada among industry, academe and government, shifting statistical indicators and target populations,

²⁶ For purposes of comparison 2010-2011 was based on 139 countries, while 2018 was based on 140.

as well as the rather limited nature of that engagement, it was seen to be incumbent on this research to undertake a deeper probe into these issues. Towards that end, a fairly extensive assessment of this situation was undertaken with in-depth thought leaders across the country. It is to that which we now turn.

In-Depth Interviews with Thought Leaders

As just seen, previous data analysis of the Canadian context has not indicated a high degree of collaboration and cooperation among the “triple helix” (Etzkowitz 1998; 2003) central to innovation – namely, industry, government and academe. Given the import of this – and the rather checkered nature of the data to date – what this research centred on was taking the pulse of this situation with 54 key “thought leaders” across Canada who occupy or had occupied senior positions in their respective organizations.

Assessing the Canadian Innovation Ecosystem

Critical Mass: Is Canada Doing Enough?

In all, three areas of questioning were deployed to tap into the interview participants’ thinking around collaboration and the issue of thickening networks as a potential contributor to innovation in the Canadian case. The most significant question in this regard directly tackled the question of critical mass. Interviewees were provided with an introductory statement indicating that an important incentive for innovation is the strength of critical mass and clusters of innovative activity that assemble the key players. Building on this, participants were then asked a broad question as to whether they thought Canada was doing enough on that front, specifically:

An important incentive for innovation is the strength of critical mass and clusters of innovative activity – i.e., bringing together big corporate players, SMEs, start-ups, university researchers, venture capital and government labs in networks of innovation.

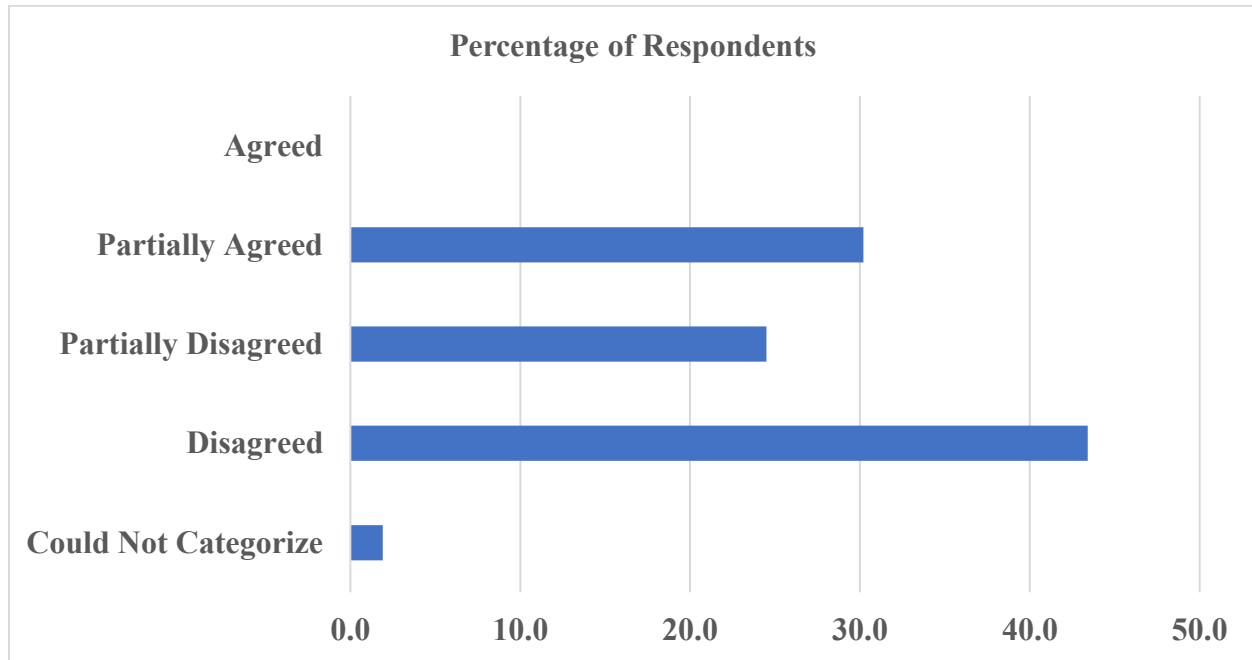
Do you think Canada is doing enough to create that critical mass?

If the participant indicated that Canada was not doing enough in this regard, there was a follow-up asking them, in their view, what initiatives needed to be undertaken – by government, business and universities. As for the responses provided, these very much tapped into the inclusive nature of those networks, their degree of dynamism and synergy and their capacity for stimulating innovation in the Canadian context. Moreover, it frequently opened up a conversation about the nature of policies and instruments being used, other approaches that might have more traction, comparative experiences with other countries and the specific challenges in the Canadian context.

As for the number of thought leaders answering this question, 53 of the 54 individuals with whom interviews were conducted were provided with this question. Only in one case was the interviewee not posed this question, as it was the intent to take a deeper dive with this individual on other issues. As such -- and based on the methodology employed throughout this research – the responses noted in Figures 8 and 9 are based on the 53 interviewees who were provided with an opportunity to directly address the critical mass issue.

In all, on this question (Figure 8), 30 per cent – not quite a third – felt that Canada was succeeding on this front, but comments were qualified. Another 25 per cent disagreed and felt the country's capacity for critical mass and clusters of innovative activity was lacking in some respect. Finally – and somewhat surprisingly – another 43 per cent clearly disagreed and were of the view the innovation system in Canada was lacking that critical mass. The remaining 2 per cent is attributed to answers which can not be definitively categorized. All told, then, on this particular and important indicator just over two-thirds (68 per cent) of respondents were not convinced Canada was doing an adequate job.

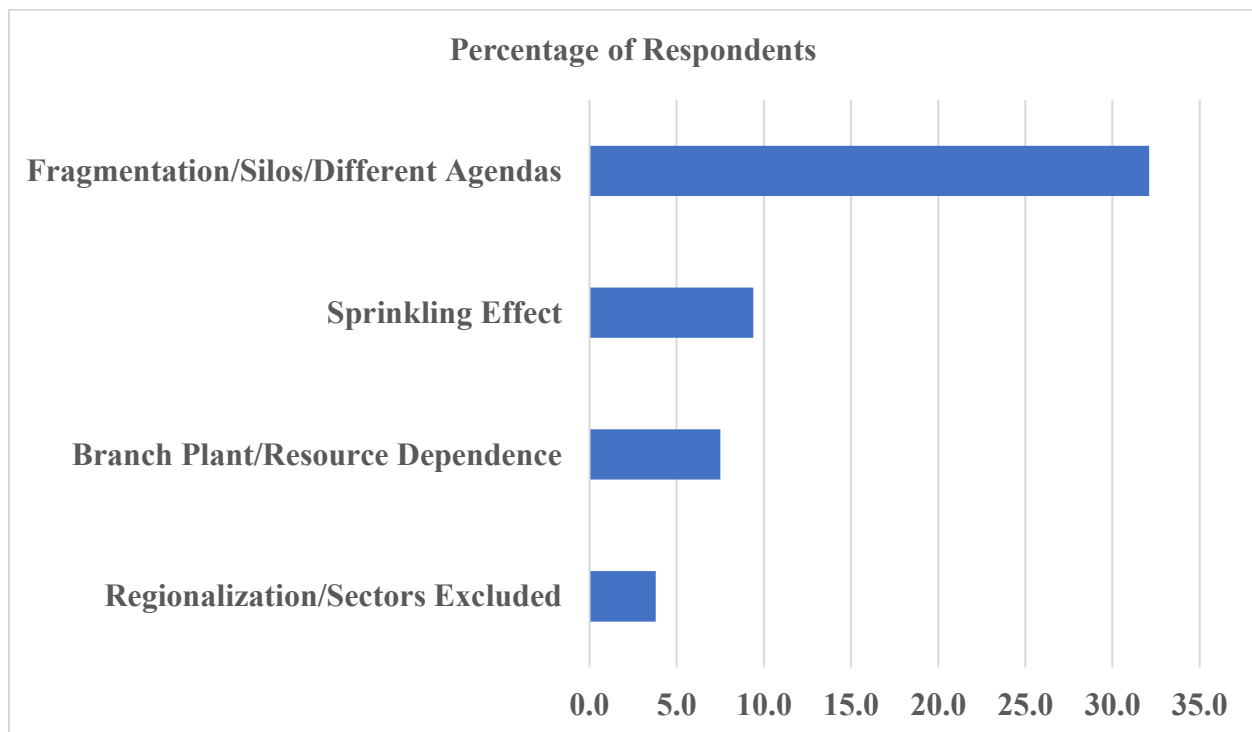
Figure 8 Critical Mass – Doing Enough?



Several prominent themes surfaced in these discussions and respondents could provide more than one answer or “challenge” (Figure 9). Most significant, almost one-third (32 per cent) of the interviewees referenced the significant fragmentation and silos that existed, particularly among business and university, although at times clearly cross-cutting government. Specifically, partnerships did not appear to be “our strength”— and it often turned on two issues. Critical Intellectual Property was “locked up” in universities and was not fully accessible for harvesting by industry. And for its part, industry did not appreciate the time required for basic research or the nature of its iterative processes rather than top-down stringently directed goals. In any event, two “silos” or “pyramids” existed, with “some” but not sufficient “cross-over” and which were vested with very different agendas – research versus commercialization – timelines and even lexicon. As one participant summed up – in a particularly telling comment-- most of the “approaches” they had seen oscillated between putting industry “first” and research “second” or the opposite with research as primary and industry secondary. They explained:

I haven't seen an approach that puts the two like on an equal footing with an equal amount of respect and dialogue for what industry brings to the table and what research brings to the table. So it's like the pendulum swings both ways but we haven't found an equilibrium yet where that dialogue can really be rich, information can flow both ways and there's a clear and easy pathway also for how to incorporate the knowledge. (I23)

Figure 9 Critical Mass - Themes Raised



Overlaid on this was also at times an historical lens wherein the various parties at the table had been focused on this issue for several decades and there was a “huge amount of rhetorical agreement” on this issue but “there’s not a lot of progress” (I4).²⁷ One statement particularly crystallized this insight and historical take on discussions around innovation challenges: “We talk a lot about working in that direction” but “then we go back in our

²⁷ With respect to quotations, as has been previously noted, anonymity is preserved through a numbering system. Reference to the Interview number is specifically used when that quotation is unique.

comfortable homes” (I5) and the issue is not consistently pursued. And, as the interviewee concluded: “It’s decades trying to get this right” (I5). Clearly there were “exceptions” to this overarching factor but overall the trend was captured as having strong elements of stasis -- and not the progress needed to push innovation aggressively forward.

Interestingly, this discussion equally elicited rich perspectives on potential instruments, policies or programs that could ameliorate the situation. Several recommended a deeper “cultural transformation” between industry and academe – even the locating of university Industry Chairs in private sector settings and again more timeliness in establishing those Chairs when needed. Similarly, from the academic and college perspective, it was suggested there needed to be more stable mechanisms for researchers dealing with smaller companies where turnover is more pronounced and where partnerships can be easily changed. Also recommended was more fluidity with Canadian companies and especially SMEs being able to draw down on university expertise to address specific industry problems as needed. One interviewee likened such a process to the cyclical nature of a “library” where research and expertise could be successfully sought out and deployed to resolve industrial challenges and then “returned” – not requiring the ongoing costs of investments in the same resource over time and freeing up university expertise to focus on other issues (I9). So too was the need for greater exposure of graduate and postgraduate students to industry referenced, although several times MITACs were mentioned as an already existing excellent program in that regard and a model that should be retained.

On a similar note – and particularly illuminating -- was the observation that a certain modest percentage of university funding needed to be established that could be drawn down upon quickly by researchers. It was suggested that this type of fund could be dedicated to

industrial needs wrestling with issues of commercialization – not to divert away from fundamental science but to add leverage. It should be noted (and it is telling of the consensus of perspectives around this issue) these views on new and more nimble cost-effective mechanisms were not restricted to industry or academe but traversed the innovation community as interviewees reflected on issues that they had observed or directly experienced.

Further, respondents were concerned about the rather open nature of targets identified. Clearly this issue and the need for more strategic honing around government and Canadian priorities surfaced most strongly in Question 2 of the in-depth interviews which dealt with targeted resourcing and issues of fragmentation.²⁸ But here too there was a need for a “roadmap” with “defined KPI’s” (Key Performance Indicators) by which to monitor success. As this interviewee reflected at the end: “I think if I had to part with one comment is that it’s difficult to assess if we are doing well or not -- without having decided what the roadmap looks like (I7).” Moreover, reflecting on the need for a robust R&D strategy, with defined priorities, they continued:

... I think maybe to go back to your overall question, I think we would benefit as a nation of coming up with a R&D innovation strategy that brings together the clusters -- the accelerators and incubators, academic institutions into the mix, the private industry you know, the IP strategies that we have. And say as a nation, our R&D is going to be focussed for the next foreseeable future – for the next 5 or 10 years ... and by the way here are the measurements that we are going to put to make sure that we are yielding for the nation, yielding for our economy and yielding for the job market. (*Ibid.*)

It is then not too much to suggest that the deficit around strategic priority-setting was also a current that traversed the answers to this question as well.

²⁸ See Chapter Two, Annex A-2, “Questions for In-depth Interviews.”

Additionally, 9 per cent of the respondents commented on what was likened to a “sprinkling” effect – wherein innovation initiatives were seeded across the innovation ecosystem but sustained and targeted efforts were lacking. Speaking to this tendency, it was remarked that “we can’t do the traditional Canadian thing of sprinkling ... all that capacity over lots of geography” (I6) or even trying to be “fair” to everyone (I30). Or as one participant commented in speaking of the policy instruments that can address the country’s innovation challenges:

You can’t just sprinkle programming funds across you know a wide variety of – of promising and other kind of areas without kind of at one point asking yourself well should we really be investing in this or that. ... There are some areas that are more promising for the economy as a whole and I think that’s kind of the federal government’s role to -- not to pick winners and losers ... but to say we seem to have critical mass in this area or that area or we have gaps in this area or that area and that’s where we need to put our incentives. (I22)

As for another 8 per cent of respondents, they referenced the branch plant nature of the Canadian economy and/or its resource dependency that hampered both R&D and the value chain necessary for successful commercialization. Finally, 4 per cent specifically noted the marginalization or regionalization of the innovation ecosystem with key clusters concentrated in specific more densely populated regions and metropolitan areas (pulling both capital and talent) and not enough attention on the “outliers” (I12). It should be noted that this issue surfaces much more strongly as well in the question below on Superclusters.

In all then, the portrait painted of Canada’s innovation ecosystem was not one that was particularly robust. Rather it was hampered by the size of the country’s geography, low density in population, lack of physical proximity for many clusters and the legacy of multinationals that undertook R&D in their own countries but did not necessarily prioritize innovation in Canada. Overlaid on this was at times also the image of Canada as continuing to be “hewers of wood and drawers of water” (I27). Further either due to the cleavages around silos or regionalization of

ecosystems, the kind of rich dialogue and interaction that is needed across the research and academic environment was found wanting – and there needed to be a pronounced effort to address this situation. Nor was this an inconsiderable issue – for if the Intellectual Property remained stranded in a sense within the academic environment, this impacted the chances for commercialization. Finally, it is worth noting that there are competing currents in these reflections, respondents searching for more directed, tangible and effective commercialization results, premised on clear indicators and “roadmaps” but also wanting to ensure that this did not choke off new areas of innovation – “pop-ups” so to speak.

Interestingly, what did emerge as an area of more vibrancy and strength, however, were the clusters around Artificial Intelligence, particularly as situated in Toronto and Montreal and the leadership Canada has exercised in this regard. For those who referenced the AI example, there was clear convergence that in this case the various pieces of the ecosystem puzzle had come together. Certainly, there was not a sense that this momentum could be automatically sustained moving forward -- rather what it more accurately signalled was that this supposedly emergent success was based on four decades of path-breaking and foundational scientific work, robust industry partnerships, seeding of investments by Canadian governments and institutions dedicated to incubating this technology. Such networks were indeed inclusive and representative of most actors within this ecosystem, but they were also cultivated and nurtured *over time*. As one interviewee succinctly put it, AI was an “overnight forty-year success” (I43).

The Superclusters

The issues around critical mass were also peeled away through a secondary line of questioning. Interviewees were asked to assess the progress of the five Supercluster initiatives that had been announced in Budget 2017. Specifically, they were read a statement:

It can be maintained that the Government of Canada's 2017 Budget Plan, particularly with the rollout of the Superclusters, set out to address some of these concerns and stimulate innovation.

In this case, the “concerns” noted hearkened back to the opening statements of the interview where the trends around innovation indicators had been highlighted.²⁹ Interviewees were then posed the following question:

Do you think with these initiatives we have finally begun to “break the back” on this problem?

The question was open-ended and participants had the opportunity to discuss other initiatives currently lacking that could further propel innovation in Canada. Indeed, the interview question was supplemented with the query:

Are there other initiatives that are lacking that could further propel innovation in Canada?

It should be noted that, not in all cases, was there time to address the specific Supercluster issue -- particularly, as this was a subset question. As such then in seven cases (out of the potential 54 respondents) there is no answer recorded for this question. That said, the reading on the Superclusters was not particularly favourable. Figure 10 depicts the aggregate overview as broken down into easily categorized assessments, with in fact 51 per cent of the respondents indicating a negative or partially negative assessment and 28 per cent of the respondents giving a positive or mostly positive review.³⁰ So the gap here was quite wide, with approximately twice the number of interviewees responding in the negative. Interestingly in 11 per cent of the cases the answer was best described as a split between positive and negative, and in 2 per cent the answer given was that there really needed to be more time to assess the

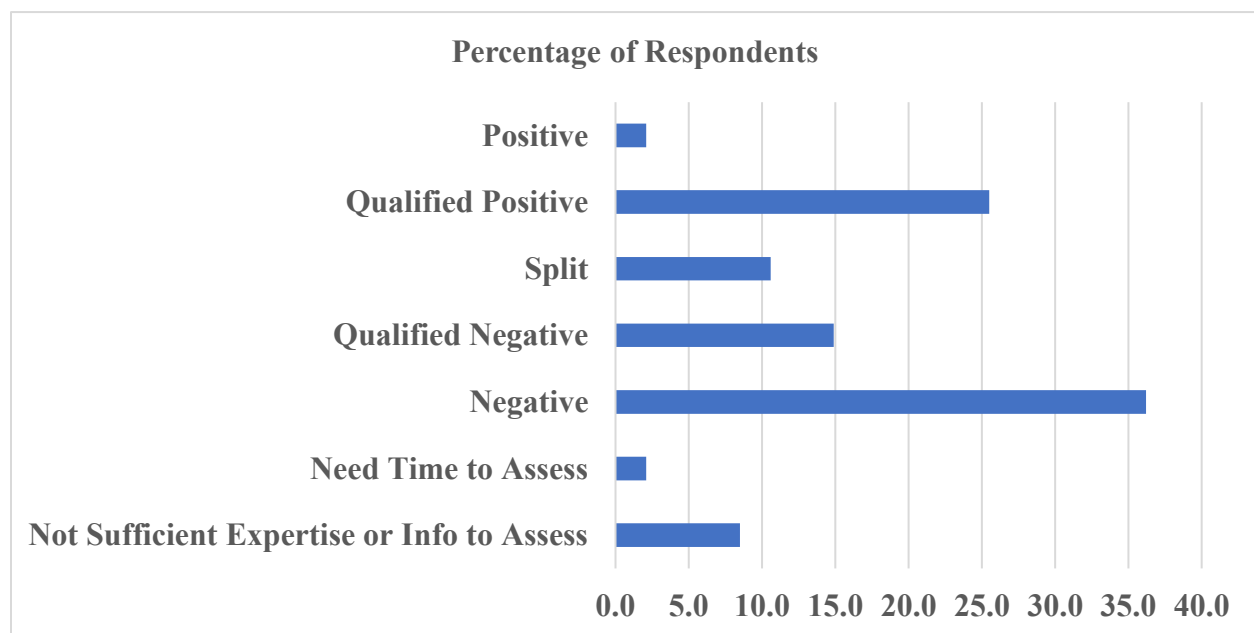
²⁹ See “Questions for In-depth Interviews: Introductory Remarks by the Principal Investigator” in Chapter Two, Research Methodology, Annex A-1

³⁰ Percentage breakdowns do not add exactly to 100, due to rounding.

Superclusters before rendering an assessment. Finally, 9 per cent of those interviewed did not feel they had sufficient expertise or information on which to answer the question.

A further dive into the thinking behind these assessments also shows some themes being quite prominent – as depicted in Figure 11. It should be noted that in this case interviewees at times gave more than one answer so the tally in Figure 11 in fact refers to the percentage of respondents focused on that particular issue. With respect to the answers actually given, of all the interviewees providing responses on the Supercluster question, 28 per cent indicated concern with the lack of “tangible results.” Several factors in this regard were mentioned including the need for specific metrics – Key Performance Indicators – that could track the impact of the Superclusters with respect to commercialization, economic growth and even jobs.

Figure 10 Superclusters: Respondent Assessment



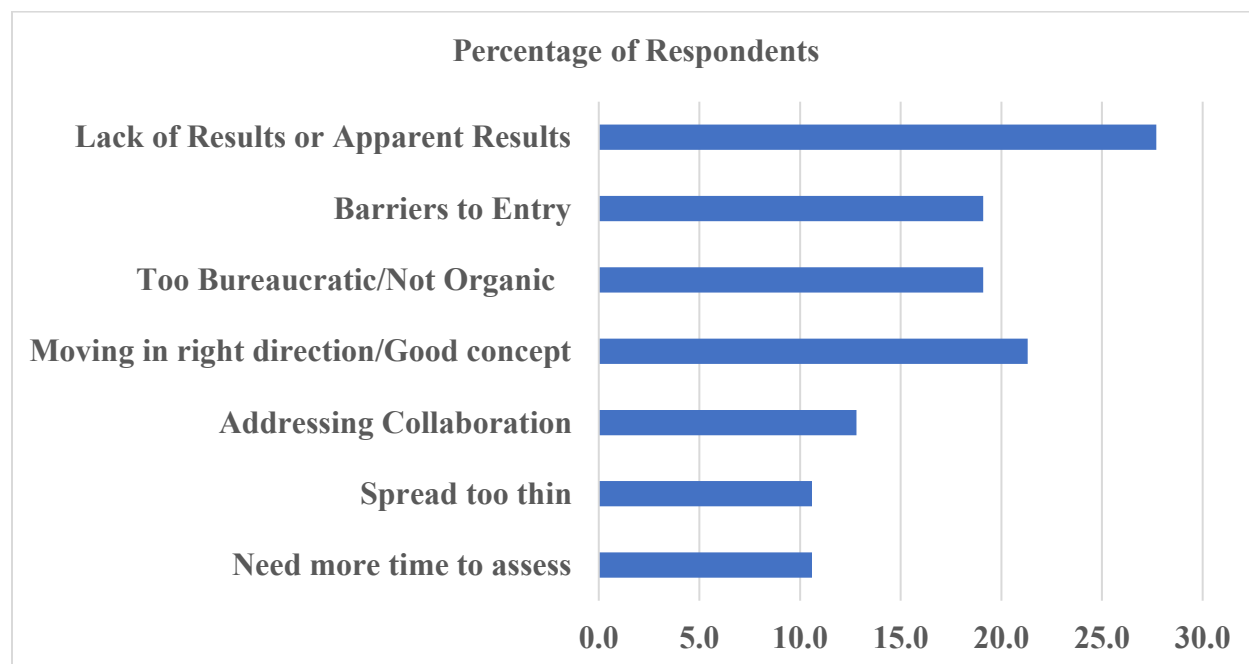
Moreover, this view was at times twinned with the perspective the clusters were a “good idea” or “great concept” but success could not actually be measured in real terms up to that point or if there were major advances these were not being communicated. Some comments were also very

forthright – that they “haven’t exactly knocked it out of the park” (I36). Highlighted as well – in 19 per cent of the cases, was that there were significant “barriers” to entry. This was particularly prominent in the case of regional areas where the view was that smaller but still vibrant centres of innovation were being “overlooked” or indeed “vastly overlooked.” Additionally in the category there was often a concern that the selection of the Superclusters was a “foregone conclusion” or that a political element had entered into the equation, given that the five clusters selected just “happened” to be located in the five regions of Canada. Interestingly the issue of the Superclusters being too “bureaucratic” and not having a more “organic” evolution also came in at 19 per cent of the respondents to this question. The main concerns here were that the initiative had essentially started “de novo,” which meant that significant time was lost setting up new agreements, new processes and basically all the “infrastructure” associated with rolling this program out – all when the intent was to accelerate and put “the foot to the floor” (I16). As one respondent indicated the clusters could have been “much more lean” (I50) and fashioned with more alignment among the five regarding processes such as IP strategy and contracting. Further the clusters might have leveraged more existing infrastructure where centres of innovation were already in place.

Additionally, however in 21 per cent of the cases there was a sound acknowledgement that the Superclusters were based on the right thinking and a “good concept” and were generally “moving in the right direction,” particularly given interruptions associated with the COVID pandemic. The import of prioritizing and – not picking “winners” but areas of focus and concentrating resources there, particularly in the context of industry-led initiatives, was seen as critical. Further, the impetus the clusters were giving to collaboration across Canada’s

innovation ecosystem and starting the right “conversations” was also highlighted, with 13 per cent falling into this categorization. Moreover, this was oftentimes articulated while recognizing

Figure 11 Superclusters: Themes Raised



there were bureaucratic impediments. Another 11 per cent of respondents mentioned that the clusters were “spread too thin” and that the \$1 billion of government funding allocated - when divided up among the five clusters and over five years - did not represent a particularly substantive investment. It was likened to a “drop in the bucket” (I6) or “peanut funding” (I8) when compared to need, geography of Canada and the task at hand. Finally, 11 per cent of the respondents indicated that it was unfair to judge the clusters at this stage – “momentum” was still building.³¹

³¹ As seen, this issue also registered in the respondent assessments in Figure 10 where answers were based on mutually exclusive categories. As earlier noted, in the case of Figure 10, 9 per cent of all interviewees indicated this dimension in their assessment.

Interestingly what stands out in these answers is that while 36 per cent had a clearly negative perspective on the clusters, almost half of those responding – 53 per cent --³² were aware of the valuable attributes that the Superclusters were having or could bring to the innovation ecosystem. And it was frequently wedded to concrete proposals for improving their design or functioning. In all – and to the heart of this research’s thesis – it was very much a key recognition of having policies and approaches in place that could essentially leaven the innovation ecosystem – and infrastructure -- and propel it forward. That this should not be a static undertaking or one wherein efforts undulate historically or where initiatives are overly centralized: these critiques and cautions speak very much to the need to focus on collaboration and thickened networks but with a fresh eye to the goal at hand, design required and the vast geography of the country as well.

Canada’s Biggest Challenge with Innovation

A third means of access to this question of thickening ecosystems was also provided in a more open question right off the top of the interview. Interviewees were provided with an opening statement indicating that “Canada has been consistently challenged by the innovation “paradox” as the Council of Canadian Academies (2013b) called it.” The statement went on to note the stronger status of S&T fundamentals in the Canadian context but also declining nature of R&D investment indicators.³³ The statement concluded that based on OECD data from 2000 onwards – specifically GERD and BERD trends -- Canada has seemingly been unable to positively impact the country’s rate of innovation. Respondents were then asked:

In your view, what do you see as Canada’s biggest challenge in dealing with these realities and challenges?

³² This number sums the positive, qualified positive, split and qualified negative responses in Figure 10. The actual total is 53.1 per cent when not rounded.

³³ See Chapter Two, Annex A-2 “Questions for In-depth Interviews” for the introductory comments.

Further, this question was supplemented with the following:

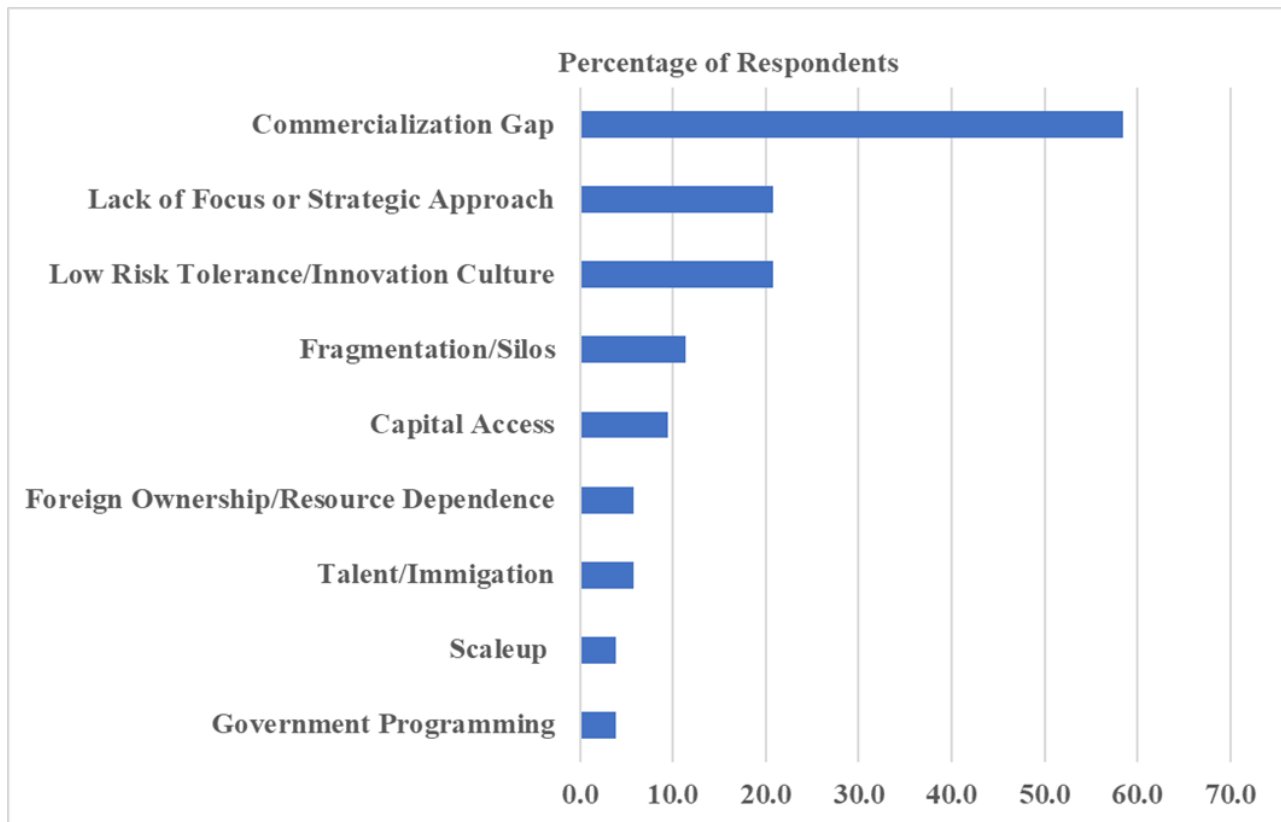
And on the policy front do you think we are doing enough to address this issue?

As with other lines of inquiry in the interview process, this very broad question opened up a detailed and extremely thoughtful range of insights on the dilemmas with which Canada was wrestling around innovation. To be noted as well, here too, 53 of the 54 interviewees were provided with an opportunity to address this issue and could provide more than one answer.

Respondents were quick to acknowledge the strength of Canada's "basic research" and success in publications, patents and indeed invention writ large – "dans les idées" – and some mentioned how in fact the Canadians "punched above our weight" in that regard. However, the theme that resonated most prominently was the failure to make the transition from invention to innovation – specifically the commercialization gap (Figure 12). Well over half the interviewees – **59 per cent** – pointed to the serious challenges Canada had in "translating results of research into innovative new products that are then produced in Canada." The country's standing in that regard was seen as "middle of the pack" on the international scene and the country compared unfavourably with nations such as Israel, South Korea, Taiwan and Scandinavian countries that had capably succeeded on the innovation front.

Certainly, the reasoning behind this position was extensive. Frequently mentioned was the tendency to try and propel innovation either through "technology push" -- and not the more dynamic and critical "market pull," be it sometimes mentioned as a national issue or specific sectoral one particularly inhabiting the biotech sector and to some degree high tech as well. So too had there been a pronounced reliance on investing in Higher Education R&D which in turn begat a "systemic problem" – i.e., the "failure from pulling HERD to BERD" (Business

Figure 12 Biggest Innovation Challenge: Themes Raised



Expenditures on R&D) (I19). Similarly mentioned was “la vallée de mort” (I39) where inventions languished in that middle ground of transporting research into commercial product. Additionally was there frequent recognition that, while Canada was good at Technology Readiness Levels (TRL) 123 of ideational creativity when it came to TRL 456 “then we hit the wall” (I33). Getting a prototype up and running and ready for an “operational environment” and deployment was often a bridge too far.

Also pronounced in the responses (and almost echoing a bit of Lundvall) was the need to, if not wed, certainly link the ideational stream to the final user at a much earlier stage in the innovation process. As one interviewee succinctly indicated, there was the need to do “research in a transdisciplinary fashion where the generation of a knowledge is not distanced from the end user” (I24). Further raised was the concern that firms can get into an R&D cycle, drawing down

on ample tax credits (and particularly SR&ED) and “never manag[ing] to get into that commercialization space” (I29).

While the commercialization issue – and lack thereof – was predominant in many ways, however, also articulated by 21 per cent of respondents was the lack of focus and “long term strategic approach” to set key priorities and sustain them. It was noted that the Canadian approach appears to be that:

“We fund that research and we hope that – we plant a thousand seeds and we hope that one of them turns into a plant that produces something” (I9).

Or as another respondent indicated the probability that technologies coming out of universities will necessarily “correspond au marché est très très faible” (I46).

Another 21 per cent of respondents attributed challenges around innovation to a culture and “mindset” of “low risk tolerance” and, given relatively easy access to North American markets, resource riches, national security and stable political environment, the “comfort” of a “low-innovation equilibrium” (I36). Other factors were also mentioned. Fragmentation within the Canadian innovation ecosystem and the tendency for “silos” also surfaced on this question – with 11 per cent specifically mentioning this issue. Highlighted as well were access to capital (for 9 per cent of respondents); foreign ownership and/or resource dependence of the Canadian economy (6 per cent), the need for more talent and immigration (6 per cent), the lack of scale-up (4 per cent) and government funding that was not sufficient “predictable,” nimble or “sustained” (4 per cent).

Certainly, it should be noted that issues around government programming and policy were probed more deeply in other questions asked of the participants. Moreover, in the case of government policy, these responses should **not** be taken as an indicator that there were few issues in this regard. But what these responses do speak to in rather unequivocal terms was that

the challenges around innovation in Canada were, and are, home-grown -- be it commercialization, lack of strategy and focus, low risk appetite or the silos inhabiting the ecosystem – and that these significantly diminished the integration and robustness of that system, robbing the innovation continuum of the essential connectors that made for a full value chain. As such, expecting to continue down this path with manifestly different results was unrealistic at best and at worst a condition that only perpetuated the “cycle.”³⁴

Interviews: An Overview

In short then, the overall perspective on the country’s extent of triadic collaboration resonated with the themes that emerged from the statistical data gleaned both from Statistics Canada and international sources. Efforts at enhanced cooperation were hampered by “silos” and fragmentation and particularly by barriers to the transformation of IP into marketable products and services. And the Superclusters, while notable for their potential, had not yet realized results – although admittedly some suggested more time was needed in making that assessment. Nor had the Superclusters adequately leveraged the existing centres of innovation activity or the existing knowledge infrastructure that could have provided a greater head start in getting these ventures up and running. And, traversing all of this was the commercialization gap that continued to stymie the country’s innovation future. Moreover, following behind as a critical factor was the lack of a “long-term” strategic approach that could establish a clear “roadmap” and guide the country forward. Overall, it was not that efforts to design such a roadmap or articulate such “vision” could not remain flexible or even create (in Blockian terms)

³⁴ Or as one respondent bluntly put the Canadian quandary and its particularly static nature: “If you always do what you always did you’ll always get what you always got.”

the “public space” for experimentation but it spoke to a kind of stasis in the current context that historically at least was not easily transcended.

Conclusion

The evidence presented here over the last twenty-year period is ultimately a narrative of disjuncture, or at the least dissonance, between intent and impact. And to that extent it robs the Developmental Network State framework -- and its key pillar around state brokering and thickening of the triple helix -- of its theoretical leverage. To be sure, the intent of federal policy both in agenda-setting and in administrative implementation was present. Across governments of different political stripes of this era – Liberal or Tory – collaboration, partnerships, “building a nation of innovators” was prioritized and seized upon as a plausible answer to the tenacious gap around commercialization – the gap between lab bench and factory floor. Moreover, as has been indicated, these priorities were not bereft of the standard tools in the public administration toolbox. Organizations were variously mandated to address this issue and fashion the nodes of linkage and technology transfer that were needed, be it IC/ISED, the granting councils or the ever-revolving assignments given to the NRC. Even an attendant IP strategy was respectively considered in all cases throughout these years. Finally, a not inconsiderate amount of funding -- \$79 billion in all – was allocated to give implementation of these initiatives the proverbial fiscal teeth.

However, what was not borne out were the indicators of success. True, data is somewhat patchy, interrupted as it is by the gaps and changing methodology in Stats Can surveys, as well as the latter-day tendency of OECD data to focus on EU rankings. Despite the discrepancies, what is illuminated is the relatively shallow character of the Canadian innovation ecosystem and,

in a particularly unsettling aspect of the data, the tendency for levels of collaboration to drop quite precipitously as in the import of innovation activity ascends.

Further, this research's efforts to round out the data portrait with the in-depth thought leader interviews also attest to the challenges that persist. Just over two-thirds of respondents found the country's endeavours to establish such networks – and the attendant “critical mass” -- to be wanting. Moreover, a host of factors were raised at the potential contributors to this situation: the siloed nature of academic/industry/government linkages; the typical Canadian response of “sprinkling” initiatives across huge geographic mass and low population density; and the lingering legacies of resource dependence or sectoral branch plant economies. At the same time, deficiencies extended to issues of regionalization and areas typically excluded from collaboration endeavours. So too were the Superclusters cast in a less than favourable light by 51 per cent of the respondents. Albeit perceived as being created with good intent (and with a smaller percentage of interviewees recognizing more time was needed to assess) the Superclusters were hampered by seeming lack of results, barriers to entry, too thin a dispersion, lacking in “organic” evolution and even a potential political overlay to regional selections. And finally, in a testament to the continuing challenges and impediments laden across the Canadian innovation landscape, 59 per cent of respondents raised the ongoing commercialization gap and, in another 21 per cent of cases, the need for a much-sharpened strategic focus.

Thus, rather than evidence of policy pull that DNS proclaims for successful innovation, what the Canadian portrait reveals is a landscape in many ways ensnared in a net of its own making. Indeed, in contrast to DNS, there is a certain homage that must be paid to the path-dependent trajectories at times articulated by scholars of historical institutionalism. The ongoing strength of Canada's research and science as portrayed through bibliometric measures; the

relatively stable pattern of HERD financed by business over the years; the ongoing data trends of internally-oriented firm collaboration (with sales and marketing) rather than outward linkages to other partners in the ecosystem: all are persistent aspects of the Canadian innovation picture. Even the ongoing rhetoric around the pressing need to address these issues and the continual tinkering with the NRC speak to path dependencies and not policy-induced change.

To be sure Artificial Intelligence ascends as an important exception to these elements of stasis, the result of a confluence of factors –science, investment, partnership—that has borne fruit. Perhaps even genomics can be cast alongside this but these are the exceptions to the rule. In large part on the issue of network thickening, Canada has become enmeshed in its own unique circumstances, be it the challenges of geography, structural economic dependence, even the culture of low risk tolerance or “low-innovation equilibrium.” In any event, if the DNS posits a rather linear model with state actions having causal effect, the continuing puzzle in the Canadian case is the collaboration issue is not so easily swayed. Moreover, if as DNS argues, the success of innovation in the US has ridden in part on a dynamic vortex of innovation networks and nodes, the Canadian case does not seemingly have that same lustre.

That said, two issues remain of import. Acknowledging the unique geographic, economic, sectoral and even cultural challenges Canada faces, what is signalled is the necessity -- even urgency – in overcoming these barriers and enabling the innovation ecosystem to thrive. Secondly, a continuation of simply more brokering or more money is unlikely to significantly change the game. It will demand sharply honed policy and public administration instruments, capable of troubleshooting problematic areas. It may be, as some respondents suggested, “nimble” funding that does not undercut fundamental science but can address fast emerging industrial needs. It may be the need for firms to draw down on research expertise as situations

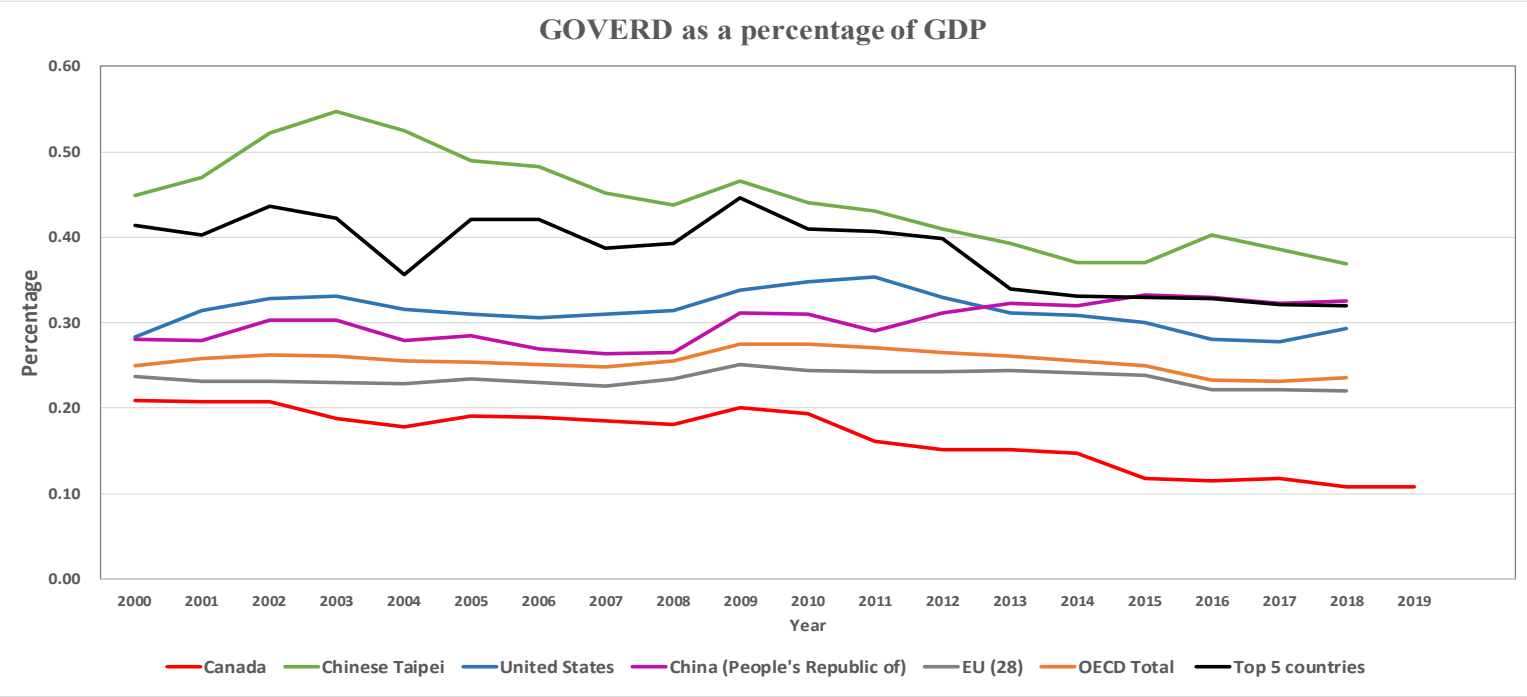
arise and be prepared to release that expertise as new challenges emerge. Further, it will require a keen eye to the challenging dilemma of strategic focus and the space for incorporating thriving innovation activity outside the metropolises. If DNS has such policy relevance in the American case, the missing piece in the Canadian puzzle requires a similar attention but with different tools; in today's parlance it requires a "circuit-breaker" with past trajectories.

Annex A – 6: Network Investment and Collaboration Indicators

Figure 1 GOVERD as a percentage of GDP

Dataset: Main Science and Technology Indicators

MSTI Variables		GOVERD as a percentage of GDP																			
Unit		Percentage																			
Country	Year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Canada		0.21	0.21	0.21	0.19	0.18	0.19	0.19	0.19	0.18	0.20	0.19	0.16	0.15	0.15	0.15	0.12	0.11	0.12	0.11	0.11
Chinese Taipei		0.45	0.47	0.52	0.55	0.52	0.49	0.48	0.45	0.44	0.47	0.44	0.43	0.41	0.39	0.37	0.37	0.40	0.39	0.37	
United States		0.28	0.31	0.33	0.33	0.32	0.31	0.31	0.31	0.31	0.34	0.35	0.35	0.33	0.31	0.31	0.30	0.28	0.28	0.29	
China (People's Republic of)		0.28	0.28	0.30	0.30	0.28	0.28	0.27	0.26	0.26	0.31	0.31	0.29	0.31	0.32	0.32	0.33	0.33	0.32	0.32	
EU (28)		0.24	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.25	0.24	0.24	0.24	0.24	0.24	0.24	0.22	0.22	0.22	
OECD Total		0.25	0.26	0.26	0.26	0.26	0.25	0.25	0.25	0.26	0.28	0.28	0.27	0.26	0.26	0.26	0.25	0.23	0.23	0.24	
Top 5 countries		0.41	0.40	0.44	0.42	0.36	0.42	0.42	0.39	0.39	0.45	0.41	0.41	0.40	0.34	0.33	0.33	0.33	0.32	0.32	



Source: *OECD Main Science and Technology Indicators* (https://stats.oecd.org/Index.aspx?DataSetCode=MSTI_PUB#)

Top 5 countries: Chinese Taipei, Iceland, Germany, Korea, Slovenia

NOTE: OECD uses totals for OECD, EU(28); as such these are excluded from the top 5

Data extracted on 03 Nov 2020 18:41 UTC (GMT) from OECD.Stat

Table 1 Industry Canada/Innovation, Science and Economic Development Strategic Outcomes and Program Activity 1999-2000 – 2019-2020

Reporting Period	1999-2000	2000-2001	2001-2002	2002-2003	2003-2004	2004-2005	2005-2006	2006-2007
Strategic Outcome*	Improving Canada's Innovation Performance	Improving Canada's Innovation Performance	Improving Canada's Innovation Performance	Improving Canada's Innovation Performance	Improving Canada's Innovation Performance	An Innovative Economy	An Innovative Economy	An Innovative Economy
Program Activity	Increased recognition of innovation as a critical success factor in all sectors	Increased recognition of innovation as a critical success factor in all sectors	Increased recognition of innovation as a critical success factor in all sectors	Increased recognition of innovation as a critical success factor in all sectors	Increased recognition of innovation as a critical success factor in all sectors	Policy Sector – S&T and Innovation	Policy Sector – S&T and Innovation	Policy Sector – S&T and Innovation
Program Activity	Expanded knowledge base, especially in fields with good opportunities	Expanded knowledge base, especially in fields with good opportunities	Expanded knowledge base, especially in fields with good opportunities	Expanded knowledge base, especially in fields with good opportunities	Expanded knowledge base, especially in fields with good opportunities	Industry Sector – S&T and Innovation	Industry Sector – S&T and Innovation	Industry Sector – S&T and Innovation
Program Activity	Accelerated commercialization and adoption of innovative processes and products by Canadian organizations	Accelerated commercialization and adoption of innovative processes and products by Canadian organizations	Accelerated commercialization and adoption of innovative processes and products by Canadian organizations	Accelerated commercialization and adoption of innovative processes and products by Canadian organizations	Accelerated commercialization and adoption of innovative processes and products by Canadian organizations	Spectrum, Information Technologies and Telecommunications Sector -- S&T and Innovation	Spectrum, Information Technologies and Telecommunications Sector -- S&T and Innovation	Spectrum, Information Technologies and Telecommunications Sector -- S&T and Innovation
Program Activity		Increased development and application of eco-efficient practices and technologies in Canada	Increased development and application of eco-efficient practices and technologies in Canada	Increased development and application of eco-efficient practices and technologies in Canada	Increased development and application of eco-efficient practices and technologies in Canada	Communications Research Centre – S&T and Innovation	Communications Research Centre – S&T and Innovation	Communications Research Centre – S&T and Innovation
Program Activity						Technology Partnerships Canada – S&T & Innovation	Technology Partnerships Canada – S&T and Innovation	Technology Partnerships Canada – S&T and Innovation

Industry Canada/Innovation, Science and Economic Development Strategic Outcomes and Program Activity 1999-2000 – 2019-2020 (cont'd.)

Reporting Period	2007-2008	2008-2009	2009-2010	2010-2011	2011-2012	2012-2013	2013-2014	2014-2015
Strategic Outcome*	An Innovative Economy	An Innovative Economy	Science and Technology, Knowledge, and Innovation Are Effective Drivers of a Strong Canadian Economy	Science and Technology, Knowledge, and Innovation Are Effective Drivers of a Strong Canadian Economy	Advancements in Science and Technology, Knowledge, and Innovation Strengthen the Canadian Economy	Advancements in Science and Technology, Knowledge, and Innovation Strengthen the Canadian Economy	Advancements in Science and Technology, Knowledge, and Innovation Strengthen the Canadian Economy	Advancements in Science and Technology, Knowledge, and Innovation Strengthen the Canadian Economy
Program Activity	Policy Sector – S&T and Innovation	Science and Innovation Sector – S&T and Innovation	Canada's Research and Innovation Capacity	Canada's Research and Innovation Capacity	Science, Technology and Innovation Capacity	Science, Technology and Innovation Capacity	Science, Technology and Innovation Capacity	Science, Technology and Innovation Capacity
Program Activity	Industry Sector – S&T and Innovation	Industry Sector – S&T and Innovation	Knowledge Advantage in Targeted Canadian Industries	Commercialization and Research and Development Capacity in Targeted Canadian Industries	Information and Communication Technologies Research and Innovation	Information and Communication Technologies Research and Innovation	Information and Communication Technologies Research and Innovation	**
Program Activity	Spectrum, Information Technologies and Telecommunications Sector -- S&T and Innovation	Spectrum, Information Technologies and Telecommunications Sector -- S&T and Innovation	**	**	**	**	**	**
Program Activity	Communications Research Centre – S&T and Innovation	Communications Research Centre – S&T and Innovation	Communications Research Centre Canada	Communications Research Centre Canada***	***	***	***	***
Program Activity	Technology Partnerships Canada – S&T and Innovation	Industrial Technologies Office – Special Operating Agency	Industrial Technologies Office – Special Operating Agency	**	Research and Development Financing	Industrial Research and Development Financing	Industrial Research and Development Financing	Industrial Research and Development Financing

**Industry Canada/Innovation, Science and Economic Development Strategic Outcomes
and Program Activity 1999-2000 – 2019-2020 (cont'd)**

Reporting Period	2015-2016	2016-2017*	2017-2018*	2018-2019****	2019-2020****
Strategic Outcome*	Advancements in Science and Technology, Knowledge, and Innovation Strengthen the Canadian Economy				
Program Activity	Science, Technology and Innovation Capacity	Science, Technology and Innovation Capacity	Science, Technology and Innovation Capacity	Science, Technology, Research and Commercialization	Science, Technology, Research and Commercialization
Program Activity	**	**	**	**	**
Program Activity	Industrial Research and Development Financing	Industrial Research and Development Financing	Industrial Research and Development Financing	Companies, Investment and Growth*****	Companies, Investment and Growth*****

*From 2016-2017 onwards the ISED Departmental Results Report lists only Results and not Strategic Outcomes.

**Blank spaces indicate that the previous year’s category of Program Activity is no longer listed in the DPR or DRR or is no longer listed under the Strategic Outcome associated with innovation.

In the case of Spectrum, Information Technologies and the Telecommunications Sector, this PA actually moved under the Strategic Outcome of A Fair, Efficient and Competitive Marketplace.

*** Between 2011-12 and 2013-14 Communications Research Canada Program Activity is rolled up under Information and Communications Technologies Research and Innovation.

In 2014-2015, the program then moves under Spectrum, Telecommunications and the Digital Economy which was housed under the Strategic Outcome of The Canadian marketplace is efficient and competitive.

**** In the Departmental Results Reports for 2018-2019 and 2019-2020, the term Program Activity is not used; rather the term Core Responsibility is used to describe initiatives.

***** This Core Responsibility includes the Strategic Innovation Fund

Methodological Notes for Network Charts

* Innovation Capacity

The category of Innovation Capacity is used to capture the development of collaboration and networking and the efforts to engender a national innovation eco-system in various IC/ISED activities throughout the 1999-2019 time period. Specifically, it includes over the years the following Program Activities (as listed in Table 1):

- increased recognition of innovation as a critical success factor in all sectors
- expanded knowledge base, especially in fields with good opportunities
- accelerated commercialization and adoption of innovative processes and products by Canadian organizations
- increased development and application of eco-efficient practices and technologies in Canada
- S&T Innovation – Policy Sector; Industry Sector; Spectrum, Information Technologies and Telecommunications Sector and Communications Research Centre
- Canada's research and innovation capacity
- science, technology and innovation capacity
- knowledge advantage in targeted Canadian industries
- information and communication technologies research and innovation
- science, technology research and commercialization.

Please note that for increased recognition, expanded knowledge base, accelerated commercialization and increased development of practices and technologies, breakdowns are not available for these individual programs. Nor (as noted below) in 1999-2000 to 2000 – 2001 is there an overall innovation program fiscal entry. However these are the categories rolled up into innovation – improving Canada's innovation performance. Note DPR 1999-2000 does not include increased development of practices and technologies.

*Innovation Financing

The category of Innovation Financing is used to capture, for the most part, what were direct targeted activities at industry to provide repayable and non-repayable contributions to foster industrial research and development. This involved over the years targeting various sectors but especially automotive, aerospace, strategic aerospace and defence and clean technologies. It includes the following Program Activities:

- Technology Partnerships Canada - S&T and Innovation
- Industrial Technologies Office – Special Operating Agency
- Research and Development financing
- Industrial Research and Development financing
- Contributions under the Strategic Innovation Fund.

1999-2000 – 2000-2001

A breakdown of innovation expenditures is not available either through the Public Accounts or the DPRs for these years.

2001-2002 - 2004-2005

Public Accounts in these years only list Departmental expenditures by Program Business Lines and as such does not map expenditures to the Strategic Outcome (SO) of An Innovative Economy. However, the DPRs for these years do include the mapping of expenditures to SOs and these are the numbers used. (Rounding is in the original DPRs).

2009-2010

For the program of Knowledge Advantage in Targeted Canadian Industries, the expenditures in the Public Accounts are used. The Program Expenditures in Knowledge Advantage in the DPR actually state 58,900,000.

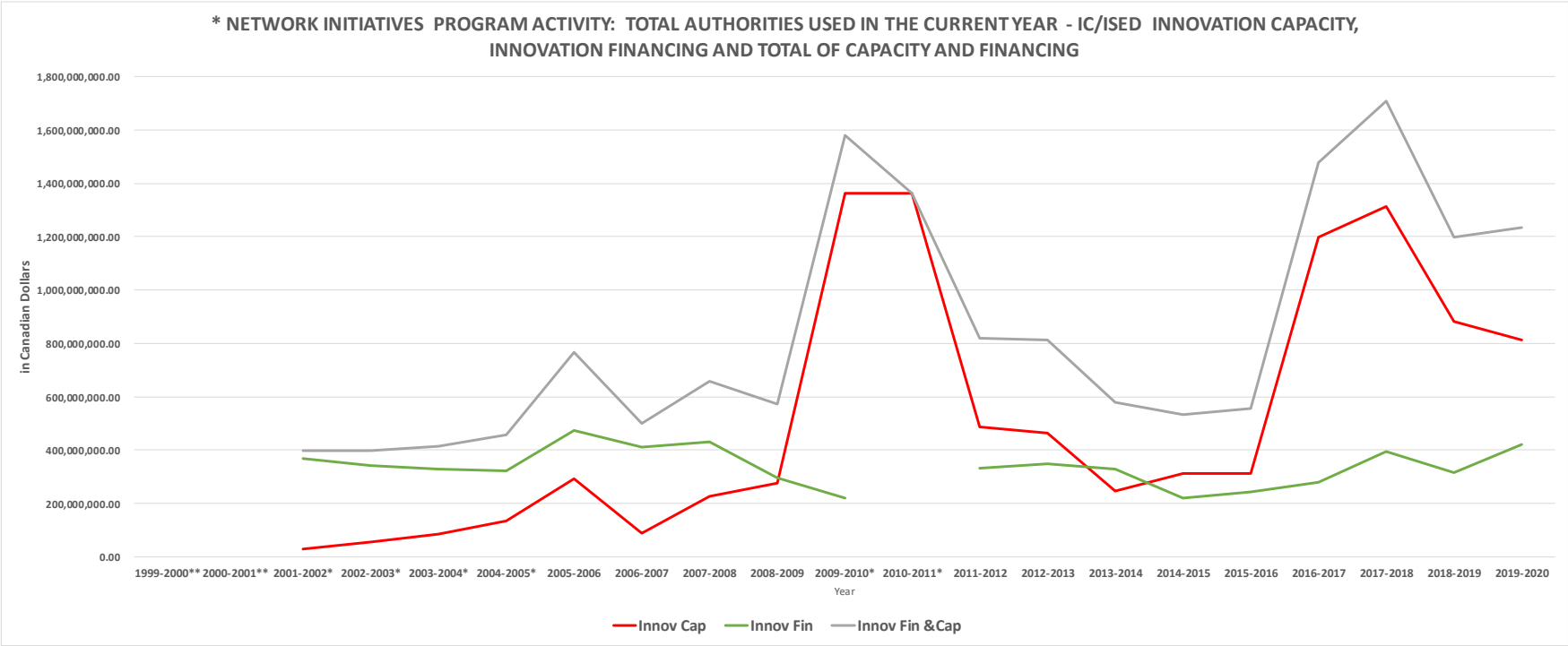
2010-2011

For the category of Canada's Research and Innovation Capacity, there is extensive variance between the expenditures listed in the Public Accounts for 2010-2011 and IC's DPR (2011, 13). The former indicates \$1,068,895,818.00 and the latter \$255,900,000 in actual spending. As usual, Public Accounts data is used.

Innovation financing for 2010-2011 is not separated out as TPC or ITO or Commercialization and R&D Financing. As such this year the category of Commercialization and Research and Development Capacity in Targeted Canadian industries is an amalgam of both networking activity and SADI contributions (IC DPR 2011, 29). Very probably it also included TPC , Bombardier C Series and Auto Innovation Fund contributions as these were referenced in the 2009-2010 DPR,(IC 2010 13). As a breakout of innovation financing and capacity is not available in this year, the funding for the Commercialization and Research and Development Capacity in Targeted Canadian Industries is included under capacity **in this year only**.

Figure 2 Federal Network Initiatives Program Activity – IC/ISED Innovation Capacity, Innovation Financing and Total of Capacity and Financing

Measure	* NETWORK INITIATIVES PROGRAM ACTIVITY: TOTAL AUTHORITIES USED IN THE CURRENT YEAR - IC/ISED INNOVATION CAPACITY, INNOVATION FINANCING AND TOTAL OF CAPACITY AND FINANCING																					
Unit	in Canadian Dollars																					
Year	1999-2000**	2000-2001**	2001-2002*	2002-2003*	2003-2004*	2004-2005*	2005-2006	2006-2007	2007-2008	2008-2009	2009-2010*	2010-2011*	2011-2012	2012-2013	2013-2014	2014-2015	2015-2016	2016-2017	2017-2018	2018-2019	2019-2020	Total of All Years
Innov Cap			30,300,000	56,500,000	84,000,000	135,800,000	291,936,393	90,192,219	226,124,503	276,999,635	1,362,261,343	1,362,056,465	485,758,514	463,478,216	247,989,346	313,406,525	311,415,582	1,197,358,867	1,313,478,869	882,662,747	813,170,459	9,944,889,683
Innov Fin			367,500,000	341,100,000	329,100,000	323,000,000	473,745,210	409,947,555	431,826,100	294,602,815	218,827,534		332,865,598	349,193,500	330,580,008	220,998,346	244,450,613	280,593,734	394,993,951	316,748,009	421,069,258	6,081,142,231
Innov Fin & Cap			397,800,000	397,600,000	413,100,000	458,800,000	765,681,603	500,139,774	657,950,603	571,602,450	1,581,088,877	1,362,056,465	818,624,112	812,671,716	578,569,354	534,404,871	555,866,195	1,477,952,601	1,708,472,820	1,199,410,756	1,234,239,717	16,026,031,914



Innov Cap - Industry Canada/Innovation Science and Economic Development Innovation Capacity Building
Innov Fin - Industry Canada/Innovation Science and Economic Development Innovation Financing
* See Methodological Notes
** A breakdown of innovation expenditures is not available either in Public Accounts or IC DPRs
Sources: IC DPRs 1999-2000 - 2004-2005;
Public Accounts 2005-2006 - 2019-2020

Figure 3 Federal Network Initiatives – Program Authorities – IC/ISED Innovation Capacity Breakdown

*FEDERAL NETWORK INITIATIVES - PROGRAM AUTHORITIES; TOTAL AUTHORITIES USED IN THE CURRENT YEAR - IC/ISED INNOVATION CAPACITY																					
Year	1999-2000**	2000-2001**	2001-2002*	2002-2003*	2003-2004*	2004-2005*	2005-2006	2006-2007	2007-2008	2008-2009	2009-2010*	2010-2011*	2011-2012	2012-2013	2013-2014	2014-2015	2015-2016	2016-2017	2017-2018	2018-2019	2019-2020
Recognition																					
Knowledge Base																					
Acc Commerce																					
Inc dev of econ																					
Ops Sector				6,500,000																	
Other			500,000	600,000	1,000,000					0											
Policy Sector			9,700,000	6,900,000	21,500,000	19,900,000	42,187,037	10,567,346	148,778,181	99,714,246											
Ind Sector			14,400,000	24,000,000	44,400,000	73,200,000	172,485,262	4,914,024	19,389,207	90,367,354											
SITT Sector			2,700,000	3,000,000	2,900,000	1,700,000	20,781,493	24,111,360	15,060,890	29,527,198											
CRC			3,000,000	15,500,000	14,200,000	41,000,000	56,482,601	50,599,489	42,896,225	57,390,837	48,737,924	46,111,852									
R&I or ST&I Cap											1,271,133,398	1,068,895,818	440,838,152	415,896,394	210,195,969	313,406,525	311,415,582	1,197,358,867	1,313,478,869		
Knowledge Adv											42,390,021	247,048,795									
ICT R&I													44,920,362	47,581,822	37,793,377						
S,T,R & Comm																				882,662,747	813,170,459
TOTAL			30,300,000	56,500,000	84,000,000	135,800,000	291,936,393	90,192,219	226,124,503	276,999,635	1,362,261,343	1,362,056,465	485,758,514	463,478,216	247,989,346	313,406,525	311,415,582	1,197,358,867	1,313,478,869	882,662,747	813,170,459

LEGEND

Recognition:	Increase recognition of innovation as a critical successfactor in all sectors
Knowledge base:	Expanded knowledge base, especially in fields with good opportunities
Acc Commere:	Accelerated commercialization and adoption of innovative processes and products by Canadian organizations
Inc dev of econ:	Increase development of economy
Ops Sector:	Operations Sector
Other	
Policy Sector	
Ind Sector:	Industry Sector
SITT Sector:	Spectrum, Information Technologies and Telecommunications Sector and Communications Research Centre
CRC:	Communications Research Centre
R&I or ST&I Cap:	Canada's research and innovation capacity or Science, technology and innovation capacity
Knowledge Adv:	Knowledge advantage in targeted Canadian industries
ICT R&I:	Information and Communication Technologies research and innovation
S,T,R & Comm	Science, Technology, Research and Commercializaiton

*See Methodological Notes

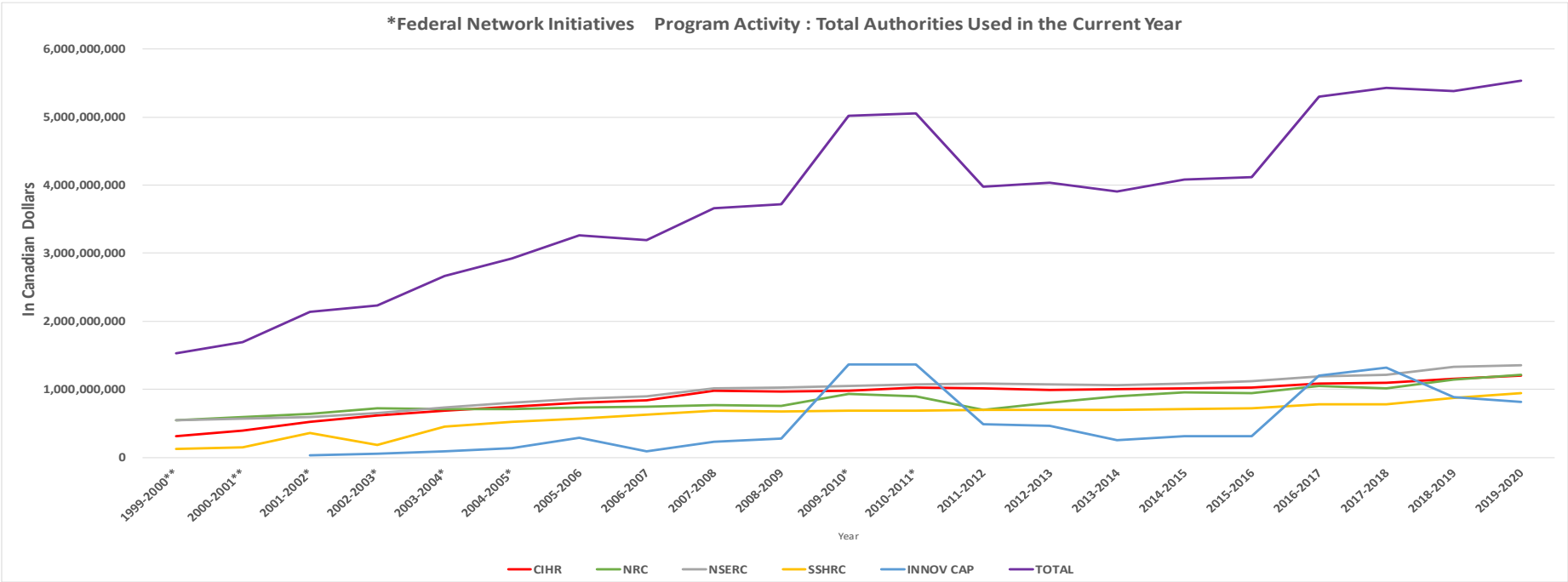
**A breakdown of innovation expenditures is not available either in Public Accounts or IC DPRs

Sources: IC DPRs 1999-2000 - 2004-2005;

Public Accounts 2005-2006 -2019-2020

Figure 4 Federal Network Initiatives Program Activity: Total Authorities Used in the Current Year

Measure	*Federal Network Initiatives Program Activity : Total Authorities Used in the Current Year																					
Unit	In Canadian Dollars																					
Year	1999-2000**	2000-2001**	2001-2002*	2002-2003*	2003-2004*	2004-2005*	2005-2006	2006-2007	2007-2008	2008-2009	2009-2010*	2010-2011*	2011-2012	2012-2013	2013-2014	2014-2015	2015-2016	2016-2017	2017-2018	2018-2019	2019-2020	Total - All Years
AGENCY																						
CIHR	310,504,413	390,035,089	524,146,861	621,424,625	686,217,269	747,972,258	800,875,508	843,269,265	974,070,783	969,415,324	983,733,066	1,026,871,276	1,009,091,392	997,052,742	997,971,988	1,017,279,382	1,026,378,153	1,081,330,344	1,097,161,185	1,150,927,127	1,202,050,854	18,457,778,904
NRC	543,520,583	591,177,394	641,247,699	718,876,736	705,485,131	712,637,634	734,862,632	742,083,857	771,150,040	757,929,665	931,013,760	903,298,393	698,503,582	804,804,912	894,418,206	955,704,916	945,077,595	1,048,740,465	1,016,523,437	1,145,203,852	1,214,601,865	17,476,862,354
NSERC	549,848,434	564,952,867	587,559,453	651,293,221	732,579,465	803,049,577	859,423,209	895,422,774	1,012,459,934	1,029,809,172	1,051,247,282	1,075,943,914	1,085,737,592	1,075,981,272	1,066,679,030	1,085,445,456	1,115,653,194	1,191,260,893	1,219,141,888	1,330,149,905	1,359,365,352	20,343,003,884
SSHRC	125,824,863	143,039,265	360,021,221	186,212,605	457,112,093	519,409,937	571,323,242	625,248,530	681,046,571	679,546,796	686,433,454	689,095,926	697,853,661	696,432,583	695,719,438	712,926,648	720,292,139	775,954,047	783,979,328	873,129,828	940,757,288	12,621,359,463
INNOV CAP			30,300,000	56,500,000	84,000,000	135,800,000	291,936,393	90,192,219	226,124,503	276,999,635	1,362,261,343	1,362,056,465	485,758,514	463,478,216	247,989,346	313,406,525	311,415,582	1,197,358,867	1,313,478,869	882,662,747	813,170,459	9,944,889,683
TOTAL	1,529,698,293	1,689,204,615	2,143,275,234	2,234,307,187	2,665,393,958	2,918,869,406	3,258,420,984	3,196,216,645	3,664,851,831	3,713,700,592	5,014,688,905	5,057,265,974	3,976,944,741	4,037,749,725	3,902,778,008	4,084,762,927	4,118,816,663	5,294,644,616	5,430,284,707	5,382,073,459	5,529,945,818	78,843,894,288

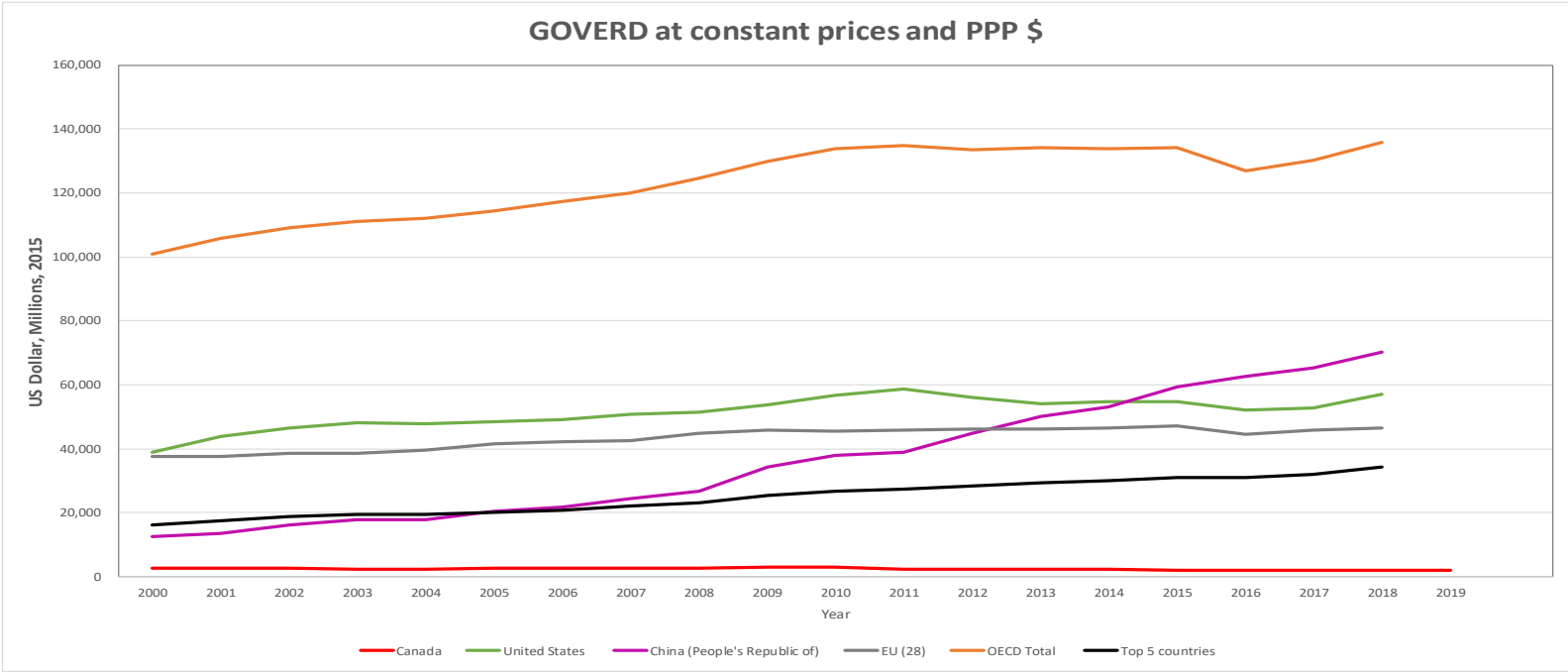


CIHR Canadian Institutes of Health Research (1999-2000 Medical Research Council)
NRC National Research Council Canada
NSERC Natural Sciences and Engineering Research Council
SSHRC Social Sciences and Humanities Research Council
Innov Cap Industry Canada/Innovation Science and Economic Development - Innovation Capacity Building
*See Methodological Notes
**A breakdown of innovation expenditures is not available either in Public Accounts or IC DPRs
Sources: IC DPRs 1999-2000 - 2004-2005;
Public Accounts 2005-2006 - 2019-2020

Figure 5 GOVERD at constant prices and PPP\$

Dataset: Main Science and Technology Indicators

MSTI Variables	GOVERD at constant prices and PPP \$																			
Unit	US Dollar, Millions, 2015																			
Year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Country																				
Canada	2,490	2,523	2,589	2,395	2,332	2,588	2,626	2,629	2,595	2,786	2,774	2,378	2,287	2,334	2,338	1,879	1,851	1,961	1,827	1,869
United States	38,997	43,711	46,440	48,115	47,703	48,367	49,130	50,614	51,334	53,856	56,788	58,671	55,858	53,897	54,669	54,666	51,963	52,583	57,153	
China (People's Republic of)	12,558	13,537	16,026	17,640	17,851	20,318	21,671	24,254	26,616	34,292	37,833	38,809	44,788	50,078	53,203	59,159	62,618	65,315	70,201	
EU (28)	37,643	37,626	38,399	38,636	39,633	41,415	42,133	42,615	44,653	45,776	45,551	45,948	46,003	46,229	46,514	47,246	44,508	45,814	46,552	
OECD Total	100,994	105,702	109,097	111,177	112,176	114,544	117,211	119,965	124,486	129,774	133,755	134,924	133,403	134,076	134,006	134,123	127,041	130,072	135,746	
Top 5 countries	16,052	17,386	18,629	19,432	19,469	20,029	20,817	21,968	22,985	25,394	26,685	27,220	28,274	29,248	30,022	31,050	31,101	32,044	34,164	



Source: *OECD Main Science and Technology Indicators* (https://stats.oecd.org/Index.aspx?DataSetCode=MSTI_PUB#)

Top 5 countries: United States, China, Germany, Japan, Russia

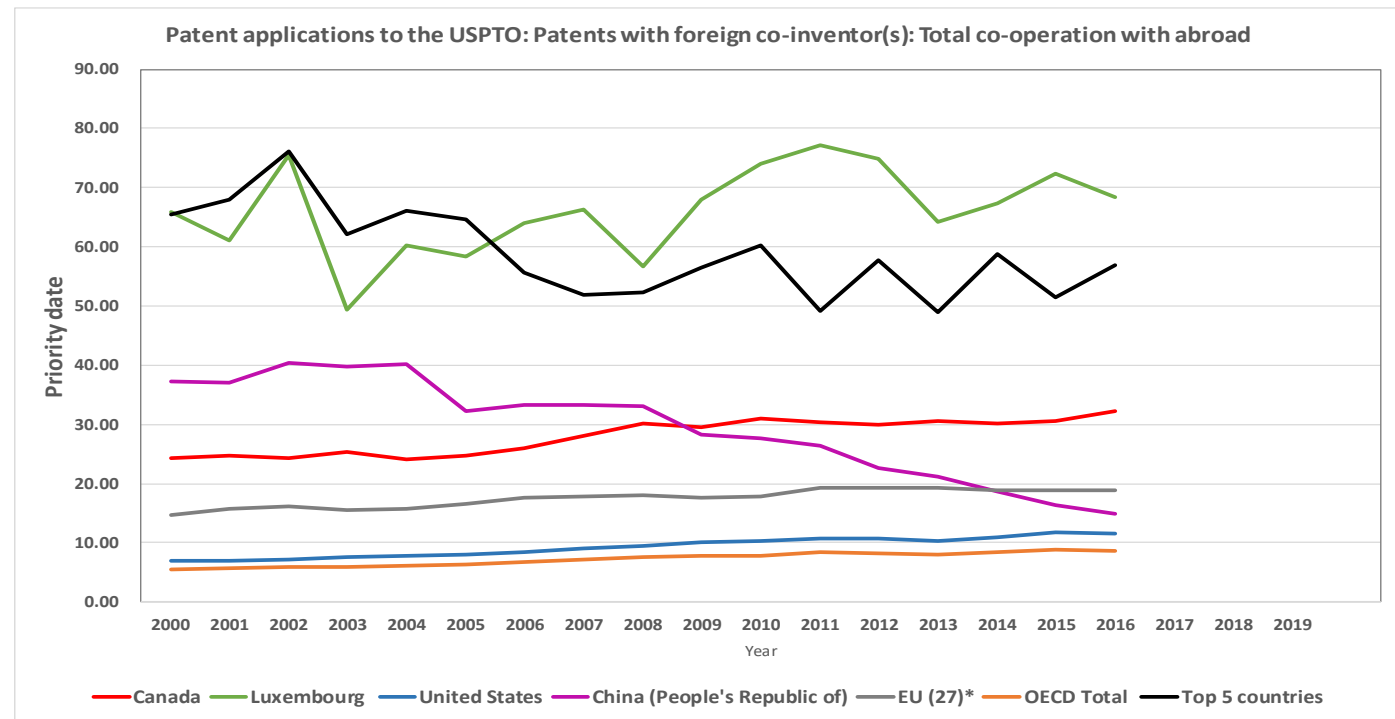
NOTE: OECD uses totals for OECD, EU(28); as such these are excluded from the top 5

Data extracted on 06 Nov 2020 21:18 UTC (GMT) from OECD.Stat

Figure 6 Patent applications to the USPTO: Patents with foreign co-inventor(s): Total co-operation abroad

Dataset: International Co-operation in Patents

Patent Office	Patent applications to the USPTO: Patents with foreign co-inventor(s): Total co-operation with abroad																			
Reference Date	Priority date																			
Year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Country																				
<u>Canada</u>	24.25	24.65	24.32	25.35	24.10	24.73	26.06	28.07	30.13	29.47	30.97	30.37	29.84	30.59	30.17	30.49	32.12			
<u>Luxembourg</u>	65.91	61.17	75.51	49.40	60.17	58.33	63.96	66.29	56.76	68.00	74.02	77.12	74.81	64.15	67.24	72.26	68.29			
<u>United States</u>	6.84	6.98	7.05	7.49	7.73	8.05	8.36	8.94	9.46	9.98	10.28	10.77	10.68	10.21	10.99	11.69	11.59			
<u>China (People's Republic of)</u>	37.26	36.93	40.35	39.72	40.20	32.17	33.23	33.32	33.04	28.28	27.67	26.37	22.57	21.07	18.75	16.35	14.79			
<u>EU (27)*</u>	14.66	15.71	16.08	15.45	15.68	16.54	17.61	17.84	17.99	17.63	17.79	19.17	19.36	19.18	18.80	18.90	18.94			
<u>OECD Total</u>	5.50	5.78	5.87	5.97	6.17	6.42	6.70	7.17	7.59	7.80	7.88	8.34	8.22	8.07	8.41	8.73	8.72			
<u>Top 5 countries</u>	65.42	67.91	76.02	62.07	66.00	64.67	55.70	51.85	52.31	56.40	60.25	49.13	57.82	49.03	58.69	51.36	56.85			



Source: *OECD Main Science and Technology Indicators* (https://stats.oecd.org/Index.aspx?DataSetCode=MSTI_PUB#)

Top 5 countries: Luxembourg, Latvia, Lovak Republic, Czech Republic, Lithuania

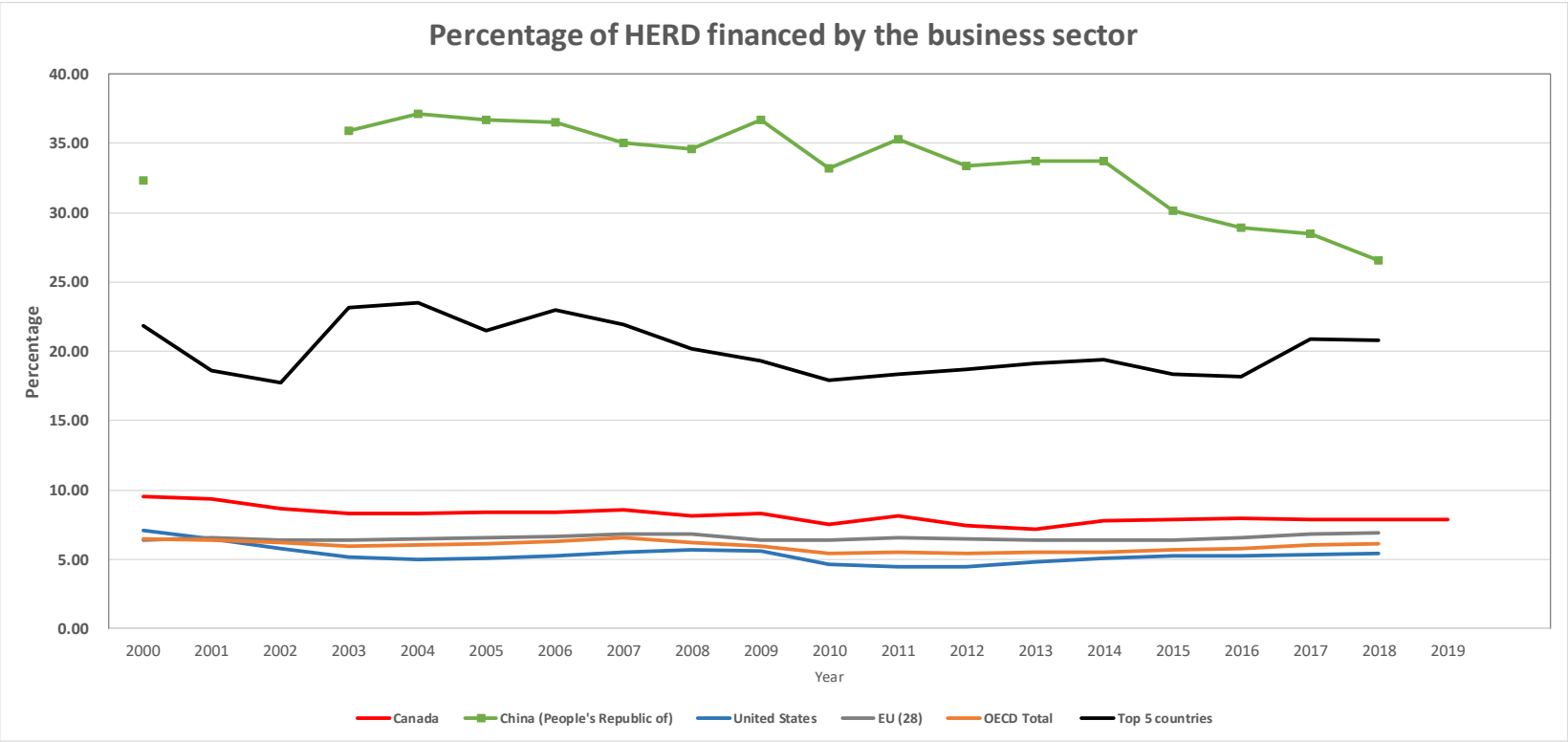
NOTE: OECD uses totals for OECD, EU(28); as such these are excluded from the top 5 * EU27 is used in this OECD data.

Data extracted on 09 Nov 2020 23:04 UTC (GMT) from OECD.Stat

Figure 7 Percentage of HERD financed by the business sector

Dataset: Main Science and Technology Indicators

MSTI Variables	Percentage of HERD financed by the business sector																			
Unit	Percentage																			
Year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Country																				
Canada	9.55	9.39	8.63	8.34	8.33	8.44	8.39	8.54	8.16	8.28	7.49	8.16	7.46	7.14	7.74	7.86	7.92	7.85	7.85	7.84
China (People's Republic of)	32.36			35.89	37.10	36.70	36.57	35.05	34.57	36.67	33.23	35.26	33.37	33.77	33.70	30.19	28.96	28.47	26.56	
United States	7.08	6.49	5.75	5.16	4.98	5.04	5.24	5.48	5.69	5.60	4.67	4.49	4.47	4.84	5.11	5.25	5.25	5.30	5.42	
EU (28)	6.37	6.52	6.41	6.38	6.44	6.57	6.63	6.86	6.78	6.42	6.36	6.55	6.44	6.39	6.35	6.42	6.53	6.86	6.93	
OECD Total	6.49	6.36	6.18	5.94	6.06	6.13	6.28	6.53	6.19	5.94	5.43	5.47	5.41	5.51	5.55	5.67	5.79	6.01	6.16	
Top 5 countries	21.83	18.58	17.77	23.18	23.54	21.48	23.00	21.91	20.19	19.31	17.93	18.37	18.69	19.15	19.38	18.32	18.18	20.92	20.84	



Source: *OECD Main Science and Technology Indicators* (https://stats.oecd.org/Index.aspx?DataSetCode=MSTI_PUB#)
Top 5 countries: China, Russia, Germany, Korea, South Africa NOTE: OECD uses totals for OECD, EU(28); as such these are excluded from the top 5
Data extracted on 02 Nov 2020 21:17 UTC (GMT) from OECD.Stat

Table 2 Source of Information that Contributed to Innovation during the Period 1997-1999
Industry by Source of Information

Innovators in Manufacturing	Percent	Reliability
Total Manufacturing Industries		
Firms that used a source of information	96.1	A
Of these, % that used the following:		
Internal sources of information		
Research and development (R&D) staff	53.4	A
Marketing staff	66.4	A
Production staff	72.5	A
Management staff	76.9	A
Other internal source	14.7	A
External sources of information		
Related firms in your corporate group (e.g. parent or subsidiary)	35.9	A
Suppliers of equipment, material and components	65.4	A
Clients	65.4	A
Competitors	36.3	A
Consultancy firms	19.2	A
Universities and colleges	8.5	A
Federal government agencies and research laboratories (e.g. National Research Council of Canada)	8.7	A
Provincial agencies and research laboratories	5.6	A
Generally available sources of information		
Trade fairs and exhibitions	68.9	A
Internet or computer based information networks	38.2	A
Professional conferences, meetings and publications	51.1	A
Other sources of information	8.7	A

Source: Statistics Canada Survey of Innovation 1999 (January 31, 2000), Table 8.1
 Original table contains breakdown of manufacturing sectors which is not replicated here
 Symbol Legend: E use with caution; A data quality: excellent; B data quality: very good

Table 3 Type and location of organizations with which business collaborated – 2001 - 2003

Type and location* of organizations with which business units collaborated and cooperated in order to develop new or significantly improved products (goods or services) or processes during the period 2001 to 2003				
Canada, innovative business units				
			Business units in collaborative arrangements	
			%	Reliability
Information and communication technology (ICT) service industries				
	Total ICT service industries		55.0	B
		Of these, % that collaborated with		
		Other business units within your firm	50.1	E
		Clients or customers	88.2	B
		Suppliers of equipment, materials, components or software	72.1	E
		Competitors	35.1	E
		Consultants	49.5	E
		Commercial laboratories / R&D enterprises	13.1	E
		Universities or other higher education institutes	29.3	E
		Federal government research institutes	8.5	B
		Provincial/territorial gov't research institutes	4.4	B
		Private non-profit research institutes	5.9	B
		Industrial associations	35.3	E
		Other types of partners	2.1	B

Source: Statistics Canada, Survey of Innovation 2003 (March 31, 2004) Table 24A.2
*Original data contains location information – not replicated here
Symbol Legend: E use with caution; A data quality: excellent; B data quality: very good

Table 4 Percentage of business units using sources of information needed for suggesting or contributing to the development of innovation during the period of 2001-2003
Canada, innovation business units

	Importance										Not relevant	
	Low		Moderately low		Medium		Moderately high		High			
	%	Reliability	%	Reliability	%	Reliability	%	Reliability	%	Reliability	%	Reliability
Information and communication technology (ICT) industries												
Total ICT service industries												
Internal sources of information for business unit												
Research and development staff	6.7	A	3.6	A	10.0	A	25.1	B	37.1	B	17.6	A
Marketing staff	5.1	A	9.5	A	21.6	B	34.2	B	24.1	A	5.5	A
Production staff	7.3	A	9.8	A	24.4	B	29.2	B	6.3	A	23.0	B
Management staff	5.7	A	5.8	A	20.9	B	34.9	B	28.9	B	3.7	A
Other business units in firm	15.7	B	9.2	A	11.5	A	10.8	A	9.1	A	43.7	B
External sources of information for business unit												
Suppliers of software, hardware, materials, or equipment	14.7	B	8.3	A	21.3	B	31.4	B	15.6	A	8.7	A
Clients or customers	3.0	A	3.0	A	10.5	A	34.2	B	47.2	B	2.1	A
Consultancy firms	28.4	B	15.4	A	19.5	B	7.9	A	4.1	A	24.7	B
Competitors and other enterprises from same industry	13.5	A	20.6	B	25.9	B	24.5	B	9.4	A	6.0	A
Universities or other higher education institutes	35.3	B	21.4	B	10.2	A	4.6	A	1.6	A	26.9	B
Federal government research laboratories	43.9	B	10.9	A	3.0	A	1.8	A	0.5	A	39.9	B
Provincial/territorial government research laboratories	45.2	B	7.8	A	2.2	A	0.3	A	0.7	A	43.9	B
Private non-profit research laboratories	44.1	B	9.7	A	2.9	A	1.0	A	0.5	A	41.7	B
Generally available sources of information for business unit												
Professional conferences, meetings, journals	4.2	A	23.0	B	23.7	B	26.5	B	15.8	A	6.8	A
Trade fairs and exhibitions	9.6	A	15.7	A	28.6	B	22.9	B	17.7	B	5.5	A
Trade associations	17.8	B	17.9	B	26.5	A	17.6	B	6.7	A	13.4	A
Internet	4.8	A	10.0	A	18.9	A	33.3	B	29.1	B	3.9	A
Other	1.2	A	1.1	A	1.6	A	2.1	A	1.1	A	93.0	A

Source: Statistics Canada, Survey of Innovation 2003 (March 31, 2004), Table 22A.2

Symbol Legend: E use with caution; A data quality: excellent; B data quality: very good

Table 5 Innovation, logging and manufacturing industries, percentage of innovative plants, by type of co-operative arrangements and geographic location of cooperation partners ^{1 2 3}

**Table: 27-10-0240-01 (formerly CANSIM 358-0092); Geography: Canada, Province or territory
Information and Communication Technology (ICT) Manufacturing Industries**

Co-operative arrangements	Type of co-operative arrangements and geographic location of cooperation partners	2005
Plants with co-operative arrangements		Percent
	Cooperation with other plants within the firm	41.3B
	Cooperation with suppliers of equipment, materials, components or software	61.0B
	Cooperation with clients or customers	84.6A
	Cooperation with competitors or other firms in sector	35.2B
	Cooperation with consultants	32.8B
	Cooperation with commercial labs or research and development enterprises	33.1B
	Cooperation with universities or other higher education institutes	39.7B
	Cooperation with colleges or technical institutes	15.2A
	Cooperation with federal government laboratories research institutes	21.6A
	Cooperation with provincial or territorial government labs research institutes	10.4A
	Cooperation with private non-profit research institutes	4.6A
	Cooperation with industrial associations	37.1A
	Cooperation with other types of partners	2.4A
	Cooperation with partners in the province or territory	70.0B
Plants with or without co-operative arrangements		
	Cooperation with other plants within the firm	13.8B
	Cooperation with suppliers of equipment, materials, components or software	20.5B
	Cooperation with clients or customers	28.4A
	Cooperation with competitors or other firms in sector	11.8B
	Cooperation with consultants	11.0B
	Cooperation with commercial labs or research and development enterprises	11.1B
	Cooperation with universities or other higher education institutes	13.3B
	Cooperation with colleges or technical institutes	5.1A
	Cooperation with federal government laboratories research institutes	7.3A
	Cooperation with provincial or territorial government labs research institutes	3.5A
	Cooperation with private non-profit research institutes	1.5A
	Cooperation with industrial associations	12.5A
	Cooperation with other types of partners	0.8A
	Cooperation with partners in the province or territory	23.5B

Source: Statistics Canada Survey of Innovation 2005 (June 2, 2006); Table 27-10-0240-01

DOI: <https://doi.org/10.25318/2710024001> - Note data for location is not replicated here

- 1 Data based on the percentage of innovative plants by type of co-operative arrangements and geographic location of cooperation partners during the period 2002 to 2004.
2. Data quality indicators: A = Very reliable; B=Reliable
- 3 An innovative plant is one that introduced a new or significantly improved product (good or service) onto the market and/or implemented a new or significantly improved production process (including improved ways of delivering goods or services) in that plant during the period under review.

Table 6 Innovation, logging and manufacturing industries, percentage of innovative plants, by the most valuable type of co-operation partner for innovation activities ^{1 2 3}

**Table: 27-10-0242-01 (formerly CANSIM 358-0094); Geography: Canada, Province or territory
Information and Communication Technology (ICT Manufacturing Industries)**

Co-operative arrangements	Most valuable type of cooperation partner	2005 Percent
Plants with co-operative arrangements		
	Most valuable type of cooperation partner, other plants within the firm	8.2A
	Most valuable type of cooperation partner, suppliers of equipment, materials, components or software	19.1A
	Most valuable type of cooperation partner, clients or customers	47.6B
	Most valuable type of cooperation partner, competitors or other firms in sector	3.2A
	Most valuable type of cooperation partner, consultants	1.9A
	Most valuable type of cooperation partner, commercial labs or research and development enterprises	3.0A
	Most valuable type of cooperation partner, universities or other higher education institutes	8.3A
	Most valuable type of cooperation partner, colleges or technical institutes	0.6A
	Most valuable type of cooperation partner, federal government laboratories research institutes	3.2A
	Most valuable type of cooperation partner, provincial or territorial government labs research institutes	0.0A
	Most valuable type of cooperation partner, private non-profit research institutes	0.0A
	Most valuable type of cooperation partner, industrial associations	4.1A
	Most valuable type of cooperation partner, other types of partners	0.8A
Plants with or without co-operative arrangements		
	Most valuable type of cooperation partner, other plants within the firm	2.8A
	Most valuable type of cooperation partner, suppliers of equipment, materials, components or software	6.4A
	Most valuable type of cooperation partner, clients or customers	16.0B
	Most valuable type of cooperation partner, competitors or other firms in sector	1.1A
	Most valuable type of cooperation partner, consultants	0.6A
	Most valuable type of cooperation partner, commercial labs or research and development enterprises	1.0A
	Most valuable type of cooperation partner, universities or other higher education institutes	2.8A
	Most valuable type of cooperation partner, colleges or technical institutes	0.2A
	Most valuable type of cooperation partner, federal government laboratories research institutes	1.1A
	Most valuable type of cooperation partner, provincial or territorial government labs research institutes	0.0A
	Most valuable type of cooperation partner, private non-profit research institutes	0.0A
	Most valuable type of cooperation partner, industrial associations	1.4A
	Most valuable type of cooperation partner, other types of partners	0.3A

Statistics Canada. Survey of Innovation 2005 (June 2, 2006) Table 27-10-0242-01
<https://www150.statcan.gc.ca/t1/tbl1/en/tv.action?pid=2710024201>; DOI: https://doi.org/10.25318/2710024201_eng
Note data for location is not replicated here.

1 Data based on the percentage of innovative plants, by the most valuable type of co-operation partner for innovation activities during the period 2002 to 2004.

2 Data quality indicators: A=Very reliable and B=Reliable.

3 An innovative plant is one that introduced a new or significantly improved product (good or service) onto the market and/or implemented a new or significantly improved production process (including improved ways of delivering goods or services) in that plant during the period under review.

Table 7 Canada Use of Collaboration Practices by Industry and Enterprise size 2014

CANADA			
Use of collaboration practices, by industry and enterprise size		2014	
Collaboration practices	North American Industry Classification System (NAICS)	Total, all enterprises (%)	Symbol Legend
Collaboration or strategic alliances with universities, technical institutes or colleges	All surveyed industries	5.2	A
	Forestry and logging	1.8	A
	Mining, quarrying, and oil and gas extraction	6.4	A
	Utilities	15.6	A
	Manufacturing	8.4	A
	Wholesale trade	3.8	A
	Retail trade	2.8	A
	Transportation and warehousing	1.6	A
	Professional, scientific and technical services	8.9	A
Collaboration or strategic alliances with government research organizations and programs	All surveyed industries	3.0	A
	Forestry and logging	0.6	A
	Mining, quarrying, and oil and gas extraction	3.5	A
	Utilities	8.4	A
	Manufacturing	5.6	A
	Wholesale trade	2.4	A
	Retail trade	1.4	A
	Transportation and warehousing	0.9	A
	Professional, scientific and technical services	4.5	A
Collaboration or strategic alliances with other companies	All surveyed industries	14.1	A
	Forestry and logging	9.7	B
	Mining, quarrying, and oil and gas extraction	19	A
	Utilities	33.3	A
	Manufacturing	17.6	A
	Wholesale trade	15.6	A
	Retail trade	5.8	A
	Transportation and warehousing	11.1	A
	Professional, scientific and technical services	25.6	A
None of the above	All surveyed industries	81.6	A
	Forestry and logging	89.1	B
	Mining, quarrying, and oil and gas extraction	77.3	B
	Utilities	58.1	A
	Manufacturing	75.7	A
	Wholesale trade	81.1	A
	Retail trade	89.9	A
	Transportation and warehousing	87.6	A
	Professional, scientific and technical services	70.5	A

Symbol Legend A Data Quality: Excellent; B Data Quality: Very Good
Source: Statistics Canada, Survey of Advanced Technology, 2014 (December 11, 2015)
Statistics Canada. Table 27-10-0316-01 Use of collaboration practices, by industry and enterprise size
<https://www150.statcan.gc.ca/t1/tbl1/en/tv.action?pid=2710031601>
DOI: <https://doi.org/10.25318/2710031601-eng>
Symbol Legend: A is very reliable; B is reliable

Table 8 Co-operation on Innovation Activities, by Type and Location of Co-operation Partners, by Industry and Enterprise Size

Canada
Total, all enterprise sizes
2015 / 2017
Percent

North American Industry Classification System (NAICS)	Innovation co-operation Partners	Parent, affiliated or subsidiary businesses	Suppliers of equipment, materials, components or software,	Clients or customers from the private sector,	Clients or customer from the public sector,	Competitors or other businesses in the sector,	Consultants and commercial laboratories	Universities, colleges or other higher education institutions	Government, public or private research institutes,	Other co- operation partners,
		Type of co-operation partner	Type of co-operation partner	Type of co-operation partners	Type of co-operation partner	Type of co-operation partner	Type of co-operation partner	Type of co-operation partner	Type of co-operation partner	Type of co-operation partner
Total, all surveyed industries	17.4 ^A	36.9^A	57.7^A	34.2^A	13.6^A	22.3^A	22.7^A	18.6^A	13.1^A	13.9^A

Table: 27-10-0178-01; Release Date 2019-03-26
Source: Survey of Innovation and Business Strategy - January 1, 2015 to December 31, 2017
DOI: <https://doi.org/10.25318/2710017801-eng>
Original table contain breakdown for various sectors of industry sectors which is not replicated here.
Symbol Legend: E use with caution; A data quality excellent; B data quality: very good; C data quality: good

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Table 9 Most Critical Co-operation Partner for the Business’s Innovation Activities, by Industry and Enterprise Size

Canada
Total, all enterprise sizes
2015 / 2017
Percent

North American Industry Classification System (NAICS)	Parent, affiliated or subsidiary businesses,	Suppliers of equipment, materials, components or software,	Clients or customers from the private sector,	Clients or customer from the public sector,	Competitors or other businesses in the sector,	Consultants and commercial laboratories,	Universities, colleges or other higher education institutions,	Government, public or private research institutes,	Other partners,
	Most critical	Most critical	Most critical	Most critical	Most critical	Most critical	Most critical	Most Critical	Most critical
Total, all surveyed industries	26.0^A	33.7^A	12.7^A	3.8^A	6.0^A	7.0^A	2.9^A	1.9^A	5.9^A

Table: 27-10-0193-01; Release Date 2019-03-26
Source: Survey of Innovation and Business Strategy - January 1, 2015 to December 31, 2017
DOI: <https://doi.org/10.25318/2710019301-eng>
Original table contain breakdown for various sectors of industry sectors which is not replicated here.
Symbol Legend: E use with caution; A data quality excellent; B data quality: very good; C data quality: good

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Table 10 Co-operation on Innovation Activities, by Type and Location of Co-operation Partners, by Industry and Enterprise Size

Canada
Total, all enterprise sizes
2017 / 2019
Percent

North American Industry Classification System (NAICS)	Innovation co-operation partners,	Parent, affiliated or subsidiary businesses, Type of co-operation partner	Suppliers of equipment, materials, components or software, Type of co-operation partner	Clients or customers from the private sector, Type of co-operation partners	Clients or customer from the public sector, Type of co-operation partner	Competitors or other businesses in the sector, Type of co-operation partner	Consultants and commercial laboratories, Type of co-operation partner	Universities, colleges or other higher education institutions, Type of co-operation partner	Government, public or private research institutes, Type of co-operation partner	Non-profit organizations, Type of co-operation partner	Households or individuals, Type of co-operation partner	Other co-operation partners, Type of co-operation partner
Total, all surveyed industries	17.8 ^A	43.0 ^B	53.0 ^B	33.4 ^A	9.0 ^A	18.8 ^A	16.0 ^A	15.6 ^A	10.2 ^A	8.0 ^A	4.6 ^A	9.3 ^A

Table: 27-10-0178-01; Release Date 2021-04-26

Source: Survey of Innovation and Business Strategy - January 1, 2017 to December 31, 2019

DOI: <https://doi.org/10.25318/2710017801-eng>

Original table contains breakdown for various sectors of industry sectors which is not replicated here.

Symbol Legend: E use with caution; F too unreliable to be published; A data quality excellent; B data quality: very good; C data quality: good.

Note two additional categories have been added since the survey of Innovation and Business Strategy 2015 – 2017 – specifically, Non-profit organizations and Households or individuals.

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Table 11 Most Critical Co-operation Partner for the Business’s Innovation Activities, by Industry and Enterprise Size

Canada
Total, all enterprise sizes
2017 / 2019
Percent

North American Industry Classification System (NAICS)	Parent, affiliated or subsidiary businesses,	Suppliers of equipment, materials, components or software,	Clients or customers from the private sector,	Clients or customer from the public sector,	Competitors or other businesses in the sector,	Consultants and commercial laboratories,	Universities, colleges or other higher education institutions,	Government, public or private research institutes,	Non-profit organizations,	Households or individuals	Other partners,
	Most critical	Most critical	Most critical	Most critical	Most critical	Most critical	Most critical	Most critical	Most critical	Most critical	Most critical
Total, all surveyed industries	28.7^B	33.0^B	13.1^A	2.1^A	6.9^A	5.3^A	3.5^A	2.1^A	1.2^A	0.3^A	3.9^A

Table: 27-10-0193-01; Release Date 2021-04-26

Source: Survey of Innovation and Business Strategy - January 1, 2017 to December 31, 2019

DOI: <https://doi.org/10.25318/2710019301-eng>

Original table contain breakdown for various sectors of industry sectors which is not replicated here.

Symbol Legend: E use with caution; F too unreliable to be published; A data quality: excellent; B data quality: very good; C data quality: good

Note two additional categories have been added since the survey of Innovation and Business Strategy 2015 – 2017 – specifically, Non-profit organizations and Households or individuals.

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**Table 12 World Economic Forum – The Global Competitiveness Report
University/Industry Collaboration in R&D* – Canada’s Ranking**

	2006-07	2008-09	2009-10	2010-11	2012-13	2013-14	2016-17	2017-18	2018	2019
Canada’s Rank	14	14	9	7	15	18	23	24	24	15
Total # of Countries	125	134	133	139	144	148	138	137	140	141

Source: World Economic Forum, *The Global Competitiveness Report* (GCR) 2006-2007, 2008-2009, 2009-2010, 2010-2011, 2012-2013, 2016-2017, 2017-2018, 2018, 2019

* For GCR 2018 and 2019, the indicator has been changed to “multi-stakeholder collaboration.”

Chapter 7

Innovation Policy and “Patient Capital”: The Status of Venture Capital in Canada

Introduction

With this chapter we come to the final piece in the DNS puzzle – that dealing with capitalization and especially “patient”¹ capital that can derisk research and promising technological pathways, transcend choke points in the spectrum from lab bench to market commercialization and, in a word, leaven innovation. Specifically, this chapter traces the fourth line of inquiry which has been proposed around federal policy, in addition to policy durability, targeted resourcing and triadic thickening of networks. Indeed, it examines whether such federal policy initiatives have been twinned with government-incented capitalization – particularly late-stage – that can bridge the gap between invention and innovation where products or processes have become market-ready. And it takes on this question in terms of public investment in venture capital: to be sure, venture capital that can provide funding but also networks, managerial expertise and hands-on mentoring enabling start-up firms as well as scaling and growth.

In addressing these issues, the chapter unfolds in four parts. Firstly, there is a brief review of the DNS framework as it revolves around the issue of capitalization and the currents of thinking contained therein. Secondly the actual policy initiatives taken by the federal government over the years from 2000 to 2020 are examined, with the import, depth and breadth of these efforts being profiled. The chapter then moves into an assessment of the implications of these policies for the real world of venture capital – along specific stages of the innovation

¹ The term is used by Mazzucato and Semieniuk (2017, 44).

spectrum. Thus, thirdly Canada's international ranking on venture capital at different stages of development are reviewed with the benefit of OECD data. Finally, the economic statistics are triangulated with the in-depth thought leader interviews on this question. Specifically examined is the extent to which venture capital in the Canadian case has been perceived as addressing the challenges around innovation, both in terms of early start-up needs and in terms of late-stage capitalization. With these findings in hand, conclusions are then proffered around the evolving nature of venture capital in Canada, the policy efforts that have been made and the application of this pillar in the Developmental Network State framework to the Canadian case.

“Patient” Capital and the DNS Framework

With respect to the DNS considerations around capital and public investment, certainly there are somewhat differing currents of thinking within the existing literature. Keller (2011) writes of the “hybrid” form of public and private venture capital associated with the Central Intelligence Agency (CIA) as it set up a new VC entity – In-Q-Tel – in 1999. Mandated to target development of specific information and communication technologies adapted to intelligence needs, it was designed to tap into the revolution occurring in IT around the volatility and “velocity” (*Ibid.*, 117) of information flows. And it was set up to specifically access commercial products emerging from mass markets, particularly in the thriving high-tech Silicon Valley region. Interestingly, In-Q-Tel functioned much like a venture capital firm, taking equity in firms, offering strategic and organizational advice and leveraging funding through other private sector partnerships. Initially funded with \$26 million, the model grew in import reaching into other federal agencies, with others such as the US Navy and Army, the Department of Energy and the FBI setting up their own venture capital initiatives.

On the other hand, Mazzucato (2015b [2013]) and Mazzucato with Semieniuk (2017) focus on the massive public investments that have flowed into innovation in the US in the post World War II period. Depicted as the American “entrepreneurial state” (as we have seen in the opening theoretical chapter), this approach emphasizes the “mission”-oriented and directed nature of this funding as it kickstarted and propelled technological developments in critical fields such as pharmaceuticals, ICT and nanotechnology. In the case of the National Institutes of Health (NIH), almost \$900 billion was vested in the NIH over the years from 1936 to 2016 (Mazzucato and Semieniuk 2017, 30) ² and it is argued that the funding was particularly germane for the new “blockbuster” drugs that have come onto the market “today” or at least by the early 2000s.

Finally, there stands the work of Block and Keller (2011) on the targeted funding of the Small Business Innovation Research program. Again, as has been earlier seen, SBIR has been particularly effective in supporting successful innovation products and firms, and in winnowing down SBIR contenders through rigorous criteria for success. And in contrast with the NIH case or even the hybrid forms of venture capital agencies, this funding is a more open process -- extremely competitive to be sure – but open to diverse technological developments and not pushed out through the lens of one dominant mission mandate. It is important not to overstate these differences of course: the various DNS contributions do share commonalities around the essential nature of the developmental network state. But these perspectives – and their objects of study -- do highlight the experimentation with capitalization and public investment which has been undertaken in the American context.

² The figure is in 2015 US dollars.

Still, all said, several key aspects do emerge around the nature of capitalization in the DNS model and it is that which is intended to be applied to the Canadian landscape. For one, there is a remarkable consistency to public capitalization initiatives. Capital, as publicly funded – and even with private partners – is “patient” (Mazzucato and Semieniuk 2017, 44) and in it for the long term. It is not subject to the vagaries of three-to-five-year terms with quick exits and immediate returns, allowing research to mature and its full benefits materialize. Secondly, capitalization “derisks” across the entire innovation spectrum from early research to development to full deployment and market entry, bridging the oft-named “valley of death” between early development and commercialization (Mazzucato 2013; also Schrank 2011). Certainly, it is particularly engaged with start-ups and the leading-edge technologies they can bring but public capital in this context also pivots to ensure that maturity and growth equally transpire. Indeed, drawing on extensive empirical studies, Mazzucato observes that the more diffuse initiatives with a general emphasis on small businesses as the genesis for innovation are misplaced and that in fact the focus should be on “young” firms with high-growth and “ambition” (Mazzucato 2015b [2013], 52-54).

Thirdly, capital in these public ventures transcends the traditional cyclical nature of Keynesian efforts, with pump-priming in downturns and drawbacks in periods of expanding economic activity. Rather investments as the annual funding of the National Institutes of Health over the years amply demonstrates continue to increase regardless of economic cycling (Mazzucato 2015b [2013], 75-77; Mazzucato and Semieniuk 2017, 30-31).³ Finally, and this is particularly important, what this public capitalization does is draw in and leverage private sector

³ For a much more wide-ranging discussion around different models for state investment banks and the intersection with cycles and Keynesianism, see also Mazzucato and Penna (2016), with the argument particularly focusing on the need for state banks to take a “market shaping/creating role.”

actors – “crowding in” – private investment to new technology pathways and opportunities.⁴

From the DNS vantage point, such public investment can in fact offer a certain degree of credibility, engaging new private actors and alliances and enabling new ventures.

What the DNS offers around this pillar of its framework, then, is an opportunity to explore the nature of Canadian policy efforts through the years as federal governments sought to incent and leverage venture capital. Moreover, it provides an opportunity to assess the characteristics of these efforts – their focus, their depth and their “patience” – and their capacity to fill noted gaps in both the venture capital and more generally innovation landscape.

Federal Policy: Catalyzing Venture Capital?

The quest to catalyze venture capital into the Canadian innovation ecosystem on the part of federal policy over the 2000s has, in large part, been a rather modest affair. Certainly, it has had a strong dependence on what may be called market “framework” initiatives claiming for the business conditions and competitive environs that could foster investment and wealth creation. Moreover, these framework policies have been often twinned with other indirect means for unlocking capital, as through marginal changes in international tax treaties intended to attract foreign and particularly American investors. Where more directed activity has occurred, there has over the years been a preoccupation with start-up firms and supporting them with both seed and early-stage capital that could enable their R&D activities and allow them to set sights on market activity. To be sure, there have been evolving trends towards a broadening scope of activity and critical, albeit intermittent, spikes of activity directed towards that end. Yet, in contrast to the DNS conclusions, on balance Canadian federal policy initiatives have not been

⁴ See the discussion in Mazzucato and Semieniuk (2017, 30 -31) and more generally of course Mazzucato (2015b [2013]; also Block (2008) on “public sector venture capitalists,” especially 181; on the challenges with private/public network relations and “governance” also Whitford and Schrank (2011).

predominantly focused on *capitalization all along the innovation continuum*; rather they have tilted towards addressing early-stage and particularly the needs of small and medium-sized enterprises. As such late-stage capitalization and the scale up and growth associated with late-stage have, with the exception of a few major policy volleys into this terrain, been matters of lesser – and less enduring -- consideration.

To a certain extent this propensity to focus on small business, or at least SMEs, and the issue of start-up capital may also be associated with the use of the Business Development Bank of Canada (BDC) as the instrument of choice in channelling publicly funded Venture Capital into the innovation ecosystem. Established specifically with a mandate and “focus on small and medium-sized enterprises” (<https://www.bdc.ca/en/about/who-we-are>), the BDC has been particularly engaged with providing capital and managerial expertise for start-up ventures and for firms that could be poised for growth. Additionally, however, federal governments throughout the years –and of different political stripes – have traditionally seen small business as a critical “engine” for economic growth and job creation. Admittedly, as will be seen, there has been a growing trend to hone this perspective to one focused on smaller firms with strong “innovation” potential and a high-growth profile. Nevertheless, there has been over the years a pattern of generically viewing small and medium-sized businesses as a particularly critical transmission belt for injecting VC into the Canadian market and for propelling innovation.

The Early Years: Moving Forward

Budget 2000 saw somewhat of an about turn on the venture capital question. The eighties and nineties had seen the creation of Labour-Sponsored Venture Capital Corporations – LSVCCs as they became known, with the funds being established by trade unions with investment channeled towards small and medium-sized businesses. (First established in 1982,

the Québec Federation of Labour's Solidarity Fund was the most notable example.)

Implemented in 1988, federal legislation began to offer lucrative tax credits for those investing in the funds. The credit thresholds did vary somewhat over the years and at the federal level were wound down at one point, but by Budget 1999 LSVCCs still offered a "tax credit equal to 15 per cent of the cost of an individual's investment in an LSVCC" with the credit capped at \$750 (Finance Canada 1999, 218). Later studies, including the insights of the OECD, as well as consultations conducted by the government in 2012 with the VC industry itself, would show that the LSVCCs were not necessarily good vehicles either for investment in capital markets or as instruments for return. Some argued they actually "displaced" more productive and "effective private funds."⁵ However, the effectiveness of the funds was not an issue of extensive concern back in the late nineties and the funds were allowed to continue for some time thereafter (until 2017), with Budget 2013 announcing the decision (Finance Canada 2013, 207-208).

Nevertheless, by Budget 2000, the Liberal government was turning a new page on the venture capital question. Recognizing that "start-up firms" were still challenged by "access to risk capital" (Finance Canada 2000b, 95),⁶ the government took a number of measures both indirect and direct to address the issue. Introduced over the years up to and including Budget 2005, these measures turned on three features: macroeconomic stability, a competitive taxation regime and direct injection of venture capital, primarily through the BDC.

Clearly, given the deficit-slaying of the Chrétien government in the mid to late nineties, there still continued a predominant focus on macroeconomic stability and fiscal discipline. By 2004 the government could announce that this was an historic moment, being the "seventh

⁵ Budget 2013 dealt with this issue (Finance Canada 2013, 207-209). The quotation is actually from the *National Post* (20 March 2012). See also *OECD Economic Surveys: Canada 2012* which the Budget references.

⁶ See also the need for "early-stage capital" in Finance Canada (2004, 133).

consecutive balanced budget ... since “Confederation.” So too was the federal debt-to-GDP ratio on a steep downward trend, dropping from a high of 68.4 per cent back in 1995-1996 and scheduled to decline to 38 per cent by 2005-2006 (Finance Canada 2004, 10). Moreover, the fiscal discipline and “sound financial management” were reinforced by a strong focus on a more globally competitive tax regime and specifically freeing up investment for small business. As Budget 2000 had articulated, such competitiveness was required to “prosper” in the new “global economy” (Finance Canada 2000, 92) and to maintain a leading edge over international competitors.

Budget 2000 in fact was a key watermark in this regard. Principal among the initiatives taken was the decision to lower federal corporate income tax rates, specifically from that of 28 per cent to 21 per cent by 2004 (Finance Canada 2000, 92), with incremental steps towards that goal being taken in the interim. Also critical, however, was a specific focus on small business, with a slashing of the taxation rate from 28 per cent to 21 per cent to be implemented within the year (Finance Canada 2000, 115). And there were other complementary measures, including a reduction in capital gains taxation, with the “income inclusion rate” falling from three-quarters to two-thirds (Finance Canada 2000, 113, 115).

Overlaid on these actions were also a series of measures intended specifically to free up venture capital – “risk capital” as Budget 2000 put it – for small business and for “start-up” companies, all of which can be categorized as a more indirect means for injecting VC into the market. Especially critical was the “capital gains rollover for small business investors.”⁷ Introduced in 2000, it ensured that individuals who had capital gains from previous investments could reinvest or rollover that money in other small businesses while deferring taxes. Strict

⁷ On this and its evolution with respect to thresholds, see Finance Canada (2000b, 95, 115); (2000a, 231); and (2003, 142, 329-330, and 364).

thresholds for such transactions originally applied, with the initial investments capped at \$500,000 but by 2003 this too was eliminated with timelines for such transactions also lengthened. More construed attempts to free up institutional investors such as pension plans as well as foreign money followed, specifically to loosen the strings on venture capital. In this case changes revolved around relaxation of the criteria for qualified limited partnerships and without getting into the details, essentially meant that large Canadian investors, including institutional ones, could more effectively leverage and access foreign capital (Finance Canada 2001, 226; Finance Canada 2003, 363).⁸ So too were there changes that could allow foreign companies to still maintain their status as a foreign entity, while keeping Canadian “investment managers” and their expertise within their operations in Canada, again as a vehicle to enhance cross-border partnerships (Finance Canada 2001, 227).

Aside from these more indirect – and, at times given tax law, quite arcane efforts to relax restrictions on risk capital – the government of the day did inject a substantive sum, \$600 million in total, into capitalization primarily through the Business Development Bank of Canada.⁹ Focused on SMEs and “early-stage capital” the government was very cognizant of the challenges young, knowledge-based firms and those without tangible physical “assets” faced in accessing pools of capital from the banking industry.¹⁰ As such a particular focus was laid on “Investing in Innovative Start-up and Early-Stage Companies” (Finance Canada 2004, 142-143), with \$80 million fronted to the BDC in Budget 2000 (Finance Canada 2000a, 114) followed by \$190

⁸ The key offending criterion had been that under a Qualified Limited Partnership, a limited partner was capped at holding a 30 per cent stake in the partnership (Finance Canada 2001, 226) but relaxation of other criteria also followed as noted above.

⁹ On the investments in venture capital over the years, including those of the respective Chrétien and Martin, Harper and Trudeau administrations, see Table 1. Allocations presented are based on a review of all Budget and Economic Statements from 2000 to 2020.

¹⁰ See in particular the discussion in Finance Canada (2004, 140-142) on how those firms “exploit[ing] leading-edge research and new technologies are ill suited to traditional forms of financing such as bank loans ...”

million three years later (Finance Canada 2003, 118, 129). Budget 2003 also saw \$20 million going to Aboriginal Business Canada to enhance business opportunities (*Ibid.*, 129) as well as \$20 million to Farm Credit Canada for the purposes of agricultural innovation (*Ibid.*, 20, 121, 157). By 2004, the government had allocated a further \$270 million – again to the Business Development Bank of Canada – to be split three ways. \$100 million would be dedicated to very early “pre-seed and seed investment” and actually was replete with specific directed objectives of funds for life sciences, biotechnology, medical technologies, environmental technologies and ICT -- areas that were research strengths and were ripe for commercialization and market entry (Finance Canada 2004, 142-143). Measures were also struck to strengthen the breadth and expertise of the industry with \$100 million for “specialized” VC funds and \$50 million for direct investment in start-ups. Farm Credit Canada was also to be the recipient of another \$20 million specifically for “venture capital financing” (Finance Canada 2004, 143).

Clearly, what can be discerned from these early years is a significant attention to the challenges around capitalization in Canada but the quest for solutions was heavily framed within fiscal stability, competitive taxation regimes and a willingness to manoeuvre at the margins in terms of opening up larger institutional and foreign flows of capital. To be sure, there were substantive efforts to also address the VC problem directly and certainly by 2004 there was a move afoot to take a more targeted approach for certain burgeoning industrial sectors. Yet here too the emphasis was limited by the focus on early-stage needs especially for SMEs and start-ups. Indeed, overall these years -- though they essentially turned the page on the more antiquated edifice of the Labour-Sponsored Venture Capital funds -- are marked by a more open and porous approach to funding and leveraging venture capital and one that essentially failed to traverse the full innovation spectrum.

“Sidecars” and Capital: Responding to Jenkins

The Tory years – January 2006 until November 2015 – did eventually signal a pivot on venture capital as the government responded to the Jenkins report and subsequently focused somewhat more on larger-scale capitalization. In all, \$857 million of public-financed venture capital was provided by the government during these years (Table 1).¹¹ Nonetheless the emphasis on enduring features of Canadian administrations, namely macroeconomic stability and a competitive taxation regime, equally remained. Thus, while the government pronounced that it was “turning a new leaf” (Finance Canada 2006b), these two key pillars around fiscal discipline and an internationally competitive taxation regime continued to be central matters of attention. Certainly, on the fiscal policy front, save for the rupture caused by the Recession, this aspect continued throughout the Conservative years in power. Especially proclaimed in the “New Government’s” economic blueprint for the years to come, *Advantage Canada*, the document stressed that “low public debt [was] essential” to Canada’s “long-term prosperity” (Finance Canada 2006a, 27). And its benefits were clearly outlined: releasing funds for investment in “other priorities,” engendering “economic stability” and, in a somewhat prescient insight given later developments, girding the “country’s ability to deal with economic shocks and challenges...” (*Ibid*, 27).

Aspiring to both enhanced accountability around the public purse and a greater measure of “discipline” federal efforts were committed to reducing the federal debt-to-GDP ratio from 35 per cent in 2006 to 25 per cent – by 2012-2013 (Finance Canada 2006a, 29-31; Finance Canada 2007, 153). Further, *Advantage Canada* laid out the target of reducing all government net debt within the country – provinces and territories included – by 2021 (Finance Canada 2006a, 30-

¹¹ See Table 1 for the sub-total for the Harper years (2008-2015) but also the specific breakdowns. Unless otherwise specified, Figures and Tables referenced in this chapter are located in Annex A - 7.

31). And despite the massive injections of funding associated with the years between 2009 and 2012, by 2010 the government did have a game plan to begin to claw its way out of debt, indicating that “balanced budgets” would return (Finance Canada 2010, 7, 11, 63). In fact, with retrenched federal spending, by 2015 a surplus of \$1.4 billion was being projected for that fiscal year (Finance Canada 2015, 3, 24, 335, 337) and, in the event, a surplus of \$1.9 billion was actually posted for 2014-15 (Receiver General 2015, Table 1). Moreover, by Budget 2015, the government appeared to be on track to hit close to its original target with a federal debt-to-GDP ratio of 25.5 per cent forecast for 2019-2020 (*Ibid.*, 344). Indeed, so was the government wedded to fiscal rigour that in 2015, they introduced legislation requiring budgets to balance on an annual basis at the federal level (Federal Balanced Budget Act 2015, S.C. 2015, c. 36, s.41), save for emergency situations. As to the details, the latter was specifically defined as “more than \$3 billion in one fiscal year” *Ibid.*, s.2) and resulting from acts of nature or grave issues of national security.

As for the other key pillar in the Government’s fiscal arsenal -- taxation policy -- this too saw an overriding emphasis on the international business “competitiveness” (Finance Canada 2006a, 73-75; 2007 233-235; 2008, 94-96; 2010, 10; 2012, 114-116; 2013, 148-150; 2014, 88-91) which such measures could bring and the concomitant “freeing” (Finance Canada 2006a, 72) of investment for economic growth. Particularly spelled out in *Advantage Canada* (*Ibid.*, 73-78; and Budget 2007 (Finance Canada 2007, 222-223; 233-240), the goal was to bring Canada’s rate of taxation to the lowest among the G-7 countries for new investment, with the overarching objective to increase returns on investment, lower the costs of capital and “spur innovation and growth.”¹² Towards this end, a rapid number of almost annual announcements were unfurled.

¹² Also see Budget 2012 regarding enabling investment to “flow to its most productive uses” (Finance Canada 2012, 115).

The federal capital tax was to be eliminated in 2006 (Finance Canada 2006b, 13). By Budget 2007, the corporate income tax rate (CIT) would be lowered to 18.5 per cent (from 21 per cent) by 2011 (Finance Canada 2007, 233) only to be announced in the Economic Statement of that same year¹³ that the CIT would be lowered to 15 per cent by 2012 (Finance Canada 2008, 94). Moreover, all of this established the path for federal policy to meet its original goal, with Canada achieving in 2014 the “lowest overall tax rate on new business investment” in the G-7 (Finance Canada 2014, 89) and, by 2015, able to declare that such taxes on new investment were 46 per cent lower than in the US (Finance Canada 2015, 76).¹⁴ And while the measure by which the ranking in the G-7 was established included provincial, territorial and municipal “statutory income tax rates,” nevertheless federal initiatives had occupied the main components of this process, with Ottawa’s efforts to bring the provinces on board further leavened with monetary “incentive[s]” (Finance Canada 2015, 74).¹⁵

Cross-cutting these efforts was also the traditional emphasis on small business. Budgets sought to sweeten the small business tax rate, with the latter downgraded from 12 to 11 per cent by 2008.¹⁶ So too was the deduction limit for access to that rate significantly increased, reaching \$500,000 by 2009.¹⁷ Escalating thresholds for Lifetime Capital Gains Exemptions were implemented, first in 2007 and again in 2014. Small business loans from traditional sources of credit – i.e., mainly the banks – had caps restructured and broadened as well, enabling those

¹³ For some reason, there does not appear to be an electronically available version of the 2007 Fall Economic Statement.

¹⁴ Interestingly, Budget 2012, drawing on a third-party report also indicated that Canada had by this time achieved the “most competitive tax rate in the G-7” (Finance Canada 2012, 115-116).

¹⁵ For the definition of this measure – the marginal effective tax rate (METR) on new business investment see Finance Canada (2015, 75).

¹⁶ Finance Canada (2008, 95). See Finance Canada (2015, 118) for an excellent summary of small business initiatives over these years.

¹⁷ It should be noted that small businesses were taxed at the more general corporate rate -- which had reached 15 per cent by 2012 as noted above – when their income threshold “exceeded[ed] \$500,000 (Finance Canada 2015, 118).

businesses with more robust revenues access to such financing.¹⁸ The import of small business to Canadian prosperity as being “critical to the health of the Canadian economy” (Finance Canada 2015, 117, 115-127) was still very much on the government’s radar, and budgetary agenda, at what would become the end of their tenure in 2015. In all, the tenacious occupation with indirect mechanisms for augmenting capital investments including the reliance on small business was very much in evidence during these Tory years.

In contrast, with respect to venture capital, a notable shift can be discerned. Years 2008 and 2010 saw some discrete one-offs, with \$75 million first being dedicated to the BDC for a new private VC fund (Finance Canada 2008, 124) and then during the height of the Recession an additional \$50 million to the BDC specifically for Southern Ontario (Finance Canada 2010, 250). But, the significant changes came with the government’s response to the Jenkins Report of 2011.

As will be recalled from Chapter Three the Jenkins Report, among other issues, undertook a deep dive on the VC situation in Canada and arrived at several findings. For one thing, they recognized that venture capital in Canada was by no means sufficient, hampering the size of deals, the capacity to capitalize firms along the innovation continuum – as the Report put it until “exit” – and, for VC, sub-par returns.¹⁹ This situation was compounded by a “limited pool of experienced ...[VC] fund managers” (Jenkins 2011, 7-13) and rather diffuse ties to international capital and markets. The venture capital market in Canada had been of late distorted by the Labour-Sponsored Venture Capital funds but additional factors were also at play. Large and ample American funds were filling the VC gap in Canada and were taking those firms

¹⁸ Specifically the cap for access to loans was increased from \$500,000 to \$1 million in gross annual revenues of the firm; so too were loan amounts doubled from \$500,000 to \$1 million. Notably these changes required legislative enactment, with the changes coming in force in June of 2015 (https://www.ic.gc.ca/eic/site/csbfp-pfpec.nsf/eng/h_la03286.html).

¹⁹ For the discussion and recommendations see Jenkins (2011, 7-11 to 7-20).

to exit, thereby harvesting the IP and repatriating outside of Canada. As a consequence of these varied conditions, the Report concluded that “innovative” firms poised for take-off were being limited by the insufficient availability of capital:

Innovative, growing firms require risk capital, yet too many innovative Canadian firms that have the potential for high growth are unable to access the funding needed to realize their potential. The Government of Canada can play an important role by facilitating access by such firms to an increased supply of risk capital (*Ibid.*, 7-17).

Given these conditions, two key recommendations were made.²⁰ The BDC was to set aside more of its extant funding for “start-up financing,” specifically as a kind of “sidecar” that would “ride along” and accompany private sector angel investors²¹ at this stage and ensure that funding for early-stage growth was available. As well, the Government was to provide the BDC with the “larger-scale, later-stage venture capital funds and growth equity funds” that could specialize in much larger deal sizes (particularly beyond a \$10 million threshold) thus alleviating current gaps and the stunted nature of domestic VC. Late-stage funding was also to be invested in tandem with private sector funds with the private sector specifically responsible for management. As the Jenkins recommendations made clear, these new publicly-funded mechanisms were to be directed and driven by the private sector, with the “market” to “determine the allocation of financing” (*Ibid.*, 7-18).

²⁰ On the recommendations, see *supra* ff. 19.

²¹ Angel investors or angel capital operate in that space dedicated to seed and start-up capital (Jenkins 2011, 2-18) and are oriented to very early-stage financing of usually high-potential firms. Such investors are generally independent of the firm owners and are not family members or close acquaintances and friends (OECD 2011a). The Jenkins Report has defined angel investors thus: “The latter [‘angel’ investors] are typically individuals who have succeeded as entrepreneurs in technology-based enterprises and who are consequently able to provide not only financial investment but also mentoring of early-stage entrepreneurs in the angel’s area of experience.” (*Ibid.*, 2-18). The dual functions of investment and mentoring are critical here, particularly for start-ups. Angel investors also typically operate in relatively loose associations or networks. For a still excellent review of angel investors, see OECD (2011a).

The government was not long in reacting to the Report and (in an almost verbatim response to Jenkins) by Budget 2012 had responded in kind. \$400 million would be allocated specifically to “increase private sector investments in early-stage risk capital and to support the creation of large-scale venture capital funds led by the private sector” (Finance Canada 2012, 60). Noteworthy as well the language employed by the government had changed. The lens was now on “young knowledge-based” and “high-growth firms” and not just small and medium-sized enterprises (*Ibid.*, 60; also 61). (Also to be provided with an additional \$100 million was the BDC, although the specifics of this allocation were not laid out.)

Moreover, following consultations that ensued with the VC industry as well as other stakeholders, by Budget 2013 the structure and roll-out of the funds had become more defined. Now captured under the title of the Venture Capital Action Plan (VCAP), the monies would flow over a seven to ten-year period, were to be co-located with private VC and the \$400 million would break in the following manner.²² \$250 million was to be used to create new national VC “funds of fund,” diversified across different VC firms, privately run and dedicated to providing “large-scale” capital. \$100 million was to be channelled into existing large-scale private VC and could be allied with provincial engagement. For the high-performing VC firms (between three and five), they could see additional top-ups from \$50 million that would be set aside for such purpose. All were intended to attract “close to \$1 billion” in private sector monies (Finance Canada 2013, 204) and did signal a pivot to larger-scale endeavours arguably further down the innovation chain.

Similarly, there was a focus on initiatives that could kickstart promising young firms for growth. Specifically, Budget 2013 set aside \$60 million go to incubators and accelerators that

²² On the rollout and structure, see Finance Canada (2013, 204-209).

could not only provide early-stage capital but also mentoring, strategic advice and bench space (in the case of the accelerators) for ramp-up (Finance Canada 2013, 205-206), with incubators falling into the private VC ambit and accelerators largely occurring with more public hosts such as universities. And in an effort to look beyond such start-up capital, the pot was sweetened with financing for firms that completed the incubation process – that had “graduat[ed]” in the words of the Budget -- with \$100 million to flow to the BDC for precisely such purposes (*Ibid*, 205-206). Additional efforts, geared to start-up, followed: given take-up another \$40 million was allocated to the incubator/accelerator “hubs” (Finance Canada 2014, 71); \$18 million was set aside for youth “entrepreneurship” (Finance Canada 2013, 207) and \$14 million for Futurpreneur (Finance Canada 2015, 131-132). Complementing these actions, the BDC was equally provided with direction to retool and, while its mandate very much remained within the purview of “helping small and medium-sized enterprises,” the lens was narrowed to “the unique needs of high-growth firms” including access to equity (over \$2 and up to \$10 million) and support for enhanced ICT.²³

These years did witness the ongoing tinkering with international tax agreements and definitions of what constituted “non-residents” and “non-resident property” in the hope of creating enhanced access to foreign investment and venture capital. Elimination of a withholding tax on interest payments (Finance Canada 2007, 239-240); eliminating of filing tax returns for non-residents where no tax was due (Finance Canada 2008, 307); restricting the meaning of what constituted “taxable Canadian property,” again to avoid filing (Finance Canada 2010, 94, 100: all were implemented. True as well, the Venture Capital Action Plan that did roll out was not targeted to sectoral areas of activity as had been the case with the preceding

²³ On the new focus on more honed initiatives for SMEs, see Finance Canada (2015, 125-126).

administration. Yet what is striking about this period is that federal policy initiatives – clearly spurred on by Jenkins recommendations – did encompass a broadened range of activity along the innovation continuum, from angel investors and seed capital to larger scale, and did target young and growing firms. At the same time as this broadened sweep of initiatives materialized however the nature of public VC was definitively still relegated to “sidecar” status, with the rigours of the market to determine capital allocations.

Scaling for Growth

If fiscal stability and “prudence” combined with taxation geared to business investment were staples of the preceding administrations – both Tory and Liberal -- with the election of the Trudeau government in November of 2015, the government did begin to move in a new direction. Certainly, Budgets continued to *speak* of “responsible” “fiscal management” (Finance Canada 2016, 50-53; 2017, 10, 23, 36-41; 2018, 21, 24-28; 2019, 15, 17-20) and “preserving Canada’s “low-debt advantage” (Finance Canada 2019, 19). And the government continued to take pride of place in maintaining the country’s low net debt-to GDP ratio – the lowest among the G7 – and a constant that prevailed even as the first shocks of the pandemic shook global economic foundations in 2020.²⁴ Even as deficits rose, the new administration articulated its longer-term objective of returning to fiscal balance and debt reduction by 2020-2021 (Finance Canada 2016, 50).

However central to the government’s agenda, and vision, was a commitment to address the needs of the middle class and fiscal policy was deemed as the “lever” (Finance Canada 2016, 16) and “tool” (Finance Canada 2017, 20) to serve that purpose. It would create the longer-term

²⁴ See Finance Canada (2020), the *Fall Economic Statement*, and the opening remarks by the Minister of Finance, Chrystia Freeland, vi; also Finance Canada (2021, 52 Chart 40) which refers to 2020 data.

growth that could buoy and sustain middle class incomes and reduce inequity. Innovation would be critical to this endeavour, as has been seen in earlier chapters, but so too would the new programming and fiscal initiatives that could enhance wage incomes and equip Canadians with the skills for the future. It was equally clear that “austerity” politics and the “rigid” ideological dimensions on which that was founded would not be the backstop for balanced budgets (Finance Canada 2018, 9, 21-22). As such then macroeconomic policy took an important new turn. Though inheriting a surplus of \$1.9 billion, the government even by Budget 2016 had begun to enter “red ink” territory. True, there were still only relatively modest modulations in the federal net debt-to GDP ratios. Still federal deficits rose from \$5.4 billion in 2015-16 (Finance Canada 2016, 234) to \$23 billion (Finance Canada 2017, 37) the next year, gradually declining to \$14.9 billion (Finance Canada 2019, 18) before the pandemic hit. As a further dimension that signalled the new course being charted, soon after coming to power, in June of 2016, the government repealed the Budgetary Balance Act (Federal Balanced Budget Act, Repealed 2016, S.C. 2016, c.7, s. 19). In sum, international competitiveness was not to be pursued in the context of an unyielding commitment to fiscal discipline.

As for taxation policy, this too was now turned to middle class needs. In December of 2015, the government introduced personal income tax changes, with a reduction to 20.5 per cent for incomes that had been subject to a rate of 22 per cent and with an increase in the rate for top personal income earners to 33 per cent, from 29 per cent (Finance Canada 2016, 56). Moreover predominant throughout the Trudeau years was an emphasis on tax “integrity,” thus closing the “loopholes” that exacerbated income inequities. Interestingly, there was a continuing emphasis on small business and, although the government did initially go back on its election promise to

cut small business tax rates to 9 per cent from 10.5 per cent, by October of 2017 they had delivered on the promise as well.²⁵

Concomitant with that – and in recognition that such smaller enterprises “had more difficulty in accessing capital” (Finance Canada 2018a, 73) was an effort to further free up capital inside smaller corporations which were holding substantial “passive investments.” Having engaged in consultations on tax issues more broadly but specifically on this issue, the government assured the VC market that any changes would still maintain the necessary “incentives ... such that Canada’s venture capital and angel investors can continue to invest in the next generation of Canada innovation” (Finance Canada 2018a, 72), and Budget 2018 spelled out the details. Such passive investments benefited from lower rates of taxation but were not being used more productively or for wealth creation inside these smaller corporations. As such Budget 2018 introduced a new threshold (with the criterion being \$50,000 or more of income earned on passive investments) where eligibility for lower small business tax rates would be “gradually reduce[d]” until it hit zero – the latter being the case when annual investment income hit a threshold of \$150,000 (*Ibid.* 73-74).

So too was there a renewed focus on Canadian taxation rates relative to other international actors, particularly with respect to the United States when in 2017 it substantively reduced corporate income tax rates. Responding to the implications this could hold for new investment on the Canadian scene, the Fall 2018 Economic Statement immediately introduced the “Accelerated Investment Incentive” (Finance Canada 2018b, 54-62). The measure enabled Canadian companies to write off or write down capital costs for new investment, including “intangible capital assets” such as patents, and positioned Canada to maintain its much-coveted

²⁵ On this issue, see, Finance Canada (2016, 220); Finance Canada (2018a, 72); and <https://www.cfib-fcei.ca/en/advocacy/federal-small-business-tax-rate>.

rank of lowest tax rate on new business investment within the G7. Still on balance it is fair to conclude that taxation policy for the Trudeau government did not serve as much as a key, albeit somewhat indirect, instrument for opening up capital flows as had been undertaken with the previous federal administrations.

With respect to venture capital, the government did introduce measures which now turned on “late-stage” growth rather than large-scale capital per se, enabling businesses to “grow” and compete internationally (Finance Canada 2017, 110). Introduced in Budget 2017, the Venture Capital Catalyst Initiative (VCCI) was to roll out over three years, starting in fiscal 2017-18 (Finance Canada 2017, 47, 83, 110).²⁶ Intended to directly support the “Innovation Agenda” and to be channelled through the BDC, \$400 million was to be provided to eligible firms. The BDC would be responsible for specific design features but Budget 2017 also laid out the key nature of this initiative. Eligibility would be dependent on the private sector capital brought to the table, the measurable “benefits” accruing to the firms and, in a rather novel approach, the “risk sharing” that would obtain between the government and private VC. In all, together with the capital leveraged through private actors, it was anticipated that \$1.5 billion would be “inject[ed]” into “Canada’s innovation capital market” (Finance Canada 2017, 83). Interestingly, the Budget documents did not specifically link the VCCI to only “high-growth firms;” nor was it overtly wedded to the scaling and innovation so integral to the Superclusters initiative. Nevertheless, it was a concerted effort to move beyond even “large-scale” to a “late-stage” growth strategy and it was clearly part of the policy mix designed to foster and strengthen innovation in the Canadian ecosystem.

²⁶ On the VC allocations during the Trudeau years – until 2020 – see Table 1.

Other directed measures accompanied this VC Catalyst Initiative. A dedicated “stream” of \$50 million of VC was set aside for Clean Tech in the Fall Economic Statement of 2018, to be purposed for clean technologies primarily in the energy and natural resources sectors (Finance Canada 2018b, 83, 111).²⁷ By 2016, BDC had launched a \$40 million fund for Women in Technology (Finance Canada 2017, 231-232) and Budget 2018 saw that topped up to \$200 million (Finance Canada 2018a, 112).²⁸ Monies were also to flow through the regional economic development agencies: \$105 million in all devoted to assisting women entrepreneurs to have their firms “scale and grow” (Finance Canada 2018a, 111). Finally, there was to be another \$14 million for Futurpreneur Canada (Finance Canada 2017, 85). In total, VC investments during this period rang in at \$769 million (Table 1).

Admittedly, there were some anomalies during this period. Inexplicably the Government had in 2016 reinstated the Labour-sponsored Venture Capital Corporations Tax Credit, in the quest to enhance “saving by the middle class” (Finance Canada 2016, 221). Nevertheless, what these measures, in large part, depict are efforts to start to scale and ready businesses for more expansionary growth.

Patterns and Policy

In applying the DNS, several key policy initiatives can be discerned over the course of the 2000s -- and over the course of administrations of different political stripes. For one, there was a very focused effort on macroeconomic stability and taxation that could yield benefits –

²⁷ It should be noted that Budget 2017 also referred to enhanced access to funding for Clean Tech firms (or as it was then named, “Cleantech” firms), specifically marking off \$207 million over the five years in the fiscal framework for equity investments as well as “working capital” among other measures (Finance Canada 2017, 97-98, 111). However, specifics relating to the VC breakdown are not provided; nor is there any reference in Finance Canada 2018. Consequently there is no entry relating to this in Table 1.

²⁸ Again this does not seem to appear in the fiscal framework and it is not known whether this was all new monies. Budget 2018 references an earlier tranche where the monies were topped up to \$70 million but the exact date is not specified. In any event, between 2016 and 2018 there was a top-up to \$200 million.

indeed liberate and “free” capital for investment. Especially predominant during the Chrétien/Martin and Harper years, even the pivot to the middle class by the Trudeau Government did not fully rupture these patterns. Pressed by American cuts to corporate taxes, the Trudeau administration itself swiftly fell into the well-worn grooves of “business investment incentives” and capital cost allowances that could foster the conditions ripe for new investment. Secondly, there was a very strong emphasis throughout these years on small and medium-sized enterprises – and particularly small business -- as a critical engine of the economy, generating growth, jobs and innovation. And while “small” was variously defined and subject to differing criteria and thresholds, this policy lens was very much a constant in the Canadian landscape over this period.

Thirdly, and to a certain extent aligned with these larger frameworks, venture capital initiatives were to be very much dependent on the decision-making of the market and market allocations regarding investment needs, and returns. There were exceptions, with the directed nature of the “Clean Tech” fund and the effort to enhance funding for women entrepreneurs, both through a dedicated fund as well as through regional economic development agencies. Still overall, the expectation was that publicly funded VC would substantively leverage private sector monies -- even in ranges hovering around the billion dollar mark, with the Canadian innovation ecosystem benefitting as a result. Indeed, ultimately, the commonality that emerges here is that the publicly vested “sidecar” continues to “ride along” the private investor -- this despite the differing political persuasions of governments or the array of measures taken.

Despite such patterns of continuity, however, what can be discerned and what is distinctive is a broadening sweep in the VC measures taken to address the innovation gap, and innovation continuum. Initially centred on the early needs of start-up capital during the early Liberal governments, then moving to the issue of large-scale capital under the Conservative

administration and finally tackling the issue of late-stage requirements, VC initiatives strove to reckon with the challenges faced. And they continued to move farther down the innovation spectrum. True, apart from commissions and advisory groups struck to assess the situation, governments of the day did not appear to partake in extensive policy discussions and analyses of their initiatives vis à vis the backdrop and initiatives of the past. But threaded through these policy efforts was a continuing focus on the challenges of capital acquisition for growing and leading-edge firms without “tangible” assets and, with each round of VC initiatives, quite discernably the policy mantle and the innovation continuum were widened. The question that remains is whether this unique Canadian patterning and the broadening sweep of publicly-funded VC -- indeed ultimately tallying to \$2.226 billion -- was sufficient to change the situation, drawing in the private dollars to create a robust market for late-stage capitalization and igniting innovation in its wake. It is to that question which we now turn.

Availability of Venture Capital: The Trends

As was indicated in Chapter Two on “Research Methodology,” the OECD provides data on venture capital as a percentage of GDP both as a “total” as well as for different stages of development including “start-up and early stage” and “later stage.” As earlier noted as well, there are certain caveats which accompany this database, with mostly missing entries between 2000 and 2006 and original compilation of the data dependent on national entities who often approach the issue with differing “methodologies.” As the OECD has indicated this situation has “improved considerably” over the years (https://stats.oecd.org/Index.aspx?DataSetCode=_INVEST); nonetheless the OECD takes the data in hand and “re-aggregates” according to their own parameters.

Those qualifications noted, two key dimensions stand out in reviewing Canada’s situation with respect to VC over the years in question (Figures 1, 2, and 3). Immediately evident and quite striking is that Canada stands as second to the United States over the period in question – for all dimensions presented, including total VC investment,²⁹ start-up and early stage, and later stage. Further, there is evidence of a trend which accelerates after the VCAP initiatives in 2013, at least for total VC and start-up and other early stage. In the case of start-up, the incline is in fact quite pronounced until a dip in 2018, followed by an upswing and another descent with the pandemic in full swing in 2020 (Figure 2). Still for the years between 2007 and 2019 (years of commonality with the US for comparative purposes), Canada experienced quite a startling increase of almost 196 per cent. The total category, to be sure, is more muted, with only an increase of 60 per cent but still showing growth (Figure 1). As for later stage, this trend line is much more undulating, showing an actual deceleration of 20 per cent over the 2007-2019 period until it rebounds to a new high in 2020 (Figure 3). Still even with the new apex, the increase over the base year of 2007 was only 24 per cent. Moreover, what is equally interesting concerning Canada’s international ranking is the country’s relationship to the top five countries on this measure – when the strength of the US data is removed from the calculation.³⁰ As Figures 1, 2, and 3 depict, Canada for the most part functions above the top five curve when the US is excluded, and this holds as well for later-stage capital.

²⁹ Total VC investment according to the OECD definition includes the sum of “early stage (including pre-seed, seed, start-up and other early stage) and later stage venture capital” (https://stats.oecd.org/Index.aspx?DataSetCode=VC_INVEST). It should be noted that the OECD database does provide a breakdown for seed capital but it has not been included as a separate indicator here. (The OECD does not hyphenate these terms for VC; for consistency, terms of early-stage and late-stage in referring to VC – when not directly quoting OECD or directly referencing their tables -- are hyphenated herein).

³⁰ Unfortunately the annual OECD average and the annual EU average do not appear in the VC investment database at https://stats.oecd.org/Index.aspx?DataSetCode=VC_INVEST.

It is worth pointing out that on this issue of international standing, in 2016, the OECD found that Israel, the US and then Canada topped the list – in that order – with respect to VC investment as a percentage of GDP (OECD 2017,158). However, for Israel, data for the period from 2015 and beyond is not available at least in the current OECD database and, as such, calculations on relational standings cannot be assessed here.

Apart from Canada's ascent in international status, secondly what stands out both for Canada and the other OECD countries in the top five is the pronounced gap with the US – on all three indicators presented. Relative to Canada – and based on the common time period of 2007 to 2019 -- American VC investment as a percentage of GDP was on average 3.3 times greater than Canada in terms of total VC; and in terms of late stage was actually 6.6 times larger. Admittedly the distance was lessened for start-up particularly given the acceleration evident in Canada on early capital, but still the gap is considerable. US investment for start-up and early stage between 2007 and 2019 averaged 1.8 times greater than the Canadian case. And while start-up VC in the US did not accelerate at the same rate as Canada (the US logging in at 112 per cent), this was more than made up for by later stage which saw a boisterous increase of 149 per cent over the period in question, compared to the deceleration its neighbour to the north was experiencing.

Thus, the picture that emerges on the Canadian VC scene is one of relative buoyancy with a thriving market at least with respect to early-stage capital and subsequent spillover into total VC figures as well. As the Canadian Council of Academies has earlier assessed (and referencing 2016 OECD data on comparative standings):

Increasing VC investment in Canada, coupled with failing investment in many European countries, has catapulted Canada from one of the weakest countries to one of the strongest (CCA 2018, 159).

So too did the Canadian Venture Capital and Private Equity Association (CVCA) in their 2019 report flag VC “performance” as “beyond positive,” with growth in deal sizes and somewhat more representation of “mega-deals” in the \$100 million and over domain.

However, the portrait that emerges here is also Janus-faced, with the quest for late-stage capitalization still being saddled with relatively small deal sizes and with an inordinate gap between Canada and the US. Certainly this issue has given the BDC cause for concern, with the Bank commenting on the “smaller average size of VC funds” and that “Canadian companies only raise half as much capital on average over their lifetimes as their US peers” (BDC 2017, 12) ³¹ So too do the CCA, while acknowledging the strides that have been made, note the continuing challenges around deal size, with the American ones “twice the size of average deals for Canadian firms” (CCA 2018, 160).

True, it would seem that the policy impacts of the VCAP initiative in 2013 and arguably VCCI in 2017 were factors being felt in the data that has been observed. True, as well, in terms of the DNS conditions being met on the issue of start-up and early-stage capital, this dimension was fully in play. But on the issue of “patient” late-stage capital enabling firms to scale and globally succeed – and to contribute to a vibrant innovation ecosystem – this is much less discernable. The very modest growth of late-stage over the years in question and the substantive difference in relational standings with the US are testament to the ongoing challenges around this last pillar of the DNS framework within the Canadian context. It remains to be seen whether the perspectives of innovation leaders reveal the same.

³¹ The BDC is referencing Pitchbook, CB Insights.

In-Depth Interviews with Thought Leaders

As with the other lines of inquiry in this research, the issue of venture capital – its adequacy and availability – was the subject of consideration in the thought leader interviews.

Specifically, participants were asked the following question:

One of the areas that several reports have commented on is the need for more venture capital for Canadian entrepreneurs – not only for injection of capital but also for the managerial expertise and networks venture capitalists can bring to the table.

Moreover, one of the areas that is deemed to be most in need of VC is late-stage capitalization as firms expand.

Would you agree with this perspective? If so, what other measures do you think are needed to strengthen our capacity in this area.

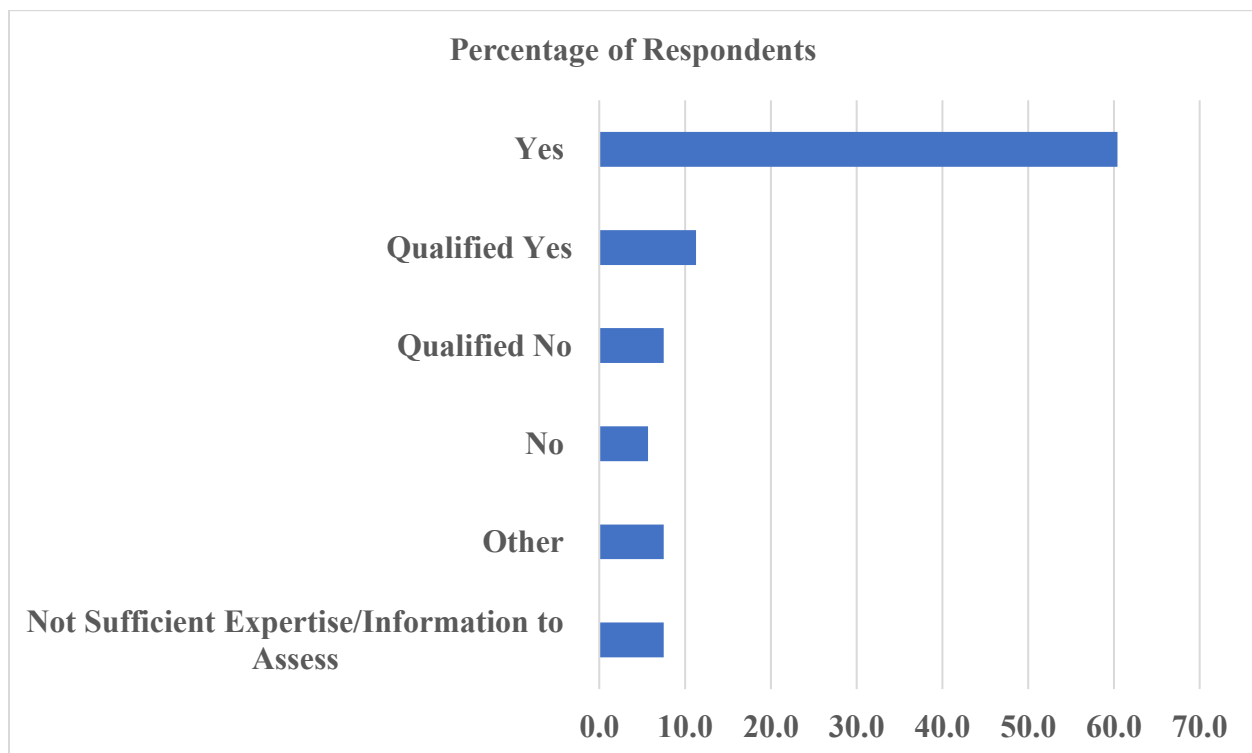
The question laid the ground for participants' reflection on the nature of VC in Canada, the challenges presented, historical trends that have materialized and mechanisms to ameliorate the situation going forward. It also equally opened up the opportunity for some provocative insights and fresh perspectives on the issue that has traditionally been perceived as impeding innovation in Canada.

In all of the 54 individuals interviewed, only one case did not deal with this issue. As for the other 53 interviewees, the data broke in a number of ways (Figure 4). Not surprisingly, given the data that has existed around venture capital in Canada, a majority of these 53 participants clearly were of the opinion that the existing situation was not adequate. Specifically 60 per cent indicated yes to this question, with another 11 per cent indicating a qualified agreement to the question – ie., yes but with certain caveats. For those in accord, as discussed below, answers were by no means restricted just to late-stage capitalization. Responses spanned both start-up (and other forms of early-stage) capital as well as that for scaleup and expansion, with participants offering a range of views on which was more critical or if in fact “les deux” were equally problematic – and inextricably linked. As one respondent commented:

We have gaps everywhere. It's not a late-stage or early-stage – we need more investment at the early stage so we can catalyse investment and also so that we can better derisk our opportunities for that later-stage investment – kind of prime it for a later-stage (I7).

As for those who qualified their agreement with the question, while admittedly small in number, issues here turned on specific matters such as it was less an outright issue of capital but ensuring that the “bits and pieces” associated with development and adoption of new technologies were well in hand before venturing into the market. Or there was agreement there was a “shortage of venture capital in Canada but not in the world and capital will flow to places where the business makes the most sense” (I16). Nevertheless, not quite three-quarters – 71 per cent – of those interviewed indicated their concerns with the availability of VC in the Canadian context.

Figure 4 Venture Capital: Need for More?



In contrast, however, six per cent of those interviewed answered with a definitive “no,” citing other factors that inhibited innovation. Funding was dependent on the quality of the

investment plan -- if there was a “good idea with commercialization embedded the money will come” (I5). Or it was dependent on the market. From a VC perspective, if there was too much money chasing too few deals, deals became overvalued and “too expensive,” a situation that actually fuelled exits as the market overheated and VC firms sought to recoup their investments or even get “80 cents on the dollar” (I25). Another eight percent of those interviewed provided a more qualified no, referencing current trends with VC now “at the table” – a development apparently catalyzed by the pandemic – or distinctly centred their answer on the risk aversion endemic in the Canadian context (a theme which is discussed below).

Interestingly, there were eight per cent of respondents who raised other issues in answer to this question. One noted the innovation “successes” that had occurred in Canada, indicating however these were mostly associated with information technology, as in the case of Shopify. Indeed, the issue was not capital but continued reliance on raw natural resource extraction: “Where the real challenges is that we have in this country we are still in this mould of digging stuff from the ground or cutting trees ... It is very painful and it’s very costly.” (I33). Or interviewees pivoted to much larger national issues associated with capitalization and decarbonization. Finally, eight per cent felt they did not have enough expertise on the issues to adequately answer the question. However, even for this group they at times leveraged their experience with commercialization to raise specific challenges they saw as present in the Canadian environs – management skills or foreign acquisitions.

Perspectives on Stages of Capital

With respect to perspectives concerning the adequacy of capital at various stages of the innovation continuum, interestingly views on start-up and related areas such as small seed funding or angel investors were relatively evenly split (Figure 5). Almost 20 – specifically 19 -

per cent of the interviewees felt that this in fact was a critical stage “to be crossed” (I41) with many small and medium-sized enterprises failing within the first five years or so and with capital – either from private VC sources -- or government grants hard to come by. Even those focused on supporting SMEs who were getting their companies and products underway noted that small “Series A” funding of under one hundred thousand was not typically available:

We typically don’t even write a cheque for less than \$100,000 – so if they only want \$20 k to do some initial validation and get off the ground we can’t help them and there’s nobody who can help them that we know who to send them to. So very small initial cheques to do that kind of initial validation work is an area where we see a gap (I23).

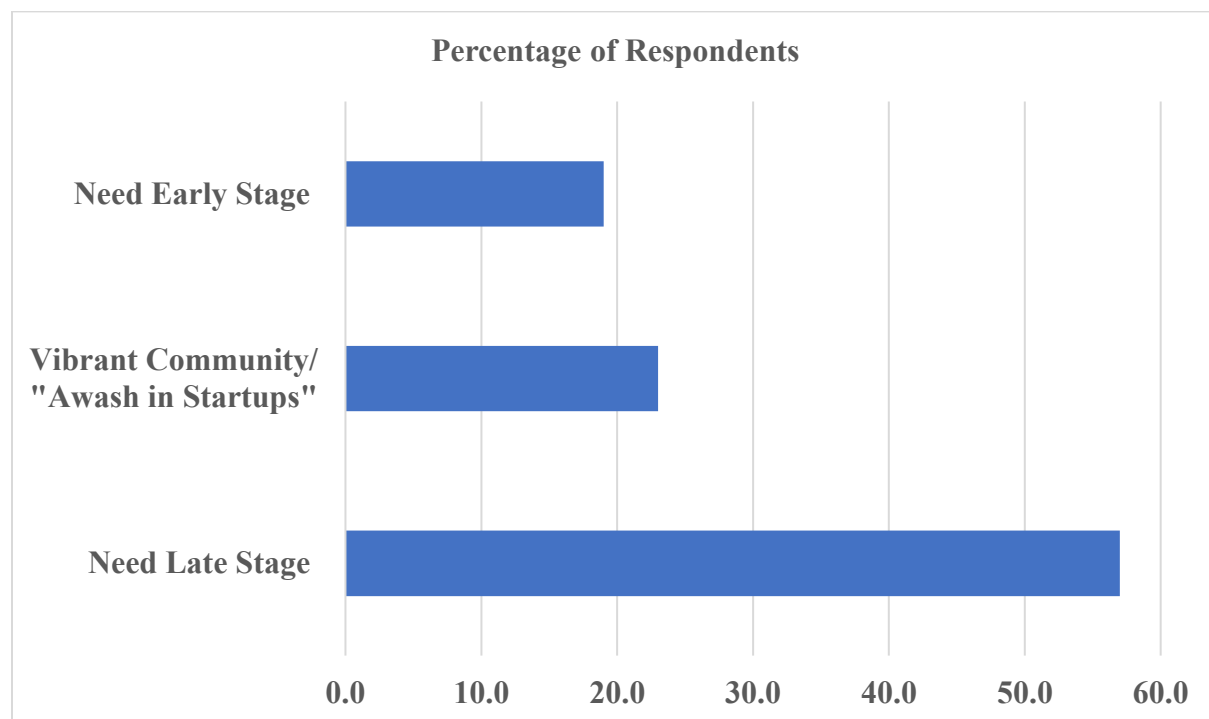
Others also commented essentially on the fragility of the enterprise in these early stages and the importance of having that “derisking” present with the “ecosystem” (I26).

On the other hand, a slightly higher percentage of 23 per cent of participants remarked on the liquidity that was available in the early stages. And here perspectives ranged from a view that there was sufficient available capital to concerns that the “emphasis” on this dimension was impeding the funding needed for real growth and scaling. As for the range of views expressed, specifically interviewees indicated that start-up capital was doing “reasonably well” (I31) or there was “plein d’argent” (I49) or “lots of money” (I48). Moreover, insights were buttressed with data. A report had indicated that 80 per cent of SMEs surveyed indicated “there’s not a lack of capital” (I15). Similarly was it noted that “Toronto has created more AI start-ups than San Francisco” (I43) or that Canada had a “very vibrant angel investment community” (I28) even within a North American context. The conclusion drawn for some was that Canada was “awash in start-ups” (I43). And the resultant focus on small deals with a number of small VC houses was not leading to the large pooling of funds required for the \$100 million and over scaleups. In

sum, the access and emphasis on early-stage was standing in the way of the growth needed for Canadian firms to be real global competitors.

Notably this split on the early-stage availability did not preclude a majority – 57 per cent – from concluding that Canada was very much in need of late-stage capitalization. There was recognition that this was a domain where “Canadian companies struggle” (I22) and it played out both in the “aggregate” amount of capital leveraged as well as in deal size, leading one participant to conclude that “we don’t have an innovation problem in the country, we have a commercialization problem and a scale problem.” (I32). Undoubtedly for those at the front end of this problem, there was a “huge gap” in the VC market, with funding of under \$100 million

Figure 5 Stages of Capital: Perspectives



not being at all adequate for the kind of growth they sought to develop. Further, in stark contrast to the US where “in the first half of 2020 more than two dozen firms raised over \$500

million,” in Canada there were in fact only “three firms in the entire country that are ever playing ... at that level” (I52).

All of this had several implications. It prevented the catalyzing R&D that led to commercialization and scale; it created a magnet to the South, Shopify being the preeminent example of the need to go to the US to get “Series A funding of \$200 million” (I7); and it led to premature buyouts of Canadian firms just as they were starting to succeed. Moreover, the gap was not being sufficiently closed. Admittedly, some participants did recognize that over recent years the federal government had taken significant steps to try and address the issue, but federal efforts still languished. Specifically, federal initiatives were not “harness[ing]” (I22) the other large financial and institutional players – namely the big banks or pension funds – and leveraging those substantive assets and expertise to address the gap.

Discussant Themes: Risk Aversion

Framed within this larger context, interviewees equally spoke to the reasons that grounded their perspectives, with three themes being particularly predominant (Figure 6).³² Over one-third of the respondents – 36 per cent – referenced the propensity in Canada for risk aversion, with considerations not confined to just one dimension – or set of actors but rather the systemic nature of this issue. Certainly, for the VC community there was recognition that with holdings of smaller pools of capital also came the tendency to “be more careful” (I48) in the investments chosen. There were also concerns registered regarding the “big banks” who tended to be “conservative” or institutional investors with funds – both of whom already had significant success and simply did not need to engage in risky ventures. But many also referenced the way

³² It should be noted that interviewees could give more than one answer so the tally in Figure 6 in fact refers to the percentage of respondents focused on that particular issue -- but it did not have to be exclusive.

in which risk aversion was more deeply embedded in the nation's culture and psyche – specifically “We are not a nation of risk takers.” (I2). Be it entrepreneurs or venture capitalists, Canadians were more reticent in their dealings and less willing to gamble all. As one participant noted:

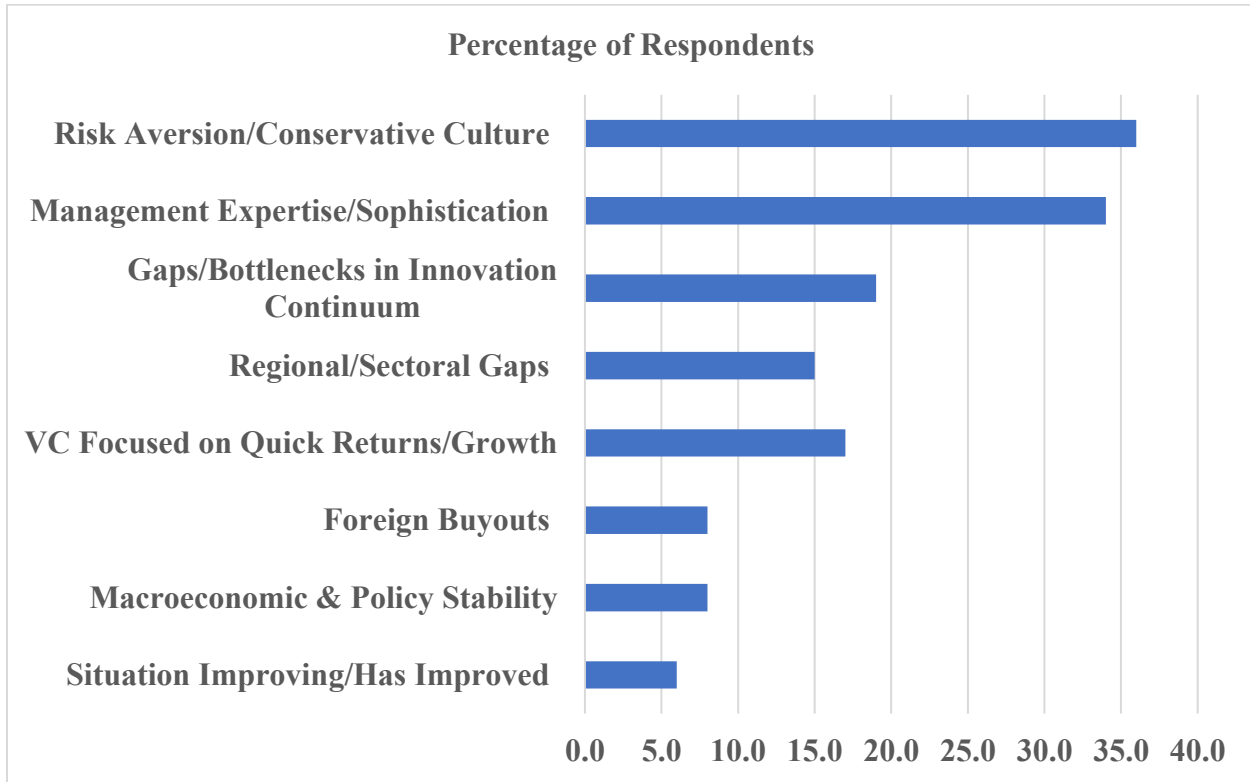
But I can say writ large Canadians are a lot -- well they're a lot more friendly full stop. We tend not to exaggerate – we tend to underpromise, overdeliver. So there are strengths associated with that. We tend to be much more collaborative and much more loyal Americans are much more risk tolerant. So there's dozens of examples where the entrepreneur goes, makes \$10 million and says alright let's do it again and risks it all whereas in Canada there's a lot more anecdotal stories of made \$10 million, alright I'm buying a cottage and I'm done. So I think the rhetoric has some basis but also I think that it could be played to our advantage (I52).

That said, some reflected on whether the Canadian risk appetite would change as capital itself increased and as the ecosystem system developed, questioning whether risk was intrinsically linked to culture or to the assuredness that came with large reserves of capital.

Discussant Themes: Management Expertise

Almost equally significant to the risk theme, 34 per cent of respondents noted the lack of management expertise and “sophistication” that characterized the Canadian VC ecosystem. And here again considerations were not singularly related to one group of actors associated with VC but rather cut across the ecosystem more generally. Firms in early growth stages often lacked the expertise and experience that could weather them through scaleup. As one respondent noted:

Figure 6 Venture Capital: Themes Raised



Money is one thing but if you have a start that keeps growing up and you give them more money it doesn't mean management of that start-up has expertise to manage or use that money properly (I41).

Further both in early stages and later, firms often were not prepared to make their "pitches" for funding, needing to "improve ... their level of sophistication" in making such asks (I35). Part of this was due to the fact that Canada lacked a sufficient number of senior managers, "seasoned" people who as in the United States had made their way up the ranks, moving from a Twitter or Google in the second tier of management to running a smaller company and then moving back into the larger entities with that experience in hand. Part of this also was the assumption that the answer lay with capital but in fact needed to explicitly be wedded to the "acquisition of managerial competence as an essential part of any innovation strategy" (I47).

So too were the VC firms not fully equipped with the necessary expertise. As one participant commented, we have “incubators” for firm development but not for VCs. Another contrasted the Canadian situation with the American one, noting that in one particular thriving area of the US with which they were familiar:

There was kind of like this amazing partnership and understanding of every microbusiness coming out of that ecosystem that people partner with. And you feel like you’re in good hands and will be there along the way and people will accept to take the risk for a ... sustained period of time. That makes all the difference. (I54)

The banking community as well was not particularly well versed in leading-edge technologies, their growth trajectories and capital needs. Nor was the education system – and particularly the business schools – doing enough to develop and sharpen these managerial competencies. Finally, the detailed and intimate knowledge needed for successful patenting strategies and Intellectual Property was often missing as well.

Participants did have thoughtful insights on the mechanisms and approaches which could be leveraged to strengthen this area. For start-up firms, networks associated with Chambers of Commerce and with larger anchor firms might provide a locus for mentoring. For VC particularly in areas such as biotech and biologics, it was important to have certain specialized funds with intimate knowledge of these domains. For venture capital more generally, it was important they too have access to the counsel and advice that came from experience. As one interviewee put it: “it’s good to start them with training wheels and have them friends with Americans or others to learn how to do the game ...” (25). So too was it suggested that the federal government should be more engaged on IP protection – noting countries like Germany that took an active role in grooming start-ups on the “value of their IP” and how to retain it (I54).

Similarly, participants had perspectives on approaches that were *not* working. That putting companies together in close physical proximity was simply the formula for international growth. That big generalized VC funds without the necessary expertise could be assumed as the only catalyst for innovation. Or that success was also contingent on the government itself reckoning with a much more strategic approach to the innovation continuum and what was needed. Indeed, overall the portrait that emerged was twofold. Management expertise was a significant gap in the innovation system, traversing many dimensions and steps were needed to address this. And for some, at least, the Canadian ecosystem still needed to mature – a process that with experience and with failure -- bred success and indeed “survival bias” (I48).

Discussant Themes: Innovation Gaps

While of lesser order other themes emerged in these discussions as well. Of those interviewed, 19 per cent highlighted the continuing and key gaps within the innovation continuum impeding progress. Not surprisingly, given Canada’s traditional record in this domain, most of the comments centred around the “so-called valley of death” as start-ups and university spin-offs made their way from bench to market. The need to “bridge” the gap between early research and development to full deployment; the instruments and agencies pertaining to the commercialization space which were needed; the value in assessing and rewarding academic research not only on publications; the importance of “transformative R&D” that could enable industrial applications: all were underlined as areas germane to the VC issue as well. Or as one participant adeptly reflected, the importance of “turning ideas into impact.”

Similarly, regional and sectoral gaps were underlined, with 15 per cent of the interviewees commenting on domains which were not being addressed by venture capital. For one thing, venture capital flowed to metropolises – first to Toronto or Montreal and then within the

North American environment to New York or California. As such, the issue was more than just VC: “C’est ... plus que capital risk” (I46). Rather capital availability was integrally linked to regional economic development strategies that could “tire innovation,” fostering the dense clusters of expertise and talent that in turn could also mobilize capital. Waterloo was cited more than once as a prominent example. Participants also noted that the situation was further exacerbated by the tendency for smaller regions to be overlooked, even when they had vibrant innovation clusters and experimentation which could be leveraged.

Specifically noted as well was the underfunding in the West and Atlantic region, a factor that bled into sectoral needs as well. The Prairie provinces were cited as “receiving only three per cent of all venture capital in Canada, with only a “portion of that going into agriculture” (I35). Given the significant capitalization needs of this sector as it transitioned from “commodities” to agri-products with high value added, large infusions of late-stage capital would be needed. Notably even food processing plants alone required investments in the order of “5, 6, 700 million” (I35). So too were oil and gas investments being impacted, particularly as the industry faced the challenges of decarbonization (I14). In this latter case this was more than just late-stage needs but rather a substantial “pivot” to a new model that would require funding in the billions – not only for oil and gas but industries such as aerospace that were carbon-dependent. The issue in fact transcended the concept of venture capital per se and necessitated large-scale restructuring:

This is not venture capitalism. This is business model capitalism of large players.... Many of those players are looking at hydrogen. This is not venture capitalism – this is big corporations with deep pockets pivoting in terms of their strategic investments. Instead of focusing on innovation leads to venture capital, we need to focus on innovative science and technology leads to big capital pivot. Let’s keep that money here in Canada. It’s here now (I44).

Discussant Themes: VC Focus on Quick Returns and Growth

Almost equally of concern, 17 per cent of those interviewed spoke to the growth dynamic embedded in venture capital availability, and the conversations here essentially broke into two sides. For venture capitalists, the imperatives of the market drove their decision-making and the need for quick returns – often within a three-to-five -year timeline. Noted on more than one occasion by participants, was that in investing in ten companies usually only one will really take off and scale:

In a portfolio of ten companies, they [VC investors] know that five of them will be dead within a couple of years. Maybe five will survive more than two years and maybe if you're lucky one will be very very successful and the others will just hang in there ... it's a game of chance – gambling (I48).

As such the venture capitalist must have the reserves to “paper” all ten and to last long enough to see returns on their investment –otherwise as one interviewee bluntly depicted “you’ll get squashed down by the other investors” (I25).

In direct contrast, for the entrepreneur seeking VC, the tight time frames and the need for the VC to “quadruple or quintuple” their returns created major barriers. Sometimes it was just easier for smaller firms to forego the VC, grow the company slowly and access what their own resources might be, although this too could make those firms susceptible to buyouts if their financial situation deteriorated. Additionally, tight time frames when accepted had implications for the innovation process itself. It definitely shortened the horizons around the long-term basic research required to stimulate innovation, creating a bias towards quick returns and sublimating the longer-term benefits from the research. Interestingly, in this context, the American case was also raised, where the space race had produced “all these spinoffs and technologies” (I41) that had evolved from early research. Time constraints also shortchanged the technology handoffs from academe to industry so germane to innovation:

I think an important thing to point out is that transfer from academic research to a start-up company is a really leaky pipe. You lose a lot on the way because there's not much funding and support in that space (I23).

As one respondent noted in synthesizing the issues at play,³³ quite simply there was a “need for risk capital to be patient” (I46). All told it is not too much to suggest that comments at times do resonate with the familiarity of the DNS framework. More importantly, however, the perspectives that emerged do not indicate that the “patient” capital so intrinsic to the DNS framework is particularly forthcoming in the Canadian case.

Discussant Themes: Other Considerations

Finally, other less prominent but still significant considerations surfaced in these discussions. Certainly, for eight per cent of respondents policy stability was an important factor. The government's macroeconomic framework needed to maintain and to signal “stability:” otherwise the country risked losing opportunities for foreign investment and risked losing “Canadian flighty money” (I25). And it was not just the stability inherent in fiscal or monetary policy. It was also the foundational elements that preserved the framework for innovation. As one participant put it:

Stability, inflation, education, research capability -- all of those underpinnings of a modern economy: they -- venture capital or any other industry in the country ... isn't going to prosper without those (I25).

Overlaid on the macroeconomic dimension were also comments regarding the need for public policy to be consistent. Notably the 2006 decision by the Harper administration that changed the fiscal rules around trust funds, subjecting them to taxation, was referenced. Specifically, an “overnight” loss of nine million dollars in the oil and gas sector was attributed to the pivot from

³³ It is worth noting that this comment was by no means solicited by the author and emerged organically from the answer to Question 5 on venture capital.

previous commitments on this issue (I14). Sharp turns in policy were less than conducive to investment availability.

Eight per cent of respondents also referenced the issue of foreign buyouts, particularly for young and growing companies which exited early and did not get the opportunity to scale. Finally, it should be noted that six per cent of those interviewed did take the position that the situation with respect to venture capital had improved. Significantly it was those with experience both in the US and Canada who particularly reflected on this issue. Contrasting the situation with two decades earlier, one interviewee noted:

It's dramatically better ... and not to mention the fact that VCCI and VCAP I think were seminal moments in our policies at the federal level that were terrific. You can throw apples and tomatoes at them in some regards but the reality is there's a bunch of firms that exist today that did not or wouldn't have ordinarily; and they are now held to account on their results and that's all good (I52).

Still in light of the budgetary initiatives that have been taken on venture capital, the relatively slim proportion of respondents assessing the situation in a favourable light is striking.

Interviews: An Overview

Overall, then, what the thought leader findings speak to are the issues generally associated with the innovation ecosystem in Canada – but as seen through the prism of venture capital. The significant gaps in the innovation continuum that revolve around commercialization; the regional and sectoral cleavages that are overlaid on this dimension; the risk aversion associated with short time frames: these issues continue to be replicated within the VC domain. So too are concerns with management expertise and maturity remarkably pronounced within the Canadian innovation landscape. While admittedly a less noted tendency in the venture capital context, policy consistency is also flagged as an area in demand of more robust attention. As for the overall perspectives held on the availability of capital, certainly for

almost a quarter of respondents there was recognition of the remarkable strides that had been made in Canada in terms of start-up funding. Nonetheless, results also demonstrated division on this dimension, with another 19 per cent indicating that the needs at early-stage had not significantly abated. As to the access to late-stage funding, here there was substantially more consensus, with 57 per cent of respondents speaking to the need for increased late-stage capitalization.

In sum, the issues identified in these interviews continue to challenge the key actors in the national innovation system – and challenge federal policy-makers to rethink traditional approaches. Most importantly, for the exercise here, the interview results do not suggest findings in any manner dissimilar to the conclusions drawn by various commissions and advisory councils over the years – or to the compelling trends evident in OECD data. Budget endeavours that have come and gone aside, for a substantial majority of participants interviewed on this question, the gap in late-stage capitalization – both in “aggregate” and in deals -- continues to obtain.

Conclusion

In terms of the fundamentals of the DNS framework around the capitalization pillar, the situation with respect to the Canadian case can best be described as nuanced, for a number of reasons. Clearly, there were efforts to engender VC within the innovation ecosystem, both through public investments as well as the leveraging that could impact private capital. Political administrations across the decades did pay frequent, if not annual, attention to the matter and the years in question were punctuated by intermittent spikes of concentrated activity – in 2003/2004, in 2013 and again in 2017. Equally, as per Mazzucato’s observations around US funding, allocations of public funding did not fall into the trap of being only countercyclical, in fact

crisscrossing the years of the Great Recession -- and the immediate aftermath. Further, for a large part of this time period at least governments turned the page on the underperforming instrument of Labour-Sponsored Venture Capital Corporations. Most importantly, as our review of federal budgetary initiatives revealed, there was a widening sweep of inclusion on the innovation spectrum from “start-up” especially in the Chrétien period, to “large-scale” capital funds under the Harper administration to a focus on “late-stage” growth in the more recent Trudeau government. Also perceptible although not predominant was a movement to “young” firms poised for growth, rather than just small and medium-sized enterprises per se.

That duly noted, however, several factors do point in opposite directions and away from the conditions associated with DNS. Specifically, and taking the full measure of these years, attention was predominantly devoted to start-ups and smaller businesses: even with the large-scale initiatives they were embedded within a context of focus on incubators and accelerators and firms at the cusp of growth. Establishing anchor firms and propelling late-stage capital development only surfaced for a time at the end of the time period studied. Indeed, and surprisingly, VC initiatives under the Trudeau administration do not appear to be directly wedded to the Supercluster effort – an initiative that held in its sights scaling for growth. As for directed and dedicated streams of funding, these too have been less evident throughout these years, although certainly there was experimentation with this during the early Liberal years and again it has come to the fore under the BDC auspices more recently.

Probably most dominant, however, has been the reliance on traditional and more indirect fiscal tools for releasing investment and venture capital into the innovation ecosystem. Macroeconomic stability and deficit-fighting have been constants of the fiscal landscape in Canada – even the Trudeau years, despite a rejection of “austerity” politics, maintaining the

country's low net debt-to GDP ratio within the G7. In parallel, taxation has been especially deployed as a critical vehicle for “freeing” venture capital and engendering investment that can propel innovation and growth. Certainly, it has followed a wide array of measures over the years, from outright cuts in corporate income tax, to more honed and somewhat arcane efforts within international tax treaties to engage large institutional investors, both domestic and foreign. And it has clearly had the propensity to return to the default mode of capital cost allowances and “accelerated investment incentive[s]” when Canadian interests were threatened by tax-cutting by neighbours to the South. Finally, overarching all of this, has been the central dependence on small business as the harbinger – and critical instrument -- for innovation and growth. Be it capital gains rollovers or downgrades in tax rates (and concomitant upgrades in deduction thresholds) or efforts to still “passive investments” that did not generate wealth, reliance on small business as a critical dimension of fiscal, taxation *and innovation* policy, has remained as a staple of federal budgetary agendas throughout these years. Direct vesting of public funds in late-stage capitalization has been much less featured.

All of this, the concentrated efforts on VC included, has had observable impacts. As the OECD data has indicated, Canada has made great strides in terms of access to and availability of venture capital, actually in terms of our research here coming up as second in rank to the US in terms of international (or at least OECD) standings on this issue. And while the OECD has previously positioned Israel actually as the leader in VC, as earlier noted further evidence would be needed to determine if that currently holds. Regardless, Canada has moved forward on the VC front and on “start-up and other early-stage” capital has experienced a growth of almost 200 per cent over the 2007 to 2019 period. With respect to “later-stage” capital, however, the situation has been much more daunting and indeed the years between 2007 and 2019 witnessed

an actual deceleration in VC growth of 20 per cent, before recently rebounding. That of course has made for some extensive gaps with the US, notably with the US weighing in at 1.8 times higher than the Canadian situation with respect to start-up capital and, in the case of late stage, with that gap rising to 6.6 times greater. So too have these trends been observed in the thought-leader interviews with a majority of participants (60 per cent) responding that Canadian VC was not adequate and a similar majority (57 per cent) indicating that there lacked sufficient late-stage capitalization, enabling “commercialization” and “scale.”

In all, then, the patterns that emerge here are not dissimilar to those found with respect to other pillars of the DNS framework in the Canadian case. The intermittent priority-setting – at least as relates to directed and concentrated periods of activity around VC; the significant resourcing (\$2.22 billion in all) equally accompanied by asymmetrical impacts relating to start-up and early-stage rather than later-stage development: here too these arise. Present as well is the stalwart commitment to macroeconomic stability and market “framework” policies that traverses these federal initiatives and claims for the investment conditions that can engender innovation. If indeed a necessary condition for innovation is “patient” public capital vested throughout the innovation chain and directed to disruptive technological opportunities, it is not unreasonable to conclude that the Canadian case has emerged in truncated form.

Annex A – 7: Venture Capital Indicators

Table 1 Federal Investments in Venture Capital: 2000 – 2020

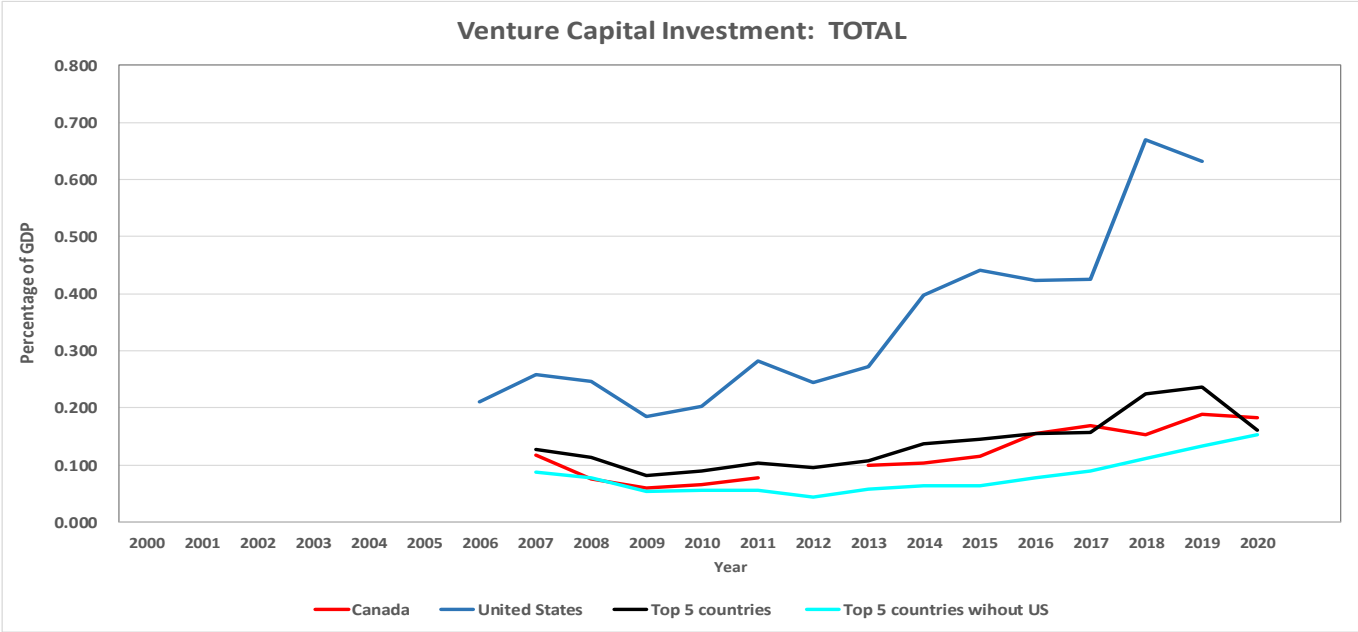
Federal Investments in Venture Capital: 2000 - 2020*																	
	2000	2003	2004	Sub-total- 2000-2004	2008	2010	2012	2013	2014	2015	Sub-total 2008-2015	2016	2017	Feb. 2018	Fall 2018	Sub-total 2016- 2018	Total All Years
Aboriginal Business Canada		20,000,000															20,000,000
Business Development Bank of Canada	80,000,000	190,000,000	270,000,000		75,000,000	50,000,000	100,000,000	100,000,000									865,000,000
Canadian Youth Business Foundation								18,000,000									18,000,000
Clean Tech															50,000,000		50,000,000
Farm Credit Canada		20,000,000	20,000,000														40,000,000
Futurpreneur										14,000,000			14,000,000				28,000,000
Innovation Hubs-Incubators/Accelerators								60,000,000	40,000,000								100,000,000
Venture Capital Action Plan**								400,000,000									400,000,000
Venture Capital Catalyst Initiative													400,000,000				400,000,000
Women in Tech***												40,000,000		160,000,000			200,000,000
Women in Tech via RDAs****														105,000,000			105,000,000
Sub-totals				600,000,000							857,000,000					769,000,000	
Total	80,000,000	230,000,000	290,000,000		75,000,000	50,000,000	100,000,000	578,000,000	40,000,000	14,000,000		40,000,000	414,000,000	265,000,000	50,000,000		2,226,000,000

* Federal investments in Venture Capital are based on a review of all Budgets and Economic Statements from 2000 to 2020; VC funding only appears for the years noted below.
** Although announced in Budget 2012, the specifics of VC allocations were provided in Budget 2013.
*** Budget 2016 delivered \$40 million; this was topped up to \$200 million in Budget 2018. However, there had been a previous top-up, although the exact date is not known.
**** RDAs: Regional Development Agencies
Sources: Finance Canada 2000 - 2020.

Figure 1 Venture Capital Investment: Total

Dataset: Venture Capital Investments

Subject	Venture Capital Investment: TOTAL																				
Measure	Percentage of GDP																				
Year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Country																					
Canada								0.118	0.076	0.059	0.065	0.078		0.099	0.103	0.115	0.156	0.169	0.153	0.189	0.183
United States							0.210	0.259	0.247	0.184	0.203	0.282	0.245	0.272	0.397	0.442	0.423	0.426	0.669	0.633	
Top 5 countries								0.127	0.113	0.082	0.089	0.103	0.096	0.107	0.137	0.144	0.154	0.157	0.225	0.236	0.162
Top 5 countries without US								0.088	0.078	0.053	0.056	0.056	0.044	0.059	0.065	0.064	0.077	0.090	0.111	0.133	0.153



Source: OECD Enterprise Statistics, Venture Capital Investments (https://stats.oecd.org/Index.aspx?DataSetCode=VC_INVEST).

Entries only begin in 2006. Also Canada has not provided 2012 data in this series.

Top 5 countries: United States, Canada, Finland, Korea, Sweden. Israel is excluded from the top 5 as 6 entries are missing.

Top 5 countries without United States: Canada, Finland, Korea, Sweden, United Kingdom.

The top 5 country average does not include years 2000 to 2006 as only Korea has entries for this period, and only the US for 2006; as such these entries would skew the data.

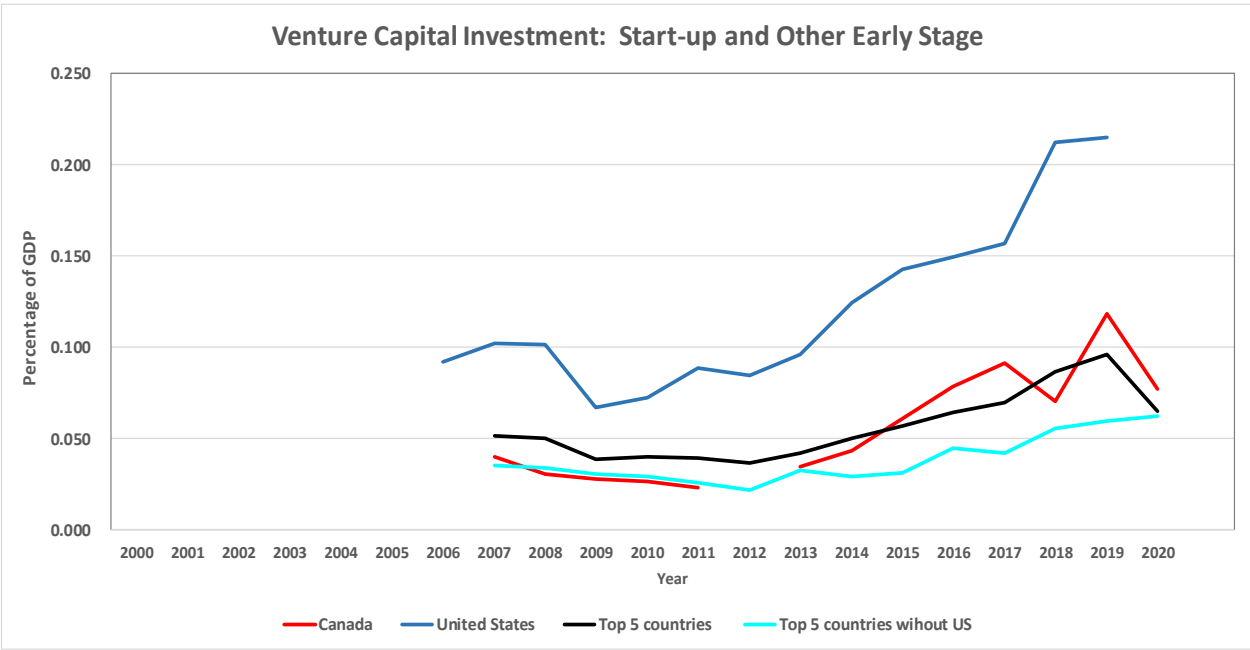
Note: OECD and EU averages are not provided in this data series; China does not report for VC.

Data extracted on 30 Nov 2021 18:50 UTC (GMT) from OECD.Stat.

Figure 2 Venture Capital Investment: Start-up and Other Early Stage

Dataset: Venture Capital Investments

Subject	Venture Capital Investment: Start-up and Other Early Stage																				
Measure	Percentage of GDP																				
Year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Country																					
Canada								0.040	0.030	0.027	0.026	0.023		0.035	0.043	0.061	0.079	0.091	0.070	0.119	0.077
United States							0.092	0.102	0.101	0.067	0.073	0.089	0.085	0.096	0.125	0.143	0.149	0.157	0.213	0.215	
Top 5 countries								0.052	0.050	0.039	0.040	0.039	0.037	0.042	0.050	0.057	0.064	0.070	0.086	0.096	0.065
Top 5 countries without US								0.035	0.034	0.031	0.029	0.026	0.022	0.033	0.029	0.031	0.045	0.042	0.055	0.060	0.063



Source: OECD Enterprise Statistics, Venture Capital Investments (https://stats.oecd.org/Index.aspx?DataSetCode=VC_INVEST)

Entries only begin in 2006. Also Canada has not provided 2012 data in this series.

Top 5 countries: United States, Canada, Sweden, Finland, Switzerland. Israel is excluded from the top 5 as 6 entries are missing.

Top 5 countries without United States: Canada, Sweden, Finland, Switzerland, Ireland.

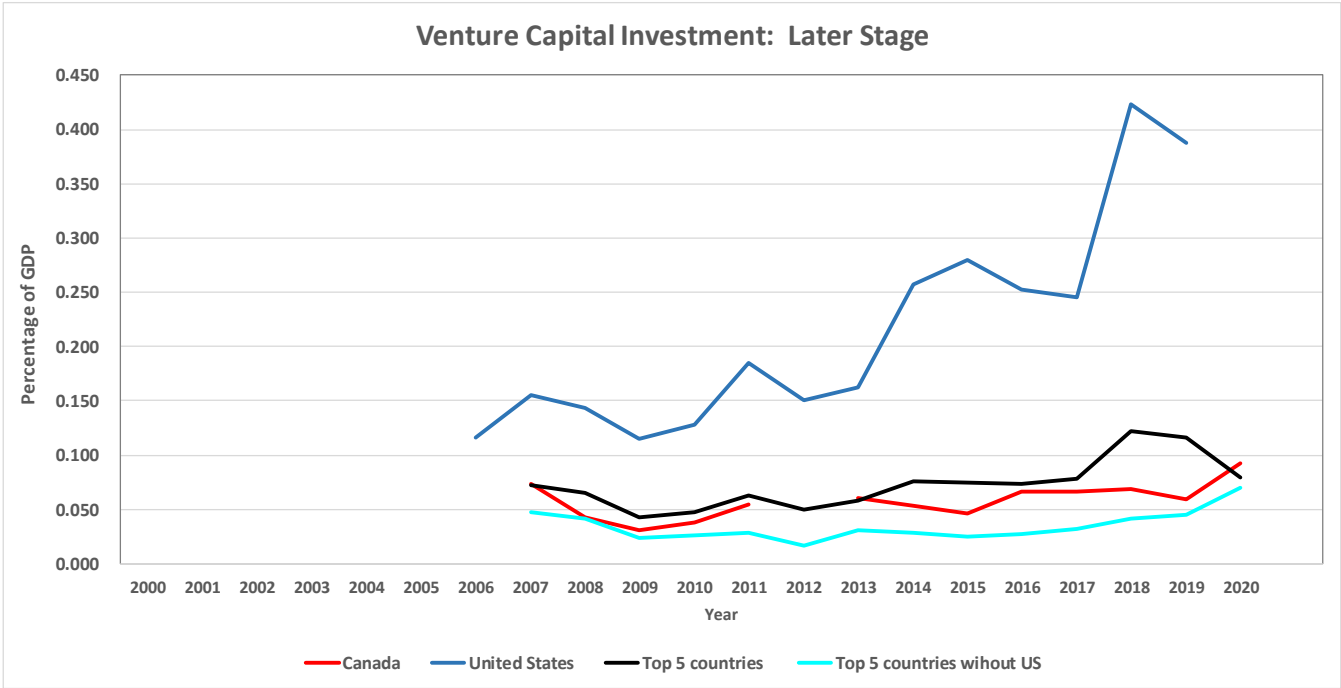
Note: OECD and EU averages are not provided in this data series; China does not report for VC.

Data extracted on 30 Nov 2021 18:50 UTC (GMT) from OECD.Stat.

Figure 3 Venture Capital Investment: Later Stage

Dataset: Venture Capital Investments

Subject	Venture Capital Investment: Later Stage																				
Measure	Percentage of GDP																				
Year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Country																					
Canada								0.074	0.042	0.030	0.038	0.054		0.060	0.054	0.047	0.067	0.066	0.069	0.059	0.092
United States							0.117	0.155	0.144	0.115	0.128	0.185	0.150	0.162	0.257	0.280	0.253	0.245	0.423	0.387	
Top 5 countries								0.072	0.065	0.043	0.047	0.062	0.049	0.058	0.076	0.075	0.073	0.078	0.122	0.116	0.080
Top 5 countries without US								0.048	0.041	0.024	0.026	0.029	0.016	0.030	0.029	0.024	0.027	0.032	0.042	0.046	0.070



Source: OECD Enterprise Statistics, Venture Capital Investments (https://stats.oecd.org/Index.aspx?DataSetCode=VC_INVEST). Entries only begin in 2006. Also Canada has not provided 2012 data in this series.
Top 5 countries: United States, Canada, Finland, Sweden, United Kingdom. Israel is excluded from the top 5 as 6 entries are missing.
Top 5 countries without United States: Canada, Finland, Sweden, United Kingdom, France.
The top 5 country average does not include 2006 as the US is the only country in the top 5 with an entry; as such it would skew the data.
Note: OECD and EU averages are not provided in this data series; China does not report for VC.
Data extracted on 30 Nov 2021 18:50 UTC (GMT) from OECD.Stat.

PART III: A POLICY STUDY IN CONTRASTS

Chapter 8

Artificial Intelligence: Unleashing Innovation

Introduction

The case of Artificial Intelligence (AI) presents a particularly interesting case study for the Developmental Network State framework not only because of the strategic and “enabling” (CCA 2018, 59-62) nature of this technology for the innovation process writ large, but also because its rather recent emergence on the S&T scene would seemingly limit the quest for the appearance of long-term policy commitments. Moreover, it challenges DNS in a very direct manner. Recent indicators have shown the immense strides AI has made -- in patents, in scientific publications (OECD 2017, 33-34) and in research discovery writ large. As such, then, the expectation of the DNS thesis is that this research domain would have benefitted from the policy conditions and levers favouring innovation – specifically, priority-setting and policy durability, targeted government resourcing and thickening of the AI ecosystem linkages. If such are not found, the argument for falsification of the framework is particularly strong.

Moreover, as noted in the Research Methodology chapter, the AI and pharmaceutical manufacturing case studies offer a particularly appealing means to test the DNS framework. Indeed, they provide an interesting study in contrasts – Artificial Intelligence an emerging technology and sector linked to digitization, productivity and innovation¹ and pharmaceutical manufacturing a mature sector that has weathered the experiences of manufacturing more generally in Canada. Further, as we shall see they provide a sharp juxtaposition of policy tools –

¹ See in particular, OECD 2017a, 2017c and 2019, with the 2019 report referring to AI as having “the potential to revolutionise production” (24).

those both enabled and those that have remained in somewhat more static form since at least the turn of this century.

However, while for AI, the argument and evidence to be gleaned do centre around federal initiatives with respect to priorities, resourcing and triadic thickening, cross-cutting this dimension is also the federal-provincial landscape on which AI operates. Indeed, in delineating the role of federal policy – and in order to gird the robustness of this analysis -- it is necessary to review not only Ottawa’s efforts (historical and recent) in this regard but also the initiatives that the Government of Québec has embarked upon in recent years. As such this inquiry into the respective federal and provincial initiatives turns on three critical areas: the historical role of the respective governments in this domain; the funding dedicated to AI initiatives over time; and the current priority-setting that both the Government of Canada and Government of Québec are dedicating to this field.

Thus, this inquiry unfolds on two levels. It primarily examines whether federal AI policy interventions have coalesced around DNS policy levers and the implications that has for Canada’s engagement with innovation and with evaluation of the DNS itself. Additionally, however, it undertakes an assessment of the federal intervention vis à vis Québec’s policy initiatives, weighing in turn history, funding and the current engagement around Superclusters and AI diffusion within industrial sectors. Employing the “quasi-experimental” approach earlier laid out (Campbell 1969, Cook and Campbell 1986),² the chapter then turns to examine innovation indicators to assess the impacts of policy initiatives. Concluding remarks focus on the relevance of this case study for the DNS framework.

² See Chapter Two, Research Methodology, “Two Sectoral Case Studies.”

Methodology

Aside from the annual time sampling of innovation indicators associated with the aforementioned “quasi-experimental” approach which will be used in this case study, a few additional notes on methodology are necessary. Specifically, from the standpoint of assessing the relative weights of federal and Québec policy interventions, several cuts into the issue have been undertaken. With respect to federal funding, not only reviewed were Budgets from 1994 onwards to the most recent Fall Economic Statement of 2020 (Finance Canada 2020) but Public Accounts going back to 1985-1986 through to 2019-2020 were equally examined for evidence of expenditures in this area. Additionally, Industry Canada/Innovation Science and Economic Development Departmental Performance Reports and Departmental Results Reports were reviewed from 1999-2000 to 2019-2020³ – a particularly important dimension in determining the timing of expenditures in this field. Extensive searches of key news releases and newspaper articles were also undertaken and findings woven into the analysis. As for the case of Québec, budgets were analysed from 2000 onwards. All budgetary and public accounts investments and expenditures are duly reported in Annex A - 8 in Figures 1, 2 and 3⁴, dealing with federal, Canadian Institute for Advanced Research (CIFAR) and Québec investments respectively.

With regard to current strategies, a variety of websites, documents and efforts by Advisory Committees have been reviewed. As for the historical dimension, existing overviews of Canadian engagement in the AI domain -- how it transpired, who the lead actors were and now are, where the centres of research developed – appear to be quite limited. There is a significant amount of material on various OECD, government and AI websites that assists with this and at least one very detailed look at the development of AI in the Canadian context (Brown

³ Unfortunately, accessible electronic DPRs and DRRs were not available prior to 1999-2000.

⁴ Unless otherwise specified, Figures and Tables referenced in this chapter are located in Annex A - 8.

2007). However, it is worth noting that what is sorely lacking in this domain is a strong, historical look at engagement of various academic, government and business representatives in the germination and development of Artificial Intelligence and associated fields of robotics over the last four decades, and the targeted resourcing that this may have entailed. Indeed, it speaks precisely to the need to engage two important components that come from the DNS framework – priority-setting, particularly not as one-offs but *over time* and the funding that sustained fundamental and basic science even when this was considered to be of “marginal” significance (<https://www.universityaffairs.ca/features//feature-article/canada-emerged-leader-artificial-intelligence/>) and viewed by many with “skepticism.” The study undertaken here is just a small step in filling that gap.

Understanding Artificial Intelligence

The OECD has succinctly defined Artificial Intelligence as “An advanced computer programming language aimed at enabling computers to emulate the human mode of reasoning.” (OECD 2007, 42). Yet, written in 2007, this scarcely begins to define the current nature of AI – based on “deep learning” and “neural networks”⁵ (LeCun, Bengio and Hinton 2015). The algorithms that enable voice recognition, deciphering the human voice and translating back into actions; the capacity for massive and rapid search engines; the means for language translation; the visual recognition properties critical to medical imaging; the computational fundamentals for driverless cars and robotics more generally: AI today is the stuff of previously futuristic visions.

Premised on computational methods that begin to mimic in the machine the intelligence of the human brain, AI and the science of neural networks and deep learning on which it rests

⁵ On the computational fundamentals behind deep learning see particularly LeCun, Bengio and Hinton (2015); also <https://www.cifar.ca/research/program/learning-in-machines-brains>; CIFAR (2018); and <https://www.universityaffairs.ca/features/feature-article/canada-emerged-leader-artificial-intelligence>.

broke with older techniques of computer programming. It moves well beyond more simplistic, even “primitive” (Gupta 2017) forms of data extraction and rests on complex and dynamic layers of “representation” that enable the machine to “depict” and “classify” (LeCun, Bengio and Hinton 2015, 436).⁶ Moreover, this recognition has been twinned with “reinforcement learning” (<https://www.universityaffairs.ca/features/feature-article/canada-emerged-leader-artificial-intelligence>) that creates means within the machine to respond essentially to cues, reacting in turn to positive reinforcements or negative implications. In a word, it works to imitate cognition.

What is quite remarkable, however, particularly given the country’s general historical challenges with innovation, is that the three scientists credited with not just contributing to this field but essentially *founding*⁷ it – Professors Bengio and Hinton, and then Professor LeCun⁸ did their work in Canada. Recently awarded the prestigious ACM A.M. Turing Award – the “Nobel Prize of Computing” – the trio has been heralded as the fathers of deep learning and indeed the AI revolution. The media release associated with the Turing Award was clear in the extraordinary significance of this work:

Working independently, and together Hinton, LeCun and Bengio developed conceptual foundations for the field, identified surprising phenomena through experiments, and contributed engineering advances that demonstrated the practical advantages of deep neural networks. In recent years, deep learning methods have been responsible for astonishing breakthroughs in computer vision, speech recognition, natural language processing, and robotics – among other applications (<https://www.acm.org/media-center/2019/march/turing-award-2018>).

Nor was that all. The statement went on to conclude that deep neural networks “are changing ...nearly every field of science and human endeavor.”

⁶ The exact quote is “Representation learning is a set of methods that allows a machine to be fed with raw data and to automatically discover the representation needed for detection or classification.” (*Ibid.*, 436).

⁷ See the footnote references in LeCun, Bengio and Hinton (2015), particularly Hinton et al. (2006); Hinton et al. (2012); Bengio et al. (2006); Bengio et al. (2001); LeCun et al. (1990); Graves, Mohamed and Hinton (2013).

⁸ Professor Hinton was Professor LeCun’s external thesis advisor (<https://www.utoronto.ca/news/am-turing-award-nobel-prize-computing-given-hinton-and-two-other-ai-pioneers>).

CIFAR: The Crucible for AI

Such lauding however, was not always the case. In fact the early work by Professors Hinton and Bengio was deemed marginal, even “fanciful,” and Hinton himself has indicated that their contributions were previously seen as being out on the “fringes” of their field (<https://www.utoronto.ca/news/am-turing-award-nobel-prize-computing-given-hinton-and-two-other-ai-pioneers>).⁹ But what was critical to their success, and to the endurance of their research, was the Canadian Institute for Advanced Research (CIFAR). A non-profit pulled together in 1982 on a shoestring budget and centred around a small hub of eminent scientists and researchers, CIFAR would become the crucible in which AI and, what was then called Artificial Intelligence and Robotics, was forged and, in large part, sustained.

Predicated on a virtual model, CIFAR¹⁰ was dedicated to a deep form of national and international collaboration, drawing scientists and scholars from across the country and, where possible, from abroad. Moreover, it functioned as a key catalyst for research, partially relieving professors from some of their administrative and teaching duties, seeking out top scholars in their respective fields and, most critically, hosting the networks and collaboration that could spawn the exchanges necessary to research breakthroughs. In the words of the Institute’s first president, it functioned as a “university without walls” (Brown, 2007, xi).

⁹ Indeed as Professor Hinton himself indicated about the award, “It’s sort of an acceptance by the computer science community that this stuff isn’t crazy” (*Ibid.*).

¹⁰ The discussion of the history of CIFAR is drawn from several sources, especially the excellent history of its early years by Brown (2007); also an archival dig into news sources: Bury (1999); Cyr (1999); *Economist* 4 Nov. 2017; *Citizen* 1989; *G&M* (1986, 1991, 1996, 2003, 2004; 2006a; 2006b; 2010a, 2010b; 2012); Hyman (1989) Immen (1985); RESEARCH MONEY (2017); <https://www.cifar.ca/cifarnews/2017/06/08/history-note-moving-on-up> and the excellent and detailed overview in IC (2013). An important part of the specific history of CIFAR is the development of the idea by the John Leyerle, actually the Dean of Graduate Studies at the University of Toronto at the time.

Further the Institute was “mission”-driven, established to focus on the large questions that had social and economic impact and that indeed concerned “humanity”.¹¹ Setting out “global” challenges in specific research domains, based on a five-year program cycle, it drew in new programs where necessary and cut old ones as needed. To be sure, the Institute, despite the initial scanty funding, cut a wide berth, housing twelve programs as far flung as the “history and nature of the Universe” to Molecular Evolution, Superconductivity, Nanoelectronics and Health of Populations (*G&M* 1991; Kapica 2004; also Brown 2007, x). As for the “search” process which underlay the programs, this was particularly rigorous, having to be multidisciplinary in nature, break new intellectual ground and draw in international collaborators – a process which often took two to four years (IC 2013a, 2) to complete.

CIFAR’s first and flagship program however was (as it was then called) Artificial Intelligence, Robotics and Society (AIRS).¹² Initially directed by Dr. William Tatton from U of T, it in fact centred around three critical hubs of activity: the deep learning associated with McGill; knowledge representation at the University of Toronto and then visual learning at the University of British Columbia. Later it would spin out a more industrial and applied arms to the activities, but in its early form, it was focused on basic science and research. Peer-reviewed after its first five-year cycle (as was CIFAR’s practice), the program was deemed an “unequivocal success” (Brown 2007, 65-67). The AI labs registered in the “top twenty to thirty in the world” (*Ibid.*, 65) and computer vision and knowledge representation among the “best ten or so internationally.” A second equally successful five-year cycle followed.

¹¹ IC 2013; it is however a direct quote from CIFAR’s website at the time.

¹² For the history of the AIRS and soon to become AIR program when the Society component was dropped see Brown (2007) ; also Lynn (1984); Immen (1985) for the commitment the then President of CIFAR made to the AI researchers.

More daunting throughout these years were the continual financial challenges CIFAR faced. As Brown's (2007) historical account has richly detailed, at times it brought the Institute to the brink of bankruptcy. Thus faced with an across-the-board cut of 50 per cent or shedding a program that had been extraordinarily successful, a difficult decision was taken in 1995 to cut the AIR¹³ Program. Nonetheless, after a hiatus at least on the science side, Professor Hinton approached CIFAR about establishing another AI endeavour, Neural Computation and Adaptive Perception (NCAP) (*Economist* 4 Nov. 2017). By 2004 (<https://www.cifar.ca/ai/pan-canadian-artificial-intelligence-strategy>), the new initiative was set up and the program, and its scholars, continued to make breakthroughs, not the least of which was stunning computer scientists in 2012 with the capacity for image recognition that "halv[ed] the next-best error rate" (<https://www.utoronto.ca/news/am-turing-award-nobel-prize-computing-given-hinton-and-two-other-ai-pioneers>; also <http://www.cs.toronto.edu/~hinton/absps/imagenet.pdf>).¹⁴ Continuing over the years, the program has now gained international recognition and indeed is presently tasked with leading the federal AI Strategy. Currently called Learning in Machines and Brains, it also has remained centred around the research communities in McGill and U of T (Professors Bengio and Hinton respectively), although now also houses a new hub, the Alberta Machine Intelligence Institute (AMII) at the University of Alberta (CIFAR 2018, 2017; <https://www.cifar.ca/ai/pan-canadian-artificial-intelligence-strategy>). Interestingly, the latter had been a crucial part of the 2004 NCAP endeavour.

Running somewhat parallel to the AI program at CIFAR was also a pre-commercialization effort to ensure that the knowledge and technology transfer needed for industry applications would occur. Propelled by the increasing challenges in squaring the needs

¹³ The Society component was dropped early on – in fact by 1984 (Brown 2007, 50-51).

¹⁴ The latter is penned by Professor Hinton and his two students in the competition.

around innovative product development and the basic science of the AIR research program, by 1987 a decision had been taken to spin out PRECARN – a Pre-Competitive Applied Research Network. The whole issue (together with an interest in joining the American space station venture) had been the subject of a substantial report by CIFAR (penned by James Ham) to the Minister of State for Science and Technology in 1985, as well testimony before the House Standing Committee on External Affairs and Defence (Parliament, Standing Committee on External Affairs and Defence, 12 December 1995). The message was unvarnished. Canada lacked “an applied research base in its industry of any significance” and it sorely needed a type of “halfway house” or “bridge” (Brown 2007, 59-61; also Bury 1999) that could span science and commercialization. PRECARN was intended to fill that gap.

Initially struck as a consortium in March of 1987, the Network was formally established with a federal charter in 1988. Tasked with establishing “collaborative” industry and academic efforts that could function across various industry sectors, PRECARN was designed to specifically target the precompetitive phase of what was then called “intelligent systems solutions” (IC DRR 1999-2000, 49).¹⁵ And it grew relatively quickly: from 22 companies initially joining the Network (Rimkus 1987) to 300 companies within the decade (Kennedy 2006). Primarily dedicated to small and medium-sized businesses, it was specifically designed to assist companies in making the transition over the “valley of death” – i.e., the leap from basic research to innovation and commercialization. If the AIR was to focus on fundamental science, this entity was to seed the applied research that pull basic invention through to commercialization. Moreover, in the intervening years when AIR was cut, this program was a

¹⁵ The history of PRECARN has been informed by the following: Bury (1999); *Citizen* (1989); *G&M* (1987, 1994, 2003a; 2004, 2006a, 2006b); Hyman (1989); Kennedy (2006).

critical component of ongoing efforts in the AI domain helping to support projects that ranged from vision systems to intricate robotics used in natural resource industries.

All said, there is widespread consensus that CIFAR functioned through these years as an important component of Canadian success in AI. Even Budget 2017 credits the advances in AI with the Institute (Finance Canada 2017, 90: also CIFAR 2018; *Economist* 4 Nov. 2017; IC 2013). Most critically, Hinton himself has indicated “... the CIFAR program was key to advancing the group’s research.”¹⁶ As such then federal policy and engagement with CIFAR – and funding – are an important historical piece of the puzzle around the Canadian study of innovation and AI.

The Federal Government and AI: An Historical Perspective

As earlier noted, an historical perspective on the federal role with respect to AI turns on three key dimensions (which indeed follow the lines of the Developmental Network State framework): priority-setting, targeted resourcing, not only of CIFAR but of other agencies and initiatives operating within the AI domain, and the degree to which a focus was placed on thickening of innovation networks. This discussion necessarily stands apart from the more detailed breakdown of funding by federal authorities over the years from 1986-1987 onwards – one that enables a direct comparison with Québec funding to date.

Targeted Resourcing

What is rather striking in a review of federal endeavours in this field is the early engagement on the issue – as articulated in its initial forms of Artificial Intelligence and Robotics – and an engagement that focused not just on CIFAR as a major hub of activity but ancillary

¹⁶ This is not a direct quote but rather is based on a U of Toronto interview with Professor Hinton (<https://www.utoronto.ca/news/am-turing-award-nobel-prize-computing-given-hinton-and-two-other-ai-pioneers>).

initiatives. With respect to CIFAR, to be sure, federal dealings with the Institute were not without its complications, and tensions. Certainly, this is not always a story of a straight progression of determined policy efforts. But what traverses these earlier years is a continuing presence in federal sponsorship of fundamental science, eventually spreading out to applied, pre-commercialization activities as well.

To be sure, initial sponsors of CIFAR were not the federal government but rather were centred around a small hub of patrons -- primarily driven by the Government of Ontario with a contribution of \$120,000, a small bevy of corporations, the latter including Lumonics, MacDonald Dettwiler and Dofasco and later Spar and the critical engagement of the University of Toronto. The J.P. Bickwell Foundation also provided early funds (Brown 2007, 56-57). By 1987-1988, however, and the result of much CIFAR lobbying, the federal government had come on board with an initial funding tranche of \$1.5 million (Figure 1).

Even with the funding established, however, the relationship between Ottawa and CIFAR was not without tensions. The story of these early years¹⁷ is one of ongoing efforts to solicit federal funding – and expanded largesse on the part of corporate sponsors – together with recurring accounts of substantial deficits. By 1994, Treasury Board was casting a very skeptical eye on CIFAR's bottom line, bathed as it was in red, and actually holding back the contribution for that year. Interventions with the Industry Minister at the time (Minister Manley) swayed the day and, in the end, there was no interruption in the annual contribution (although the actually money flowed after the close of the government's fiscal year). However, new conditions were set. CIFAR would now have the Herculean task of matching the federal contribution by leveraging two times the federal amount. By 2002,¹⁸ under the new leadership of Chaviva Hošek

¹⁷ The account here is drawn from Brown (2007, 192-207 and especially 197-198).

¹⁸ Chaviva Hošek actually became President of CIFAR in January of 2001.

at the Institute (and a former policy advisor to Prime Minister Chrétien), President Hošek was able to set new terms in the relationship with Ottawa. The federal matching formula returned to 50/50 and, more importantly, there was an unequivocal commitment made by Ottawa for a \$25 million grant to be spread over five years. As Brown indicates in writing of the critical agreement reached in April of 2002, “The implications of the new agreement were enormous: the grant signalled strong recognition of the federal government of the importance of CIAR’s [sic] research programs to Canada” (Brown 2007, 26). Indeed, from thereon, the annual contributions continued to flow.

Thickening the Innovation Ecosystem

In addition to targeting the basic science in which CIFAR was engaged, an engrained part of this story is also the federal government’s engagement on PRECARN and thickening the networks and ecosystem of innovation more generally. Significant funding was provided to the Pre-Competitive Applied Research Network over a series of years starting around the late eighties and stretching to 2010-11.¹⁹ Certainly the federal government viewed it as a critical piece in the triadic (business-academic-government) linkages necessary to sustain a robust national innovation system. The Minister of State for Science and Technology at the time, Dr. John Gerrard, in somewhat effusive terms viewed its projects as “translating into increased competitiveness for business of all sizes in a wide range of industry sectors” (Bury 1999). Ongoing Industry Canada Departmental Performance Reports also highlighted the leverage these projects were having and the large consortia involved, as well as the “high” (IC DPR 2005, 22) rate of success for the projects involved (IC DPR 2000, 48-49; 2001 37, 62, 64; 2002 57; 2003, 55; 2004, 20; 2005, 92). As John Manley, the Minister of Industry, succinctly reflected in an

¹⁹ See the discussion on what start date for this in “Funding AI” below.

interview in 1999, Canada had “historically underperformed” in “industrial R&D” and “making Canada the most connected nation” was critical to addressing this challenge (Cyr 1999). In that context, he went on to specifically highlight the work of PRECARN (among others) in forging the partnerships that could “facilitate innovation” (*Ibid.*, 5).

So too was there support for another spinoff from CIFAR – the Institute for Robotics and Intelligent Systems (IRIS). Designed as one of the government’s first Networks of Centres of Excellence, IRIS was charged with further enriching the linkages and connectivity necessary for applied research. Its niche was, however, particularly unique. As the Research Directors of PRECARN (who formally managed the IRIS at the time) explained:

IRIS projects are still applied research projects, but they’re more theoretical, farther from the development of a sellable product. IRIS projects start to build the links between the research, the theory and the industry. (Bury 1999, 3).

If CIFAR was the more research-oriented thrust of AI in these years and PRECARN the agency focused on getting products to market, IRIS was the warp that held these elements together. For its part, federal funding over the period from 1989 to 2006 (https://www.nce-rce.gc.ca/NetworksCentres-CentresReseaux/PreviouslyFunded-FinancesAnterieurement/NCE-RCE_eng.asp) flowed out in several tranches, initially oriented to building capacity and then moving more directly into the applied research functions.

To be sure, there were other elements of federal engagement on the AI front, particularly in the context of establishing the Canadian Space Agency (CSA), seizing an opportunity to work the Americans on the international space station, and specifically the intelligent systems and robotics intended for the first Canadarm (see Brown 2007, 57-61; Ham 1985). Moreover, CIFAR together with SPAR Aerospace were at the forefront of propelling the decision to set up

the CSA and making the arguments to the Minister of State for Science and Technology at the time.

Not to be excluded as well in this picture was the funding that went towards research in quantum computing. Certainly, machine learning and the quantum field have a deep synergistic relationship. The processing of extremely large amounts of “raw” data and associated computational infrastructure are required for the machine learning, learning reinforcement and cognition so essential to Artificial Intelligence and its sophisticated algorithms.²⁰ Succinctly explained in the words of Québec’s Comité d’orientation de la grappe en intelligence artificielle (and further referencing the relation between data science and IVADO), the relationship between quantum and AI is made clear:

Le développement de solutions en IA requiert des quantités massives de données pour entraîner et actualiser les algorithmes. Ces données doivent être préparées, structurées, transformées, analysées et interprétées (Comité 2018, 19, 71-73; also CIFAR 2019a, 1).

In this context, then, albeit starting later than with CIFAR, federal Public Accounts do register significantly large federal expenditures for the Institute of Quantum Computing at the University of Waterloo from 2009-2010 onwards (Figure 1). The later date is not particularly surprising, however, given that the Institute itself was only formed (under the leadership of Blackberry’s Mike Lazaridis and then University of Waterloo president, David Johnston) in 2002.

Moreover, it is worth noting that although CIFAR funding has been maintained to current days and their presence (as discussed below) on the federal AI strategy is even more critical, by 2010-11 federal funding support for PRECARN per se had essentially run its course. Although

²⁰ See in particular Gupta et al. (2017) from the Institute of Electrical and Electronics Engineers (IEEE).

PRECARN was lobbying for another tranche of \$150 million both under with the Martin and Harper administrations (Kennedy 2006, ReSearch Money 2007), that in itself did not pan out.

Policy Durability and Federal Priority-setting

Equally interesting in this account of the federal role with respect to AI was the degree to which this can be seen as an example of focused priority-setting and the policy durability that is essential to an understanding of Developmental Network States. In this regard, an in-depth evaluation of CIFAR by Industry Canada published in 2013 is particularly telling regarding the federal perspective on the program. As the report concluded, CIFAR clearly met the government's objectives around "relevance," priorities and cost effectiveness. It fostered new knowledge that impacted the large social, economic and health questions of societal and policy concern and it occupied a particular role that turned on critical "fundamental research." As the *Evaluation* put it:

There is a continued need for publicly-funded fundamental research as a means to foster innovation and provide social and economic benefits to Canadian society. CIFAR responds to this need by delivering large-scale research programs designed to achieve knowledge breakthrough (IC 2013, 30).

Further it was directly aligned with the priorities of the Conservative administration at the time, as set out in *Mobilizing Science and Technology to Canada's Advantage* (IC 2007), as well as the specific objectives of the department responsible for supporting the program – Industry Canada (IC 2013, 16). CIFAR's "vision, mission and expected results" were deemed to be in line with the Department's priorities around advancing science and technology and, more to the point, "consistent with" this particular "strategic outcome" (*Ibid.*, 16). So too was the "virtual" model that CIFAR heralded "cost-efficient," operationally functioning well below the administrative overhead usually associated with such types of non-profit organizations. To be sure, there was a call for more enhanced performance measures (*Ibid.*, 20 -23) to probe impacts

more deeply, but on balance – particularly for an evaluation of this type – it spoke to the strengths of the program and the need for government to keep focused on this “niche” in the innovation ecosystem. Nor was this a one-off so to speak. The earlier Progress Report by the government on the success of the *Mobilizing* venture also highlighted the worth and international status of the program (IC 2009, 28).

Yet, what is uniquely interesting about the AI case is the significant continuity in the federal government’s engagement on this file and indeed the prescience involved in supporting CIFAR and PRECARN – even several years before the government’s S&T Strategy of 1996 (IC 1996).²¹ To be sure, it was in part a direct response to the Ham report to the Minister of State for S&T outlining the critical need for linkages between fundamental research and that of applied. Further a decade later, it did align closely with the *Achieving Excellence* (2001a, 2001b) vision of the Liberal administration and of course, as clearly stated, that of the Conservative government’s efforts around S&T working to Canadian “advantage.” But what is intriguing – and speaks more directly to the import of policy continuity in priority-setting – is that AI in this country has not been any “overnight” success. It has been the outgrowth of many years of brilliant academic scholarship, tenacious focus by a relatively small number of companies and universities and federal support that continued to seed and foster these efforts *over decades*—albeit at times with the inevitable tensions around fiscal need. It is in fact testament to the *longue durée*.

²¹ Federal S&T and Innovation Strategies from the late nineties onwards are examined in Chapter Four: “Government Priority-Setting: Policy Coherence, Continuity and Challenges.”

Superclusters and Supply Chains: Recent Federal Policy

By 2017, the federal government had moved well beyond specific, targeted initiatives that were instrumental in seeding AI and had embarked on a much grander venture. Rolled out over the period between 2017 to present day, federal policy has pivoted on three fronts: business-led innovation, a “Pan-Canadian AI strategy” and the tasking of an advisory committee to proffer counsel on “responsible” use of AI. Firstly, as announced in Budget 2017, there was to be substantial funding²² for Superclusters – designated as “dense” “clusters” (Finance Canada 2017, 79-80) or hubs of economic activity pulling together all the key actors in the innovation ecosystem community. From business incubators and start-ups to large “anchor” corporations, to universities and research institutes, to the technologists, venture capitalists and consultants that provided managerial expertise and capital, these superclusters were to form a critical platform for driving and sustaining innovation (<https://www.ic.gc.ca/eic/site/093.nsf/eng/00017.html>; <https://www.ic.gc.ca/eic/site/093.nsf/eng/00009.html>). Much in the image of the recommendations of the Advisory Council on Economic Growth (2017), these were to function as “engines of growth,” being a “magnet” for talent, attracting international investment and propelling business-led development that could spur commercialization on home ground.

To be sure, initially, in the Budget announcement, these clusters were still only broadly defined, focussing on agri-food, advanced manufacturing, clean technology, clean resources, digital technology and health/bio-sciences and were to be established through competitive processes run by ISED. As for digital technology, it was left open-ended at this point. It was only through the government’s announcement of 15 February 2018 (ISED NR 2018 15 Feb.) that Artificial Intelligence and the SCALE.AI was named as one of the Superclusters – to be

²² The specifics of the Supercluster initiative – its various component and total funding – are discussed in Chapter Six: “Collaborative Research Networks: Thickening the ‘Triple Helix’ of Innovation.”

specifically located in Québec and spanning the Montreal – Waterloo “corridor.” Focused on deep learning and algorithms to optimize supply chains, the cluster was intended to cut across all key sectors of economic activity – retail, transportation, shipping, aeronautics, financial services, oil and gas, health and infrastructure. And its purpose was clear. Designed to enhance productivity, find supply chain efficiencies and diffuse AI methods and technology into the economy writ large, the cluster was to provide the “match-making” and collaboration that could traverse firms both large and small, foster academic-industry partnerships and pull in the capital critical to growth.²³ Furthermore it was to demonstrate technology “leadership,” function as an agent for expanding digital capacity and literacy within the supply chain and ensure “cross-compatibility” of technologies and innovation platforms. It was even charged with embedding Canadian IP and AI approaches into international standards – a requisite element in ensuring export growth -- to further solidify Canadian leadership in the global innovation “race.” Indeed government statements at the time forecast that the Supercluster could engender \$16.5 billion of economic activity and 16,000 jobs over the next ten years (ISED NR 2019 27Jn.) and provide Canada with the “momentum” to become a world leader in this field, not only in research but in commercialization as well. In a word, the Supercluster was designed for AI to “scale.”

Targeted mechanisms and funding have accompanied these statements with SCALE.AI having an acceleration program (<https://scale.ai.ca/acceleration/>) that supports promising startup businesses and technology incubators (to total 100 in all). And after due evaluation, companies may access up to \$50,000 for AI activity. Certified training programs further supplement these packages (<https://scale.ai.ca/trainings/>). As for the initial number of projects which have rolled

²³ On the AI Supercluster see ISED (NR 2018 15 Feb.; 2019 27 Jn.; 2020 Jan. 14); and in particular, for quotations, <https://www.ic.gc.ca/eic/site/093.nsf/eng/00017.html>.

out under the AI Supercluster, they have amply illustrated these dimensions. Engaging several key “anchor” firms (Thales, Element AI, CAE) they have ranged from leveraging AI for forensic accounting of fraudulent activity to detecting faults in aeronautical equipment, managing agricultural supply chains, forecasting inventory, to handling shipping and ice forecasting (CEDQ NR 2018 5 Dec; ISED NR 2018 9 Oct.; 2019 27 Jn; 2020 14 Jan; Scale.AI NR 2019 27 Jn., 2020 14 Jan.; <https://www.globenewswire.com/news-release/2020/01/14/1970313/0/en/Scale-AI-awards-1-7M-to-Plotly>; <https://nrc.canada.ca/en/research-development/research-collaboration/programs/artificial-intelligence-logistics>). Additionally, they have focused on the health field – from medical imaging and diagnosis to patient care – and AI for management of utility grids (ISED NR 2020 14 Jan.). Nor has federal policy limited projects to those just associated with the Supercluster – with funds flowing from the Strategic Innovation Fund to support promising AI initiatives such as that with MindBridge (ISED NR 2019 12 Jn.) and the Creative Destruction Lab, in the latter case with sites spread across the country (ISED NR, 2018 9 Oct.). So too has the policy had an international dimension with negotiations ensuring that the Canada-EU Comprehensive Economic and Trade Agreement (CETA) had a component ensuring Canadian access by the Superclusters to EU collaborations and partnerships (ISED NR 2019 12 Jn.).

In all, federal policy on this front has been quite distinct and quite expansive – and it is worth noting (as the following section will illustrate) that Québec’s efforts have been directly aligned with the Supercluster initiative. As Pierre Fitzgibbon, Minister of Economy and Innovation of Québec commented at the time:

Thanks to the mobilization of an unprecedented network of researchers and partners, and the government support announced today, supply chains will be transformed, and we may also potentially usher in a new chapter in Quebec’s economic history. *We are proud to*

contribute to the activities of Canada's artificial intelligence supply chain supercluster, SCALE .AI. (PMO NR 2018; emphasis added).

If SCALE.AI has been business-led, the second major aspect of federal initiatives has focused more on the research dimension of AI. Specifically, Ottawa embarked in 2017 on a pan-Canadian Artificial Intelligence Strategy. To be delivered by CIFAR, the Strategy has as its overriding objectives “deep investment” in the country’s “machine learning research and training” and continuing global leadership on the part of Canada in the AI domain (CIFAR 2019a, 3). Essentially resting on four pillars, the Strategy has focused on enhanced AI research; ensuring the “interconnectedness” of Canada’s three major centres of scientific excellence; “thought leadership” around the responsible use of AI, particularly in a democratic context and generally advancing a Canada-wide “research community” (<https://www.cifar.ca/ai/pan-canadian-artificial-intelligence-strategy>). Towards these ends, together with the expertise in Canada’s historically-rich AI communities – the University of Alberta, Université de Montréal and the University of Toronto – CIFAR has moved forward on several fronts. Forty-six distinguished AI Research Chairs had been appointed by the spring of 2019, at a total cost of \$86.5 million (CIFAR 2019, 10-21). Three research institutes have been established – AMII, MILA and the Vector Institute – drawing on the university infrastructure and specific research domains of Richard Sutton at U of A, Yoshua Bengio at U of M and Geoffrey Hinton at U of T respectively. An AI and Society Program has been launched, putting out calls for proposals around not only the economic but ethical and legal implications of AI. Finally, while not yet as developed, efforts are going forward for establishing the training and national partnerships that can advance the AI research cause more generally.

Thirdly – and finally -- in terms of Ottawa’s AI endeavours, an Advisory Committee on AI has been struck and duly tasked with “inform[ing] the Government of Canada’s development

of AI-related policy” (www.ic.gc.ca/eic/site/132.nsf/eng/00003.html; ISED NR 2019 14 May; <https://www.cifar.ca/cifarnews/2019/05/15/members-of-cifar-community-to-advise-canada-on-ai>). To be sure, terms of reference for the Committee could benefit from a more distinct delineation between the mandates of the Pan-Canadian AI Strategy and that of the Advisory Committee. Moreover, the mandate is exceedingly broad in nature extending from enhancing Canada’s AI research position on the world stage to drawing down on the economic benefits from AI to ensuring AI reflects the country’s “values.” That said, however, two key components stand out in this initiative. It is charged with a focus on the commercialization dimension of the innovation continuum, specifically creating a working group to study this question and the economic gains which domestically-based AI and AI IP can reap. Secondly, it is to provide a focus on the societal and civil impacts of AI. In this context, it is to particularly offer guidance on implementing the objectives embedded in the *Canada-France Statement on Artificial Intelligence*.²⁴ The latter, announced on 7 June 2018, has been designed to promulgate not just the scientific and economic benefits of AI but also “human-centric” concerns that revolve around “human rights” and the use of AI for greater societal and indeed global purpose. And given the federal engagement with France on setting up an international panel (ISED BK 2019 16 May, NR 2019 6 Jn.) to reflect on these larger challenges around AI, this piece of the government’s overall approach is a critical one.

All of this evidences an exercise of policy muscle on the part of federal authorities – and specifically along the DNS lines of argument. In terms of priority-setting and the institutional mechanisms and vehicles needed for implementation, targeted resourcing and direct government

²⁴ On the *Statement* and follow-up actions see https://www.international.gc.ca/world-monde/international_relations-relations_internationales/europe/2018-06-07-france_ai-ia_france.aspx?lang=eng; ISED (NR 2019 16 May); PMO (NR 2018 6 Dec).

programming, as well efforts to densify the country's AI networks and ecosystem, what has been apparent are distinct efforts to enable the AI innovation community – research and industry alike – to grow, and to thrive. Moreover, interestingly, overarching this has been a commercialization impulse that has threaded its way through policy initiatives, from PRECARN to IRIS to SCALE.AI., showing remarkable continuity. PRECARN alone, the principal commercialization vehicle, lasted twenty years. Certainly, all of this stands in sharp contrast to the more limited and often more diffuse commercialization thrusts that have been manifested: around priority-setting or targeted resourcing or triadic networking or, as soon will become apparent, in pharmaceutical manufacturing as well. In short, what has been evidenced in the AI case is a clear and demonstrable policy push to engender not only domestic R&D but export growth and leadership positioned on an international stage.

Québec: Leveraging AI

Budget Agenda

Those aspects considered, it is valuable to assess the respective weight and influence of the province of Québec in AI. Interestingly, what clearly emerges here is in fact a fairly well integrated federal-provincial tapestry. This is certainly not a question of provincial policy being fully autonomous from, or a countervailing force, to federal initiatives. Nor is it, as we have seen, one of federal endeavours being a meagre effort only launched in Budget 2017.

In fact, in terms of funding and the initiatives around Artificial Intelligence, these formally first appear in Québec budgets in March of 2017. *Le Plan Économique du Québec* of 2017 is an important, even visionary, document particularly focused on a large “research and innovation” agenda. Spanning a broad number of sectors from life sciences to advanced manufacturing to forestry to public policy itself, this agenda was designed to build “le Québec de

demain” (GQ 2017a, B91; also B92-130). And, AI, embedded as it was within this plan, was a critical component of provincial action at the time.

That said, however, Québec’s initiative around AI was equally focused on supporting and leveraging the federal supercluster – SCALE.AI. Specifically, Québec was allotting \$100 million, to be delivered between 2016-2017 and 2021-2022 to the SCALE.AI “super-grappe en intelligence artificielle” (GQ 2017a, B93). Directly targeted at ensuring that the rich ecosystem of research, start-ups and increasingly major corporate players such as Google and Facebook that had built up around Montreal could go the distance, the initiative was targeted at making the Québec AI community a respected international “hub” (*Ibid.*, B104). As such, SCALE.AI was intended to traverse a wide breadth of sectors, including transportation, energy, business and finance, and was to integrate the “logistics” and “optimization” essential to supply chain efficiencies (*Ibid.*, B104-107).²⁵ Moreover, it was dedicated to ensuring the deeply collaborative nature of this endeavour. Sustaining a “masse critique” of talent and leading-edge researchers necessary to AI efforts; a fertile business environs that could facilitate business start-ups -- and growth; the VC lifeblood that could engender the scaling; and responsible dialogue around the “societal impacts” of this new technology (*Ibid.*, B106-107): all were an integral and interwoven part of the Québec plan.

One year later, the Québec government expanded their efforts further, allocating an addition \$60 million over the period from 2017-2018 to 2019-2020 for projects that propelled AI algorithms and technology into supply chains (GQ 2018, D46). Centred around the concept of vertically integrated industrial sectors that could take advantage of supply chain efficiencies, rigorous “logistics” that could evaluate demand and supply and “reseaux intelligent” that could

²⁵ The author has relied upon the official English version of the Budget – GQ 2017b -- for translation.

traverse the whole process, the initiative was focused on extending AI deeply into economic activity. Equally important, users would share “solution platforms” that could advance the integration of the new technology (*Ibid.*, D47-53).

Undoubtedly, by 2019, however, Quebec was articulating a grander vision that went beyond the AI Supercluster per se. Premised in part on the report of the Artificial Intelligence Steering Committee that by then had been tabled, Budget 2019-2020 put forward a five-year plan of \$329.3 million centred around intensifying the pace and adoption of AI (GQ 2019, D37-41). Ranging from extensive training, to recruiting top-grade AI research talent, to integrating AI potentially across all viable Quebec sectors, the plan was focused on breaking down barriers that impeded progress. As such increasing access to vast amounts of “raw” data and enhanced “computation power” (“la puissance de calcul”) and supporting businesses interested in AI were also key components of the initiative. Most critical, \$100 million was to be dedicated to the research institutes that remained the founding pillars for success, namely MILA (now having been established), IVADO the Canada First Research Excellence Network, SCALE.AI itself and Prompt-Quebec an agency dedicated to “front line” industry-academic collaboration (*Ibid.*, D40-41).

Accelerating Diffusion

By May of 2018, the AI Steering Committee had also proffered its advice, setting out a very activist ten-year plan that called for a funding investment of \$500 million in order to accelerate the adoption of AI and ensure continuing research and technology advances. Taking issue with the still “fragile” nature of talent recruitment to the AI community in Québec, the underdeveloped state of industry-academic networking and the lack of sufficient IT infrastructure, the report set its sights on “les efforts stratégiques pour créer au Québec le plus

important écosystème d'intelligence artificielle en Amérique du Nord" (IA Comité 2018a, 74). And towards this end, the report moved out on essentially five fronts. Firstly, there was to be concerted action around Québec's AI research capacity including a "substantial" (AI SC 2018b, 24; IA Comité 2018a, 26)²⁶ allocation of funding to MILA (originally the Montreal Institute for Learning Algorithms). So too was this to be twinned with 20 to 30 new provincial AI research chairs – separate from the federal Research Excellence chairs – but to be "complementary" (AI SC 2018b, 26-28; IA Comité 2018a 27-29) and which would seek federal participation as well. Secondly, digital literacy needed to be advanced throughout the province's educational system. An ongoing "talent watch" ("une veille talent") would be created to ensure the retention of the scientific and applied expertise so necessary to AI progress (AI SC 2018b 30-40; IA Comité 2018a,35-42). STEM skills were also to be broadly "democratized"²⁷ including leveraging the STEM programs that had been introduced by Ottawa in Budget 2017.

Of third import, there was the need to simply "accelerate" the adoption of AI via a number of mechanisms (see AI SC 2018b; 41-56; IA Comité 2018a, 44-63). The existing network of technology transfer and liaison agencies were to act as interlocutors in assisting industries to use AI, with ten in particular to be chosen as "champions" (AI SC 2018b, 51; IA Comité 2018a, 56) in that regard. There was to be an ask for enhanced resources of the NRC's Industrial Research Assistance Program (IRAP). "Data trusts" (AI SC 2018b, 41-46; IA Comité 2018a, 44-50) -- anonymized data and the essential lubricant for efficient AI learning and functioning – would need to be established. As for the initial markets required to catalyze design and AI diffusion, public procurement – both federal and provincial – would be leveraged (AI SC

²⁶ The author has relied upon the English translation of the Steering Committee Report – 2018b. However the references in the French version of the Report are also listed.

²⁷ The exact quote is "promouvoir « ... la démocratisation des sciences » IA Comité 2018a, 41.

2018a, 55-56; IA Comité 2018a, 60-62). Fourthly, an international “observatory” needed to be created, tasked with looking at the ethical and societal issues associated with “responsible” AI (AI SC 2018a, 57-61; AI Comité 2018a, 66-68). Finally, support structures needed to be put in place to “advance” this whole project, including a significant expansion in IT infrastructure and computing power and a governance body tasked with ensuring the requisite coordination within the ecosystem was taking place (AI SC 2018b, 63-69; IA Comité 2018a, 70-76).

In all, then the report’s strategy was an ambitious agenda – one that sought to not only maintain Québec’s AI research success but also provide impetus to the technology transfer and commercialization needed within industrial and retail supply chains. So too was it an agenda that used leading nations in the AI domain – China, Finland, even Britain – as international benchmarks for the type of agenda Québec needed to pursue.

Yet what stands out in these recommendations of the Steering Committee is not only the grandeur of the vision, and the detailed articulation of the steps needed for implementation, but the leverage that is to be gained from federal initiatives as well. Be it the recommendations for federal participation in the provincial research chairs, the efforts to expand digital literacy, the proposed injection of federal funds into IRAP to support tech transfer or access to the Innovation Solution Canada’s procurement program, the Committee’s report does not dismiss federal efforts. Rather these are an integral part of the tapestry that makes the AI ecosystem whole – and complete. And that MILA stands as a central pillar on which a lot of this rests equally speaks to the synergies between Ottawa’s federal strategy and provincial efforts to build on the pioneering work that thrust Montreal – and Canada -- into the international AI community.

Federal and Provincial Roles: An Assessment

In sum, then, as ambitious and extensive as Québec policy and funding have been around AI, these have definitively not been severed from federal initiatives. Rather they have been directly aligned with the fundamentals articulated in Budget 2017 and with the SCALE.AI Supercluster formally announced 15 February 2018 (ISED NR 2018 15 Feb.) Undoubtedly, a deeper probe into the history of Québec's efforts (beyond the capacity of this inquiry) would reveal funding and policy building blocks that supported the development of the central players that came to be in IVADO – namely, l'Université de Montréal, HEC Montréal et Polytechnique Montréal. Undoubtedly there would also be an important line of inquiry around policy directed at maintaining a commitment to research and innovation. Equally, an argument could be levelled that it might be worthwhile to evaluate the province's efforts in terms of the DNS model as well.

However, future research prospects aside, what stands out in this review is the extent to which in federal and provincial policy efforts were synergistic and dedicated to a collaborative venture, if not regime. And, in this respect, it directly poses the central question of whether such efforts have paid off in the innovation indicators for the AI domain. It is to this question –and a central test of the thesis for the DNS model – to which the last part of this chapter will shortly turn.

Funding AI

As for the central question of federal funding of Artificial Intelligence, what clearly stands out in reviewing Public Accounts from 1985-1986²⁸ onwards is the historical breadth of the investments being made, not only for CIFAR but for other complementary initiatives such as

²⁸ Earlier Public Accounts were reviewed prior to 1987-1988 to ensure the “start” date for funding was accurate; also IC (2013a, i) with respect to CIFAR.

PRECARN and Quantum. As Figure 1 indicates, initial investments in CIFAR started to flow in 1987-1988, continuing to the present day. To be sure, in the case of CIFAR it is a somewhat challenging exercise tracking the investments – and particularly the respective funding shares by Ottawa, provinces and “other” contributors – i.e., corporations, foundations, individuals, research institutes and universities. However, there is sufficient information to piece together stretches of time and what is evidenced, except for 2007-2008, are federal contributions which run at about one-third of total CIFAR funding between 2008-2009 and 2019-2020, with exceptional peaks of 42 per cent in 2013-14 and 2019-2020 (Figure 2). Even the 2007-2008 federal share of just over one-quarter (26 per cent) can be attributed to a “one-time” special allocation by the province of Ontario (the specifics of which are not accessible) which boosted total provincial investments to \$11.3 million in that year (IC 2013, 26.) Indeed, for the overall period for which contribution data is available, the federal proportion rings in at exactly 33 per cent. It should be highlighted as well that the federal contributions for 2017-2018, 2018-2019 and 2019-2020 specifically exclude designated funds from the \$125 million provided to CIFAR for a Pan-Canadian AI Strategy – and deal with operational funding only.

As for earlier periods of funding, while there is generally not access to the specifics of the federal share between 1987-1988 and 2007-2008, a review of Brown’s (2007) historical work does provide a somewhat limited window on contributions at that time. Specifically, in 1995-1996 for which data is available, a federal grant of \$3.5 million²⁹ accounted for over just one-third of the total amount of CIFAR revenues in that year, with provincial allotments totalling \$1.8 million and the private sector contributing to \$1.5 million (*Ibid.*, 199-202). As such the federal grant provided a “stable financial base” (*Ibid.*, 201) for CIFAR’s activities at the time.

²⁹ The actual amount expended in 1995-1996 was somewhat less; see Figure 1.

Moreover, as for PRECARN -- the Pre-competitive Applied Research Network -- at least \$55.5 million was provided between 1989-1990 and 2010-2011 (Figure 1). And while the specifics of funding over the decade of the nineties cannot be fully verified, this is in itself still a substantial underestimation. Industry Canada reports that by 31 March 2003, \$65 million had been “provided to PRECARN” (IC, DRR 2003, 55). As well, the Department’s Performance Report for 1999-2000 specifically highlights that funding had been rolling out in different tranches or “phases,” going on to note successes of the Network, including number of projects, “unprecedented” dollars leveraged and the sectoral approach which had been created to diffuse “intelligent systems” more broadly (IC DRR 1999-2000, 48-49). With respect to Quantum Computing (also illustrated in Figure 1) here too Ottawa has been allocating funds over a significant period of time, initial investments starting in 2009-2010 and totalling \$80.0 million by 2019-2020 (RGC 1986-1987 – 2019-2020).

As for more recent actions, clearly funding has focused around the Supercluster initiative, with \$230 million to be allocated over five years starting in 2019-2020 and running until 2023-2024 (ISED DP 2019, 15),³⁰ \$125 million provided for in Budget 2017 for the Pan-Canadian AI Strategy (Finance 2017), as well as additional stand-alone investments. With respect to the latter, this has included the important \$93.6 million for the Institute for Data Valorization (IVADO) – the consortium of l’Université de Montréal, HEC Montréal et Polytechnique Montréal. Provided through the Canada First Research Excellence Fund, the project, “Deep Learning and Optimization for the Knowledge Revolution” is focused on AI and “big data mining” (<https://www.hec.ca/en/news/2016>; also <https://www.cfref-apogee.gc.ca/results->

³⁰ Public Accounts for 2017-2018, 2018-2019, 2019-2020 and 2020-2021 do not provide breakdowns for expenditures specifically for SCALE.AI (Receiver General for Canada 2018, 2019, 2020, 2021).

resultats).³¹ Additionally, \$25 million which has been dedicated to the Creative Destruction Lab (ISED NR 2018 9 Oct.), an entity based out of the University of Toronto focused on supporting start-ups and ensuring their “scale-up” and growth.

In sum, then, the federal government has invested almost three-quarters of a billion dollars -- \$739.4 million -- in AI since 1987-1988 (Figure 1). As noted, this underestimates the PRECARN contribution – possibly by about \$40 million based on the data available. Similarly, it does not take account of the funding of the IRIS network for although the time span for funding of the network is reported (from 1989 to 2006) actual dollars invested are not ([https://www.nce-rce.gc.ca/NetworksCentres-CentresReseaux/ PreviouslyFunded-FinancesAnterieurement/NCE-RCE_eng.asp](https://www.nce-rce.gc.ca/NetworksCentres-CentresReseaux/PreviouslyFunded-FinancesAnterieurement/NCE-RCE_eng.asp)). Indeed, all of this stands as testament to the long-term interest and investment by federal authorities in this field.

As for Québec funding, and as indicated in Figure 3, it has taken a particularly activist role of late, expending or committing to expend \$504.7 million dollars by 2023-2024. Broken down, investments have included \$160 million leveraged to the SCALE.AI Supercluster (GQ 2017, GQ2018), including optimization of supply chains. As well, the Québec government – or at least the Ministère d’Économie et Innovation – contributed to CIFAR with a \$5.35 million grant (<https://www.cifar.ca/cifarnews/2019/03/13>). Further there was \$10 million of support for the Montréal arm of the Creative Destruction Lab which Ottawa was funding as well (QC 2018, D23).

As for AI adoption more broadly, fully \$329.3 million was to be expended or committed for the period starting in 2018-2019 and running out to 2023-2024 (Figure 3).³² Certainly some

³¹ The actual project is “Data Serving Canadians: Deep Learning and the Optimization for the Knowledge Revolution.”

³² It should be noted that, in Québec’s *Budget 2019-2020* (GQ 2019, 37), there is reference to an additional allocation of \$20 million for “computational power” in the Quebec Infrastructure Plan and \$48.5 million for

of these sums were dedicated to Scale AI and IVADO -- \$15 million and \$35 million respectively (GQ 2019, D 40) but the remainder as earlier noted cut a wide berth from “talent” monitoring to the mechanisms for wide-spread AI diffusion to appropriate governance.

Clearly a more in-depth and forensic-type of investigation would be needed to get a full appreciation of Quebec investments. It is very likely that support for the three founding institutions of IVADO -- l’Université de Montréal, HEC Montréal et Polytechnique Montréal -- received provincial funding over the years and it would be valuable to do a deeper dive on support Quebec may have given in the past to “computational” infrastructure, although here again the term seems to first appear in 2019-2020 (and of course is noted in the report of Québec’s AI Steering Committee). However, based on a twenty-year review of all Québec budgets, what is apparent is that formal commitments around Artificial Intelligence first appear in 2016-2017. More broadly, however, particularly given the Government of Ontario’s early financial support for CIFAR, an examination of provincial activities and how they too may have leveraged R&D around AI and its “transformational” character would be an exceedingly interesting area of study. Such might be a particularly valuable line of inquiry with regard to the DNS thesis and how it might apply in federal-provincial contexts. That said, however, in terms of assessing the federal role in AI, and its precursors around intelligent systems and robotics, it is very much a topic of direct application to the DNS framework. That federal policy – and funding – constitute a distinct driving force from the late eighties onwards must be factored into AI and the DNS equation.

“technologies that support artificial intelligence” in the 2019-2029 Québec Infrastructure Plan. All to say the \$329.3 million tally is an estimate.

Innovation Indicators

Given these conditions, then, it is likely we would find further positive implications with respect to innovation indicators. To assess the impact of federal policy initiatives on AI, two key dimensions are evaluated: filings to the United States Patent and Trademarks Office (USPTO) for Artificial Intelligence (Figures 4 and 5) and venture capital investments in AI for OECD countries (Figures 6 and 7). In the latter case, the time series is more limited, spanning the period between 2012 and 2020. As for the percentage of BERD performed in AI, unfortunately OECD does not provide this data as it does with pharmaceutical manufacturing. Nor could data be found that tracks R&D investment on an annual basis which, as we shall see, is readily available in the case of pharma. Those caveats noted, however, the AI patent filings do enable comparison with the pharmaceutical case study and the venture capital is a useful valuable proxy for innovation – and where capital is flowing.

And on these two dimensions, the data is in fact quite robust. With respect to patent applications to the USPTO, by 2017 AI applications had peaked at a quite phenomenal 419 per cent over the base year, very similar to the increase by the top five nations (Figure 5). Admittedly, certain aspects did diminish the full impact of this performance. For one thing, the top five nations started from a higher numeric base in patent filing. Additionally, key comparator nations also underwent unprecedented levels of growth, with the US seeing a 603 per cent increase over 2000 and China a 12,389 per cent ascent over the same time period – an extraordinary number even by their standards. As such, Canada's relative standings have not budged much and indeed, if anything, have descended ever so slightly, with Canada standing in 2017 at 3.9 per cent of US performance, down from 5.2 per cent in 2000 (Figure 4). Similarly, with respect to the top five, Canada operated at 13.5 per cent in 2017, down from 14.2 per cent in 2000 and 13.5 per cent over the full time series. Still, despite these mitigating influences, all of

this was sufficient to garner the country a ranking of eighth (out of 45 nations) over the full time series.³³ Indeed, overall, the country's performance has been strong and is testament to the gains that have been made on the AI front. Nevertheless, akin to warnings in the Naylor report about strategic enabling technologies (2017, 40-43), Canada's position with respect to AI can not at all be taken for granted, given the global race afoot on this front.

As for the other indicator used – “estimated VC investments in AI start-ups based in OECD countries, by year” (Figures 6 and 7), this too has shown very solid performance. Canada, by OECD standards, ranked fifth among 38 nations for the period between 2012 and 2020 and in fact after a somewhat slower start achieved a 1,025 per cent increase over the base year of 2012. True, Canada's VC investments in USD millions were far superceded by the United States, but as Figure 6 shows, this holds true for all other countries as well, with the United Kingdom coming in second on the list but at only **5.5 per cent** of the US total. Interestingly, Canada's estimated VC investments in AI stand at 44.2 per cent of the UK for the whole time period – certainly a substantial difference although by 2020 the gap had narrowed somewhat to 47.6 per cent. Here too, as with patents, strong gains are evident over the time series for contender nations, with Japan increasing their investments by 18,080 per cent over the time period and Korea displaying an increase at almost twice that – at 31,300 per cent (Figure 7).

In the end, however, these innovation indicators do speak to the progress that has been made on the AI front. And while the pace of competitor countries is very strong, in terms of the argument advanced herein, it does demonstrate positive implications of federal policy which is prepared to invest and prioritize over the long term. Moreover, it does so not just through slices or snippets of time but through the relative strength of an annual data series.

³³ Based on author's calculations.

Conclusion

To conclude, then, there has been an active and engaged federal presence on the AI file, and ancillary components such as Quantum Computing, which has displayed a surprising degree of historical continuity. The successes of Artificial Intelligence in the Canadian context have not emerged suddenly or overnight but have been the constructs of sustained policy endeavours and research excellence over the course of almost four decades. It is at this intersection of the knowledge breakthroughs of esteemed scientists, early business engagement, and federal tenacity that AI has thrived and is now the focus of a pan-Canadian approach designed to sustain the country's leadership in this field.

As for alignment with the Developmental Network State model, what has been clearly evidenced is how federal levers coalesced around policy durability, targeted funding and the central cause of thickening the AI ecosystem. Moreover, all of this has been further amplified in recent years by the sustained push around Superclusters and scaling and priority-setting in a “pan-Canadian” context. And while important not to overstate this observation, the Canadian federal role has elements similar to the type of historic engagement that has distinguished the Defence Advanced Research Projects Agency's (DARPA) long-term engagement on innovation in the American context. Clearly the latter is of a scale and nature that is much more expansive—but the element of continuity is abundantly apparent in the Canadian case.

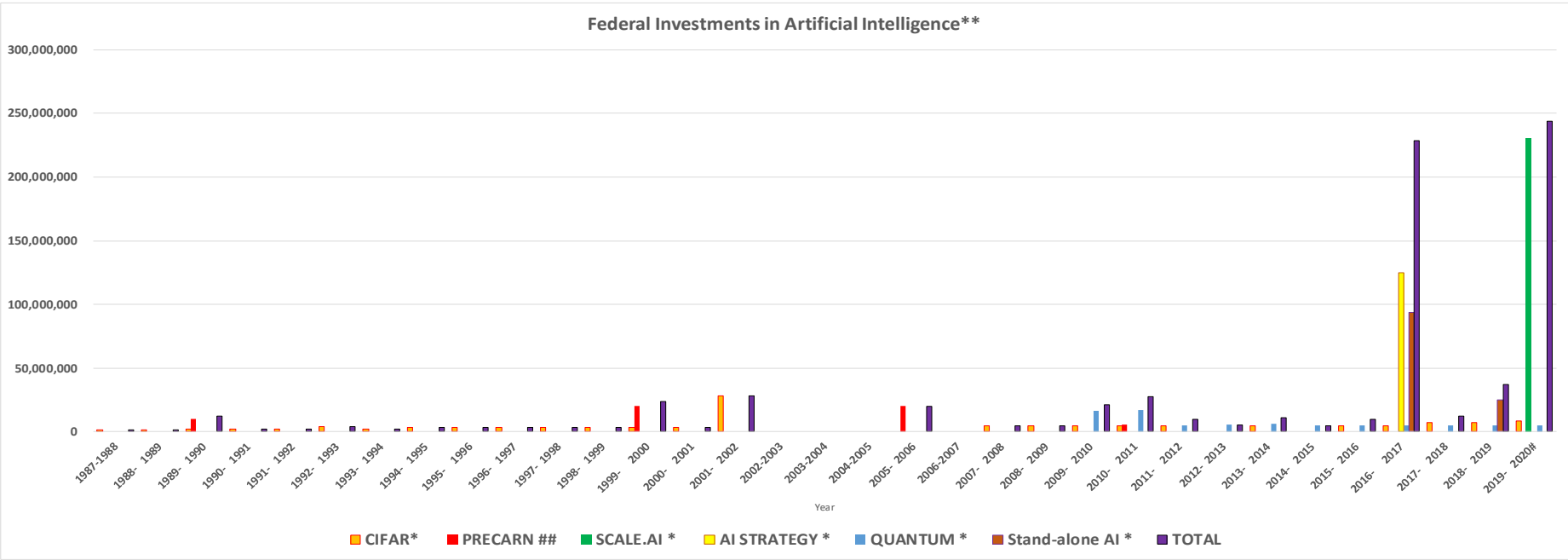
As for Québec, in the last few years, it certainly has displayed an activist presence on the AI file. And, through its AI Cluster Steering Committee, it has projected an expansive vision for the future, one around which the Quebec hub in AI can rally -- and thrive. Nonetheless, Québec engagement has been definitively aligned with federal initiatives around both AI superclusters and broad diffusion of AI into industrial sectors, as much as around the “talent watch” and research enhancement central to the AI Pan-Canadian Strategy. This has not been a narrative of

competing forces and policy authorities. Nor does this occlude the weight of federal endeavours in this field, nor the federal capacity – and administrative means – that has helped seed this area over the long term. All said, then, this journey through AI – both historical and current – offers important evidence of the DNS framework and important insights into the dynamics and factors that have allowed innovation in Artificial Intelligence to thrive.

Annex A – 8: Artificial Intelligence Indicators

Figure 1 Federal Investments in Artificial Intelligence

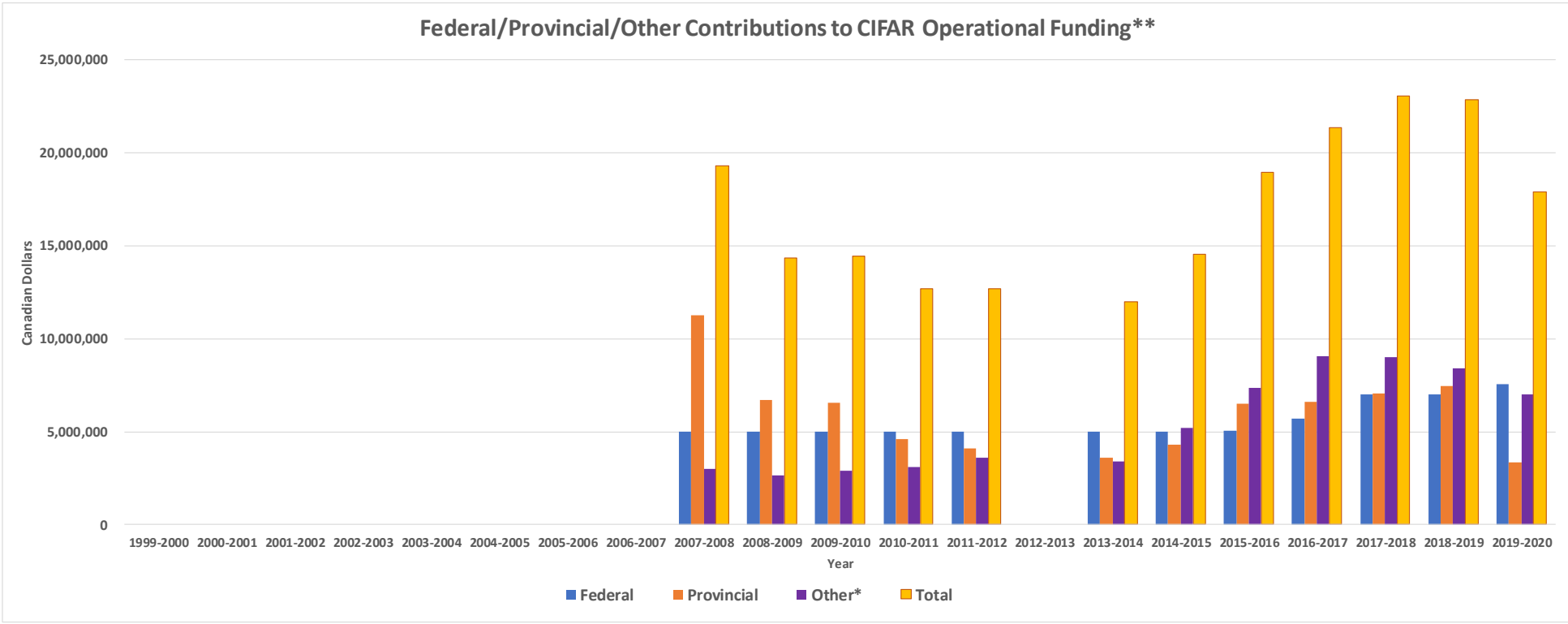
Measure Unit													Federal Investments in Artificial Intelligence**																											
Year													Canadian Dollars																											
	1987-1988	1988-1989	1989-1990	1990-1991	1991-1992	1992-1993	1993-1994	1994-1995	1995-1996	1996-1997	1997-1998	1998-1999	1999-2000	2000-2001	2001-2002	2002-2003	2003-2004	2004-2005	2005-2006	2006-2007	2007-2008	2008-2009	2009-2010	2010-2011	2011-2012	2012-2013	2013-2014	2014-2015	2015-2016	2016-2017	2017-2018	2018-2019	2019-2020#	Total						
CIFAR*	1,500,000	1,500,000	2,000,000	2,000,000	2,250,000	3,750,000	1,940,000	3,497,500	3,361,342	3,500,000	3,500,000	3,500,000	3,500,000	3,490,000	28,490,000						5,000,000	5,000,000	5,000,000	5,000,000	5,000,000		5,000,000		5,000,000	7,000,000	7,000,000	8,500,000	130,278,842							
PRECARN ##			10,000,000										20,000,000					20,000,000						5,500,000									230,000,000	230,000,000						
SCALEAI *																																								
AI STRATEGY *																														125,000,000				230,000,000						
QUANTUM *																																								
Stand-alone AI *																							16,500,000	17,000,000	5,000,000	5,500,000	6,000,000	5,000,000	4,975,000		5,000,000	5,000,000	5,000,000	79,975,000						
TOTAL	1,500,000	1,500,000	12,000,000	2,000,000	2,250,000	3,750,000	1,940,000	3,497,500	3,361,342	3,500,000	3,500,000	3,500,000	23,500,000	3,490,000	28,490,000				20,000,000		5,000,000	5,000,000	21,500,000	27,500,000	10,000,000	5,500,000	11,000,000	5,000,000	9,975,000	228,600,000	12,000,000	37,000,000	243,500,000	739,353,842						



* CIFAR - Canadian Institute for Advanced Research; PRECARN Pre-competitive Applied Research Network; AI STRATEGY- Pan-Canadian Artificial Intelligence Strategy; QUANTUM - Institute for Quantum Computing QUANTUM; Stand-alone AI: \$93.6 million to IVADO Canada First Research Excellence Fund; \$25 million to Creative Destruction Lab
Sources: CIFAR, Quantum : Public Accounts 1985-1986 - 2019-2020; ** PRECARN: Finance Canada 1994-2020; also IC DRR 2005-2006; Fin. Post 1989; Scale.AI: ISED DP 2019; ISED 2018a; AI Strategy: Finance Canada 2017; Stand-alone AI: IVADO Canada First Research Excellence: <https://www.hec.ca/en/news/2016>; also <https://www.cifref-apogee.gc.ca/results-resultats>
Creative Destruction: University Affairs 2017; ISED 2018 9 October (News Release)
**Note : For CIFAR and Quantum Public Accounts 1985-1986 - 1986-1987 indicate no entries
*** Note: Blank indicates no entry in sources – ie., Public Accounts or Budgets
Note: The \$230 million for SCALE. AI is based on the ISED Departmental Plan for 2019-2020 (ISED 2019, 15); it is based on planned allocations not final expenditures.
Note: Total investments in PRECARN are underestimated. A reference in IC DRR 2002-2003 (55) indicates that by 2002-2003 \$65million had already been invested in the agency.
As DRRs are unavailable electronically for the period prior to 1999-2000, this cannot be tracked on an annual basis. However it indicates that approximately \$50 million was invested in PRECARN prior to the Budget 2000 announcement.
Note: Stand alone investments are the following: \$93.6 million for the Canada Research Excellence Fund in September 2016 and \$25 million to the non-profit Creative Destruction Lab in 2018.

Figure 2: Federal/Provincial/Other Contributions to CIFAR

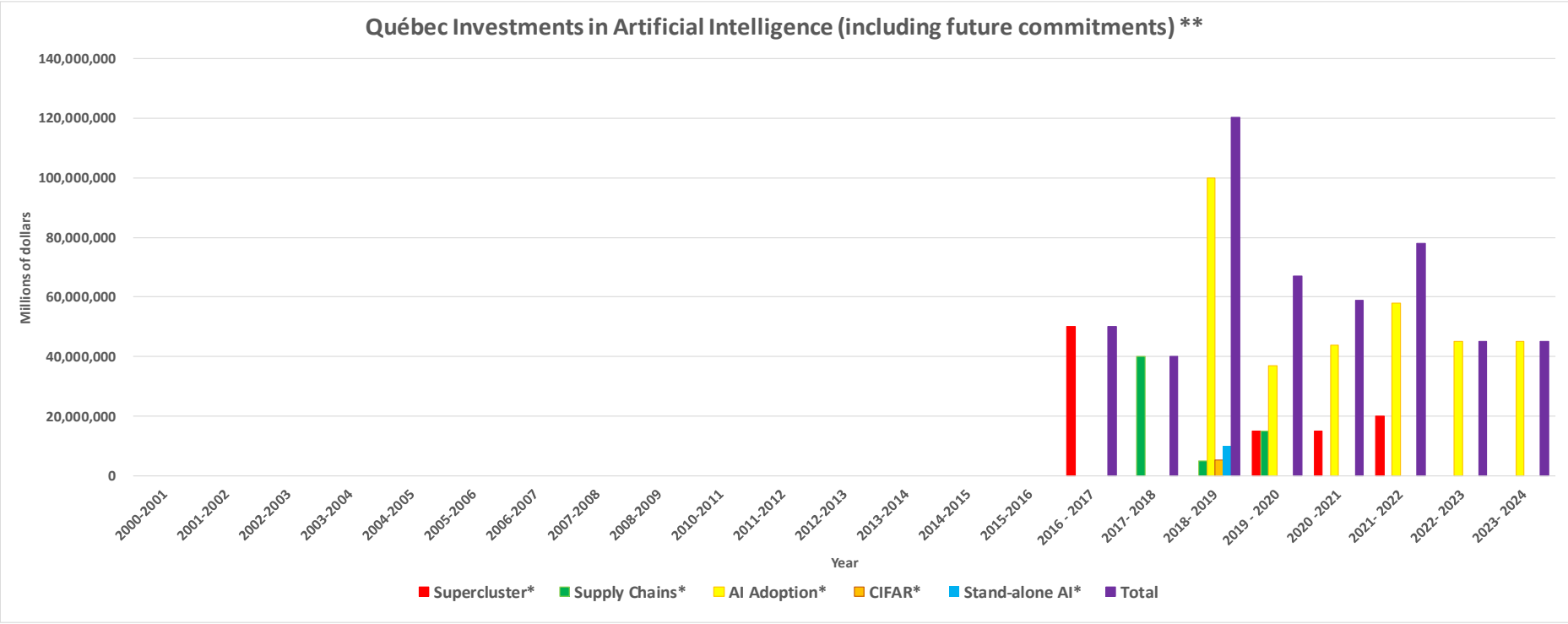
Measure								Federal/Provincial/Other Contributions to CIFAR Operational Funding**														
Unit	Canadian Dollars																					
Year	1999-2000	2000-2001	2001-2002	2002-2003	2003-2004	2004-2005	2005-2006	2006-2007	2007-2008	2008-2009	2009-2010	2010-2011	2011-2012	2012-2013	2013-2014	2014-2015	2015-2016	2016-2017	2017-2018	2018-2019	2019-2020	Total
Federal									5,000,000	5,000,000	5,000,000	5,000,000	5,000,000		5,000,000	5,000,000	5,070,000	5,680,000	7,000,000	7,000,000	7,550,000	67,300,000
Provincial									11,269,000	6,700,000	6,555,000	4,600,000	4,100,000		3,581,000	4,324,000	6,492,000	6,595,000	7,044,000	7,450,000	3,362,000	72,072,000
Other*									3,001,000	2,632,000	2,876,000	3,079,000	3,589,000		3,423,580	5,193,151	7,358,000	9,047,000	9,008,000	8,387,000	6,993,000	64,586,731
Total									19,270,000	14,332,000	14,431,000	12,679,000	12,689,000		12,004,580	14,517,151	18,920,000	21,322,000	23,052,000	22,837,000	17,905,000	203,958,731
Federal %									26%	35%	35%	39%	39%		42%	34%	27%	27%	30%	31%	42%	33%



Sources: CIFAR 2020, 2019, 2018, 2017; 2015; also IC 2013a.
*Other includes research organizations, universities and others, corporations, foundations and individuals
**Note: No entries indicate CIFAR Annual Reports not electronically available

Figure 3 Québec Investments in Artificial Intelligence

Measure							Québec Investments in Artificial Intelligence (including future commitments) **																	
Unit							Millions of dollars																	
Year	2000-2001	2001-2002	2002-2003	2003-2004	2004-2005	2005-2006	2006-2007	2007-2008	2008-2009	2010-2011	2011-2012	2012-2013	2013-2014	2014-2015	2015-2016	2016 - 2017	2017- 2018	2018- 2019	2019 - 2020	2020 -2021	2021- 2022	2022- 2023	2023- 2024	Total
Supercluster*																50,000,000			15,000,000	15,000,000	20,000,000			100,000,000
Supply Chains*																	40,000,000	5,000,000	15,000,000					60,000,000
AI Adoption*																		100,000,000	37,000,000	44,000,000	58,100,000	45,100,000	45,100,000	329,300,000
CIFAR*																		5,350,000						5,350,000
Stand-alone AI*																		10,000,000						10,000,000
Total																50,000,000	40,000,000	120,350,000	67,000,000	59,000,000	78,100,000	45,100,000	45,100,000	504,650,000

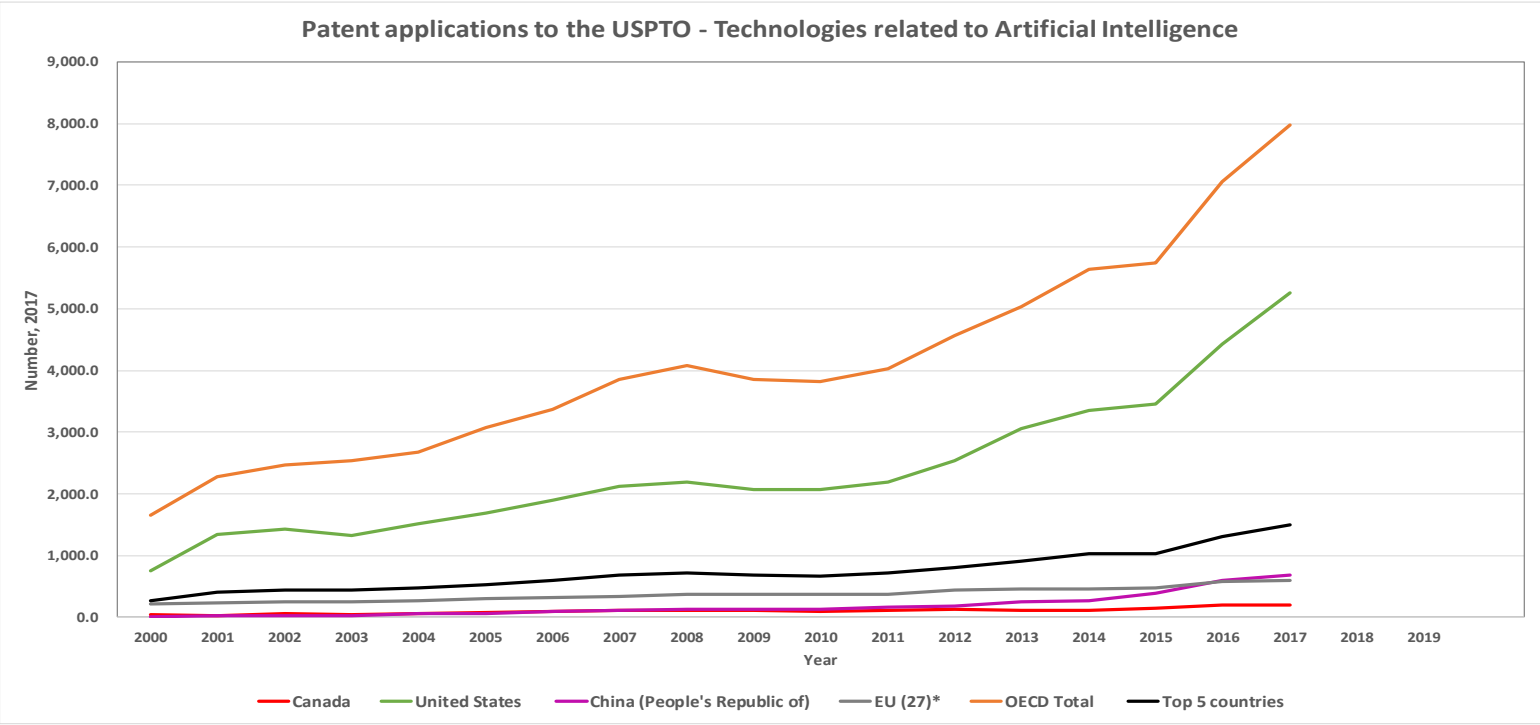


* Supercluster: to create an AI super-cluster; Supply Chains; Development of projects for supply chains optimized by AI; AI Adoption: Speeding up the adoption of AI; CIFAR: Funding to CIFAR; Stand-alone; Funding to Creative Destruction Lab
Sources: Supercluster: GQ 2017; Supply Chains: GQ 2018; AI Adoption GQ 2019; CIFAR: <https://www.cifar.ca/cifarnews/2019/03/13>; Stand-alone GQ 2018; also GQ 2000 - 2016
** Note: Review of GQ Budgets from 2000-2016 indicates no entries

Figure 4 Patent Applications to the USPTO – technologies related to Artificial Intelligence

Dataset: Patents by Technology

Patents Office & Patents			Patent applications to the USPTO - Technologies related to Artificial Intelligence																		
Reference country	Inventor(s)'s country(ies) of residence																				
Reference Date	Priority date																				
Technology domains & IPC			Technologies related to Artificial intelligence																		
Unit			Number, 2017																		
Year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	
Country																					
Canada	39.2	34.2	56.0	45.2	59.3	79.5	86.9	110.2	105.6	110.9	88.4	107.7	133.9	113.9	118.6	147.9	196.1	203.3			
United States	748.3	1,343.5	1,420.9	1,321.5	1,508.9	1,686.2	1,889.0	2,113.7	2,198.7	2,073.9	2,070.8	2,195.2	2,537.3	3,052.6	3,357.1	3,455.5	4,426.6	5,257.8			
China (People's Republic of)	5.4	26.2	23.1	30.4	53.0	60.9	86.6	108.4	123.2	122.3	130.3	162.2	186.1	254.2	274.1	386.2	597.1	676.5			
EU (27)*	209.0	237.5	245.1	253.7	261.7	308.4	314.7	341.7	379.1	369.4	369.5	370.8	437.2	452.0	453.0	472.8	580.7	594.6			
OECD Total	1,647.4	2,285.4	2,472.7	2,530.2	2,669.4	3,070.4	3,374.8	3,846.4	4,077.2	3,849.6	3,813.4	4,033.3	4,564.7	5,037.4	5,635.7	5,744.9	7,055.0	7,986.7			
Top 5 countries	275.8	399.1	433.9	443.8	476.5	527.2	599.2	688.3	721.4	678.3	673.8	716.5	806.7	904.7	1,028.3	1,037.1	1,299.9	1,500.7			

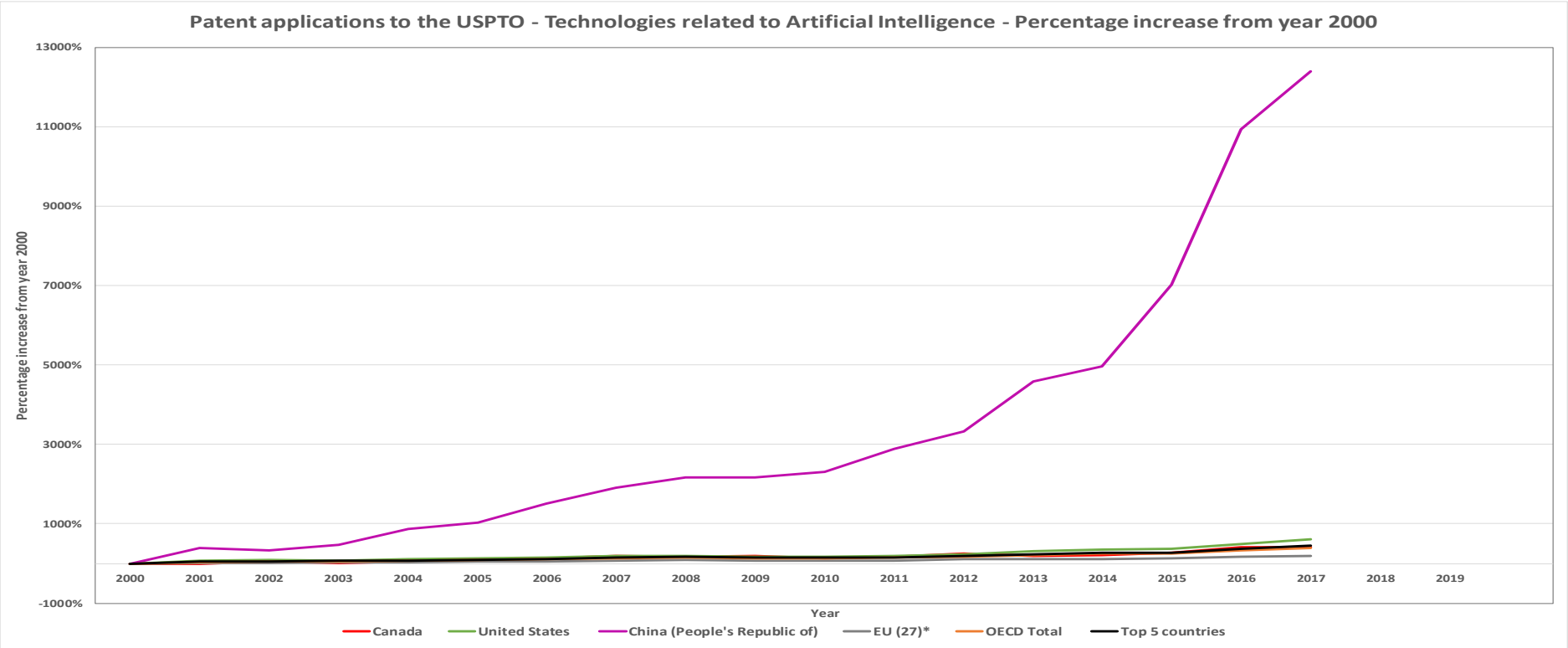


Source: *OECD Main Science and Technology Indicators* (https://stats.oecd.org/Index.aspx?DataSetCode=MSTI_PUB#)
Top 5 countries: United States, Japan, China, Korea, Germany
NOTE: OECD uses totals for OECD, EU(27); as such these are excluded from the top 5. *EU(27) is used in this OECD data.
Data extracted on 16 Nov 2020 03:29 UTC (GMT) from OECD.Stat

Figure 5 Patent Applications to the USPTO – technologies related to Artificial Intelligence - Percentage increase from year 2000

Dataset: Patents by Technology

Patents Office & Patents		Patent applications to the USPTO - Technologies related to Artificial Intelligence - Percentage increase from year 2000																			
Reference country		Inventor(s)'s country(ies) of residence																			
Reference Date		Priority date																			
Technology domains & IPC		Technologies related to Artificial Intelligence																			
Unit		Percentage increase from year 2000																			
	Year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Country																					
Canada		0%	-13%	43%	15%	51%	103%	122%	181%	169%	183%	126%	175%	242%	191%	203%	278%	401%	419%		
United States		0%	80%	90%	77%	102%	125%	152%	182%	194%	177%	177%	193%	239%	308%	349%	362%	492%	603%		
China (People's Republic of)		0%	383%	326%	461%	879%	1024%	1498%	1901%	2174%	2158%	2306%	2895%	3335%	4592%	4959%	7029%	10924%	12389%		
EU (27)*		0%	14%	17%	21%	25%	48%	51%	63%	81%	77%	77%	77%	109%	116%	117%	126%	178%	185%		
OECD Total		0%	39%	50%	54%	62%	86%	105%	133%	147%	134%	131%	145%	177%	206%	242%	249%	328%	385%		
Top 5 countries		0%	45%	57%	61%	73%	91%	117%	150%	162%	146%	144%	160%	193%	228%	273%	276%	371%	444%		

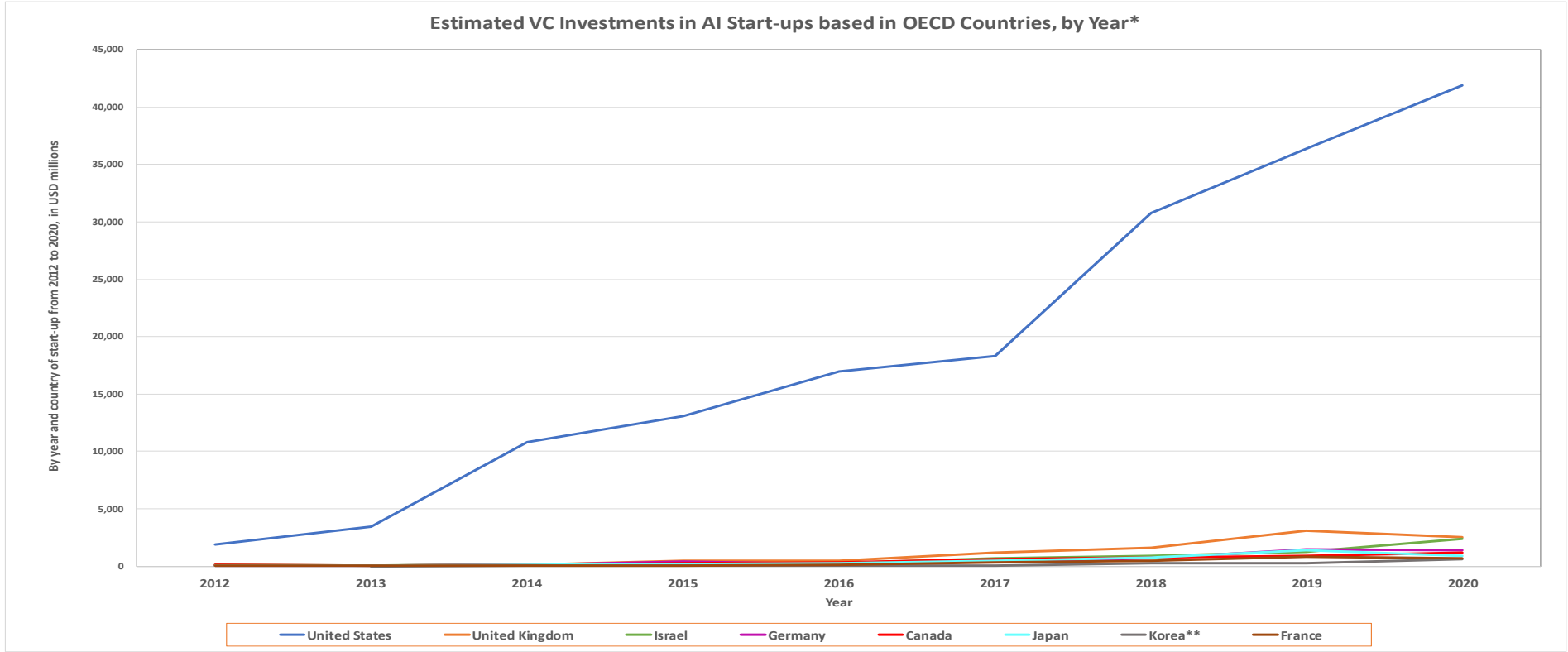


Source: *OECD Main Science and Technology Indicators* (https://stats.oecd.org/Index.aspx?DataSetCode=MSTI_PUB#)
Top 5 countries: United States, Japan, China, Korea, Germany
NOTE: OECD uses totals for OECD, EU(27); as such these are excluded from the top 5. *EU(27) is used in this OECD data.
Original data extracted on 16 Nov 2020 03:29 UTC (GMT) from OECD.Stat; percentage increases are author's calculations

Figure 6 Estimated VC investments in AI start-ups based in OECD countries, by year

OECD *Venture Capital Investments in Artificial Intelligence*, September 2021, No. 319

Measure	Estimated VC Investments in AI Start-ups based in OECD Countries, by Year*									
Unit	By year and country of start-up from 2012 to 2020, in USD millions									
Year	2012	2013	2014	2015	2016	2017	2018	2019	2020	Total
Country										
United States	1,868	3,462	10,799	13,096	16,930	18,346	30,768	36,375	41,870	173,513
United Kingdom	38	55	140	497	492	1,174	1,567	3,076	2,529	9,567
Israel	102	65	147	186	272	684	857	1,247	2,365	5,926
Germany	29	40	80	386	180	375	655	1,481	1,350	4,675
Canada	107	31	117	218	312	592	729	914	1,204	4,224
Japan	5	27	85	152	224	428	738	1,376	909	3,944
France	19	16	26	68	143	301	492	809	710	2,585
Korea**		2	23	14	34	58	257	260	628	1,275
Total***	2,221	3,793	11,592	14,995	19,000	22,677	37,100	47,358	53,667	212,403



*Data is presented only for 8 of the 38 countries in the OECD dataset.

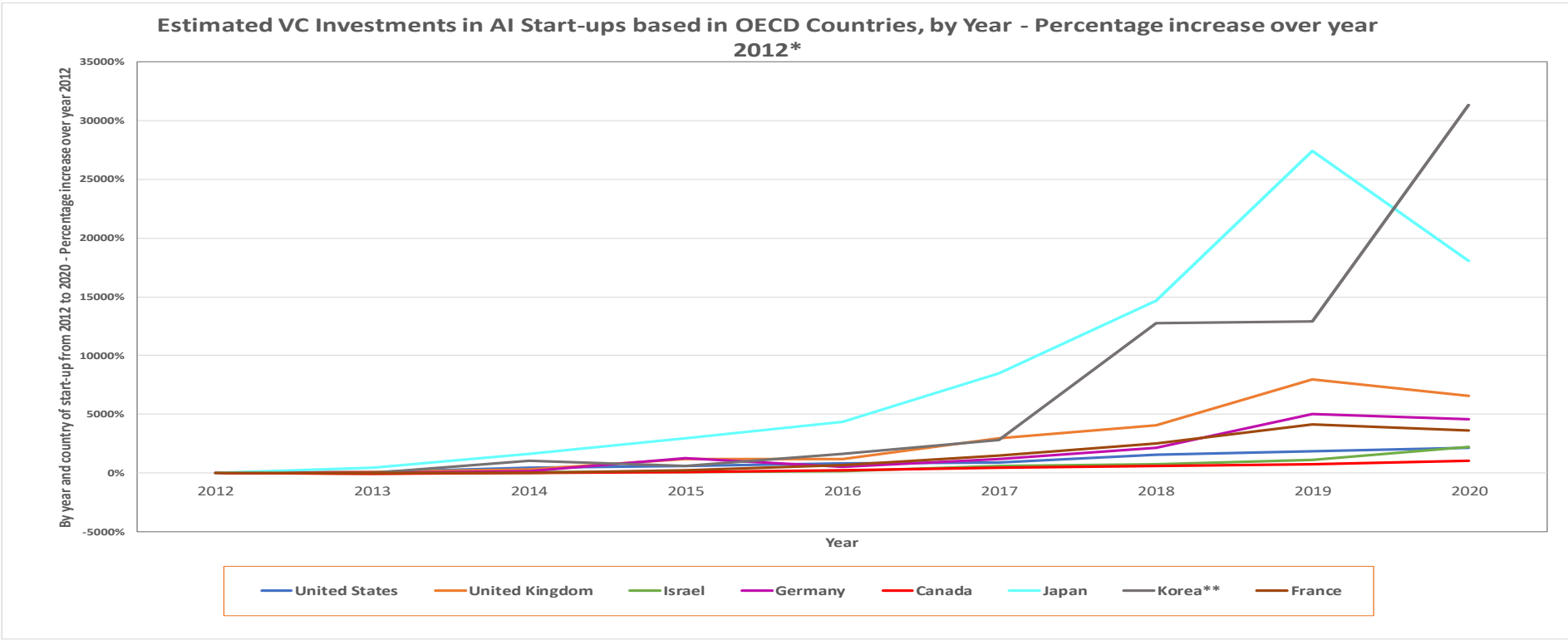
** There is no data entry for 2012 for Korea

*** Total here represents OECD totals for all 38 countries

Source: OECD 2021, processed by JSI AI Lab of Slovenia, based on Prequin data of 23/04/21, www.oecd.ai; Table A.1.

Figure 7 Estimated VC investments in AI start-ups based in OECD countries, by year - Percentage increase over year 2012

Measure	Estimated VC Investments in AI Start-ups based in OECD Countries, by Year - Percentage increase over year 2012*								
Unit	By year and country of start-up from 2012 to 2020 - Percentage increase over year 2012								
Year	2012	2013	2014	2015	2016	2017	2018	2019	2020
Country									
United States	0%	85%	478%	601%	806%	882%	1547%	1847%	2141%
United Kingdom	0%	45%	268%	1208%	1195%	2989%	4024%	7995%	6555%
Israel	0%	-36%	44%	82%	167%	571%	740%	1123%	2219%
Germany	0%	38%	176%	1231%	521%	1193%	2159%	5007%	4555%
Canada	0%	-71%	9%	104%	192%	453%	581%	754%	1025%
Japan	0%	440%	1600%	2940%	4380%	8460%	14660%	27420%	18080%
France	0%	-16%	37%	258%	653%	1484%	2489%	4158%	3637%
Korea**		0%	1050%	600%	1600%	2800%	12750%	12900%	31300%



*Data is presented only for 8 of the 38 countries in the OECD dataset.
** There is no data entry for 2012 for Korea
*** Total here represents OECD totals for all 38 countries
Source: OECD 2021, processed by JSI AI Lab of Slovenia, based on Prequin data of 23/04/21, www.oecd.ai; Table A.1; percentage increases are author's calculations.

Chapter 9

Pharmaceutical Manufacturing: The Innovation Conundrum

Introduction

As with Artificial Intelligence, the pharmaceutical manufacturing case study is equally a valuable test case for the DNS lens, although in this instance it throws into relief the challenges associated with a mature industrial sector. Moreover, while the selection of this study was undertaken three years prior to the writing of this chapter, it has proven to be particularly prescient given the COVID-19 pandemic and the challenges around pharmaceutical manufacturing highlighted by those events.

That noted, the inquiry around pharmaceutical manufacturing is mounted on several fronts. To be sure, the chapter initially reflects on the selection of this case study and the richness it can potentially bring to an assessment of the DNS framework. However, it then moves on to highlight key attributes of the industry, particularly as they relate to the innovation process, the social and private “value” of innovation contained herein, the unique nature of market demand, as well as competing perspectives on the current trends within the industry that challenge the wellspring of innovation itself. These reflections are not included as afterthought; an understanding of the Canadian context cannot be gleaned without some reckoning with the characteristics and structure of the pharmaceutical and medicines manufacturing industry writ large. These sections are followed by a brief historical overview of Canada’s endeavours with patents and innovation and the policy priorities that have emerged throughout these years. Government incentives for R&D investment, Canada’s engagement with international trade agreements (in which patent exclusivity is generally couched) and federal efforts to kickstart a

nascent domestic industry all constitute dimensions of this historical reach into policy agenda-setting.

The chapter then takes an in-depth dive into the essentials of the DNS framework as these pertain to the 2000s. Policy durability and federal priority-setting are examined. So too is targeted resourcing -- both the legacies and gaps -- and particularly as this pertains to biotechnology as well as efforts to thicken the sector's innovation ecosystem. And, on this latter front, the shifting sands on which experimentation with triadic thickening occurred are equally examined. Furthermore, recent federal efforts to deal with the current conjuncture and the need for a pharmaceutical base around vaccines are subjected to some scrutiny. As such, then, the intent is to provide a solid analysis by which to contrast and compare the AI and pharmaceutical case studies and the depth these studies bring to our understanding of the DNS framework. Finally, as the earlier Methodology chapter laid out, this case study concludes with a review of the relevant R&D investment and patent indicators that speak to innovation. À la Campbell (1969), it is hoped this can provide some evidence on causal sequencing or at least open a window to that line of reflection.

As with AI then the intent is to set up the parameters to test the DNS line of reasoning and particularly to draw out if a shallow or robust set of levers on the part of the federal government has impacted the pharma sector. Should it prove to be the former, the argument for weakness of the sector is made and it still provides evidence for the DNS hypotheses. Should it provide the latter -- a particularly robust set of policy actions -- evidence mounts for falsification of the DNS thesis. The story that unfolds is undoubtedly more complex than simple causal and linear sequencing but this is an effort to untangle certain essentials while appreciating the global landscape on which Canadian domestic policy does manoeuvre.

Structure of the Pharmaceutical Manufacturing Industry

The issue of the structural characteristics, and particularly the innovation processes within the pharmaceutical manufacturing industry, is significant on a couple of fronts. For one thing its unique features, including the leverage of monopolistic exclusivity and pricing through patents as well as high intensity R&D and historical trends of declining productivity, make for a particularly interesting test case for the application of DNS and the potential imprints of state policy on innovation. By no means is this an instance of a few policy levers propelling or even enabling a steady stream of important discoveries in varying Therapeutic Classes of drugs.¹ Nor is it in any sense a hearkening back to a linearly-directed technology push² with its base in fundamental science (although therein may lie some of the Canadian dilemma). Rather it is the interwoven complexity of an industry with specific features and challenges that provides the landscape on which government policy and efforts manoeuvre.

Secondly, it is worth noting that pharmaceutical manufacturing is where both DNS contributors (Mazzucato 2015b [2013]; Mazzucato and Roy 2018; Vallas et al., 2011) as well as evolutionary economists such as Malerba et al. (2016, especially 151-153) have signalled the massive influx of funding and research that the American government has provided to the industry over the last several decades. In this sense, then, it quite appropriate to evaluate the nature of Canadian federal efforts in this regard and the extent to which the industry may or may not have been receptive to any such initiatives.

With respect to the industry's actual characteristics, as the literature on this issue has well

¹ Malerba et al. (2016) note that a “therapeutic class” of drugs refers to drugs that are related in the sense that they address similar or related disease conditions (166).

² On demand pull and technology push, see the seminal work by Dosi (1982), and as referenced in Mazzucato and Roy (2018). Although the latter draw on Dosi's work to discuss the “blindness” of the market, it is a somewhat overstated interpretation of Dosi's analysis.

established, certainly the sector is highly R&D intensive (DiMasi 2002; DiMasi et al, 2016; Malerba and Orsenigo 2002, 2015; Malerba et al, 2016; Mazzoleni and Nelson 1998; Paul et al. 2010; Shih et al. 2018).³ This is manifested in a number of ways, including the long lead times between initial scientific research and development and actual launch of the product as well increasing length of clinical trials for efficacy and safety. Indeed, there is remarkable consistency among key contributors to this literature. Pammolli et al. (2011), in their study of R&D extending over 28,000 “compounds” for the period starting in 2000, find that the average time for development and marketing was 13.9 years for products making their way onto the market from 2000 on. The data also showed an accelerating trend, with average time for similar development and launch being 9.7 years in the 1990s (*Ibid.*, 429). Similarly, Paul et al. (2010, 205) find a timeline of 13.5 years for New Molecular Entities⁴ getting regulatory approval in 2007, although notably this did not include a final phase of “validation.” And while DiMasi et al. in their seminal work in 2016 do find a slight deceleration in the costs associated with final Phase III human clinical testing, the overall intensity of the R&D process had not been significantly alleviated.⁵

Moreover, intersecting with the lead times is the unique and variable nature of the innovation process in the discovery of new therapeutics. More specifically, the discovery and development process here is, to a great extent, shielded from spillovers, with breakthroughs in one therapeutic area not being effectively leveraged for new therapeutic initiatives (at least beyond refinements in usage or delivery) – a unique process which Malerba et al. capture as

³ Also see Pammolli et al. (2011), although focused on the productivity “crisis” per se it necessarily implicates the intensive nature of R&D in pharma.

⁴ A New Molecular Entity is “A medication containing an active ingredient that not been previously approved for marketing in any form in the United States.” (Pammolli et al. 2011, 429).

⁵ See especially DiMasi et al. (2016), Table 5.

“low cumulateness” of knowledge (2016, 164).⁶ Additionally, and historically, the industry has been dependent on “quasi-random” search procedures that do not start out with a particular target in sight (*Ibid.*, 161). Rather they are infused with a certain degree of scientific “curiosity” combined (at least for large firms) with reliance on extensive data sources and labour-intensive screening efforts and winnowing to move the discovery process forward. To be sure, there has been much written on how such screening can be more efficiently undertaken – particularly with respect to optimally calibrated portfolios of therapeutic classes under development, shortened cyclical times for trial (especially at early stages) and general process improvements leveraged from other manufacturing industries.⁷ Still, the whole exercise, at least for drugs outside the domain of biotechnology,⁸ is characterized by a certain degree of “serendipity.”⁹

With respect to the intensive R&D nature of the industry, there is also the exorbitant level of cost of taking a therapeutic from the discovery stage through to final approvals. A critical series of studies undertaken from the late seventies through to about 2010 – largely by the same authors and, in most part, replicating the same methodology -- have meticulously traced the accelerating costs and failure rates of drug development (Hansen 1979; DiMasi et al 1991, 1995

⁶ This section on the innovation process does rely heavily on Malerba et al. (2016) and their comprehensive analysis of its unique characteristics, especially 162-164. The work also contrasts the more fluid discovery processes of the computer industry – where indeed breakthroughs can facilitate “products serving new markets” (*Ibid.*, 79; also 43-92) -- with pharmaceuticals. But also see earlier work by Malerba and Orsenigo (2002) where, interestingly, they go somewhat further and characterize the process as “shaped by *lack* of cumulateness” (667 and 669-673; this author’s emphasis); as well Malerba and Orsenigo (2015).

⁷ There is a wealth of literature on this subject here and our work here only scratches the surface of this. However, see in particular the seminal work by Paul et al. (2010) and Pammolli et al. (2011); as well Harrison (2016); Kwong (2015); Morgan et al. (2018); Ruso et al. (2011); Scannell et al. (2012); Shih et al. (2018). For an excellent discussion from a Canadian perspective and still very much a time-worthy analysis see Campbell and Pal (1989, especially 55-58).

⁸ It is beyond the scope of this research to deal with differences that may exist in the search process for biotechnology. Suffice it to say at least for Malerba et al. (2016), they do distinguish between biotech and more traditional prescription drugs and put their focus on the latter. Earlier works by Malerba and Orsenigo (2002, 2015) do not delve into that distinction, although Malerba and Orsenigo (2015) do discuss the emergence of biotech historically in their later writings.

⁹ This phrase which nicely captures the partially random acts of screening new therapeutics is employed by Malerba and Orsenigo (2002).

and DiMasi et al. 2016). Three findings in these studies by DiMasi et al. are particularly salient for our purposes. For one thing – for the period from 1995 - 2007 with respect to development stages and the “latter part” of the 2000s for final marketing of a therapeutic (DiMasi et al., 2016, 24, 26)¹⁰ – the authors estimate the average “out-of-pocket” or cash outlay costs for a new drug at \$1.4 billion in 2013 dollars. For fully “capitalized” costs, including the cost of both equity and debt, the figure weighs in at \$2.6 billion, again in 2013 dollars. Secondly, this is not a one-time spike; the studies show the costs over the four decades they have examined have been accelerating,¹¹ in the last round logging an annual increase of 8.5 per cent (above inflation) and actually moving from \$179 million (2013 dollars) per drug in the late seventies and early eighties to the 2,558 million figure (2013 dollars) calculated for the first decade of the aughts (*Ibid.*, Figure 3). Thirdly, this has coincided with an increasing rate of failure or “attrition” in drug discovery undertaken as the pharmaceutical moves through various stages of animal and human testing, the authors estimating an approval or “success” rate of 11.83 per cent per drug in their most recent study (*Ibid.*, 23).¹²

To be sure, Mazzucato and Roy do take these works to task, not the least for their omission of the injection of “value” and specifically the \$804 billion the National Institutes of Health in the US invested in pharmaceuticals from 1934 to 2015 (Mazzucato and Roy 2018, 108) as well as its reliance on fully “capitalized” costs which also inflate value.¹³ So too do they highlight that these studies received support from the Tufts Centre for Drug Development which

¹⁰ In the case of the timelines for final marketing following US Food and Drug Administration approval, the time series in the study ends in 2013 (*Ibid.*, 26).

¹¹ See also Grabowski and Vernon (1994) on the early studies.

¹² Interestingly, this lower success rate obtains notwithstanding the slight deceleration in costs for final Phase III human testing and a propensity by companies to dispense with failures more quickly; see DiMasi et al. (2016, Table 5).

¹³ The DiMasi et al. studies include in the costing of capital equity capital, debt and a calculus based on after-tax costs of capital (DiMasi et al. 2016, 24).

has linkages to the industry itself. That said, a few considerations are of value here and do mitigate against dismissing the contributions and longitudinal nature of these studies.

Specifically on the capitalization issue the DiMasi et al. evidence also breaks down the cost for straight cash outlays in development and here too the data show an increase from \$524 million to the aforementioned \$1,395 million in constant US 2013 dollars (DiMasi et al. 2016, Figure 2 and 31). DiMasi et al. also reference similar studies, albeit not with the same degree of longitudinal force, which find similar levels of expenditures and attrition. And, finally, they do indicate from the outset that public expenditures in the drug discovery process are not included. Nonetheless, Mazzucato and Roy's insights on the undervaluation of state funding in the acceleration of breakthrough drugs – and the twin pincers in which governments both in the upfront funding of science and the later costs associated with national health find themselves – still stands.

All told, then these various dimensions of innovation within pharmaceuticals have very specific implications for the industry itself. It results in a highly segregated industry with low “aggregate” or overall concentration, twinned with large multinational and heavily-invested R&D companies jockeying for leadership in “segmented” markets associated with unique classes of therapeutic drugs (Malerba et al. 2016; also Malerba and Orsenigo 2002 and 2015). And it relegates to the periphery small start-ups and especially biotech companies (often borne out of university research labs) who need to leverage partnerships with the large MNLs to develop their discoveries and gain market access. Moreover, it creates a strong proclivity for patents, both to maintain monopolistic pricing and reap surplus from the sunk costs per drug in R&D, although admittedly less for commercialization per se and more for initial market advantage and associated pricing.¹⁴ Some argue it has also lent itself to a “me too” approach to drug

¹⁴ On this latter point see the insightful and comprehensive discussion of the nature of patents, invention and innovation, by Mazzoleni and Nelson (1998); also Mazzoleni (2011).

development, where the original patent (and discovery science vested therein) is retained and drugs are developed essentially within this orbit, thus leading to incremental forms of innovation rather than radical breakthrough drugs.

Finally, and probably most concerning, this unique constellation of factors, together with trends to more mergers and acquisitions aimed at garnering efficiencies and forging partnerships with smaller firms as well, has evidenced an observable decline in productivity (Comanor and Scherer 2013). And while the trends may not be as dramatic as the “ice age”¹⁵ some suggest may evolve, nonetheless the literature is replete with the productivity challenges now being faced.¹⁶ Indeed, recent literature continues to affirm the barriers to success surrounding the ineffective means for selecting therapeutics for development and, in particular, the “absence of a sharp *ex ante* definition of the target ...” (Malbera et al. 2016, 160; Malerba and Orsenigo, 2002, 2015; Shih et al. 2018). Moreover, trends to financialization within the industry and efforts to draw profits from share buybacks may also be exacerbating the productivity issue (Mazzucato and Roy 2018) – or at least not creating the reinvestment in R&D that is needed. The strong emergence of generic companies which challenge the exclusivity of patents, as well as the “inelasticity” of demand associated with national health care costs¹⁷ also establish new conditions for price competition and associated R&D investments.

This is not to suggest of course that this constellation of industry factors forge a crucible in which state policy is trapped. It is to suggest however that government policy – and

¹⁵ Paul et al., (2010) refer to concerns that have developed within the industry

¹⁶ See ff 7 but also DiMasi et al. (2016); Lingardt et al. (2008); Malerba et al. (2016); Munos (2009); OECD (2018c). With respect to other relevant literature on the productivity question, see Paul et al. (2010) on the longer “cycle times” for the clinical phases; on narrow “pipelines” of development with an overreliance on final and most expensive stages of testing, *Ibid.* but also DiMasi et al. (2016) and DiMasi (2002); and on the increasing complexity of science and therapeutics needed or even exhaustion of potential in certain scientific domains, Malerba et al. (2016, 163-164) and, as referenced in *Ibid.*, Pammolli et al (2011).

¹⁷ On national health care expenditures more globally see OECD (2015).

specifically Canadian federal efforts at not only catalyzing innovation but also kickstarting a nascent pharmaceutical manufacturing industry -- must at least be considered within this broader context and historical experience. And it is to suggest that, as a case study, it makes for a particularly illuminating assessment of the DNS framework.

Patents and Protection: The Historical Experience

The early history of Canadian pharmaceutical manufacturing¹⁸ – and the federal priority-setting it did, or did not, inspire – is probably most appropriately viewed through the lens of Canada’s Intellectual Property regime, both legislative and regulatory and specifically as that regime pertained to patents. Indeed, it is not too much to suggest that from 1923 to 1995, if not to a decade later, the issue of patent monopolies and associated pricing and the exclusions to patentability afforded through “compulsory licensing” by the state to “third party” companies dominated the federal agenda in pharmaceuticals, yielding a variety of policy manoeuvres, and results. Interestingly, however, and as we have oft seen in the Canadian experience, this was not a case of a consistent trajectory of determined priorities, nor even political parties that maintained a consistent ideological position on the issues at stake. Rather federal government efforts remained fraught with competing objectives: nurturing a Canadian pharmaceutical manufacturing industry, maintaining investment flows for R&D from American multinationals in Canada and stabilizing rising drug prices as the Canadian welfare state (and its associated health care costs) was established and evolved. Moreover, by the early eighties these developments were traversed by the sharp force of trade negotiations, both bilateral and

¹⁸ On the Canadian experience with IP rights and pharmaceutical manufacturing for this early period but also as Canada entered into free trade agreements, see especially the very rich analysis of Bill C-22 in Campbell and Pal (1989, 53-106); also Cohen (2003/2004); Doern and Sharaput (2000); Doern, Phillips and Castle (2016); Eastman Commission (1985); Grootendorst, Bouchard and Hollis (2012); Harrison (2001); Knopf (2018); Lalitha (2005); Levy and Weiser (1993) on NAFTA in particular; Smith (1993); Tancer (1997); and Zuijdwijk (2018).

multilateral in nature, that propelled the issue of the nation's IP regime to the front of the national agenda. So too did these developments leave a trail of commissions, studies and inquiries in their wake as the federal government wrestled with competing priorities and tried to square increasingly complex policy requirements. In bright contrast to AI with its persistent although more muted policy agenda, the pharmaceutical case study throws into relief a government whose efforts were caught in a triple squeeze of international challenges, domestic industrial needs and the imperatives of national welfare.

The Early Years: Establishing a Canadian Manufacturing Presence

Apart from Italy (which did not have patent legislation), Canada was for a long time unique among developed countries for the way in which it more casually treated patent rights and, according to some observers (Knopf 2018), flexed its sovereignty with international colleagues in this domain. In fact, Canada's first foray into this area was as early as 1923 when the federal government (under whose auspices Intellectual Property rights fell) introduced amendments to the Patent Act that allowed for exemptions to patents through "compulsory licensing" (Eastman Commission 1985, 1-4; Lalitha 2005; Lexchin 2016, 139).¹⁹ Specifically, such licensing involved a process by which government could authorize a "third party" company or individual to produce the same pharmaceutical drug in Canada as long as the drug was manufactured in Canada.²⁰ Moreover, the third party entity could do so without notifying the

¹⁹ With respect to the issue of the Canadian experience with IP rights and the pharmaceutical manufacturing industry, there is a significant although not overly extensive literature. See the extensive account by Lexchin (2016) (particularly from the pharmaceutical cost perspective); also Cohen (2003/2004); Doern and Sharaput (2000) (particularly on the trade-off between the "protection" function of IP for inventors versus the "dissemination" role for the benefits of society at large); Doern, Castle, and Phillips (2016); Gorecki and Henderson (1981); Grootendorst et al. (2012); Levy and Weiser (1993) (for an unabashed defence of strengthening IP rights in NAFTA); Harrison (2001); Daley et al. (2020); Smith (1993) and Tancer (1997). All contributions speak to varying "takes" on these years but with recognition of the significant changes that were introduced.

²⁰ The Eastman Commission captures the essence of the 1923 legislation: compulsory licences were "to be granted for the manufacture, use, and sale of patented processes" (Eastman 1985, 1).

patentee. Intended to stimulate the creation of a domestic manufacturing industry – dominated as the Canadian pharmaceutical scene was by American multinationals – in fact the new amendment had little effect. In an historical review of the period, the Eastman Commission reported (based on an Economic Council of Canada study) that between 1935 and June 1969 only 49 applications for compulsory licences were submitted to the Patent Commissioner for authorization and of these only 22 were granted (Eastman Commission 1985, 2).²¹

What was evidenced however is that by the early sixties as the government put the pieces in place for a national health care plan²² the cost of pharmaceuticals was rising (as companies responded to both productivity issues and more stringent demands for efficacy and safety). Moreover, as observers of these years have noted (Gorecki and Henderson 1981; Smith 1993) in relatively rapid succession a number of commissions of inquiry were established. Specifically struck were the seminal Director of Investigation and Research Combines Investigation Act of 1961 which focused particularly on “an Inquiry under Section 42 of the Combines Investigation Act, Relating to the *Manufacture, Distribution and Sale of Drugs*” (Hall, 1964, 40), the Restrictive Trade Practices Commission in 1963 (Commission 1963), the Royal Commission on Health Services or the Hall Commission in 1964 and, by 1967, a study that had been undertaken by a special committee of Parliament inquiring into “drug costs and prices.” All of these underlined the challenging nature of rising drug costs and need for change, and particularly for the Hall Commission, the implications for financing out of public coffers.

²¹ Lexchin reports that the figures were 49 applications between 1923 and 1969 (2016, 169), with 22 being granted. We have relied here on the Commission’s data instead; Smith (1993) also uses the Eastman stats.

²² The Medical Care Act was established in 1966 (<https://www.canada.ca/en/health-canada/services/health-care-system/reports-publications/health-care-system/canada.html>); also see Smiley (1976) on the build up of the post-war welfare state in Canada and the complex cost-sharing arrangements of “executive federalism” that underpinned it especially, 54-82.

Faced with these issues, in 1969, the Liberal government of the day undertook another amendment to the Patent Act, widening the application of “compulsory licensing” still further, this time to include not just the manufacture but also the “import” of “medicines” required for production processes. Moreover, the legislation established a royalty system wherein the generic manufacturers would provide to the patentee four per cent of the “net selling price of a drug in its final dosage form” (Smith 1993). And this time, unlike 1923, it did help to spur the growth of domestic generic manufacturing industry (Lalitha 2005, 1357) but it also raised the ire of American multinationals, a fact that was played out in numerous court proceedings that US brand name companies undertook to challenge the legislation. It also played out in the opposition of Canadian brand name companies that were subsidiaries of the American companies. As Justice Joyal of the Federal Court of Canada pointedly noted: “The artillery of legal process and the ammunition of skillful pleadings have been the tools of war in expressing dissatisfaction with the policy of Parliament,” albeit that these cases were only infrequently “successful” (Silversides, 23 January 1986).

Thus, by the early eighties the stage was set for a new battery of initiatives on the pharmaceutical front. Specifically in 1984, the government duly established another commission – this time the “Commission of Inquiry on the Pharmaceutical Industry” under the leadership of U of T economist Harry Eastman – to assess the situation and options available. Reporting back in February of 1985, the Commission made two key findings relevant at least for the analysis herein. In quite an arresting statement, the Commission essentially dismissed the notion that Canada could be a thriving R&D hub of pharmaceutical investment and activity, concluding in blunt language that:

Canada does not now possess either the scientific manpower or the physical infrastructure that would make it a major world centre for basic pharmaceutical

research. Nor in the opinion of the Commission, would it be wise for government to seek to create such an environment in competition with heavily supported long-established centres in other countries (Eastman 1985, 423; as referenced in Lexchin 2016, 188).

At the same time, however, they found that despite the outcry about compulsory licensing this regime had not in fact damaged or “supplanted” the brand-name pharmaceutical industry; sales of compulsory licensed generics had only constituted three per cent of total pharmaceutical sales in 1983.²³ Furthermore, the generics had garnered for Canadian “consumers and taxpayers” savings of \$211 million. In light of this evaluation, not surprisingly, the Report concluded that the compulsory licensing regime in Canada should be maintained, although it should be amended to offer four years of exclusivity to the brand name companies (Eastman Commission 1985, xxi).

Bill C-22: Compulsory Licensing and R&D

These recommendations were not to be considered, however.²⁴ Before the Commission could report a new Tory government with Brian Mulroney as PM had been elected in September of 1984 and, more importantly, the need for IP protections was thrust quite rapidly to the front of the national agenda. For one thing, by the early eighties American trade representatives were engaged in international trade negotiations under the Uruguay Round of GATT and by 1984 had also engaged on a bilateral free trade deal with Canada. And protection of IP, and specifically pharmaceuticals, was a recognized objective in the American negotiations. (Interestingly, the

²³ See the summary in Eastman 1985, xvii -xxxi. There are a few key contributions on the Eastman report and its findings, although with the exception of Lexchin rather brief assessments. See Lexchin (2016); also Cohen (2003/2003); Harrison (2001). However, the report itself is best read in the original.

²⁴ The substance of the amendments contained in Bill C-22 (as discussed in the analysis below) do not indicate alignment with the Eastman recommendations. This is also the considered view of Campbell and Pal writing: “And in the final analysis, the Conservative government rejected the expert advice of a Royal Commission and simply pushed ahead with an approach that reflected its political goals.” (*Ibid.*, 55). It also appears in journalistic accounts at the time. Less convincingly, however, Doern, Castle and Phillips take an opposed position, stating briefly that the Eastman Commission “recommendations” “informed Bill C-22, to amend the Patent Act” (Doern, Castle and Phillips, 2016, 243). True, the amendment of the Act was forthcoming but the legislation by no means was intended to support the compulsory licensing regime: indeed, it was specifically aimed at strengthening pharmaceutical protection through patents and dismantling elements of compulsory licensing.

lead for the Advisory Committee to the President on Trade Negotiations was Robert Pratt, the head of the Pharmaceutical Manufacturers Association in the US (Harrison 2001, 514)). By the time of the Shamrock Summit between Mulroney and Reagan in March of 1985, none other than the President himself had brought the issue of compulsory licensing forward as the number three item on his agenda (*Ibid.*, 511; Crann 30 November 1986 (referenced by Harrison 2001, 5112) and Lewington and Waddell 9 October 1987). Certainly, the American position was clear and, by November 1986, the Mulroney government had introduced another round of amendments to the Patent Act in the form of Bill C-22 (An Act to amend the Patent Act and to provide for certain matters in relation thereto 33rd Parliament, 2nd Session, 1986-1987) with Royal Assent finally being given a year later.

Bill C-22 was a watershed moment for pharmaceutical manufacturing, and for R&D more generally, in Canada. It was also a Bill thrust into a firestorm of advocacy, threats, politicking and opposition. Specifically, Bill C-22 was intended to change the law around compulsory licensing, authorizing ten years of exclusivity for patent holders (after June 27, 1986) if the applicant for the license intended to “import the medicine” (Bill C-22, s. 41.11) and seven years of exclusivity for the patentee (after June 27, 1986) if the applicant intended to use “the invention for the preparation or production of medicine” (Bill C-22, s. 41.12) – i.e., for manufacturing in Canada. For the first time, it also called upon generics intending to import or manufacture to provide the patent holder with a “notice of compliance” indicating they were seeking such licensing authorization. Additionally, and thus similar to American law, it now provided 20 years of patent protection from filing of a patent instead of the 17 years from the granting of a patent that were previously in the Act, this twenty-year coverage obviously to run its course if third parties were not seeking a compulsory licence (Bill C-22, s.46). The proposed

legislation also called for a new reporting body to be established, the Patented Medicine Prices Review Board which would be tasked with monitoring the price of pharmaceuticals in Canada “to ensure that prices” were “not excessive” *and* taking remedial action if necessary (Receiver General 1989, 5-3). And, in an unusual twist, the Board would also be responsible for reporting annually on the state of R&D investment in the industry and its ratio to sales within the Canadian context (Bill C-22, particularly 41.25; Grottendorst et al., 2012; Lalitha 2005; Lexchin 2016, especially 138-143; Receiver General for Canada 1989, 5-3; Smith 1993).

As noted, the Bill proved to be a subject of exceeding controversy.²⁵ Certainly, the Americans continued to pressure the Canadian government and its Trade Minister to deal expeditiously with the IP issue and eliminate the compulsory licensing legislation. While the issue was shrouded in some secrecy, it was reported that upon inking a negotiated free trade deal 3 October 1987, the document initially referenced Bill C-22 as having been “agreed” upon (Lewington and Waddell 9 October 1987; Harrison 2001, 519), only to disappear from the text a few days later. The Canadian government at first disavowed the linkage between the Bill and the FTA negotiations, serving up to some heated exchanges in the Commons as well.²⁶

For its part, the Pharmaceutical Manufacturers of Canada during this period were actively lobbying for ten to twelve years of patent exclusivity, threatening to withhold not only \$35

²⁵ On the blow-by-blow accounts of this period see in particular the detailed and rich account by Campbell and Pal (1989); also Harrison (2001) who also references Campbell and Pal (1994); Tancer (1997); and Doern and Sharaput (2000) who offer a more expansive view of Intellectual Property and particularly patent legislation as it has travelled through time in the Canadian context. But see also the extensive journalistic reporting at the time, especially Crann (30 November 1986); Delean (27 August 1987); Eklove (21 October 1987) (who was Executive Director of the Canadian Drug Manufacturers Association – the generics); Erola (28 September 1987) (who was President of the Pharmaceutical Manufacturers Association of Canada at the time); Gibbens (5 June 1984); Lewington and Waddell (9 October 1987); O'Donnell (as referenced by Harrison 2001, 519); Orr (24 September 1987); Silversides (23 January 1986 and 20 February 1986); Hall (26 November 1986) (who was President of the Consumers' Association of Canada); Ross and Poirier (4 November 1987); Silversides (23 January 1986 and 20 February 1986); Waddell (10 October 1987) and *The Globe and Mail* (8 June 2012, no author).

²⁶ See especially Waddell (10 October 1987); also Cohen (2003/2004, 9) on the position of Pat Carney, Trade Minister at the time.

million in investments for “clinical research” (Silversides 20 February 1986) but also \$315 million that had been earmarked for Montreal-based pharmaceutical companies (Delean 27 August 1987) unless the Bill was passed. Arrayed on the other side, consumer advocacy associations and anti-poverty groups were articulating the Eastman recommendations as the path forward. Even the Canadian Conference of Catholic Bishops intervened on the matter, opposing the legislation on the grounds of concerns for the “elderly and the poor” (Campbell and Pal, 1989, 80). Further, in the midst of this all, a Liberal-dominated Senate refused to pass the Bill, twice sending it back to the Commons and seeking not only the Eastman recommendations but clauses enshrined in the Bill which would detail commitments by the brand pharmaceuticals in Canada to R&D investment – all of which provoked varying positions on the constitutionality of that as well.²⁷

In the end, the government was successful in negotiating a commitment from the Pharmaceutical Manufacturing Association of Canada to invest more robustly in R&D. The deal that was cut was an R&D investment of “8 per cent of sales by the end of 1991 and 10 per cent by end of 1996” in exchange for the longer periods of market exclusivity before compulsory licenses could be authorized (Smith 1993; Tancer 1997, 294). PMAC did pen a letter to Minister Wilson, responsible for Industry, Science and Technology at the time, indicating their commitment to doubling R&D output and achieving the ten per cent goal (PMPRB 2016, 6, ff1). However, the accord was not enshrined in any legislative amendments; instead, it was left to the Patented Medicine Prices Review Board to function as a watchdog on the situation and to the goodwill of the pharmaceuticals to abide by the agreement. As for Bill C-22, after its Third Reading in the Commons it finally gained Royal Assent in November of 1987.

²⁷ On the constitutionality issue, see Forsey, 7 November 1987.

The telling of these events is important for what they do -- and do not -- signify. Albeit caught in the cross-currents of international trade pressures, domestic standoffs and drug prices writ large, what emerges is a federal government which did persevere in efforts to maintain an R&D presence in the Canadian context and to stimulate foreign investment in pharmaceutical manufacturing. And that it did so in the face of the “political costs”²⁸ associated was testament to the dogged tenacity with which it advanced this legislation. To be sure, the effort was not borne of a more enduring nature, with clearly determined priorities that the federal government consistently pursued. Nonetheless it acts a unique and (as we shall see) an historic marker of an initiative undertaken that spoke to Canada’s innovation and, in this context, R&D conundrum. Equally important – à la Rosenberg and Campbell –²⁹ it enables this analysis to undertake a time-sequenced tracking of priority-setting (however challenging this may have been for the government at the time) and the investment indicators that follow. It enables this analysis to compare and contrast with the later period of developments from 2000 on, as well as with the AI experience. Most crucial as a test for the DNS framework, in the end it allows for reflections on the relationship between policy and investment and its potentially causal implications.

The After Years: A Hardening of the IP Regime

It is not the intention here to engage in a lengthy discussion of IP developments following the events of Bill C-22. However, three key aspects in this later period are worthy of attention. First, as for the period from Bill C-22 onward, there has been a subsequent hardening of

²⁸ On this point see Campbell and Pal and their reference to the “political costs, embarrassments, and misery” associated with Bill-C22 (1989, 98). For Campbell and Pal certainly the investment issue looms large and they carefully detail the public comments by various Ministers and the Prime Minister himself on the importance of establishing the new patent legislation and the R&D investment and burgeoning biotechnology field which this served. However, for them it also speaks to the complexity and cleavage harboured by the “real world of Canadian politics” including industrial divisions (between generic companies and the multinationals), regional divides (between Québec and the rest of Canada), and the “bicameral” issues that played out with an unelected Senate.

²⁹ See the discussion in Chapter Two on Research Methodology for the case studies.

Canada's IP regime and protections for patent holders. Secondly, it was *initially* accompanied by a reaffirmation of the commitment to R&D that had been made by the brand name companies – ie., the Pharmaceutical Manufacturers Association of Canada. Thirdly, the various international trade agreements (plurilateral and multilateral) in which Canada has been a signatory have also witnessed a strengthening of Intellectual Property rights, including dispute settlement mechanisms that narrow nation-state legislative *and* judicial authorities.

With respect to the domestic front, in the aftermath of the legislative amendments, the Free Trade Agreement between Canada and the United States was duly signed 1 January 1989 -- remaining silent on the IP front -- and coming into force on 1 January 1994.³⁰ Despite the absence of provisions in the FTA, however, the US continued to exert pressure³¹ on Canada to eliminate the compulsory licensing clauses that remained in the Patent Act and in June of 1992 the government introduced Bill C-91 and amendments to that effect. The Bill (which came into force 4 February 1993) essentially stripped the Patent Act of its earlier protections for generics and revoked compulsory licensing going forward from 20 December 1991. As Smith (1993) at the time summarizes, “generic producers will not be able to market a copy of a patented medicine until the patent has expired.” Certainly, there was a grandfathering provision for compulsory licenses that had existed prior to that date. Further there were two caveats that enabled generics to leverage information from a patent to proceed with regulatory approvals of

³⁰ There is no such dedicated chapter on Intellectual Property in the FTA (External Affairs, FTA, 1987) as is found in the NAFTA agreement in Chapter 11 (Canada, NAFTA 1992). See Tancer's observation (1997, 291) on the lack of “substantive coverage” of IP in the FTA. With respect to the copy of the FTA noted above, it is the text that “faithfully reproduces the text initialled on December 10, 1987” (Canada External Affairs, FTA, 3) and which then went forward to the respective parties for signature.

³¹ For an excellent overview of the Special 301 watch provision in the US trade legislation and how it was leveraged in dealing with their trade partners see Harrison (2001). The provision was used in monitoring Canada.

their proposed copy and it further allowed generics to amass inventory six months prior to a patent expiry – loopholes that would ricochet back on the government at a later date.³²

In toto, however, Bill C-91 moved Canada onto comparable IP terrain with other countries, dismantling the compulsory licensing edifice that had been built. Similarly, it is worth noting that the Act has been accompanied both in 1993 and in following years by increased strengthening of regulatory provisions that enable patentees to “petition” through the courts generics who wish to reproduce a copy of the patent. And although there was some effort in 1998 to streamline some of the regulatory provisions, the upshot has been to gird the exclusivity period for patentees. Further, as one expert scholar of this domain has assessed, regulatory outcomes have spawned rounds of litigation and costs both for patentee and generics within the courts (Grootendorst et al. 2012).

Moreover, it is also worth noting that the Liberal government elected in October of 1993 did not move to roll back the legislative changes that had been wrought³³ – despite the clamour that had been earlier heard in the Upper Chamber. Rather the new legislative framework was kept intact. Indeed, regulatory changes which followed the signing of the Canada-European Trade Agreement (CETA) in 2016 under the auspices of a Liberal government have expanded the period of exclusivity for pharmaceutical patentees who experience delays in regulatory approvals.³⁴

³² By 2000, the “stockpiling” caveat had fallen in a World Trade Organization panel ruling brought on by the European Union (Doern et al., 2016, 244).

³³ Cohen argues that this was a “meaningful policy shift” for the Liberals (2003/2004, 11). Be it a policy shift or acknowledgement of the realities of NAFTA, nevertheless the Liberals did not reintroduce changes. There may be a more compelling argument enunciated by observers such as Knopf (2018) and Zijldwijk (2018) on the implications of international trade treaties that spawned more directed and protective monopolies for patentees – namely, this was a trend that essentially locked in nations.

³⁴ On CETA and the subsequent regulations, see the discussion in Knopf (2018, 375-376).

With respect to R&D and the second of our considerations, following Bill C-91, PMAC made a public proclamation to the government, reaffirming their commitment to invest ten per cent of sales into R&D with \$400 million to flow by the “end of 1996” (Canada, House of Commons, Standing Committee on Industry 1997). As well PMAC was to provide \$200 million to a joint research fund with the Medical Research Council. The commitment however was blunt on the nature of the exchange, indicating that this was built on the premise that “international and national business regulatory environments ... will not undergo substantial change” (*Ibid.*). What is significant is that, in the intervening years, no such similar accord has emerged – or at least there is no public record of such.

Finally, and thirdly with respect to the obligations vested in international trade treaties, what has emerged are external dispute settlement mechanisms. These mechanisms enable an aggrieved party to challenge not only domestic trade initiatives but also relevant rulings of domestic courts – should they cause injury to an “investor” or “state” claimant.³⁵ The mechanism in the form of an “investor-state” dispute settlement mechanism first appeared in the North American Free Trade Agreement (to which Canada was a signatory) and clearly provided for external arbitration in the case of an irresolvable trade dispute between an investor and a state signatory to the agreement (Canada, NAFTA 1992, Articles 1115 – 1138). However, another form – “state-to-state” dispute settlement mechanisms – quickly thereafter emerged in the World Trade Organization’s multilateral treaty (TRIPS)³⁶ governing IP rights.

Moreover, in the NAFTA case during 2012-2013 this played out quite clearly in a case involving Eli Lilly wherein the American pharmaceutical company contested Canadian judicial

³⁵ On these developments, see Zuijdwijk (2018, especially 394-399); also Knopf (2018); Daley et al. (2020).

³⁶ TRIPS stands for Trade-Related Aspects of Intellectual Property Rights. See Knopf (2018), Zuijdwijk (2018); also WTO at https://www.wto.org/english/tratop_e/trips_e/trips_e.htm.

decisions – including that of the Supreme Court of Canada – regarding their claims. Nor was the issue of minor portent. Rather it turned on a central question of the “promise doctrine” established by Canadian courts – i.e., that a patent could be deemed invalid if not living up to its stated claims. Eli Lilly challenged the SCC decision, triggering the NAFTA dispute settlement clause and setting in a motion an arbitration panel that ruled on the matter. Significantly, the arbitration panel did not uphold the Eli Lilly’s claim of “arbitrariness or discrimination” but on the grounds that there was “no fundamental or dramatic change in Canadian patent law” (Knopf, 2018, 374). As legal scholars have observed this left the door open to future decisions that could have implications for Canadian courts, and jurisprudence – should there have been actions deemed to be precipitous in nature. Commenting on these international trends and the concomitant tendency in agreements to extend the provisions in bilateral or plurilateral agreements to treaties with more widespread membership, Zuijdewijk has insightfully concluded:

Thus, the international system promotes increasingly higher levels of protection of IP rights that countries such as Canada cannot, in practice, reverse. This raises serious questions ... and some are questioning *whether Canada has gone too far in setting levels of IP rights protection that may be at odds with its economic interests and desire to promote an innovation economy* (emphasis added (Zuijdewijk 2018, 399)).

Implications for the DNS Framework

In the end, then, to be distilled from this brief journey through Canada’s historical experience is the unique period from 1987 to 1993 lends itself quite readily to identifying federal policy initiatives and tracing their implications for R&D investment and innovation. Moreover, what it assembles is the means to contrast and compare with later government endeavours in this domain. Indeed, what it provides are the tools by which the DNS framework can be subjected to a rigorous analysis – and through which Campbell’s “quasi-experimental” methodology can be tested. Additionally, however, this telling of patent law and pharmaceuticals lays bare the

significant challenges that policy in this area must face -- and it in turn portends the challenges that federal policy, priorities and resourcing would encounter throughout the 2000s.

The 2000s: Changing Policy Direction

Priorities – Patents and Investment: A Weakened Link

In contrast with this previous era, the years through 2000 to 2020 did not witness any equivalent or even similar effort to forge a public commitment from pharmaceutical companies and especially MNEs to a specific level of R&D investment. If anything what these years starkly depict are not only the specific lack of any such entente, but also clearly declining trends in R&D investment, together with weakened policy assumptions about the linkage between hardened IP regimes and concomitant R&D expenditures. And, there are a number of markers which enable a policy read of these years vis à vis the pharmaceutical industry in the country.

For one, the Patented Medicine Prices Review Board (PMPRB) can be seen as the bellweather by which any such policy commitment or changes would be registered. As has been earlier noted – and flowing from the 1987 legislation that had enacted Bill C-22 -- the PMPRB mandate was specifically predicated on the “dual” pillars of regulation and reporting (PMPRB, *Annual Report 2019* <https://www.canada.ca/en/patented-medicine-prices-review/services/annual-reports.html>, 3).³⁷ It was specifically tasked with annually monitoring and regulating “excessive” price increases, including having an enforcement function that enables price rollbacks or even monetary penalties as deemed necessary. However, it was also responsible for tracking the R&D expenditures of all “patentees,” particularly in relation to the 1987

³⁷ This statement was repeated annually in the reports (PMPRB *Annual Reports 2003, 2004, 2005, 2006, 2007, 2008, 2009, 2010, 2011, 2012, 2014, 2015, 2016, 2017, 2018, 2019* <https://www.canada.ca/en/patented-medicine-prices-review/services/annual-reports.html>). Note that the *Annual Reports* do not bear a publication date, although generally there is a dated covering letter. Electronic versions of the reports are only available from 2003 onwards. Also note below that both the *Discussion Paper* (PMPRB 2016) and *Strategic Plan* (PMPRB 2015) do bear publication dates and are referenced as such.

commitment made by the pharmaceutical companies to attain R&D expenditures equal to ten per cent of their annual sales revenue by 1996. It is worth noting that no such similar commitment is registered anew in the Board's Annual Reports over the 2000s.

To be sure, the consumer protection mandate under which the Board operated was primary. As the PMPRB Acting Chairman indicated in the 2016 *Annual Report* on the event of the Board's thirtieth anniversary³⁸ and while acknowledging the dual functions of regulation and reporting, the Board was a "consumer protection agency" (PMPRB *Annual Report 2016* <https://www.canada.ca/en/patented-medicine-prices-review/services/annual-reports.html>, 1). So too in the *Guidelines Modernization Discussion Paper* was the genesis of the Board in 1987 depicted as the "consumer protection pillar of Bill C-22" (PMPRB 2016, 6). Moreover, this function was particularly reinforced by Canadian jurisprudence over the years, including by the Supreme Court of Canada in 2011 (PMPRB 2015, 25) and particularly by the Federal Court of Appeal in 2015 which held that "the construction of the language in the Act that relates to the PMPRB must focus on the persons in need of protection from excessive pricing (consumers) and not on those in a position to cause such pricing (patentees)" (PMPRB, 2015, 16). As for patentees, in that same ruling in November 2015 (*Canada (Attorney General) v. Sandoz Canada Inc.* [2015] FCA 249) the Federal Court found that "patentee" was to be interpreted broadly, including not "ownership of a patent" but equally those who might "exercise 'all rights in relation to a patent'" (*Ibid.*, s.18) – i.e., licensees -- and similarly upheld the interpretation that medicines included not just "name brand" companies but also "generics" (*Ibid.*, s. 17). Additionally, under the mantle of the Patent Act, the PMPRB monitored prices and costs of drugs, including on an international basis that involved six other countries deemed

³⁸ The Chairman's message was penned in September of 2017, thus the 30 years.

“comparators” for Canada – namely, the United States, Britain, France, Germany, Italy and Switzerland.

Despite the consumer-oriented focus, however, since 1988 the Board has dutifully tracked the R&D expenditures – again against the benchmark of the PMPRB seven -- on the ratio of R&D investment to sales.³⁹ Certainly it has been a task that has been extensively undertaken, breaking the data down by type of research, performer and regional concentration. On the ratio indicator, it further distinguishes the expenditures not just for those members of the Pharmaceutical Manufacturing Association of Canada who originally penned a commitment to the ten per cent goal but equally all “patentees.” (It is worth noting that PMAC later became known as Rx&D and, more recently, Innovative Medicines Canada). And what is clearly evident in the Board’s reports from 2003 onwards is a continuing, and steep, decline in R&D expenditures below the ten per cent threshold.⁴⁰

This development has given the Board pause. As early as 2009, the Board noted a disturbing countertrend wherein nations of comparative standing had achieved “R&D-to-sales ratios well above those in Canada despite patented drug prices that are on average not substantially higher (or even less) than prices in this country,” particularly singling out France as such an example.⁴¹ By 2012, however, the argument was more pointed and the assumed policy linkage between lower prices and higher levels of investment was openly contested and “questioned” (PMPRB 2012, 45). By 2016, the Board opined that Bill C-22 had been predicated on the view that “patent protection and price were key drivers of pharmaceutical R&D

³⁹ See PMPRB *Annual Reports 2003, 2004, 2005, 2006, 2007, 2008, 2009, 2010, 2011, 2012, 2013, 2014, 2015, 2016, 2017, 2018, 2019* (<https://www.canada.ca/en/patented-medicine-prices-review/services/annual-reports.html>).

⁴⁰ These trends will be discussed at greater length below, see especially Figure 1.

⁴¹ PMPRB *Annual Report 2009* (<https://www.canada.ca/en/patented-medicine-prices-review/services/annual-reports.html>, 42).

investment” and thus a “choice” determined on the “assumption that Canada would come to enjoy comparable levels of R&D” to countries with a vibrant pharmaceutical environs and associated R&D (PMPRB 2016, 6). But, in the face of mounting evidence to the contrary, this assumption had now begun to fray:

The coupling of high Canadian patented drug prices and record low investment in R&D has many questioning the effectiveness of the PMPRB in meeting the government’s 1987 policy objectives (*Ibid.*).⁴²

And while this perspective may pivot more around unfettered conscious policy choice; and while this rendering may not be as inclusive of the circumstances regarding a hardening international IP regime in tandem with Canada’s free trade negotiations and the particularly competitive pressures the country was under at the time, nevertheless it underscores the clear challenges pharma R&D was encountering. Such hindsight vision aside, however, the Board’s mandate both in its original incarnation and as it has evolved did not extend beyond reporting on R&D and policy-wise the issue, for them at least, has been left there. Rather the Board has focused, via its *Discussion Paper* (PMPRB 2016) and associated consultations as well as its *Strategic Plan* (PMPRB 2015), on reasserting its consumer mandate and acting as a counterweight to “excessive” pharmaceutical costs.

Akin to the PMPRB reporting, neither do Government of Canada and particularly ISED documents register evidence of an industry-government entente akin to that of the earlier era.⁴³

⁴² See also PMPRB *Annual Report 2019* (<https://www.canada.ca/en/patented-medicine-prices-review/services/annual-reports.html>, 69).

⁴³ With respect to ISED documentation, see in particular on clinical trials in Canada https://www.ic.gc.ca/eic/site/lsg-pdsv.nsf/eng/h_hn01774.html; on clinical trials and manufacturing https://www.ic.gc.ca/eic/site/lsg-pdsv.nsf/eng/h_hn01779.html ; on the Canadian “pharmaceutical industry profile” https://www.ic.gc.ca/eic/site/lsg-pdsv.nsf/eng/h_hn01703.html; on Canada as “an increasing part of the global pharmaceutical value chain,” https://www.ic.gc.ca/eic/site/lsg-pdsv.nsf/eng/h_hn01777.html; on “academic-industry collaboration in the commercialization of health research” https://www.ic.gc.ca/eic/site/lsg-pdsv.nsf/eng/h_hn01724.html and finally the report on *Canada’s Pharmaceutical Industry and Prospects*, ISED (2013).

Albeit somewhat dated documentation at times, definitely acknowledged are the global forces “transforming” (IC 2013, 5) the industry. The slowing sales growth and onset of genericization in pharmaceutical products; the shift away from more saturated traditional markets to emerging ones, especially in India, Brazil and China; a diminishing pipeline of productivity for new medicines and therapies: all are duly identified as causal factors impacting pharmaceuticals and R&D expenditures in particular.⁴⁴ So too – and especially – is the onset of the “patent cliff” (*Ibid.*, 19) from 2007 onwards as blockbuster drugs reach the end of their exclusivity but are not “offset” (*Ibid.*, 14)⁴⁵ by revenues flowing in from the more specialty and “niche” markets that have developed. As for the Canadian situation, this too is singled out for special attention. The limited number of Canadian headquartered MNEs; the shallow nature of the Canadian market for pharmaceuticals; the impacts of mergers and acquisition as consolidation has diminished the pharmaceutical industry in Québec (and especially Montreal) and Ontario: it is recognized that “declining R&D activities in Canada by global MNEs has weakened the research environment” (*Ibid.*, 27). Certainly, the tepid nature of the Canadian venture capital market at that time was noted but so too were “most” MNEs “spend[ing] less than 1% of their global R&D investment in Canada” (*Ibid.*, 16). Such impacts registered, however, there is a notable absence of reference to the more ambitious ten per cent goal of R&D to sales that an earlier era had witnessed.

As for strongholds in the Canadian industry, the SWOT⁴⁶ analysis undertaken by the government as well as other documentation highlight the thriving state of Canada’s biopharma and biotechnology industry centred admittedly as it is around SMEs (*Ibid.*;

https://www.ic.gc.ca/eic/site/lsg-pdsv.nsf/eng/h_hn01702.html; <https://www.ic.gc.ca/eic/site/lsg->

⁴⁴ See on these aspects as well as the specific Canadian situation noted below, the seminal discussion in ISED (2013).

⁴⁵ The exact word used is “offsetting.”

⁴⁶ SWOT stands for Strengths, Weaknesses, Opportunities, Threats.

[pdsv.nsf/eng/h_hn01728.html](https://www.ic.gc.ca/eic/site/lsg-pdsv.nsf/eng/h_hn01728.html); https://www.ic.gc.ca/eic/site/lsg-pdsv.nsf/eng/h_hn01772.html).

As well the robust clinical trials infrastructure and supporting research expertise that Canada has in place is duly referenced, Canada attracting four per cent of global clinical trials by 2016

(https://www.ic.gc.ca/eic/site/lsg-pdsv.nsf/eng/h_hn01774.html;

https://www.ic.gc.ca/eic/site/lsg-pdsv.nsf/eng/h_hn01779.html), as is an extensive ecosystem of networks and partnerships (<https://www.ic.gc.ca/eic/site/lsg-pdsv.nsf/eng/home>;⁴⁷

https://www.ic.gc.ca/eic/site/lsg-pdsv.nsf/eng/h_hn01724.html).

That noted, however the “challenges” around Canada’s research environs are clearly distinguished in government analysis of the industry and the barriers it faces. Yet when it comes to facing down such impediments the policy efforts at least in the documentation available fall somewhat short. There is the claim that “an increase in government policy supporting R&D *may* further strengthen Canada’s expertise in niche areas within biologics and oncology (IC 2013, 26; emphasis added)” and the traditional go-to approach of regulatory streamlining and competitive investment environs twinned with patent protection for incenting foreign investment are indicated. But beyond these rather narrow and traditional pathways, it is clear that the onus also specifically rests on industry and the Canadian offshoots of multinationals to devise the “strategies” that can garner a “bigger share of the investment pie” (*Ibid.*, 24). It is up to industry to wrestle down these issues. In short, not only is there no evidence of forging an accord with industry to secure higher levels of R&D investment through these decades of the 2000s but neither is there evidence of one in the making.

It is worth noting as Niosi, with Bas and Zhegu, have pointed out, there was consideration given to mandating the new Canadian Institutes of Health Research with R&D

⁴⁷ See the overview on this home page for “Canadian life science industries.”

objectives. Specifically, there was the suggestion the CIHR would focus on “doubl[ing] pharmaceutical R&D from C\$800million/year to C\$1.6 billion/year” (Niosi, with Bas and Zhegu 2014, 45). However, as RESEARCH MONEY at the time indicated (and to which Niosi, with Bas and Zhegu refer) these objectives were harboured in a discussion paper (26 May 1999). There is no evidence that the goal was embedded in the actual authorities given to the CIHR. A close review of the governing legislation for the CIHR, as well as Public Accounts and Departmental Performance Reports describing the mandate of the CIHR at the time, gives no reference to this objective; nor do these documents indicate that this “target” was every acted upon.⁴⁸

Finally, before moving on to the resourcing initiatives that did surface in Budgets around genomics and NCE over the aughts, it is important to acknowledge the work of the Economic Strategy Table on Health and Biosciences (Canada’s EST 2018f). Certainly, the Table has set an ambitious agenda, particularly carving out the urgent need for late-stage venture capital that can build Canadian “anchor” firms and ensure the move to commercialization, and arguing as well for a broadened SR&ED that can enable access by companies in Canada that have majority foreign ownership. So too do they claim for an “agile” regulatory environment that can harmonize federal/provincial/ territorial assessment regimes and diminish wait times for products entering the market, as well as more expansive procurement efforts that recognize innovation and “value” and not just lowest price. As with the other Tables, they also set extremely ambitious objectives, targeting a doubling of growth in the health and biosciences sector by 2025 (*Ibid.* 2-3). Yet, if we are to leverage this case study to ultimately to test the innovation indicators across

⁴⁸ See the discussion in Chapter Six on the Canadian Institutes of Health Research under “Critical Federal Players” for the governing legislation and relevant Departmental Performance Reports. For Public Accounts, see Receiver General 2001 and 2002.

the 2000s against those of the nineties and the policy efforts vested therein, here too no reference to ensuring R&D through public commitments by the industry surfaces.

Targeted Resourcing: The Legacy, the Gaps

The Canadian Biotechnology Strategy: Import and Consequences

In concert with these findings, similarly does an extensive review of targeted resourcing -- specifically all Budget documents from 1999 through to 2021⁴⁹ -- fail to yield evidence of any such new policy endeavour, akin to 1987, that would have evoked a commitment by pharmaceutical companies to renewed R&D expenditures in Canada. Rather what these years depicted were policy initiatives on pharma that tended to coalesce around two goals: strengthening the biotechnology and biopharmaceutical industry in Canada and creating Networks of Centres of Excellence and, for a rather limited time period, Centres of Excellence for Commercialization and Research and “Business-Led” initiatives.

With respect to biotechnology, it is important to note that this focus by the federal government did not emerge suddenly on the policy scene. As early as 1983 the federal government had forged the National Biotechnology Strategy (NBS) (IC 1998, 4; Canada 2003, 2-3). Admittedly this initial version of the Strategy revolved around a rudimentary “industrial development” approach (Canada, CBAC 2006, 8) primarily focused on R&D and complementary HR requirements (IC 1998, 4). However, it was also an early recognition of the transformational capacity of biotech and the need to accelerate Canada’s efforts in this regard. By the late nineties in the face of the “revolution” that biotech as a potent “enabling technology” was ushering in, the extensive markets and wealth it could generate and public concerns around associated ethical and safety issues, the Minister of Industry – Minister Manley -- was

⁴⁹ See “Methodological Note” in Annex A - 9.

commissioned to update and revamp the NBS as necessary. A Task Force was duly struck in 1997 to undertake the necessary consultations and work and by 1998 the new Canadian Biotechnology Strategy (CBS) had been launched. So too did Minister Manley mandate the National Biotechnology Advisory Committee (NBAC) at the time to provide a “report card” on the state of the sector and the international context in which it was operating.⁵⁰

To be sure, the NBAC Report of 1998 – *Leading in the next millennium* (IC, NBAC 1998) – and one which fed into the broader consultations developing around the CBS struck a visionary chord. In looking back on this document, its projected path for a cohesive and “coherent” national policy on biotech is quite striking in this regard. Likening the revolutionary nature of biotech as being akin to the “internal combustion engine and electricity” of the twentieth century, the Advisory Committee advocated for Canada positioning itself as the “number three global player” in biotech markets, a target that would necessitate achieving \$5 billion in sales” by 2005 (*Ibid.*, 1-2). Further this would be dependent on significantly increasing R&D, in fact “ratios of R&D to revenue” (*Ibid.*, 11) to align with global comparators. And it specifically articulated a five-point strategy to get there. It called upon the federal government to demonstrate “political” leadership – indeed “championship” (*Ibid.*, 11) in taking Canada into the next “millennium” – a role that would fall under the mantle of Industry Canada. It advocated for a concerted “commercialization” thrust to achieve this undertaking, one which would necessitate measures to attract the talent, create the funding (including venture capital) and establish the tax environment that would enable such competitiveness (*Ibid.*, 2-3 and especially 12-23). Further, while it argued for the pivot to commercialization and international ranking in capturing the biotech market, it did recommend the strategic “reinforcement of

⁵⁰ On this history, see Canada (2003) and IC NBAC (1998).

Canada's science and technology base" (*Ibid.*, 3) particularly so for the "genomic sciences" so key to biotechnology. It additionally noted the import of patent protection aligned with international "standards" and a regulatory regime both "transparent" and efficient (*Ibid.*, 3, 46-59) which could undergird the growth of the sector. Finally, it recommended federal engagement with stakeholders – governments, industry, academe and citizens alike – both to wrestle with the risks of biotech as well as to enhance national understanding and "awareness" of the issues at play (*Ibid.*, 60-69). In all, the National Biotechnology Advisory Committee essentially laid out the policy framework that could transport the industry into the new century.

Certainly, the Canadian Biotechnology Strategy when it rolled out did leverage some of these elements although it was a slightly more tempered affair. Turning on the notion of Canada being a "responsible world leader in biotechnology" and echoing many of the themes of NBAC, it too enunciated the need for public "dialogue," an innovation agenda predicated on a "scientific base," critical "investments in R&D" and the necessary accompanying regulatory regime (IC 1998, especially 8-9). And it was to create a holistic enterprise that could reap the benefits of biotech from a social, economic, and environmental perspective. Moreover, budgets soon followed in quick succession that did target significant resources towards these goals.

Budget 1999 saw investments in biotech R&D to be deployed by the federal government (Finance Canada 1999, 111) and, most critically, Budget 2000 launched Genome Canada with an initial endowment of \$160 million (Finance Canada 2000, 15 and 111). Taking a page from the NBAC 1998 report, "[g]enomic science" was deemed critical to realizing the full potential of biotechnology and the economic impact which this could have (*Ibid.*, 111).⁵¹ Funding was thus duly dedicated to establishing five regional centres across the country and enabling much more

⁵¹ As Budget 2000 stated "Biotechnology is poised to be a major engine of the new economy and is expanding our understanding of all living organisms" (*Ibid.* 111).

expansive research initiatives leveraging the investments to date from academe, industry as well as provincial governments. Moreover, scientists and innovators would be able to access the cutting-edge “technologies” to facilitate and rapidly advance their work. By Budget 2004 funding of Genome Canada had climbed to \$375 million (Finance Canada 2004, 136) and by fiscal year 2005-2006 the government had injected another \$225 million into the newly created organization (Figure 2). Genomics itself was heralded as nothing less than “a breakthrough discipline ... poised to transform the landscape of the 21st century” (Finance Canada 2004, 136).

So too was this endeavour accompanied in Budget 2004 by increased venture capital financing and more accessible tax credits. \$250 million would flow through the Business Development Bank of Canada (BDC) to support the “start-up and early-stage” needs of companies directly engaged in enabling technologies such as biotech and the life sciences generally (Finance Canada 2004, 142). Further among a host of other tax initiatives intended to foster growth and scale-up of innovating SMEs, there would be enhanced “access” to SR&ED (*Ibid.*, 144-147). Indeed, what was featured were type of types of initiatives that NBAC had previously targeted for biotech companies with long R&D cycles (before profitability) and with attendant vulnerability to acquisition at these more precarious early stages of development (IC, NBAC 1998, 16-23).

True by 2006 some of this shine had worn off. Certainly, Genome Canada has continued to receive funding with a total of almost \$1.3 billion invested from its genesis in 1999-2000 to fiscal year 2019-2020 (Figure 2).⁵² However, the 2006 *Action Agenda* articulated by the Canadian Biotechnology Advisory Committee (created in the wake of 1998 and the CBS) and

⁵² Figure 2 is based on Public Accounts numbers. It should be noted that the most recent report by Genome Canada indicates that it has received \$1.6 billion to date (https://www.genomecanada.ca/sites/default/files/gc_ar2021.en-web.pdf, 5; <https://www.genomecanada.ca/en/20-years-collaborating-future>, 3).

which called for a more tightly integrated “national policy” with specific and “measurable” results appears to have been left unattended by the federal authorities (Canada CBAC 2006). The Committee itself openly indicated that their efforts to engage the government back in December of 2004 had failed to achieve results and they in turn had decided to forge ahead with the much-needed reboot they felt the 1998 Canadian Biotechnology Strategy required (*Ibid.*, 5).

Interestingly, the current references to the CBS on the government’s website (while acknowledging the historical context) do speak of the Strategy still in the present tense.⁵³ Nonetheless there are no further Annual Reports by the Canadian Biotechnology Advisory Committee following 2006 and following the *Action Agenda* of that year as well. Even a complete review of Budget documents through to 2019 does not offer much in the way of a biotech focus. After 2005, the next aspects featured are in 2012 with the creation of a “Canadian Technology Accelerator” as part of the government’s commercialization thrust and intended to introduce growing Canadian firms to American markets and venture capital (Finance Canada 2012, 63; also I20.) As for Budget 2013 it simply and briefly indicates a training initiative – specifically internships – for the biotech field (Finance Canada 2013, 76). And at least until Budget 2021 it is unclear that the federal policy focus on biotech has been driven to the same extent, and with the same regard for action initiatives, as in the past.

Notably IP has been a partial exception to this trend. In 2013 Industry Canada did issue a paper (penned by Torys LLP) on “International Patent Strategies for Biopharmaceutical Small and Medium-sized Enterprises (SMEs) in Canada” cautioning smaller firms to build a “robust patent portfolio” and to align with MNEs eager to leverage new pharmaceuticals that inject

⁵³ See for example, “the CBS operates within a policy framework which has defined the following objectives and principles: ... or similarly “The CBS is managed through an infrastructure of federal committees and supported by the Canadian Biotechnology Secretariat” (<https://www.canada.ca/en/health-canada/services/science-research/emerging-technology/biotechnology/role/canada-biotechnology-strategy.html>).

innovation and raise productivity as well (IC Torys 2013) Moreover, latter years have seen a federal IP Strategy in 2018 which focuses also on the import of strategic patent efforts on the part of SMEs, as well as taking aim at the practice of “trolls” who seek damages with baseless claims of patent infringement (Gallini and Hollis 2019, 33-38). The recent Canada-United States-Mexico Agreement as well as the Canadian-European Trade Agreement have also extended patent protection for certain pharmaceuticals (*Ibid.*, ff 55).

Despite the noticeable gaps in policy over the latter part of the 2000s (and of course up until 2020/21), biotechnology as a sector has continued to thrive. According to BIOTECCanada the national industry association, the sector is replete with a vibrant “ecosystem” of “approximately 900” biotech firms (BIOTECCanada <http://www.biotech.ca/wp-content/uploads/2020/10/solving-for-today-building-for-tomorrow.pdf>, 8) with the industry spanning medical and biopharmaceuticals, forestry, agriculture and agri-food and environmental technologies. Moreover, according to ISED, the biopharmaceutical component of the industry lays claim to 158 Canadian companies (https://www.ic.gc.ca/eic/site/lsg-pdsv.nsf/eng/h_hn01728.html) – albeit small or medium-sized and thus not “anchor” firms.

So too has Genome Canada excelled in its endeavours, now with six regional centres (Alberta now separate from the original Prairie component) and providing access to ten technology platforms such as proteomics and computational genomics (<https://www.genomecanada.ca/en/about/technology-platforms>). A 2015 Industry Canada evaluation of the organization found that it was aligned with the priorities of the government of the day, was exceeding its leveraging objectives with regard to federal monies, had attracted significant provincial funding of the various regional centres, had ably nurtured genomics research talent and had advanced “the breadth and depth of knowledge in genomics” (IC 2015,

13). In short, in the more prosaic language of government evaluations, it was “achieving its expected results” (*Ibid.*, ii). And while it still found certain gaps with respect to the commercialization thrust on the part of Genome Canada, it should be added in all fairness the non-profit had only launched its applied research competition in 2012 as part of the broader commercialization effort on the part of the Harper administration. It is worth underlining as well that the evaluation found that Genome Canada was positioned “within the top five countries in the world” in terms of its publications (*Ibid.*, 15-16).

Similarly Doern, Castle and Phillips (2016) in their quite sweeping analysis of “science, technology and innovation” and associated policy domains have underlined the positive role which Genome Canada has played, although they too sound a cautionary note about its commercialization impacts. Admittedly, they do approach the agency more in terms of its institutional machinery and the types of funding grants which it has been allocated but they clearly conclude that it has played an “integrative”⁵⁴ role in research, forging partnerships both on a national and international scale. It has in fact been an activist force “exerting leadership in the genomics space” (*Ibid.*, 306).

As for the organization’s endeavours a half-decade later, Genome Canada has managed to parlay federal funding into a “1:1.4” ratio (https://www.genomecanada.ca/sites/default/files/gc_ar2021.en-web.pdf, 26). It is currently leading a national effort (partnering with Britain) of genomic “sequencing” in relation to the COVID-19 virus (*Ibid.*, 6, 8-9). And, not unlike AI, it has recently in Budget 2021 been the recipient of \$400 million for a Pan-Canadian Genomics Strategy with monies deemed to flow in 2022-23 (Finance Canada 2021,150).

⁵⁴ The exact word used is “integrator” *Ibid.*, 306.

With respect to genomics in particular there is a remarkable similarity to the AI case study. A policy impetus and targeted funding in place over the “longue durée;” a scientific prowess grounded in historic roots⁵⁵ (and some would suggest as far back as Banting and Best); fulsome engagement by academe and provincial governments: these have been mainstays in the genomics case as well. As for industry representation, certainly there has been private sector participation, albeit less so than in the AI case with the seminal participation of SPAR Aerospace in the genesis of the Canadian Institute for Advanced Research. Nevertheless, this too has benefited from the federal resourcing, attendant policy framework and rich ecosystem that has generated international recognition.

With respect to biotechnology more generally, this also has been nourished particularly in the early part of this century by government largesse and a concerted strategic focus on the sector. That there has been a more tepid federal policy effort from 2006 onwards has seemingly not diminished the growth of biotechnology firms, although clearly the industry still lacks the large MNEs presence that can support commercialization and augment the investment in R&D. Certainly, if the IC report on this issue (IC Torys 2013) is any indication, the federal orientation was to prepare such Canadian SMEs with the IP savvy to align with large multi-national companies, thus feeding the innovation pipeline that has been diminished (by among other factors) the so-called patent cliff. Of course, what all of this speaks to in the context of the DNS framework is the import of early policy engagement – and a sustained and durable – presence following. That the federal policy around biotech does present such lacuna and that the Canadian Biotechnology Strategy lacked the reinvigorated update for which that CBAC had

⁵⁵ It is worth noting, as Budget 2001 pointed out in flowing \$10 million of funding to advance the work of genomics in cancer treatments, that Dr. Michael Smith of the BC Cancer Research Centre was awarded the Nobel Prize in 1993 for “his work on DNA sequencing” (Finance Canada 2001, 116).

advocated did create vulnerabilities – vulnerabilities which became particularly pronounced with the onset of the pandemic in March of 2020.

Shifting Sands: Triadic Linkages and NCEs

With respect to the federal policy effort to thicken triadic linkages creating innovation ecosystems that surfaced throughout these years, these are best viewed through the lens of the Networks of Centres of Excellence (NCE) program and particularly its two important spin-offs -- the Centres of Excellence for Commercialization and Research (CECR) and the similarly-focused Business-Led Networks of Centres of Excellence (BL-NCE). Articulated in the economic planning document of the new Harper administration, *Advantage Canada*, these entities were to take a more “rigorous” and “systematic” (Finance Canada 2006a, 60) approach to the issues around commercialization, ensuring projects were vetted for innovation potential, strengthened collaboration between industry and academe and that a healthy dose of competition informed the screening process. And the initiatives were to align with the priorities that had been presented in the government’s *Mobilizing agenda* (IC 2007b), including those around the health and life sciences sector. The programs were duly launched in Budget 2007 (as seen in Chapter Five), the new networks being mandated to “bridge the gap” between invention and market ⁵⁶– specifically via the CECRs – but also to drive an agenda centring on industry “needs” (Finance Canada 2006, 62) and “real-world challenges” – via the BL-NCEs (https://www.nce-rce.gc.ca/_docs/NetworksCentres-CentresReseaux/BLNCE-RCEE_eng.pdf). With respect to program life, the CECRs operated on a typical five -year cycle (NCE 2017, 1) although the BLs were on a tightened length of four years (PMN 2012, iv). What surfaces strongly in this effort

⁵⁶ The exact words used to describe CECRs were “to bridge the innovation gap from Canada’s world-class researchers to the marketplace” (https://www.nce-rce.gc.ca/_docs/NetworksCentres-CentresReseaux/CECR_eng.pdf).

however are two competing trends: the relatively robust ventures these programs brought to the fore including for the health and life sciences sector *and* the essentially short-lived duration of these programs.

Evaluations of the CECR and BL-NCE Programs were undertaken in 2017 (NCE 2017) and 2012 (PMN 2012)⁵⁷ respectively, with the Programs on track in meeting their objectives. The Centres – four in the case of the BLs and twenty-nine in case of the CECR -- were evaluated against the usual types of indicators and were found to be aligned with Government of Canada and specifically NCE program priorities. Moreover, they were fulfilling critical roles, the CECR occupying an important commercialization “niche” held by “few other federal” efforts (NCE 2017, vi) and offering up agility in terms of different design models. Depending on the CECR network, their business model could support collaborations that spanned the full innovation spectrum or concentrate on particular areas such as those closer to start-up or the last stages to market. Interestingly those occupying the full spectrum – the “commercialization arm” – networks were especially located within the health and life sciences sector. As for the BL-NCEs, they too were positioned strategically, assisting companies to make the important leap from “proof of concept” to “product development” (PMN 2012, iii). Further, the programs were operating efficiently, with the Commercialization and Research Networks particularly lean with an administrative overhead of only five per cent. For the BLs, the evaluation did note the slower rollout with which these entities had wrestled as they came to grips with various IP agreements among the participants. Still, it was anticipated this was well “behind” them and the BLs were definitely “meeting the needs of network members” (*Ibid.*, iv-v).

⁵⁷ See in particular the Executive Summaries NCE 2017, iv – vii and PMN 2012, i-viii.

Moreover, the Centres were having positive impacts. The CECR especially was found to have created an environment where network-supported companies were outpacing non-affiliated companies in terms of expansion in sales, hires and, most importantly for our purposes here, R&D investments (NCE 2017 vi). The Evaluation does register the challenges in assigning direct outcomes but notes that econometric modelling was employed to measure impacts on companies affiliated with the CECRs and (essentially a control group of) those who were not. As for the BL-NCEs, given the length of time in operation, they too were enabling the tech transfers and “mobilization” of research so critical to the program and indeed to the government’s overall agenda at the time, although it was acknowledged that further assessments of longer duration would be needed.

Leveraging of outside and especially private sector resources was also a strong suit, with the CECRs managing a 1:2.30 ratio (i.e., pulling in \$2.30 for every federal dollar received) and the BL networks also surpassing the usual stipulation for bringing in equivalent dollars to the federal funding (see NCE 201, vi). To be sure, as with most evaluations, certain issues do surface. It was felt that the CECRs, in their efforts to reach an autonomous and “self-sustaining” model, were not tending sufficiently to academic-industry collaboration and concentrating more on private inter-sector initiatives – a tendency that would require tracking. Further there needed to be strengthened engagement with provincial innovation and specifically “commercialization” ventures. As for the BLs, it was acknowledged the logic model and performance measurement strategy allocated to them put too much undue emphasis on publications and not enough on “technology readiness levels.” This too would require refinement but on the part of government. Yet overall, the evaluations were remarkably sanguine in their assessments and in fact in both

cases the evaluation reports recommended that the government continue “to deliver” the networks (NCE 2017, vi; PMN, vii), giving them the time and space to realize their full potential.

That said, however, this in fact was not to be. As seen in Chapter Five, the CECRs and BL-NCEs were rolled up in Budget 2018 and now were to be located -- in what form it was not clear – within ISED’s Strategic Innovation Fund. Specifically, “consolidation” was to occur (https://www.nce-rce.gc.ca/Programs-Programmes/CECR-CECR/Index_eng.asp). Tables 1 and 2 provide a list of the CECRs and BLs in the health and life sciences sector, including funding, duration and location and, as can be seen, 13 of the 15 CECRs and one of the two BLs, will have been wrapped up or will have been terminated by the end of 2021. Moreover, this has included Accel-Rx which has in its own words has operated to assemble “critical mass,” operating to integrate the efforts of seven other Centres. Further leverage here has been quite exceptional with Accel-Rx drawing in \$8.90 for every federal dollar received or in aggregate terms \$44.6 million for the \$5 million federal dollars spent (https://www.nce-rce.gc.ca/NetworksCentres-CentresReseaux/PreviouslyFunded-FinancesAnterieurement/CECR-CECR/AccelRx_eng.asp). Moreover, relative to results, the Centres have by no means been a funding sink, with in fact only \$306.3 million expended on the CECRs in the health and life sciences sector and with \$52.2 million expended on the BL-NCEs, a sum of just over \$350 million (\$358.5) in total.

In all then what defines the experiments with the Centres of Excellence for Commercialization and Research and the Business-Led ones as well is not that they were not successful. Rather it is the rather narrow timelines they were given to succeed and reach their full potential when taken in the context of overall funding over the last two decades. Indeed,

remarkably, some of the Centres forged international alliances as with Germany,⁵⁸ as well as partnerships and funding from critical MNEs, including AstraZeneca, Pfizer, Johnson & Johnson and Eli Lilly.⁵⁹ Further they assembled both up-front early capital for growing companies and access to major research infrastructure,⁶⁰ as well as in many cases generating viable company spin-offs. Lastly, as a review of the Centres in Table 1 indicates and a somewhat deeper dive as well into their missions, at least five of the Centres (C3i, CDRD, CCAB, IRICoR, PREVENT) were involved with development of antibodies and therapeutics, immunology and/or vaccines, including a “pan-provincial vaccine” effort.⁶¹ It is then particularly germane to the policy durability issue in the Canadian context that these efforts had been or were about to be suspended just as the pandemic -- and the ensuing criticality of R&D in pharmaceuticals -- hit.

It should be noted in concluding this section that Figure 2 also provides a tally of critical federal investments in Health and Life Sciences R&D over the period from 1999-2000 to the 2019-2020. Certainly, it is a worthy investment: just over \$20 billion in total during this period. But what is striking about the Figure, apart from the Canadian Institutes of Health Research and Genome Canada, is the general absence of continuity in funding.⁶² Akin to the pattern with the

⁵⁸ See https://www.nce-rce.gc.ca/NetworksCentres-CentresReseaux/PreviouslyFunded-FinancesAnterieurement/BLNCE-RCEE/CQDM_eng.asp.

⁵⁹ *Ibid.*; https://www.nce-rce.gc.ca/NetworksCentres-CentresReseaux/CECR-CECR/CDRD-CRDM_eng.asp; https://www.nce-rce.gc.ca/NetworksCentres-CentresReseaux/PreviouslyFunded-FinancesAnterieurement/CECR-CECR/NEOMED_eng.asp.

⁶⁰ See https://www.nce-rce.gc.ca/NetworksCentres-CentresReseaux/CECR-CECR/CCRM_eng.asp.

⁶¹ See in particular: https://www.nce-rce.gc.ca/NetworksCentres-CentresReseaux/CECR-CECR/CDRD-CRDM_eng.asp; https://www.nce-rce.gc.ca/NetworksCentres-CentresReseaux/PreviouslyFunded-FinancesAnterieurement/CECR-CECR/C3i_eng.asp; https://www.nce-rce.gc.ca/NetworksCentres-CentresReseaux/PreviouslyFunded-FinancesAnterieurement/CECR-CECR/CCAB_eng.asp; https://www.nce-rce.gc.ca/NetworksCentres-CentresReseaux/CECR-CECR/IRICoR2_eng.asp; https://www.nce-rce.gc.ca/_docs/NetworksCentres-CentresReseaux/CECR-CECR/PREVENT_eng.pdf; https://www.nce-rce.gc.ca/NetworksCentres-CentresReseaux/PreviouslyFunded-FinancesAnterieurement/CECR-CECR/NEOMED_eng.asp. It needs to be indicated this review is still just based on a review of what is on the NCE websites and does not speak to any medical knowledge; as such this is not intended to be an exhaustive list.

⁶² There is an interesting anomaly with the review of the Public Accounts – particularly in light of the decision by the federal government to fund the University of Saskatchewan Vaccine and Infectious Disease Organization – International Vaccine Centre as indicated in Table 3. Public Accounts for 2010-2011 show an entry for the Centre’s

CERCs and BL-NCEs, here too is displayed a rather intermittent pattern of targeted resourcing and affinity for sustained policy endurance related to pharmaceuticals.

Innovation Indicators

As indicated in the methodological chapter at the outset of this research, the intent behind the case studies was to benchmark federal policy initiatives against innovation indicators – particularly with respect to R&D investment and patents, sampling frequent time periods for this type of inquiry. As earlier noted as well, this type of “quasi-experimental” approach (Campbell 1969 and Cook and Campbell 1986) enables the capacity to draw conclusions regarding impacts of federal policy on innovation, specifically using three pillars in our theoretical framework – policy durability, “targeted” resourcing and thickened networks. While Campbell does argue for “separate samples of time” given that the more pristine environment of labs is not possible for pulling out correlations, in fact this research has gone a step beyond. In several cases, given both OECD and PMPRB data, it is possible to track indicators on an annual basis at times back to the genesis of policy/resourcing initiatives in the 1987-1988 period.

The most telling indicator of course is the R&D expenditures-to-sales ratio which PMPRB meticulously tracked following the 1987 enactment of Bill C-22 and the ancillary entente between the federal government and the Pharmaceutical Manufacturers Association of Canada. As will be recalled, the latter set the objective at attaining a ratio of ten per cent by 1996. The data is reproduced in Figure 1⁶³ and, as the graph indicates, there is a noticeable

Biosafety Level II Containment Facility of \$571,228 under Western Economic Diversification transfer payments but equally this is then essentially taken off the ledger under “adjustments, warrants and transfers.” As a result no entry is provided for authorities used in the current year. A close review of Public Accounts over the period from 1999-2000 to 2019-2020 shows no similar entry related to the University’s Centre. Had there been, it would have indicated some continuity in the funding. It should be noted however that the Vaccine and Infectious Disease Organization in Saskatoon (presumably the University of Saskatchewan one) is an important participant in the Pan-Provincial Vaccine Enterprise CERC.

⁶³ Unless otherwise specified, all Figures and Tables referenced in this chapter are located in Annex A – 9.

upward swing in the ratio in the early years as PMAC honoured their commitment. True, there is a slight discrepancy between the trend lines of “all patentees” and what is now called Innovative Medicines Canada (IMC) (previously the Pharmaceutical Manufacturers Association of Canada between 1965 and 1999 and thereafter Rx&D until 2015). And while all patentees do modestly outpace IMC from 1989 to 1992 then IMC gains more ground and generally maintains a small edge or equivalency until 2019.

More critically, however, what the ratios depict is a strong upward trend in the early years, with all patentees and IMC reaching 10.6 per cent and 10.7 per cent respectively by 1993, three years earlier than had been anticipated, with both groups then peaking in the year 1997. Thereafter the ratios almost consecutively fall off, hitting the nadir of 3.9 per cent – again for both groups – by 2019 and which in fact is well below the figures for 1988. Interestingly, the effects of policy appear to be felt well into the early 2000s with relatively robust figures for the R&D-to-sales ratios, but as policy initiatives become more muted or intermittent, there is visible continuing decline. Moreover, there is a particularly noticeable descent during the 2011-2013 period ⁶⁴-- a period in which there was a strong contraction and consolidation within the industry and particularly so in the Canadian context (see IC 2013, 16-17). Further these impacts were particularly felt in Québec and Ontario where the industry was primarily concentrated, annual increases in R&D expenditures dropping “by 13.8%” in Québec and “8.5%” in Ontario over the 2011-2012 period (PMPRB *Annual Report 2012* <https://www.canada.ca/en/patented-medicine-prices-review/services/annual-reports.html>, 45).

⁶⁴ Ratios for all patentees fell 18.8 per cent between 2010 and 2011 and again declined 15.4 per cent between 2012 and 2013 (author’s calculations based on Figure 1). PMPRB also highlights that total R&D expenditures for all patentees dropped 15.9 per cent between 2012 and 2013 (PMPRB *Annual Report 2013* <https://www.canada.ca/en/patented-medicine-prices-review/services/annual-reports.html>, 33).

As for Canada's performance vis-à-vis its global competitors, these figures also provide compelling evidence of similar trends. Canada, relative to the six other nations PMPRB had selected for international pharmaceutical comparisons, had always registered poorly on the ratio indicator, from 2000 to 2010⁶⁵ being the second lowest in this grouping (with only Italy having a lower standing). By 2011 however the tide had shifted, and Canada now stood on the lowest rung of this national grouping, a position which it has continued to hold up to 2017 when the latest data was available. While in 2010 the "aggregate" ratio for "all seven comparator countries was 22.5%, three and a half times" (PMPRB *Annual Report 2010* <https://www.canada.ca/en/patented-medicine-prices-review/services/annual-reports.html>, 45) that of Canada, two years later this gap had widened further. By 2017, the "PMPRB7" grouping, as the Board called it, now registered an aggregate R&D-to-sales ratio "**six times**" that of Canada (PMPRB *Annual Report 2019* <https://www.canada.ca/en/patented-medicine-prices-review/services/annual-reports.html>, 69). As for Switzerland the leading nation in this category, it has stood consistently above 100 per cent, in 2017 holding a ratio of 116.3 per cent -- a stark contrast to the 4.1 per cent number registered by all Canadian patentees in that year (*Ibid.*, 69).

Similarly are these trends pronounced in the OECD's historical BERD data for the pharmaceutical industry. As Figure 3 indicates, and which traces the percentage of BERD performed in the pharmaceutical industry from 1987 onwards, Canada shows an uptick from 1994 (when numbers are first available) through to 2002, peaking at 8.6 per cent and declining thereafter to a low of 2.94 per cent – an extremely steep descent of essentially two-thirds, i.e.,

⁶⁵ The author was not able to avail herself of earlier PMPRB reports. However, PMPRB 2005 notes the 2000 data (*Annual Report 2005* <https://www.canada.ca/en/patented-medicine-prices-review/services/annual-reports.html>, 61). On Canada having the second lowest ranking, see PMPRB *Annual Report 2005*, 61; 2006 under "the Global Context;" 2007, 59; 2008, 39; 2009, 42; 2010, 68; 2011, 53; 2012, 45. With respect to Canada having the lowest ranking see PMPRB *Annual Report 2013*, 37; 2014, 48; 2015, 52; 2016, 57; 2017, 61; 2018, 63; 2019 69, all of which can be found at <https://www.canada.ca/en/patented-medicine-prices-review/services/annual-reports.html>.

65.8 per cent. Actually, 2017 falls below the original level at the beginning of the time series. Switzerland still holds sway over the other countries on this indicator and remarkably, here too in 2017, the top five countries from the OECD data set register an average which is almost six times (5.69) greater than that of Canada.⁶⁶

Equally so are these undulations in innovation indicators present in patent applications to the United States Patent and Trademark Office (USPTO), (Figure 4). Viewing the historical data from OECD which is fortunately available, Canada goes from a base line of zero patent applications in 1987 to a high point of 744 by 2003, rapidly falling off thereafter and hitting 112 applications for the latest available data in 2017 – the latter constituting a quite precipitous drop of 85 per cent. It is worth highlighting that, with respect, to the interviews that were undertaken, at times, these too elicited observations on historical developments on the Canadian pharmaceutical scene. Specifically noted was how “R&D and production in Canada ... largely has been hollowed out over the last ten years” and the particular impacts contraction had on the industry in Québec and especially Montréal (I36; also I43).

Undoubtedly, in wrestling with the issue of some causal sequencing, the undulations in these innovation indicators do resonate with the structural conditions which the pharmaceutical industry more broadly faced over the last decades. As noted at the outset of this chapter, the “patent cliff” that emerged as IP exclusivity over blockbuster drugs dropped off; consolidations undertaken by MNEs in the wake of genericization; a declining productivity “pipeline;” newly emerging markets: all have been factors influencing the industry and propelling decisions concerning production and innovation. Yet, as the PMPRB data particularly illustrates, following the 1987 agreement over the ten per cent objective of R&D expenditures to sales, there

⁶⁶ As with all of the OECD averages for the top five countries used in this research, these are this author’s calculations.

was a concerted effort by the industry to attain this objective in the early years, with investments then receding almost on a consistent annual basis from 2005 onward. In this context, and based on the quasi-experimental methodology of Cook and Campbell, it is then not reckless to conclude that federal policy was impacting these innovation trend lines. Policy durability, the 1987 entente itself, targeted resourcing and network initiatives: the cyclical nature of these ventures have had manifest influence on developments in R&D. And that exceptions have rested with biotech and genomics also speaks to the presence of federal policy initiatives that have countered the more downward trends. Certainly, those initiatives have helped to facilitate an environs that has enabled biotech SMEs, albeit by no means large anchor firms that could disrupt the downward patterning. Further, and in keeping with a consistent trajectory on the Canadian innovation landscape that has been witnessed with regard to HERD-type investments and fundamental research, they have sustained an internationally-recognized research prowess in the field of genomics science. But what all of this speaks to is how the absence or even shallower nature of DNS conditions may negatively impact innovation success and how that in fact can play out over the decades in question.

Coming Full Circle: R&D in the Age of COVID

It was the original intent of this research to deal with federal innovation policy between the period of 2000 and 2020 and in fact both the design and initial research for this case study were undertaken prior to the onset of COVID. The enormous implications of the pandemic for pharmaceutical research and development as well as for manufacturing, however, do necessitate further inquiry – one beyond a postscript and which speaks to the vulnerabilities exposed in federal innovation policy relevant to the pharmaceutical case. Undoubtedly the crisis has spawned a battery of initiatives, as the months following March of 2020 have fully witnessed.

Yet, what is striking is not the rapidity with which initiatives flowed – necessarily demanded by the epic crisis at hand – but rather the extremely large number of initiatives unleashed really without the anchor of an integrated and overarching R&D strategy; without the guidance of a “millennium”-type strategy as articulated back by the National Biotechnology Advisory Committee at the cusp of the 21st century in 1998.

Certainly, the intent on the part of political leadership was clear and the efforts were a definitive testament to the pharmaceutical capabilities that had admittedly been “lost.” In the words of the Prime Minister:

Today, we are investing in our biomanufacturing capacity so that we have the made-in-Canada vaccines and treatments we need to protect Canadian, now and in the future, and recover from the impacts of COVID-19 (PMO NR 2021 2 Feb.).

Or, more pointedly, as the Minister of Innovation, Science and Economic Development, the Honourable François-Philippe Champagne stated:

Our government is *bringing back* the vaccine manufacturing capacity that Canadians expect and need. These investments will help to ensure that Canada has modern, flexible vaccine manufacturing capabilities now and in the future (*Ibid.*, emphasis added).

Even more pronounced were the words of Budget 2021 which, in highlighting the investments in the “life sciences and bio-manufacturing sector” indicated that these would “restore... capabilities that have been lost” (Finance Canada 2021, 147).

Such positioning duly noted, what followed in quick succession was a series of initiatives designed to mitigate or at least alleviate the crisis. Announced in March of 2020 was a plan to partner with and “mobilize” industry, ensuring the manufacturing of medical supplies and equipment (PMO NR 2020, 20 March) and similarly a \$1 billion initiative to “mobilize science,” creating the research edifice that could engender a “domestic supply of vaccines” (PMO NR 2020, 23 March). So too overlaid on this were advisory committees or more specifically “Task Forces” mandated to advise on promising vaccine candidates and therapeutic treatments for

COVID, as well as the separate entity of a biotechnology steering committee. And as Table 3 illustrates, between March of 2020 and March 2021 (prior to the 19 April Budget), at least 34 initiatives were unfurled with funding both for the private and public sector, focusing on R&D in vaccines and therapeutics as well as biomanufacturing production capacity. Key among them was resourcing for AbCellera developing an “antibody therapy” and Medicago for a vaccine “candidate” and production capability, as well as funding for such traditional public entities as the Canadian Institutes of Health Research and the National Research Council for research, industrial assistance and in the case of NRC also manufacturing facilities for “biologics.” All said the tally came to approximately \$1.09 billion at least in terms of commitments – and this was without counting \$600 million earmarked for the Strategic Innovation Fund in case that might involve double counts to what was publicly released.

What is noteworthy in this list is not only the rather unspecified nature of the initiatives that surfaces as times – as with 47 “research teams” or the 370 research “projects” anticipated by the tri-councils – but also at least at this earlier stage of news releases by the federal government the absence of linkage to past R&D resourcing in the health domain. Contrasting the March 2020 – March 2021 initiatives in Table 3 with Figure 3, it is unclear how the former links to federal R&D investments in health and life sciences over the past two decades, the critical exceptions of course being Genome Canada and the Stem Cell Network. Nor is it clear how it might link to the Networks of Centres of Excellence around pharmaceuticals and particularly those centred around commercialization that had gone before. True \$50 million was to flow through the existing Next Gen Manufacturing Supercluster and while public documents do not speak to it (PMO NR 2020 31 March) (or at least the brevity of News Releases does not enable such), it could be assumed this would generate certain synergies. True as well some of the

funding undertaken in the face of the pandemic was housed under the umbrella of NRC's Industrial Research Assistance Program. But the larger challenges of how the \$1.09 billion in spending would make for an integrated R&D agenda, beyond the merits of a case-by-case approach, is unclear.

If it is wrong to raise the integration issue at such an early stage of rollout by the government, especially given the numerous pressures it was facing, Budget 2021 may be a better vehicle to assess the policy durability question. Certainly, it is a question of some import as it speaks not only to continuity in federal resourcing but the kind of continuity in R&D that would not necessitate the effort to “rebuild” after dealing with a “lost” past. It should be noted at the outset it is not our intent to try and align the \$1.09 billion figure in Table 3 with the Budget 21 document at this time. Suffice it to say reconciliation will occur, to be gleaned from subsequent Public Accounts but to try and identify the exact intersection of that \$1.09 billion with the funding in the Budget at this time would be a premature and likely error-prone exercise.

Overall, and clearly articulated as a government “priority” and critical component of Budget 2021, the investment in the “Bio-manufacturing and Life Sciences Sector” was a \$2.2 billion affair (Finance Canada 2021, 72) to be rolled out over seven years. It was an effort to restore the “foundational” resources needed for the country’s “talent pipeline and research systems” and to “support the growth of Canadian life sciences firms” (*Ibid.*, 72). And, as an earlier News Release had harkened (albeit with respect to hunting out viable vaccine and therapeutics candidates), “no stone” was to be left “unturned” (ISED NR 2020 5 August). The usual recipients were listed: \$500 million for the Canada Foundation for Innovation; \$250 million for the tri-councils (NSERC, CIHR and SSHRC); \$1 billion for the Strategic Innovation

Fund to support and groom “promising domestic” firms in the life sciences sector.⁶⁷ There was a new \$250 million for adMare, an initiative aimed at scaling up SMEs, although interestingly there was no association with the Technology Accelerator initiative that had gone before. And the University of Saskatchewan’s Vaccine and Infectious Disease Organization was plucked out for a \$59.2 million investment to facilitate its R&D (as had been earlier signalled in December of 2020 although at a smaller amount (ISED NR 2 February 2021)). Beyond that the Budget did single out the scientific prowess of Canada’s clinical trial community and infrastructure, providing \$250 million to the Canadian Institutes of Health Research to advance that work and similarly \$45 million was dedicated to the Stem Cell Network. Moreover, what appears to be in addition to the \$2.2 billion tally, as we have earlier seen, \$400 million was set aside for the Pan-Canadian Genomics Strategy. Other initiatives rounded out the Budget with \$500 million to NRC’s Industrial Research Assistance Program to enable the growth of “2500” SMEs and, although admittedly somewhat limited, \$50 million was set aside for venture capital in the sector.

Despite its inclusiveness, however, two concerns are evidenced by the Budget. Overall, it is still very much aligned with growing domestic SMEs into “global champions” (*Ibid.*, 20) -- an orientation that still lacks the “anchor firms” so central to the pharmaceutical industry and, as was seen in the late eighties and nineties, so critical as well to this country’s R&D. Indeed, this approach is one which, in the interim, leaves Canadian R&D ripe for acquisition, the recently approved buyout by Pfizer of Trillium Therapeutics, an “early-stage life science” firm (Silcoff 2021, 24 August; 28 October: B8) specializing in cancer treatments, standing as an excellent case in point. In the telling words of the Economic Strategy Table on Health and Biosciences which foreshadow such acquisitions: “We need to reorient and incentivize companies to build to scale,

⁶⁷ With respect to the items in Budget 2021, see particularly Finance Canada 2021, 71-73; 76-77; 146; on genomics and clinical trials below see 150; on IRAP and VC below, 139.

not build to flip” (EST 2018f). Secondly, and of direct import to this research, the Budget investments are largely absent the linkage to previous Networks of Centres of Excellence centred on pharmaceutical R&D and particularly those pertaining to commercialization -- genomics sequencing and stem cell research notwithstanding.

In the end, then, the pandemic has cast policy in a blinding new light and as a result both Budget 2021 and the sequence of initiatives launched in the year previous have portrayed the absence – or at the very least shallow nature -- of an overarching strategy to direct the resourcing. Latter-day events have not been akin to the Strategy that the National Biotechnology Advisory Committee had called for back in 1998 – nor the prescience and breadth it connoted. Nor has it been vested with the longer-term impacts for R&D similar to the 1987 entente that was struck between government and industry. It may of course be some time before it is possible to get a good grasp on the R&D expenditures being undertaken by firms, particularly given the enormous fluctuations occurring economically and with business investment. But what can be seen in this historical telling of events is that this lack of strategy is not just the result of policy forged in the context of a dual crisis of epic proportions with respect to health and economy but in fact also tracks easily within the confines of durability challenges that have persisted in federal policy. And it speaks to both the strengths of that policy – fundamental science, research infrastructure, prowess in clinical trials and growing small and medium-sized enterprises – as well as to its weaknesses. The intermittent policy bursts, the need for robust ecosystems that can sustain commercialization; policy that is ill-equipped to forge continuity with past investments; and the requisite edifice of anchor firms capable of longer-term commitments to R&D: these are features, and enduring ones, that also highlight the current vaccine conundrum.

Conclusion

This research was undertaken with the intent of comparing two very different case studies within the context of the DNS framework – one centred on a mature sector, pharmaceutical manufacturing, and the other on the emerging field of Artificial Intelligence. And the effort has truly proven to be a study in contrasts. As has been seen, in the case of AI, its success has been driven by not only federal resourcing and, at times largesse, but also policy endurance. Equally so, however, it has also been nurtured by a vibrant innovation ecosystem, with active engagement from the very beginning by academe, anchor firms such as Spar Aerospace, an institute – CIFAR – committed to long-term success and specific provinces prepared to coordinate with the larger endeavour. Moreover, overarching this has been outstanding science – and scientists who brought to the table international breakthroughs and stature and mentored a generation of domestic talent as well.

As for the pharmaceutical sector, it was first driven by an entente engendered by federal policy initiative, and admittedly circumstance, but whose effects rather quickly waned. As has been seen, R&D investment fell off rather precipitously during the decades in question, with other innovation indicators (BERD, patents) also relaying the challenges the sector faced vis à vis international competitors. Biotech did initially benefit from federal policy and strategic efforts as well as resourcing, and genomics in particular has witnessed active federal support over the longer term. Moreover, in general, there has been substantial resourcing, at least \$20 billion in critical federal investments in health and the life sciences over the 1999-2000 to 2019-2020 period.

Yet, writ large, federal innovation policy around pharmaceuticals has not been successful in reigniting the R&D investment so essential to both discovery and commercialization and that might have gone some way in girding the country for the COVID pandemic to follow.

Admittedly of course the pharmaceutical sector is not as straight-forward a case as AI given the structural features of that industry and the international context in which it operates. But that federal policy and funding around health and life sciences and pharmaceuticals in particular have been prone to intermittent endeavours has not helped to mitigate the situation. Nor has the fact that NCE commercialization vehicles were deemed to be rather short-lived affairs. Now faced with the substantive task of nurturing a domestic industry around vaccines and therapeutics, the policy cycle begins anew.

In conclusion, then, the Development Network State framework is particularly valuable in illuminating the factors that typified – and have shaped -- the Canadian trajectory regarding pharmaceuticals. The gaps in policy consistency; a network ecosystem of rather limited duration – at least for purposes of getting product to market; and a research component surfacing again as one of the country's traditional strengths: these have continued to be hallmarks of the country's experience. Further, however, the case study lends itself as well to some interesting implications for the theoretical framework itself, suggesting at least that mission consistency on the part of the state and thickened, effective triadic networks are not only sufficient conditions for innovation success but rather essential conditions that require tending.

Annex A – 9: Pharmaceutical Indicators

**Table 1 Centres of Excellence for Commercialization and Research (CECR) -
Health and Life Sciences**

Name	Funding \$ million	Duration	Location
Accel-Rx Health Sciences Accelerator – Accel-Rx	16.0	2014-2021	Vancouver, BC
Centre for Commercialization of Cancer Immunotherapy - C3i	15.0	2016-2021	Montréal, QC
Centre for Commercialization of Regenerative Medicine - CCRM	30.0	2011-2023	Toronto, Ont.
Centre for Drug Research and Development - CDRD	23.0	2008-2018	Vancouver, BC
Centre for Imaging Technology Commercialization – CIMTEC	13.3	2011-2018	London, Ont.
Centre for Probe Development and Commercialization – CPDC	39.2	2008-2023	Hamilton, Ont.
Centre for the Commercialization of Antibodies and Biologics - CCAB	16.5	2014-2021	Toronto, Ont.
Centre for Surgical Invention and Innovation – CSii	14.8	2009-2017	Hamilton, Ont.
Centre of Excellence for the Prevention of Organ Failure – PROOF Centre	15.0	2008-2013	Vancouver, BC
Centre of Excellence in Personalized Medicine – Cepmed	13.8	2008-2014	Montréal, QC
Institute for Research in Immunology and Cancer – Commercialization of Research – IRICoR	15.0 25.0	2008-2014 2018-2024	Montréal, QC
MedDev Commercialization Centre- MDCC	14.9	2014-2017	Ottawa, Ont.
NEOMED Institute – NEOMED	13.5	2014-2020	Montréal, QC
Pan-Provincial Vaccine Enterprise- PREVENT	15.0	2008-2017	Saskatoon, Sask.
Prostrate Centre’s Translational Research Initiative for Accelerated Discovery and Development – PC – TRiADD	26.3	2008-2018	Vancouver, BC
TOTAL FUNDING	306.3		

Sources: https://www.nce-rce.gc.ca/NetworksCentres-CentresReseaux/ByProgram-ParProgramme_eng.asp#blnce; https://www.nce-rce.gc.ca/NetworksCentres-CentresReseaux/PreviouslyFunded-FinancesAnterieurement/CECR-CECR_eng.asp.

Table 2 Business-Led Networks of Centres of Excellence (BL-NCE)
Health and Life Sciences

Name	Funding \$ million	Duration	Location
CQDM	22.2	2009-2020	Montréal, QC
Exactis Innovation – Exactis	33.0	2014-2024	Montréal, QC
TOTAL FUNDING	52.2		

Sources: https://www.nce-rce.gc.ca/NetworksCentres-CentresReseaux/ByBrogram-ParProgramme_eng.asp#blnce; https://www.nce-rce.gc.ca/NetworksCentres-CentresReseaux/PreviouslyFunded-FinancesAnterieurement/BLNCE-RCEE_eng.asp

**Table 3 Federal Investments in Vaccine and Therapeutics R&D and
Pharmaceutical Manufacturing Capacity between March 2020 and March 2021**

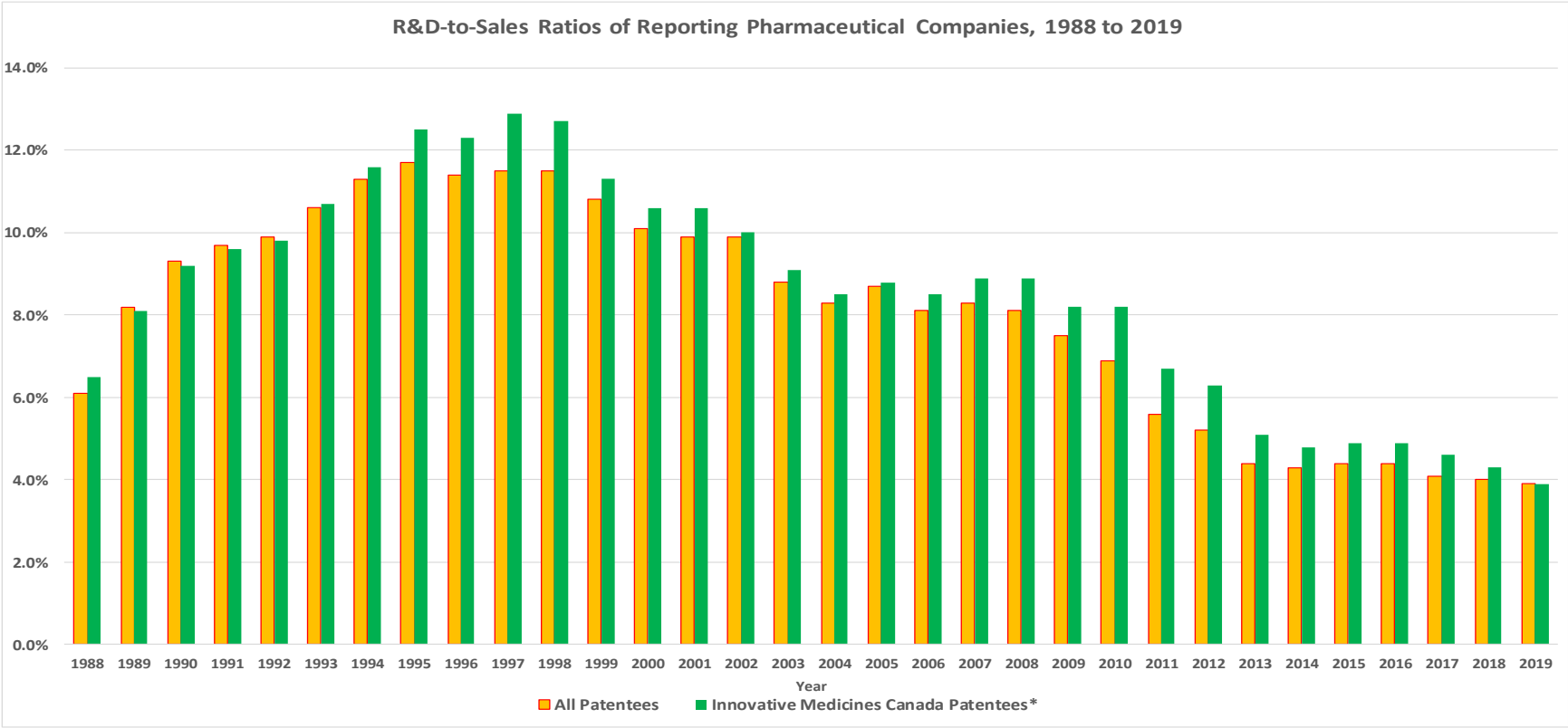
Name of Company	Funded \$ Millions	Type of R&D
AbCellera	175.6	Antibody therapy research and construction of production facility
Arch Biopartners	6.7 (up to)	Advance lead drug candidate for organ inflammation
Biodextris Inc	1.3	PMO NR 2020 20 Mar
BlueDot	1.3	Pre-clinical development of its nasal COVID-19 vaccine candidate
Bold Therapeutics	0.289	Prepare efficacy data in live SARS-COV-2 for clinical trials & support manufacturing
Canadian COVID-19 Genomics Network	40.0	Led by Genome Canada, coordinate a COVID-19 viral & host genome sequencing effort
Canadian Immunization Research Network	10.3 over 2 yrs. (& 5.0 ongoing)	Vaccine-related research and clinical trials
Canadian Institutes of Health Research	6.0	Create Canadian Network of COVID-19 Clinical Trials Networks
Canadian Institutes of Health Research	114.9	Research projects that accelerate development, testing & implementation of countermeasures to COVID-19
Data monitoring initiative	10.0	Coordinate & share pandemic-related data
Edesa Biotech Inc.	14.0 (up to)	Development of a monoclonal antibody therapy (EB05)
Entos Pharmaceuticals	5.0	Clinical trials for Covigenix VAX-001 vaccine candidate
Glycovax Pharma	4.0	Clinical trials of COVID-19 vaccine candidate
Immune Biosolutions	13.44 (up to)	Develop and advance its therapeutic candidate from preclinical to Phase II clinical trials
IMV Inc.	3.0	Advance clinical development of vaccine candidate
Immunovaccine Technologies Inc.	5.4	Clinical trials of its DPX-COVID19 vaccine
JN Nova Pharma	4.609	Development of drug to block coronavirus infection
KABS Laboratories	54.2 (up to)	Expansion of manufacturing facilities
Laurent Pharmaceuticals	4.167	Clinical development of LAU-7b antiviral and &inflammation controlling therapy
Medicago	173.0	Advance virus-like particle vaccine candidate and establish biomanufacturing facility
National Research Council Biologics Manufacturing Centre	126.0	New Biologics centre for vaccine production
National Research Council - Pandemic Response Challenge Program	15.0	Accelerate development of diagnostic tools and medical

		countermeasures to protect against COVID-19
National Research Council Industrial Research Assistance Program & Innovative Solutions Canada	15.0	Fund COVID-19 specific challenges
NSERC/SSHRC/CIHR	19.0	Leverage research expertise for (370) projects related to COVID-19
Next Generation Manufacturing Supercluster	50.0	Develop and scale-up in-demand technologies, equipment & medical products
Novocol	37.2 (up to)	Expand biomanufacturing facilities
Precision NanoSystems Incorporated (PNI)	25.1	Expand production of ribonucleic acid (RNA) vaccines
Precision NanoSystems Incorporated (PNI)	18.2 (up to)	Advance development of COVID-19 vaccine candidate through clinical trials
Providence Therapeutics	4.7	Phase 1 clinical trials of its PTX-COVID19-B mRNA vaccine candidate
Qu Biologics	0.110 (up to)	Provide proof-of concept evidence for preventative treatment & therapeutic use
Support 47 Research Teams	27.0	Accelerate development, testing & implementation of measures against COVID-19
Stem Cell Network	0.675	New research projects and clinical trial for cell therapy
Symvivo	2.8	Advance its bacTRL-Spike oral DNA vaccine candidate in clinical trials
University of Saskatchewan Vaccine and Infectious Disease Organization – International Vaccine Centre (VIDO-InterVac)	46.0	Accelerate its development of COVID-19 vaccine candidate and complete manufacturing facilities
Variation Biotechnologies Inc.	56.0 (up to)	Clinical trials for vaccine candidate
TOTAL *	1,089.990	

*Excludes ongoing
Sources: ISED NR 2020 5 Aug.; ISED BK 2021 2 Feb.; ISED NR 2021 16 Mar.; ISED NR 2021 5 Aug.;
PMO NR 2020 20 Mar.; PMO NR 2020 23 Mar.; PMO NR 2020 31 Mar.; PMO NR 2020 23 Oct.; PMO NR 2021 2 Feb.
See especially ISED BK 2021. 2 Feb. and PMP NR 2021 2 Feb.; also note that all descriptions are quotations from the various News Releases.

Figure 1: R&D-to-Sales Ratios of Reporting Pharmaceutical Companies, 1988 to 2019

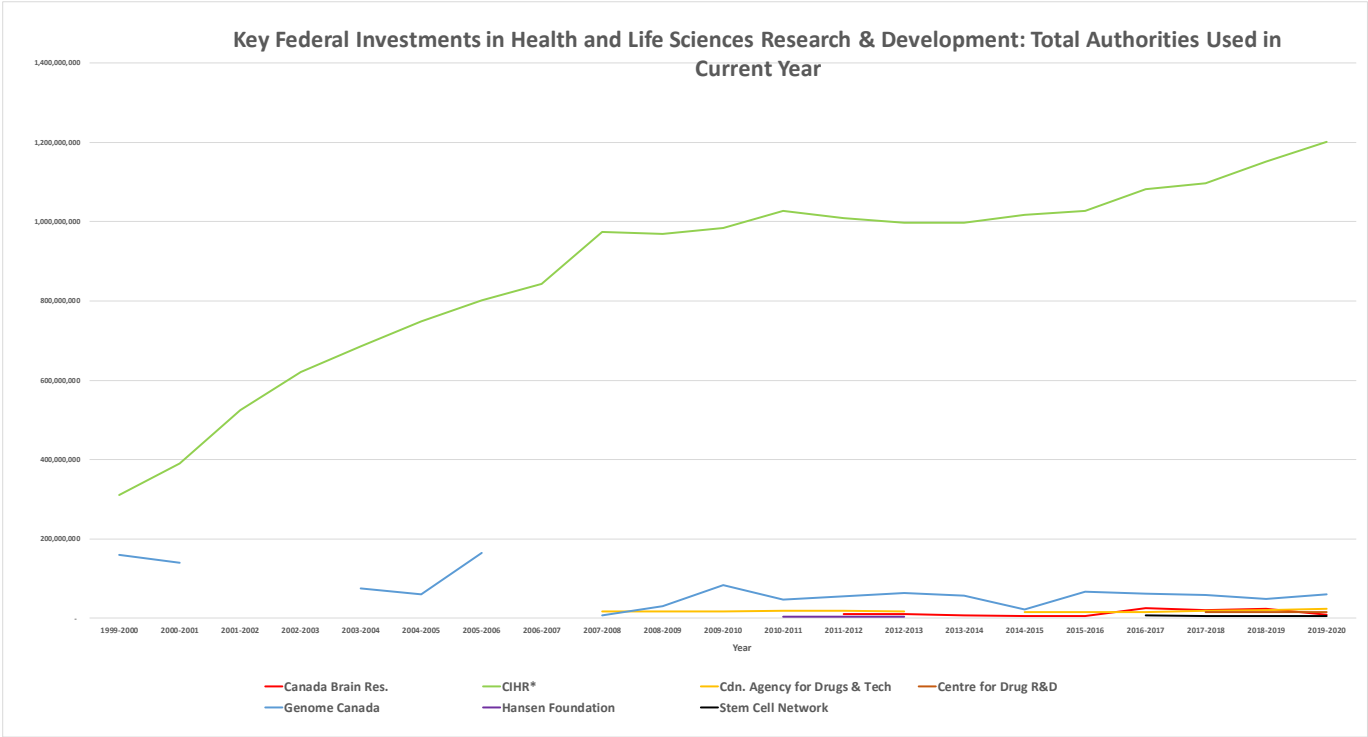
Measure	R&D-to-Sales Ratios of Reporting Pharmaceutical Companies, 1988 to 2019																															
Unit	Percentage																															
Year	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
All Patentees	6.1%	8.2%	9.3%	9.7%	9.9%	10.6%	11.3%	11.7%	11.4%	11.5%	11.5%	10.8%	10.1%	9.9%	9.9%	8.8%	8.3%	8.7%	8.1%	8.3%	8.1%	7.5%	6.9%	5.6%	5.2%	4.4%	4.3%	4.4%	4.4%	4.1%	4.0%	3.9%
Innovative Medicines Canada Patentees*	6.5%	8.1%	9.2%	9.6%	9.8%	10.7%	11.6%	12.5%	12.3%	12.9%	12.7%	11.3%	10.6%	10.6%	10.0%	9.1%	8.5%	8.8%	8.5%	8.9%	8.9%	8.2%	8.2%	6.7%	6.3%	5.1%	4.8%	4.9%	4.9%	4.6%	4.3%	3.9%



* Innovative Medicines Canada was previously known as Canada's Research-Based Pharmaceutical Companies - Rx&D (1999-2015) and previous to that the Pharmaceutical Manufacturers Association of Canada (1965-1999) (<http://innovativemedicines.ca/about/our-history/>).
Source: PMPRB *Annual Report 2019* (<https://www.canada.ca/en/patented-medicine-prices-review/services/annual-reports/annual-report-2019.html>)

Figure 2: Key Federal Investments in Health and Life Sciences Research and Development: Total Authorities Used in Current Year

Measure	Key Federal Investments in Health and Life Sciences Research & Development: Total Authorities Used in Current Year																					
Unit	In Canadian Dollars																					Total of All Years
Year	1999-2000	2000-2001	2001-2002	2002-2003	2003-2004	2004-2005	2005-2006	2006-2007	2007-2008	2008-2009	2009-2010	2010-2011	2011-2012	2012-2013	2013-2014	2014-2015	2015-2016	2016-2017	2017-2018	2018-2019	2019-2020	
Canada Brain Res.													10,000,000	10,000,000	6,747,567	5,404,909	6,180,793	24,992,085	20,000,000	23,500,000	8,497,963	115,323,317
CIHR*	310,504,413	390,035,089	524,146,861	621,424,625	686,217,269	747,972,258	800,875,508	843,269,265	974,070,783	969,415,324	983,733,066	1,026,871,276	1,009,091,392	997,052,742	997,971,988	1,017,279,382	1,026,378,153	1,081,330,344	1,097,161,185	1,150,927,127	1,202,050,854	18,457,778,904
Cdn. Agency for Drugs & Tech									17,215,784	16,903,966	16,903,967	17,903,967	18,903,967	16,903,967		16,058,769	16,058,769	16,058,769	18,058,769	20,058,769	23,058,769	214,088,232
Centre for Drug R&D																						48,000,000
Genome Canada	160,000,000	140,000,000			75,000,000	60,000,000	165,000,000		6,700,000	29,500,000	82,900,000	46,900,000	55,100,000	64,000,000	56,900,000	22,700,000	67,400,000	61,900,000	59,100,000	48,400,000	60,400,000	1,261,900,000
Hansen Foundation												4,500,000	4,500,000	4,500,000								13,500,000
Stem Cell Network																		6,794,532	5,205,468	6,000,000	6,000,000	24,000,000
TOTAL	470,504,413	530,035,089	524,146,861	621,424,625	761,217,269	807,972,258	965,875,508	843,269,265	997,986,567	1,015,819,290	1,083,537,033	1,096,175,243	1,097,595,359	1,092,456,709	1,061,619,555	1,061,443,060	1,116,017,715	1,191,075,730	1,215,525,422	1,264,885,896	1,316,007,586	20,134,590,453

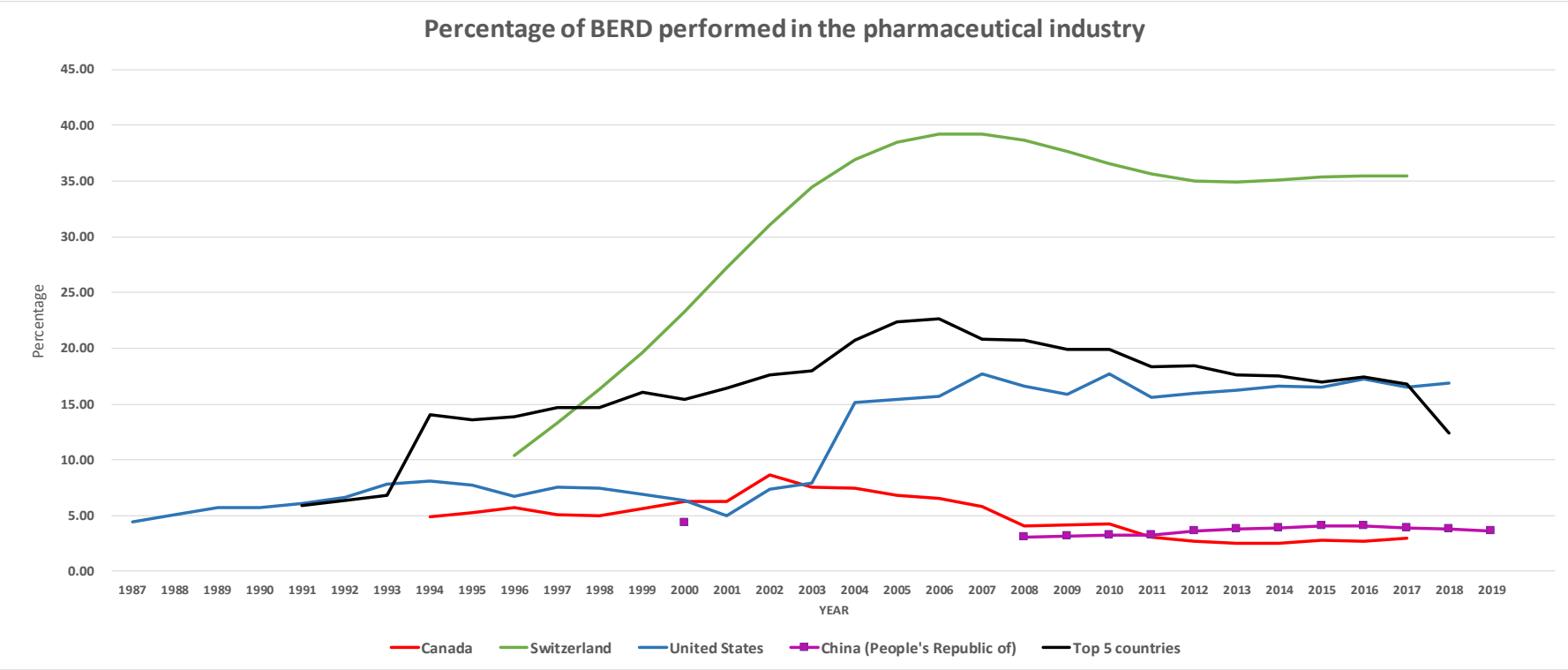


Canada Brain Research Fund Program
Canadian Agency for Drugs and Technologies In Health
*CIHR: Canadian Institutes of Health Research (1999-2000 - Medical Research Council)
**Centre for Drug Research and Development
Genome Canada
Rick Hansen Foundation
Stem Cell Network
Sources: Public Accounts 1999-2000 - 2019-2020

Figure 3: Percentage of BERD performed in the Pharmaceutical Industry

Dataset: Main Science and Technology Indicators

MSTI Variables	Percentage of BERD performed in the pharmaceutical industry																																
Unit	Percentage																																
Year	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Canada								4.93	5.26	5.73	5.05	4.96	5.60	6.23	6.28	8.60	7.53	7.47	6.81	6.58	5.82	4.05	4.18	4.23	3.07	2.71	2.51	2.54	2.78	2.65	2.94		
Switzerland										10.36	13.35	16.37	19.64	23.25	27.21	31.06	34.40	36.91	38.48	39.18	39.19	38.63	37.66	36.56	35.60	35.02	34.93	35.13	35.36	35.46	35.47		
United States	4.45	5.06	5.69	5.73	6.04	6.67	7.79	8.05	7.73	6.76	7.55	7.49	6.90	6.33	5.02	7.33	7.95	15.11	15.40	15.71	17.73	16.56	15.91	17.71	15.62	15.93	16.25	16.62	16.49	17.25	16.55	16.91	
China (People's Republic of)														4.37								3.04	3.17	3.21	3.21	3.61	3.83	3.88	4.06	4.02	3.91	3.81	3.60
Top 5 countries					5.94	6.35	6.78	14.05	13.56	13.86	14.69	14.73	16.03	15.43	16.39	17.63	17.96	20.69	22.33	22.60	20.79	20.74	19.86	19.91	18.35	18.45	17.63	17.52	16.93	17.46	16.75	12.41	



Source: OECD Main Science and Technology Indicators (https://stats.oecd.org/Index.aspx?DataSetCode=MSTI_PUB#)

Top 5 countries: Switzerland, Hungary, United States, Japan, Germany

NOTE: Due to the fact the data entries are started from 1987, many countries were missing data in the early years.

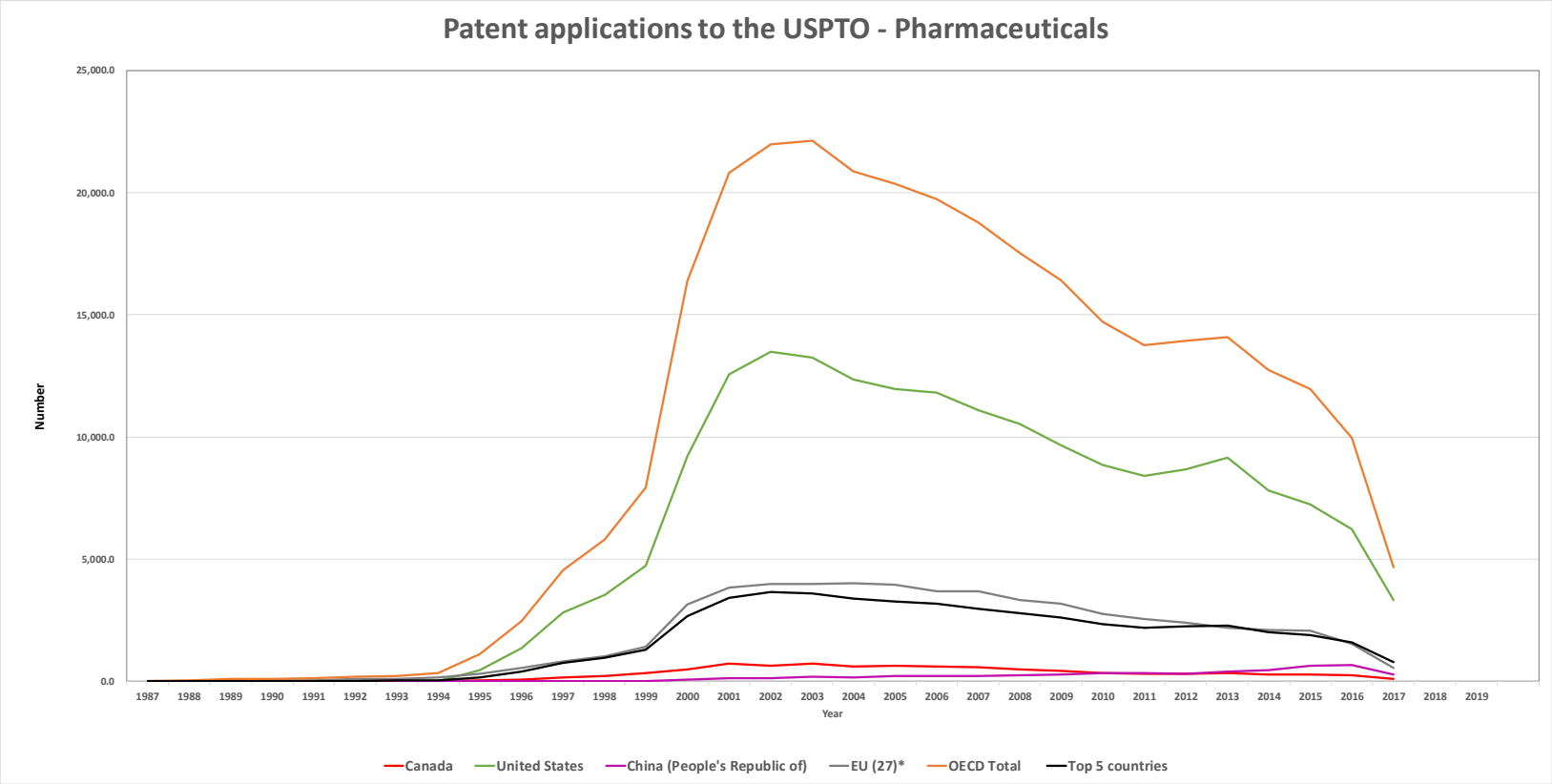
As a result, the methodological standard for being excluded in this case is if the country is missing one-third of the data entries.

As well, should the average for the top 5 countries miss 2 data points or more in a particular year, the average for that year is excluded; as such the top 5 average for 1987 to 1990 respectively as well as 2019 is excluded.

Data extracted on 19 Aug 2021 14:49 (UTC) GMT from OECD .Stat

Figure 4: Patent Applications to the USPTO – Pharmaceuticals

Dataset: Patents by Technology																																		
Patents Office & Patent		Patent applications to the USPTO - Pharmaceuticals																																
Reference Country		Inventor(s)'s country(ies) of residence																																
Reference Date		Priority date																																
Technology domains & IPC		Pharmaceuticals																																
Country	Year	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Canada		0.0	0.5	2.0	1.0	6.3	6.0	1.8	16.7	35.8	74.7	147.8	213.3	337.4	482.6	721.3	649.6	744.2	619.8	634.0	622.3	585.8	492.1	441.4	348.6	318.0	323.3	344.7	292.8	278.0	239.4	111.6		
United States		1.2	3.0	3.1	5.1	14.3	18.3	25.1	22.8	453.8	1,344.4	2,812.3	3,541.3	4,728.5	9,228.5	12,560.1	13,489.3	13,252.4	12,355.9	11,976.3	11,826.5	11,104.6	10,537.0	9,676.9	8,871.9	8,397.0	8,678.2	9,161.5	7,798.4	7,251.0	6,218.9	3,335.7		
China (People's Republic of)		0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	1.0	1.6	5.7	9.0	22.7	62.1	121.5	118.8	207.2	175.7	222.1	227.6	237.3	261.6	296.0	347.0	329.2	314.0	396.6	450.4	646.5	659.8	295.9		
EU (27)*		5.8	16.5	31.5	38.3	48.7	106.8	112.1	174.0	311.0	539.8	820.6	1,028.7	1,421.3	3,157.9	3,828.0	3,986.3	3,976.6	4,016.5	3,968.4	3,697.0	3,679.4	3,333.0	3,169.4	2,769.2	2,540.5	2,392.4	2,192.3	2,108.9	2,060.9	1,532.9	553.7		
OECD Total		14.0	36.0	91.2	96.0	146.0	190.3	235.7	346.8	1,123.5	2,476.9	4,564.6	5,818.8	7,932.1	16,393.9	20,821.5	21,978.5	22,130.6	20,860.0	20,355.7	19,735.1	18,784.3	17,514.6	16,420.4	14,707.8	13,746.0	13,943.1	14,094.4	12,727.2	11,973.0	9,975.3	4,661.1		
Top 5 countries		1.2	4.2	12.3	12.8	19.0	23.2	31.9	46.8	177.2	401.8	764.8	959.5	1,293.9	2,686.1	3,425.5	3,645.3	3,607.2	3,392.1	3,283.5	3,182.8	2,976.3	2,803.4	2,613.7	2,339.0	2,203.3	2,243.5	2,295.3	2,025.4	1,904.7	1,589.9	780.2		



Source: *OECD Main Science and Technology Indicators* (https://stats.oecd.org/Index.aspx?DataSetCode=MSTI_PUB#)
Top 5 countries: United States, Japan, Germany, United Kingdom, France. Canada ranks 6th on this indicator.
NOTE: OECD uses totals for OECD, EU(27); as such these are excluded from the top 5. * EU(27) is used in this OECD data.
Data extracted on 18 Aug 2021 14:16 UTC (GMT) from OECD.Stat

Methodological Note

With respect to the investments gleaned from Budgets and Public Accounts for the years in question, it is worth noting the techniques employed. In addition to a standard visual review of the Budget documents for all investments around innovation, S&T and R&D, specific electronic search techniques were employed to find references within the documents. The fact that all sources used were available electronically facilitated this.

Specifically Budgets 1999 through to 2021 were searched for the following terms: Canadian Institutes of Health Research, CIHR, health, Genome Canada, genomics, life sciences, pharmaceutical, pharmaceutical manufacturing, drug research and development, R&D, regenerative medicine and stem cells. Public Accounts from 1997-1998 through to 2019-2020 were duly searched for the terms: Brain, Canadian Agency for Drug Research and Development, Canadian Centre for Drugs and Technology, Canadian Institutes of Health Research, CIHR, Genome Canada, Hansen, MaRs, Stem Cell, University of Saskatchewan., vaccines.

Conclusion

Introduction

This research journey began in an effort to cast a new and discerning eye on a continuing enigma of Canadian federal policy – namely, initiatives undertaken since 2000 by various political administrations to accelerate Canada’s rate of innovation and close a demonstrable innovation gap, in large part, without apparent success. Indeed, the very straightforward question posed at the outset of this dissertation was *why such results* and, towards that end, we have specifically drawn on the theoretical framework of the Development Network State literature to address the issue. The research inquiry which followed was a systematic effort to isolate, observe and analyse the findings as constructed around the key pillars that animate the DNS framework – and around the modifications to which our subsequent theoretical reflections led. Moreover, it was an effort to use a standard methodology and tools – both quantitative (in the sense of economic and statistical data) and qualitative that could be leveraged in laying bare the evidence, the patterning that appears and drawing conclusions around the applicability of the DNS for this Canadian case study. To be sure, the use of the DNS approach has cast this case study in a comparative light, as the DNS is drawn primordially from the American – and, in many ways, successful experience with innovation -- and this has served as the first application to the Canadian context. In fact, given the relatively paucity of DNS applications to other polities -- and states -- beyond the US one, it can also be seen as helping to contribute to a larger comparative endeavour. But, more importantly, it has served as a deep dive into federal policy and the unique features that characterize both its ruptures and continuities, its strengths and weaknesses and the prevailing tapestry these dimensions reveal.

As such, then, concluding remarks are structured around five areas. There is a brief reprise of the DNS pillars of argumentation in terms of the strengths this brings to innovation debates and the lines of research inquiry which it enables. Against the backdrop of the health of the Canadian innovation system, there is a review, pillar by pillar, of the evidence and findings for policy durability, “targeted” resourcing, triadic thickening of networks and “patient” sustained capitalization; and there are conclusions offered for what this means in terms of a holistic assessment of the DNS to the Canadian case. Comments then turn to the case studies and the causal implications this has for understanding federal policy and innovation. Additionally, reflections are offered on potential domains, both comparative and domestic, for further research. Finally, closing comments speak briefly to implications for the future, given the recurring nature of the pandemic and reverberating shocks that have been felt in national policy agendas and implementation.

The DNS Framework: Leveraging Its Strengths

As will be recalled from the theoretical chapter, a review of the seminal contributions on innovation and national innovation systems showed some elements to be found wanting. Specifically, the NIS literature – albeit reckoning with the intricate dynamics of the firm and eschewing neoclassical thinking blinded to the complex institutional features that characterize national success, and failures -- was notable for its undertheorization of the state. So too was historical institutionalism characterized, in large part, by a lack of engagement with specific issues of innovation. Moved by the force of its paradigmatic and indeed seismic shift away from traditional social sciences at the time (including economic theories of class and modernization), its focus has been the state: its autonomy, its policies, the imprint of these legacies – and their evolution – and the conjunctural openness that at moments transform not only the state but the

polity itself. For HI, the engagement has been with the “big questions” (Skocpol 2007) that are transported through the march of history.

That said, the Developmental Network State framework was found to provide an approach that could serve to integrate respectively the strengths of these two streams in conceptually grasping the innovation question and the comparative advantages for growth that innovation bestowed on nations. In short, it offered a conceptual means to mend the gap between the extant literature on National Innovation Systems and the intricate interplay with state policy, and state engagement. And in adopting the DNS four elements were found to be central to capturing the success of the US on the innovation front since the post-war period: “targeted” resourcing toward technological challenges and breakthroughs that can release innovation; brokering by the state that can help to establish triadic linkages among industry, government and academe and “patient” risk-ready capitalization along the innovation continuum that enables and sustains research, development and most critically market deployment.

As for the critical pillar centred on mission-oriented continuity in national priorities, here some resculpting was required. Assumptions of continuity needed to be conceptually surfaced, vested as they were in a mantle of national security that prevailed in the American case since the post-World War II period and thus more accommodated to a comparative landscape. Specifically employed was the concept of policy durability that rode on two elements. It encompassed policy coherence as agendas and priorities are set over time but, drawing on currents present in HI – specifically Skocpol and Finegold (1982) -- also the concept of state administrative capacity to establish and implement initiatives of reform. So too in the case of brokering was the concept extended to a thickening of triadic networks that could animate innovation.

The Argument: The Evidence

These meso tools in hand, the inquiry then turned to taking the “pulse” of the Canadian innovation system. Drawing on the conclusions of numerous commissions and advisory bodies and particularly using a number of standard OECD indicators over the last decades, what was portrayed was the nature of the country’s innovation conundrum. Key indicators -- Gross Expenditures on R&D, Business Expenditures on R&D, ICT investments, filing of patents and the various efforts to cut into these dimensions through percentage of GDP, constant dollars and percentage growth -- have largely shown an ongoing decline since 2001. The stalwart exception to this has of course been Higher Education Expenditures in R&D, where Canada’s position among the top five countries has remained relatively steadfast, though here too the comparative race has tightened. All told, despite very pronounced efforts at times on the part of the federal government over the last twenty years, the commercialization challenge of taking research through to market product or process -- namely, the innovation gap -- has remained a continuing feature of the Canadian context. Hence it forms a particularly interesting case of applying the DNS framework.

Turning then to the four pillars in the framework, and taking first the question of policy durability, what the objective evidence reveals is a political landscape dominated by an ever-growing number of priorities over these years. In all, twenty-one priorities have been variously articulated over the years. Clean energy and the bio-sciences portray more ongoing levels of continuity but these clearly have been the exception and not the rule. Moreover, for the Liberal administrations of Chrétien/Martin and Trudeau which respectively anchor this time period under study, priority-setting was equally accompanied by an ever-increasing range of ambitious and complex innovation targets -- both for R&D and for commercialization more generally. The Harper years between 2007 and 2014 did witness a more limited agenda-setting but even here the

mould was broken by 2014 as priorities and “focus” expanded again. Interestingly, overlaid on this was a hardening administrative apparatus around Industry Canada and eventually the Innovation, Science and Economic Development portfolio but the strengthened state capacity did not operate in parallel with agenda-setting. Rather it unfurls a schism within the policy durability element, where policy coherence and priority-setting *and* administrative capability also essential to reform implementation are separate, establishing their own trajectories.

Not surprisingly, the in-depth thought leader interviews confirm this reading, with fully fifty per cent of respondents indicating that consistency in federal innovation priority-setting was not the country’s strong suit – was not “sufficient” as the question asked and another sixteen per cent responding affirmatively but with a qualified answer. Equally significant, the majority of interviewees pointed to the need for equipping innovation policy with “strategic focus” and mission – one that (for almost a quarter of respondents) could outlive political cycles and the policy “fingerprints” that inevitably ensued. In short, if policy durability is in fact a necessary condition for innovation, Canada’s case and federal policy were not meeting that bar, offering in their stead a much shallower version and a more freely undulating set of priorities.

With respect to the second pillar around “targeted” resourcing, this too revealed the more limited nature of federal efforts to tackle the innovation problématique. Not that federal investments have languished; in fact, over the period 1999-2000 to 2019-2020 federal S&T funding has tallied to \$211 billion (Chapter Five, Figure 5)¹ and has displayed robust countercyclical tendencies, the government continuing to pump out significant funding even during the Great Recession years. As for investments in research, despite administrations of different political stripes, these too have shown remarkable consistency, the total here as well

¹ Chapter Five, Figure 5 indicates that the data for 2018-2019 and 2019-2020 is based on preliminary estimates.

weighing in at the not insignificant \$93 billion (Chapter Five, Figure 16) for the years in question. Yet, the pattern also displays countervailing tendencies that diminish the effectiveness of targeted resourcing such as the more diffuse and indirect nature of Science, Research and Experimental Development tax credits. Or, as was revealed, there exists the oscillation between a focus on science and then on commercialization that marks different political administrations or indeed, in the case of the Trudeau era, that presents as competing budgetary objectives within the same government administration. Moreover, these swings have been especially pronounced in the case of Networks of Centres of Excellence focused on commercialization (CERC, BL-NCE) where program time lines have been shortened and where overall expenditures pale in comparison with other initiatives.

There have been the constants of macroeconomic stability and market framework policies and the import of a low net debt-to-GDP ratio, although there was some latter-day modest easing by the Trudeau administration – that is pre-pandemic. And there have been the constants in funding around genomics, bio-sciences, theoretical physics, AI and in the tending to research infrastructure that have established Canada as a global contender in these domains. The indicators around HERD and the country’s prominent place in international rankings are testament to the research investments that were launched first in the Chrétien era – with the intent of kickstarting innovation -- and have been the subject of ongoing attention over the years. But, on balance, the resourcing dimension has shown a more checkered history with respect to a laser focus on innovation and choke points in the innovation continuum, with a concomitant capacity to pull funding when goals are not being met. These trends also surfaced in the thought leader interviews, with two-thirds of respondents attesting to the “fragmentation” inherent in federal innovation programming. True there was recognition that there had been significant

improvements over time, but this was contained within a larger perspective that spoke to lack of strategic coordination and continuity, the resultant “sprinkling” effects of intended initiatives and a proclivity to add programming rather than appropriately winnow.

As for the third pillar of the framework centred on triadic thickening of innovation networks, this feature stands out as particularly unique and in fact presents the greatest challenge for application of the DNS. Certainly, policy *intent* on the part of consecutive governments, as well as the attendant resourcing over the years have been amply evident. Be it collaboration for “excellence” or “mobilization” or a “nation of innovators” replete with Superclusters, triadic thickening has been very much on government agendas – be it Liberal, Conservative or Liberal again. So too have there been the accompanying institutional vehicles and respective mandates intended to act on these agendas, nurturing and enabling innovation – Industry Canada, Innovation Science and Economic Development, the tri-councils, NRC, the Networks of Centres of Excellence as has been seen. Moreover, equally has there been extensive funding -- \$79 billion over the 1999-2000 to 2019- 2020 period (Chapter Six, Figure 4). Yet, policy *impacts* have remained largely resistant to these endeavours and the triadic patterning of networks in the Canadian case historically has proven to be very shallow, with the numbers indicating that troughs in the data particularly surface when innovation “activities” are most at stake.

These trends have also been borne out in the interviews, with just over two-thirds of respondents indicating that Canada was not doing enough to create critical mass, and with respondents highlighting the “fragmentation” and “silos” that characterize the country’s innovation ecosystem, as well the regional exclusion that obtains. There have been exceptions: business financing of HERD, scientific collaborations and the rather two-edged sword of international cooperation on the patent front. But in terms of the broad strokes where DNS-type

levers typically propel triadic endeavours and innovation, enabling technological opportunities and breakthroughs (à la the American experience) this situation has remained particularly elusive in the Canadian case. And to that point, the majority of respondents also noted the biggest challenge to innovation remained centred on the commercialization gap.

It is of course highly unlikely that thickened networks are only tangential to innovation and not in fact relevant factors in the innovation formula so to speak. Yet, what the evidence around this third pillar does depict is the weight of historically set patterns particularly difficult to rupture and, be it around business financing of HERD or scientific strengths and collaboration or inward linkages among firms, these have established trajectories that have fallen into well-worn grooves; and in that sense it does rob the DNS of some of its theoretical leverage. As Chapter Six has noted, a certain homage needs be paid to historical institutionalism in this context. At the very least, it will require sharply honed policy tools to disturb this equilibrium.

Finally, with respect to the fourth pillar and venture capital, here the situation initially presents as quite robust. Indeed, on all three OECD indicators -- total VC, start-up and other early-stage as well as later-stage -- the analysis undertaken in this research shows Canada in second rank next to the United States over the years in question (Chapter Seven, Figures 1 – 3). As for an earlier calculation in 2016 by the OECD, it also indicated Canada in the top three contenders with Israel, the US and then Canada in that order. Moreover, as the trend lines illustrate, there is a noted acceleration in VC both for the total category as well as start-up following the Venture Capital Action Plan introduced by the Conservatives in 2013. At first blush VC would seem to be a model instance of patient capital fuelled by government-incented initiatives and ripe for innovation opportunities and growth within the Canadian ecosystem.

Still the situation here as well is more fine-grained than that. For one thing, as has been evident in other dimensions of the Canadian case, federal policy efforts around VC have been subject to intermittent spikes of activity. Furthermore, and as also been seen in the case of targeted resourcing, there is a definitive tendency to rely on indirect means of enabling innovation – specifically by liberating investment through taxation and the oft-mentioned stability of fiscal levers and attendant “framework” policies. This has been more pronounced in earlier Liberal and Conservative administrations, but this default also traverses the more recent Liberal efforts when American tax cuts threatened. So too there is an ongoing propensity to see the capitalization question through the lens of small and medium-sized enterprises, rather than anchor firms per se. And while the VC takeoff has been fuelled by an ever-broadening mantle of activities – from start-up to large-scale and finally to late-stage requirements – late-stage in the Canadian context still pales in comparison to American deals both in numbers and in deal size.

As for the thought leader discussions, they in large part mirror these tendencies, with recognition of the strides that have been made and almost a quarter of respondents indicating on the start-up issue, there does exist a “vibrant” community. On late-stage capital, however the concerns continue to linger – with a majority clearly aware of the ongoing needs on this front and the bottlenecks this presents within the innovation continuum and to commercialization efforts. In sum, if on VC, federal endeavours have been on the cusp of meeting the high bar of “patient” capitalization along the innovation chain – of meeting this dimension of the DNS framework – it still pulls up short.

What all of this suggests of course is that federal innovation policy, viewed through the DNS lens, has developed in a unique and rather truncated form. Be it the jaggedness of priority-setting, or changes in the targets of resourcing, or more intermittent efforts at VC or even the

ensuing gap between networking efforts and actual implementation, pillar by pillar, federal policy has left elements untended. It cannot be said to have fully realized the potential of these levers or laid down the conditions that can amply foster and sustain innovation. At the same time, what this Canadian case study highlights is that the situation is also quite nuanced and cannot be cast in stark terms or understood in the simplicity of binary choices. On the contrary, what this pillar-by-pillar review has shown repeatedly are the government efforts undertaken to address the challenges of comparative advantage and growth on a global scale. Innovation *has* been a priority for different administrations through these decades under study; by no means has it been an afterthought or untethered policy without voice or advocate or (*pace* Doern, Castle and Phillips (2016)) just a lower rung on the hierarchical agenda ladder. Nor has it been undertaken without attention to resources or interpellated through institutional machinery and mandates devoid of linkages between academe, government and industry. And particularly since 2013, there have been real impacts on capitalization – for start-up and other forms of early-stage capital. Indeed, it is not that the policy levers were not undertaken or frequently refashioned to try and gain results. It is that on balance the levers deployed in these four domains of study have not had their full richness and have not had the depth or endurance to resolve the innovation enigma.

Case Studies and Consequences

If these observations provoke reflections on causal sequencing, the case studies employed in this research – Artificial Intelligence and pharmaceutical manufacturing – were specifically designed to address such questions as the force of policy impacts on innovation and how these play out over time. Armed with a “quasi-experimental” approach (Campbell 1969; Cook and Campbell 1986), the cases centred on whether federal government initiatives and

investments in policy durability, “targeted” resourcing and thickening networks affect rates of innovation and whether these accelerate or wane over time. While a time-sampling approach at different intervals – three years or five or ten – might well have served the purpose, fortuitously both the OECD and the Patented Medicine Prices Review Board hold historical series of annual statistics on innovation indicators; so too do these data sets include comparator nations. A challenge did emerge on the AI side in that understandably AI statistics do not have a time series that can reliably date back into the late eighties but that is simply the nature of the technology at hand. Nonetheless, the basis for the comparison does rest on solid ground. The cases selected provide for a study in contrasts, with a mature manufacturing sector and a newly-emerging area that is a strategic enabler for innovation, thus creating a robust test of the DNS model on different fronts. Moreover, while not initially chosen with this intent in mind, there is an historical continuity in the base line, in both instances critical policy forays into these domains being undertaken in the late eighties and, uniquely enough, specifically in 1987.²

Taking each in turn, in the case of pharmaceutical manufacturing, federal government efforts around innovation, and specifically enhancing R&D expenditures, have been quite limited in this regard. Certainly, the government has been faced with an industry, largely of multinationals, in the grip of structural challenges: increasing costs, long lead times for drug development, declining productivity and a spate of mergers and acquisitions that have also served to dampen productivity. Further, the reverberations of restructuring have also been felt in regional locations of Canada that had been centres for pharmaceutical manufacturing. That said, there has been strong historical proclivity on the part of MNLs to protect intellectual property and patents -- all of which came to a head in 1987 as American interests sought to dismantle

² This refers to the beginning of funding in the AI study and to the legislation of 1987 in the pharma case. See Chapter Eight, Figure 1 and Chapter Nine, “Bill C-22: Compulsory Licensing and R&D.”

Canada's compulsory licensing regime and create patent exclusivity. The government complied but not before it managed to negotiate a deal with the pharmaceutical manufacturers to invest ten per cent of their sales earnings into R&D by the "end of 1996." And, for a while, the impacts of this first (and on the issue of R&D targets *only*) policy volley held. As was seen in Chapter Nine (Figure 1), there was a pronounced ascent in R&D-to-sales ratios until 1998, after which the numbers declined, in fact to a nadir below the initial data when the deal was struck.

Moreover, later endeavours have proven to be of lesser import and certainly have been in large part more fleeting. Precisely on this issue of policy durability, certainly no such similar entente with MNLs has since emerged. As for other initiatives, while there has been continuing support for genomics and an earlier strategy wedded to biotech, federal interest has been largely limited. On the matter of federal funding, admittedly there has been relative largesse (\$20 billion in all on specific initiatives (Chapter Nine, Figure 2)) but here too the data shows spikes of activity and relatively undulating targets, save for CIHR and genomics. Most consequentially, however, the Centres of Excellence for Research and Commercialization and Business-led Centres of Excellence including those around vaccine development and immunology, were given program end dates and rolled into the Strategic Innovation Fund – this on the cusp of the global pandemic that was about to occur.

As the case study has shown, the impacts of these ventures have been clearly reflected also in another range of innovation indicators employed to assess impacts. Similar to the R&D-to-sales ratios, both the percentage of BERD performed in the pharmaceutical industry (Chapter Nine, Figure 3) as well as patent applications (Chapter Nine, Figure 4) have steadily waned, although with a slight time lag that starts around 2001/2002. In fact, in the case of BERD, here too the most recent numbers drop below the beginning of the data series for Canada in 1994. To

be sure, the support for genomics has translated into a field of acclaimed scientific endeavour and exercise of “leadership in the genomics space” (Doern, Castle and Phillips 2016, 306) and there has developed a relatively thriving community of smaller biotech firms. But on balance, the innovation indicators presented in this case study represent a robust testament to the implications of languishing policy initiatives -- ones that specifically coalesce around key pillars of the DNS framework.

If pharma demonstrates the implications of absent federal policy levers, it is in distinct difference to AI. In this case, while the first federal policy venture with funding of CIFAR (or CIAR as then called) occurred in 1987-1988, and while some early tensions did occur, financial support continued on the part of the federal government and has remained in place to present day. True, the early years did not see particularly large tranches of federal monies, but as has been shown, more significantly, these funds were critical in sustaining CIAR as it weathered several financial difficulties. Furthermore, this was buttressed by other efforts: thickening of triadic networks that have continued to flourish and, in a pattern now unique to this research, federal initiatives committed to a sustained presence for commercialization – specifically PRECARN and its mandate around “translating” discovery into “increased competitiveness.”³ Also significant, although more of late, has been the funding for the Institute for Quantum Computing whose research as well has deep synergies for Artificial Intelligence. Moreover, federal support has continued to expand through the years, recently culminating in an AI Strategy and the Supercluster for SCALE.AI.

Clearly, of course, there were a confluence of factors that initially propelled AI. The breakthroughs in AI, today heralded, were borne of the internationally acclaimed science -- and

³ See Chapter Eight, “Thickening the Innovation Ecosystem.”

scientists -- operating out of CIAR and within the Canadian environs (Hinton, Bengio and LeCun). Early beginnings were also grounded in the engagement of industry and large firms such as SPAR, the commitment of academe at U of T, the tenacious efforts of CIAR leadership and initially the interest of the Government of Ontario as well. So too has the Québec government had a presence in this field and formed part of the rich landscape on which federal initiatives are taken. But, in contrast with pharmaceutical manufacturing – and in direct alignment with the DNS framework -- federal government engagement in the AI domain has been both directed and sustained.

This of course is equally evident in the innovation indicators presented in the case study and while Canada does not top the list of international rankings, the pace of change on these indicators has been stunning and has landed the country as a recognized leader in the field.⁴ In short, if the “quasi-experimental” approach enables research to probe causal sequencing and the impact of distinct initiatives, both the vigour and continuity of federal efforts around Artificial Intelligence and the shallow, time-limited nature of policy spikes in pharmaceutical manufacturing visibly make the case.

DNS: A Research Agenda Going Forward

While the examination of Canadian federal innovation policy has served an important purpose in applying DNS, all of this does suggest the outlines of research agendas going forward – both to test the framework and more importantly to hone its dimensions outside of its American origins. As the data in Chapter Three on the “Health of the Canadian Innovation System” has demonstrated, smaller industrialized comparator nations -- Israel, Japan, Korea, Finland, Sweden, even at times Denmark – have fared exceedingly well on these innovation

⁴ See Chapter Eight, Figures 4 and 5; also Figure 6.

indicators over a two-decade period. It would be extremely valuable to conduct a larger comparative exercise that studies their innovation policies as well as their successes and their failures on the four pillars that DNS posits. Particularly intriguing as well would be an examination of how these nations have steered issues of policy durability relative to Canada (and to one another) and whether they have been able to overcome the cycling of priorities that can be ushered in with each new political mandate. Contemplation could also be given to even Germany in this exercise given its historic integration of networks and tight alignment of industry needs and applied science via its renowned Fraunhofer-Gesellschaft. And without overstretching such ambitions, thought could be given to a branch of such research that more directly engages economic questions such as the interplay of innovation policies and national industrial structure and economic dependencies as well export orientation (à la Katzenstein (1985a)).

Similarly, but now turning inwardly – and as the AI study suggests -- it would be beneficial to turn to subnational levels of government and the policies they have forged around the four pillars of the DNS framework. Ontario with its manufacturing base and Alberta with its focus on oil, gas and clean energy immediately come to mind. But Québec in particular has been instrumental in steering an innovation path that has not only embraced Artificial Intelligence and digitization but, as we have seen, has been forward-thinking in its visionary goals around innovation strategies, economic growth and international status in areas where the province has comparative advantage. So too could there be a kind of downward cascade that more directly takes on the issue of meso levels of analysis and devolved forms of governance. And while the Canadian contributions on regional innovation systems (Niosi) as well as “clusters” of civic capital and growth (Wolfe) have been tightly conceptualized and empirically-driven, there too

further opportunities might exist to consider at least the interplay with federal policy along the four dimensions of the DNS. Particularly intriguing might be how insulated these meso innovation systems are from swings in policy priority-setting and oscillations in policy at the federal level.

Finally, on a more distinct note, there is an array of studies which could roll out around specific government programming. Certainly, the issue of the Centres of Excellence for Research and Commercialization and the Business-led Centres of Excellence could well deserve a deeper dive, probing the networks built, the indicators of success, the company spin-offs, the venture capital assembled and how this traversed different sectors. Indeed, overall this research could address what has been lost and potentially gained, with the programs formally ended and funding rolled in under the Strategic Innovation Fund. So too could the clean energy portfolio and its dedication to innovation under Natural Resources Canada be evaluated, not just in terms of budgetary commitments but in terms of priority-setting, targeted expenditures and ecosystems that serve that broader domain of decarbonization.

All to say, then, this research and this framework open up rich veins for future inquiry and public policy and public administration implications that can be drawn from that. Moreover, they do not need to be undertaken in a segmented and siloed fashion but rather can be launched in the more multidisciplinary spirit that is intended to inform this dissertation.

Final Reflections

In concluding, what is clear is that if the Developmental Network State is equipped with the policy pillars that can activate, enable and sustain innovation, Canada – and federal policy over the past two decades – has been missing certain essential ingredients. To be sure, the country has been well served by an enduring and vibrant core of more upstream activities:

internationally acclaimed scientific research and enabling infrastructure, prowess in genomics and biosciences more generally, as well as the linkages that have accompanied these particular strengths. Present as well as has been the integrated funding of higher education R&D by business and the stellar ranking of the country's HERD investments within the international community. So too has there been the focus on SMEs and the start-up and early-stage capitalization that has particularly borne fruit, even by the rigorous standards of international assessment. And of course there has been the exceptional case of AI where the various dimensions of the DNS framework have successfully congealed over time, characterized by outstanding scientific breakthroughs and, even on standard innovation indicators, transporting Canada towards the front of global endeavours in this field.

Yet, this is by no means the full portrait. As has been reviewed in detail, there has not been sustained evidence of policy endurance and continuity that goes beyond political cycles and fashions the longer-term strategies that can ignite innovation. As for resourcing, despite its significant -- even extensive -- largesse and its capacity to move well beyond Keynesian countercyclical levers, it too has manifested patterns of oscillation between research and commercialization. Moreover, this has brought the attendant impacts on both entrepreneurs and academe who struggle to keep pace. Equally significant, there has there been the continuing challenge around the triadic thickening of the innovation ecosystem and forging the linkages that can transcend "silos" and "fragmentation." With respect to capitalization, notwithstanding the progress to date, the late-stage capital so critical along the innovation chain and especially for growth of anchor firms is still found wanting. And overlaid on all of this has been the ongoing gap around commercialization, with efforts here that have proved at times to be more fleeting

and admittedly have not been well served by ruptures and discontinuities. Certainly this issue resonated strongly within the thought leader community.

Indeed, the challenge that emerges is not just that innovation policy has developed in truncated form but that it has tracked within the confines of more historically adept and enduring strategies: upstream R&D, fiscal policy and market frameworks, the indirect reliance on taxation and SR&ED credits; even the SME lens through which innovation and capitalization are often conceptualized. Garnering international recognition and success, these policies have proven both durable and highly resilient. There is herein the weight of historical trajectories – and successful ones – in which, and through which, the multifaceted dimension of federal innovation policy and initiatives need occur. And in this context it is not untoward to consider that historical institutionalism has some theoretical currency in understanding the weight and endurance of this unique constellation of factors within the Canadian environs. Admittedly it provides unique terrain on which DNS-type initiatives must manoeuvre.

In short, the Canadian case study throws into relief aspects which may require some theoretical honing of the DNS framework itself. It comes back to our very initial considerations and concern around the embedded nature of national security “mission” vested in the American experience and the need to conceptually surface this assumption of durability if the framework were to transport to other national contexts. Perhaps it also suggests that the policy durability associated with overarching mission is in fact an anchoring condition that enables the other dimensions to follow suit. Certainly, the AI case amply demonstrates success riding on federal policy presence over large swaths of time. While replete with networking, targeted funding, commercialization vehicles and more recently scaling efforts and a focused strategic plan, nonetheless it remains primarily characterized by its endurance and continuity.

Thus, perhaps durability through the years is a necessary condition that then leverages targeted resources or thickening of the ecosystem or capitalization that is “patient” and risk-ready. The allure of the AI case and the implications it holds for the DNS aside, however, it is well beyond the scope of this inquiry to ferret out a definitive answer to this issue. As suggested in the section on future domains of research, it would require a deeper and more extensive comparative undertaking. But it speaks again to the comparative pull of the DNS framework and the sharpening it may well need to move beyond the uniqueness of the American experience and success with innovation.

In the end, then, this is rather a cautionary tale, centred as it is on the dissonance between policy intent and impact and the DNS framework does much to illuminate the dimensions that make federal innovation policy such. Specifically, it brings a new lens to the reasons why successive federal administrations have struggled so vigorously throughout the 2000s in moving the scale on standard OECD innovation indicators and positively impacting Canada’s rate of innovation. And it highlights the unique and truncated shape of innovation policies as they have endeavoured to establish the agendas, funding, networks and capital that can provide a formula for advancing Canada on this front. It also suggests, however, the more durable, directed and strategic path which the federal administration has to forge as it begins to pick up the tools for a post-pandemic future. Indeed, the conjunctural openness provided at this point may well be the seismic shift needed for federal administrators – and policies – to reckon with past challenges, avail themselves of these tools and push forward.

Bibliography

Books and Articles

- Allen, Matthew M.C., and Maria Aldred. 2009. "Varieties of Capitalism, Varieties of Innovation? A Comparison of Old and New EU Member States." *Journal of Contemporary European Research* 5(4): 581-596.
- Alvesson, Mats, and Kaj Sköldbberg. 2018. *Reflexive Methodology: New Vistas for Qualitative Research*. 3rd ed. Los Angeles, London: Sage Publications.
- Amable, Bruno. 2003. *The Diversity of Modern Capitalism*. Oxford: Oxford University Press.
- Amenta, Edwin, and Theda Skocpol. 1988. "Redefining the New Deal: World War II and the Development of Social Provision in the United States." In *The Politics of Social Policy in the United States*, edited by Margaret Weir, Ann Shola Orloff and Theda Skocpol, 81-122. Princeton: Princeton University Press.
- Anderson, Robert, Theodore Cohn, Chad Day, Michael Howlett, and Catherine Murray. 1998. "Introduction: Innovation Systems in a Global Context." In *Innovation Systems in a Global Context: The North American Experience*, edited by Robert Anderson, Theodore Cohn, Chad Day, Michael Howlett, and Catherine Murray, 3-20. Montreal and Kingston: McGill-Queen's University Press.
- Angus, Douglas E., and Heather M. Karpetz. 1998. "Pharmaceutical Policies in Canada: Issues and Challenges." *Pharmacoeconomics* 14 Suppl (1): 81-96.
- Applebaum, Richard P., Rachel Parker, Cong Cao, and Gary Gereffi. 2011. (Reprinted 2016). "China's (not so Hidden) Developmental State: Becoming a Leading Nanotechnology Innovator in the Twenty-First Century." In *State of Innovation: The U.S. Government's Role in Technology Development*, edited by Fred Block and Matthew R. Keller, 217-235. London and New York: Routledge.
- Barrington Moore, Jr. 1966. *Social Origins of Dictatorship and Democracy: Lord and Peasant in the Making of the Modern World*. Boston: Beacon Press.
- Baumgartner, Frank R., Bryan D. Jones, and Peter B. Mortensen. 2018. "Punctuated Equilibrium Theory: Explaining Stability and Change in Public Policymaking." In *Theories*

- of the Policy Process*, edited by Christopher M. Weible and Paul A. Sabatier, 55-101. 4th ed. New York: Westview Press.
- Belderbos, Rene, Bart Leten, and Shinya Suzuki. 2013. "How global is R&D? Firm-level determinants of home-country bias in R&D." *Journal of International Business Studies*. 44 (8) October/November: 765-786.
- Berman, Elizabeth Popp. 2008. "Why Did Universities Start Patenting? Institution-Building and the Road to the Bayh-Dole Act." *Social Studies of Science* 38 (6): 835-871.
- Berman, Sheri. 2016. "Institutions and the Consolidation of Democracy in Western Europe." In *The Oxford Handbook of Historical Institutionalism*, edited by Orfeo Fioretos, Tulia G. Falletti and Adam Sheingate, 403-416. Oxford: Oxford University Press.
- Berman, Sheri. 2019. *Democracy and Dictatorship in Europe*. Oxford: Oxford University Press.
- Block, Fred. 2007. *Revising State Theory: Essays in Politics and Postindustrialism*. Philadelphia: Temple University Press.
- Block, Fred. 2007. "Understanding the Diverging Trajectories of the United States and Western Europe: A Neo-polanyian Analysis." *Politics & Society* 35 (1): 3- 33.
- Block, Fred. 2008. "Swimming against the Current: The Rise of a Hidden Developmental State in the United States." *Politics & Society* 36 (2): 169-206.
- Block, Fred. 2011. (Reprinted 2016.) "Innovation and the Invisible Hand of Government." In *State of Innovation: The U.S. Government's Role in Technology Development*, edited by Fred Block and Matthew R. Keller, 1-26. London and New York: Routledge.
- Block, Fred. 2012. "Explaining the Transformation in the US Innovation System: The Impact of a Small Government Program." *Socio-Economic Review* 30, September: 1-28.
- Block, Fred, and Mathew Keller, eds. 2011a. (Reprinted 2016). *State of Innovation: The U.S. Government's Role in Technology Development*. London and New York: Routledge.
- Block, Fred, and Matthew Keller. 2011b. (Reprinted 2016.) "Where Do Innovations Come From? Transformations in the U.S. Economy, 1970-2006." In *State of Innovation: The U.S. Government's Role in Technology Development*, edited by Fred Block and Matthew R. Keller, 154-172. London and New York: Routledge.

- Bonvillian, William B. 2018. "DARPA and its ARPA-E and IARPA clones: a unique innovational organization model." *Industrial and Corporate Change* 27 (5): 897-914.
- Boyer, Robert. 2015. *Économie politique des capitalismes*. Théorie de la régulation et des crises. Paris : La Découverte.
- Boyer, Robert, and Y. Saillard. 2002. *Théorie de la régulation, l'état des savoirs*. Paris: La Découverte.
- Box, Richard C. 1992. "An examination of the debate over research in public administration." *Public Administration Review* 52: 62-69.
- Box, Richard C. 2005. "'Dialogue' and 'Administrative Theory & Praxis': Twenty-Five Years of Public Administration Theory." *Administrative Theory & Praxis* 27 (3) September: 438-466.
- Bradford, Neil and David A. Wolfe. 2013. "Governing regional economic development: innovation challenges and policy learning in Canada." *Cambridge Journal of Regions, Economy and Society* 6: 331-347.
- Bradford, Neil and David A. Wolfe. 2017. "Learning through governance." In *The Elgar Companion to Innovation and Knowledge Creation*, edited by Harald Bathelt, Patrick Cohendet, Sebastian Henn and Laurent Simon, 723-738. Cheltenham, Glos, UK: Edward Elgar Publishing Limited.
- Bramwell, Allison, Jen Nelles, and David A. Wolfe. 2008. "Knowledge, Innovation and Institutions: Global and Local Dimensions of the ICT Cluster in Waterloo, Canada." *Regional Studies*. 42 (1): 101-116.
- Brown, Robert Craig. 2007. *A Generation of Excellence: A History of the Canadian Institute for Advanced Research*. Toronto: University of Toronto Press.
- Bruland, Kristine, and David C. Mowery. 2005. "Innovation through Time." In *The Oxford Handbook of Innovation*, edited by Jan Fagerberg, David C. Mowery and Richard R. Nelson, 349-379. Oxford: Oxford University Press.
- Bush, Vannevar. 1945. *Science, the Endless Frontier, A Report to the President on a Program for Postwar Scientific Research*. Washington, DC: US Government Printing Office.

- Campbell, Donald T. 1969. "Reforms as Experiments." *American Psychologist* 24 (4): 71 – 100.
- Campbell, Robert M., and Leslie A. Pal. 1989. *The Real World of Canadian Politics: Cases in Policy and Process*. Peterborough, Ontario: broadview press.
- Canadian Startup News. 2017. "Digital Finance Institute Report." 12 April.
- Castle, David, and Peter W.B. Phillips. 2011. "Science and Technology in Canada: Innovation Gaps and Productivity Traps. In *How Ottawa Spends, 2011-12: Trimming Fat or Slicing Pork*, edited by Christopher Stoney and G. Bruce Doern, 163-179. Montreal & Kingston: McGill-Queen's University Press.
- Castle, David, and Peter W.B. Phillips. 2016. "A New Government and Its 'New Innovation Agenda.'" In *How Ottawa Spends, 2016-2017: The Trudeau Liberals in Power*, edited by G. Bruce Doern, and Christopher Stoney, 141-166. <https://carleton.ca/sppa/wp-content/uploads/How-Ottawa-Spends-2016-2017.pdf>.
- Chesnais, François. 1993. "The French National System of Innovation." In *National Innovation Systems: A Comparative Analysis*, edited by Richard R. Nelson, 192-229. Oxford: Oxford University Press.
- Cohen, Jillian Clare. 2003/2004. "Canada and Brazil Dealing with Tension between Ensuring Access to Medicines and Complying with Pharmaceutical Patent Standards: *Is the Story the Same?*" Comparative Program on Health and Society. Unpublished manuscript.
- Cohrs, Rachel. 2019. "Biologic exclusivity provision stripped from revised USMCA deal." *Modern Healthcare*. 10 December.
- Collier, David. 1995. "Translating Quantitative Methods for Qualitative Researchers: The Case of Selection Bias." *American Political Science Review* 89 (2) June: 461-466.
- Cook, Thomas D., and Donald T. Campbell. 1986. "The Causal Assumptions of Quasi-experimental Practice." *Synthese* 68 (1): 141-180.
- Cooke, Philip. 1998. "Introduction: Origins of the Concept." In *Regional Innovation Systems: The Role of Governances in a Globalized World*, edited by H.J. Braczyk, P. Cooke, and M. Heidenreich. 2nd ed.. London: Routledge.

- Comanor, William S., and F.M. Scherer. 2013. "Mergers and innovation in the pharmaceutical industry." *Journal of Health Economics* (32): 106-113.
- Conran, James, and Kathleen Thelen. 2016. "Institutional Change." In *The Oxford Handbook of Historical Institutionalism*, edited by Orfeo Fioretos, Tulia G. Falleti and Adam Sheingate, 51-70. Oxford: Oxford University Press.
- Crouch, Colin, and Wolfgang Streeck, eds. 1997. *Political Economy of Modern Capitalism Mapping Convergence and Diversity*. London: SAGE Publications Ltd.
- Crowley, Brian Lee and Kristina Lybecer. 2012. "Improving Canada's drug patent protection: Good for Canada, good for trade. *Policy Options* 1 March.
- Culpepper, Pepper D. 2011. *Quiet Politics and Business Power: Corporate Control in Europe and Japan*. New York: Cambridge University Press.
- Culpepper, Pepper D. 2016. "Capitalism, Institutions, and Power in the Study of Business." In *The Oxford Handbook of Historical Institutionalism*, edited by Orfeo Fioretos, Tulia G. Falleti, and Adam Sheingate, 453-466. Oxford: Oxford University Press.
- Dahl, Robert A. 1947. "The Science of Public Administration: Three Problems." *Public Administration Review* 7 (1) Winter: 1-11.
- Dahl, Robert A. 1961. *Who Governs? Democracy and Power in an American City*. New Haven and London: Yale University Press.
- Daley, Brian R., Bianca Pietracupa, Renaud Garon Gendron, and Camille A. Provencher. 2020. "'Made in Canada': The challenges of increasing domestic production of pharmaceuticals." November. Norton Rose Fulbright. <https://www.nortonrosefulbright.com/en/knowledge/publications/267cfb99/made-in-canada-the-challenges-of-increasing-domestic-production-of-pharmaceuticals..>
- de la Mothe, John, and Gilles Paquet, eds. 1998. *Local and Regional Systems of Innovation*. Norwell, Mass: Kluwer Academic Publishers.
- de la Mothe, John, and Gilles Paquet, eds. 2000. *Information, Innovation and Impacts*. Norwell, Mass: Kluwer Academic Publishers.
- della Porta, Donatella. 2008. Comparative analysis: case-oriented versus variable-oriented research." In *Approaches and Methodologies in the Social Sciences: A Pluralist*

- Perspective*, edited by Donatella della Porta and Michael Keating, 198 – 222.
Cambridge: Cambridge University Press.
- De Noni, Ivan, Luigi Orsi, and Fiorenza Belussi. 2018. “The Role of Collaborative Networks in Supporting the Innovation Performances of Lagging Behind European Regions.” *Journal of Evolutionary Economics*, 47 (1): 1–13.
- Denney, Steven, Travis Southin, and David A. Wolfe. 2021. “Entrepreneurs and cluster evolution: the transformation of Toronto’s ICT cluster.” *Regional Studies* 55 (2): 196–207.
- Dietz, T., E. Ostrom, and P.C. Stern. 2003. “The Struggle to Govern the Commons.” *Science* 302: 1907–12.
- DiMasi, Joseph A. 2002. “The value of improving the productivity of the drug development process: faster times and better decisions.” *PharmacoEconomics* 20: 1–10.
- DiMasi, Joseph A., and Henry G. Grabowski. 2007. “The cost of pharmaceutical R&D: is biotech different.” *Managerial and Decision Economics* 28 (4–5): 285–291.
- DiMasi, Joseph A., Henry G. Grabowski, and Ronald W. Hansen. 2016. “Innovation in the pharmaceutical industry: New estimates of R&D costs.” *Journal of Health Economics* 47: 20–33.
- DiMasi, Joseph A., Ronald W. Hansen, Henry G. Grabowski, and Louis Lasagna. 1991. “Cost of innovation in the pharmaceutical industry.” *Journal of Health Economics* 10 (2): 107–142.
- DiMasi, Joseph A., Ronald W. Hansen, Henry G. Grabowski and Louis Lasagna. 1995. “Research and development costs for new drugs by therapeutic category: a study of the U.S. pharmaceutical industry.” *PharmacoEconomics* 7: 152–169.
- DiMasi, Joseph A., Ronald W. Hansen, and Henry G. Grabowski. 2003. “The price of innovation: new estimates of drug development costs.” *Journal of Health Economics* 22 (2) :151–185.
- Doern, G. Bruce. 1972. *Science and Politics in Canada*. Montreal and London: McGill-Queen’s University Press.

- Doern, G. Bruce, ed. 2006. *Innovation, Science, Environment: Canadian Policies and Performance, 2006 – 2007*. Montreal and Kingston: McGill-Queen's University Press.
- Doern, G. Bruce, David Castle, and Peter W.B. Phillips. 2016. *Canadian Science, Technology, and Innovation Policy: The Innovation Economy and Society Nexus*. Montreal & Kingston: McGill-Queen's University Press.
- Doern, G. Bruce, and Jeffrey Kinder. 2007. *Strategic Science in the Public Interest: Canada's Government Laboratories and Science-Based Agencies*. Toronto: University of Toronto Press.
- Doern, G. Bruce, and Richard Levesque. 2002. *The National Research Council in the Innovation Policy Era: Changing Hierarchies, Networks and Markets*. Toronto, Buffalo, London: University of Toronto Press.
- Doern, G. Bruce, and Richard W. Phidd. 1983. *Canadian Public Policy: Ideas, Structure, Process*. Toronto, New York, London: Methuen Publications.
- Doern, G. Bruce, and Markus Sharaput. 2000. *Canadian Intellectual Property: The Politics of Innovating Institutions and Interests*. Toronto: University of Toronto Press.
- Doern, G. Bruce, and Christopher Stoney, eds. 2009. *Research and Innovation Policy: Changing Federal Government-University Relations*. Toronto: University of Toronto Press.
- Donatella, della Porta. 2008. "Comparative analysis: case-oriented versus variable-oriented research." In *Approaches and Methodologies in the Social Sciences: A Pluralist Perspective*, edited by Donatella della Porta and Michael Keating, 198-222. Cambridge: Cambridge University Press.
- Dosi, Giovanni. 1982. "Technological paradigms and technological trajectories: A suggested interpretation of the determinants and directions of technical change." *Research Policy* 11: 147-162.
- Dosi, Giovanni. 2013. "Innovation, Evolution and Economics: Where We Are and Where We Should Go." In *Innovation Studies: Evolution & Future Challenges*, edited by Jan Fagerberg, Ben R. Martin and Esben Sloth Andersen. Oxford: Oxford University Press.
- Edler, Jakob, and Jan Fagerberg. 2017. "Innovation Policy: What, Why and How." *Oxford Review of Economic Policy*, 33 (1): 2-23.

- Edquist, Charles, ed. 1997. *Systems of Innovation: Technologies, Institutions and Organizations*. London: Pinter.
- Edquist, Charles. 2005. "Systems of Innovation: Perspectives and Challenges." In *The Oxford Handbook of Innovation*, edited by Jan Fagerberg, David C. Mowery, and Richard R. Nelson, 181-208. Oxford: Oxford University Press.
- Ergas, Henry. 1987. "Does Technology Policy Matter." In *Technology and Global Industry: Companies and Nations in the World Economy*, edited by Bruce R. Guile and Harvey Brooks. Washington, D.C.: National Academy Press.
- Esping-Andersen, Gøsta. 1985. *Politics Against Markets: The Social Democratic Road to Power*. Princeton, New Jersey: Princeton University Press.
- Esping-Andersen, Gøsta. 1990. *The Three Worlds of Welfare Capitalism*. Princeton, New Jersey: Princeton University Press.
- Etzerodt, Søren Frank. 2021. "Explaining economic growth in advanced capitalist democracies: varieties of capitalism and welfare production regimes." *Comparative European Politics* 19 (4) August: 471-493.
- Etzkowitz, Henry. 1998. "The Triple Helix of Academic-Industry-Government: The U.S. National Innovation System." In *Innovation Systems in a Global Context: The North American Experience*, edited by Robert Anderson, Theodore Cohn, Chad Day, Michael Howlett, & Catherine Murray, 127-147. Montreal and Kingston: McGill-Queen's University Press.
- Etzkowitz, H., and L. Leydesdorff. 2000. "The Dynamics of Innovation: From National Systems and "Mode 2" to Triple Helix of University-Industry-Government Relations." *Research Policy*, 29: 109-23.
- Evans, Peter B. 1985. "Transnational Linkages and the Economic Role of the State: An Analysis of Developing and Industrialized Nations in the Post-World War II Period." In *Bringing the State Back In*, edited by Peter B. Evans, Dietrich Rueschemeyer and Theda Skocpol, 192-226. Cambridge: Cambridge University Press.
- Evans, Peter. 1995. *Embedded Autonomy: States and Industrial Transformation*. Princeton: Princeton University Press.

- Evans, Peter. 2011. Reprinted 2016. "Foreword." In *State of Innovation: The U.S. Government's Role in Technology Development*, edited by Fred Block and Matthew Keller, v-vii. New York: Routledge.
- Evans, Peter B., Dietrich Rueschemeyer, and Theda Skocpol. 1985. "On the Road toward a More Adequate Understanding of the State." In *Bringing the State Back In*, edited by Peter B. Evans, Dietrich Rueschemeyer and Theda Skocpol, 347-366. Cambridge: Cambridge University Press.
- Fagerberg, Jan. 2005. "Innovation: A Guide to the Literature." In *The Oxford Handbook of Innovation*, edited by Jan Fagerberg, David C. Mowery, and Richard R. Nelson, 1-26. Oxford: Oxford University Press.
- Fagerberg, Jan. 2017. "Innovation Policy: Rationales, Lessons and Challenges." *Journal of Economic Surveys* 31 (2): 497-512.
- Fagerberg, Jan. H. Landström, H., and Martin, B.. 2012. "Exploring the Emerging Knowledge Base of 'the Knowledge Society'." *Research Policy* 41: 1121-31.
- Fagerberg, Jan, Ben R. Martin, and Esben S. Andersen. 2013. "Innovation Studies: Towards a New Agenda." In *Innovation Studies: Evolution & Future Challenges*, edited by Jan Fagerberg, Ben R. Martin and Esben Sloth Andersen, 1- 17. Oxford: Oxford University Press.
- Finer, Herman. 1941. "Administrative Responsibility in Democratic Government." *Public Administration Review*. 1 (4) Summer: 335-350.
- Fischer, Frank. 2003. *Reframing Public Policy: Discursive Politics and Deliberative Practices*. Oxford: Oxford University Press.
- Fischer, Frank and Herbert Gottweis. 2012. "Introduction." In *The Argumentative Turn Revisited: Public Policy as Communicative Practice*, edited by Frank Fishcer and Herbert Gottweis, 1-27. Durham and London: Duke University Press.
- Florio, Massimo, Francesco Giffoni, Anna Giunta, and Emanuela Sirtori. 2018. "Big science, learning, and innovation: evidence from CERN procurement." *Industrial and Corporate Change* 27 (5): 915-936.

- Fong, Glenn. 2001. "ARPA does Windows: The Defense Underpinnings of the PC Revolution." *Business and Politics* 3 (3): 213-237.
- Foray, D., D. Mowery, and R. R. Nelson. 2012. "Public R&D and Social Challenges: What Lessons from Mission R&D Programs?" *Research Policy*, 41 (10): 1697-1902.
- Freeman, Christopher. 1987. *Technology Policy and Economic Performance: Lessons from Japan*. London: Pinter.
- Freeman, Christopher. 1988. "Japan: A New National System of Innovation?" In *Technical Change and Economic Theory*, edited by Giovanni Dosi, Christopher Freeman, Richard Nelson, Gerald Silverberg, and Luc Soete. London and New York: Pinter Publishers Limited.
- Freeman, Chris, and Luc Soete. 1997. *The Economics of Industrial Innovation*, 3rd ed. Cambridge, Mass.: The MIT Press.
- Friedrich, Carl J. 1940. "Public Policy and the Nature of Administrative Responsibility." *Public Policy* 1 (1): 1- 20.
- Fuchs, Erica R. H. 2009. "Cloning DARPA Successfully." *Issues in Science and Technology* 26 (1) Fall: 65-70.
- Fuchs, Erica. 2011. Reprinted 2016. "DARPA Does Moore's Law: The Case of DARPA and Optoelectronic Interconnects." In *State of Innovation: The U.S. Government's Role in Technology Development*, edited by Fred Block and Matthew R. Keller, 133-148. London and New York: Routledge.
- Gallini, Nancy, and Aidan Hollis. 2019. "To Sell or Scale Up: Canada's Patent Strategy in a Knowledge Economy." IRPP Study, 72 August.
- Gertler, Meric S., and Tara Vinodrai. 2009. "Life Sciences and Regional Innovation: One Path or Many?" *European Planning Studies* 17 (2) February: 235-261
- Gleeson, Deborah, Joel Lexchin, Ronald Labonté, Belinda Townsend, Marc-André Gagnon, Jillian Kohler, Lisa Forman, and Kenneth C. Shadlen. 2019. "Analyzing the impact of trade and investment agreements on pharmaceutical policy: provisions, pathways and potential impacts." *Globalization and Health* 15 (Suppl): 78 <https://doi.org/10.1186/s12992-019-0518-2>.

- Globerman, Steven, and Bacchus Barua. 2019. "Pharmaceutical Regulation, Innovation, and Access to New Drugs: An International Perspective." January. Vancouver, B.C.: Fraser Institute. <http://www.fraserinstitute.org>.
- Goertz, Gary, and James Mahoney. 2012. *A Tale of Two Cultures: Qualitative and Quantitative Research in the Social Sciences*. Princeton and Oxford: Princeton University Press.
- González, Paula, Inés Macho-Stadler, and David Pérez-Castrillo. 2016. "Private versus social incentives for pharmaceutical innovation." *Journal of Health Economics* 50: 286-297.
- Gorecki, Paul K., and Ida Henderson. 1981. "Licensing of Drugs in Canada: A Comment on the Debate." *Canadian Public Policy*. 7 (4) Autumn: 559-568.
- Grabowski, Henry, and John Vernon. 1994. "Innovation and Structural Change in Pharmaceuticals and Biotechnology." *Industrial and Corporate Change* 3(2): 435- 449.
- Grillitsch, Markus and Michaela Trippl. 2018. "Innovation Policies and New Regional Growth Paths: A Place-Based System Failure Framework." In *Innovation Systems, Policy and Management*, edited by Jorge Niosi, 329-358. Cambridge: Cambridge University Press.
- Grootendorst, Paul PhD, Ron Bouchard PhD LLM, and Aidan Hollis PhD. 2012. *CMAJ*. 184 (5) 20 March: 543-549.
- Gupta, Sayantan, Subhrodip Mohanta, Mayukh Chakraborty, and Souradeep Ghosh. 2017. "Quantum machine learning-using quantum computation in artificial intelligence and deep neural networks: Quantum computation and machine learning in artificial intelligence," 2017 8th Annual Industrial Automation and Electromechanical Engineering Conference (IEMECON): 268-274.
- Hacker, Jacob S. 2002. *The Divided Welfare State: The Battle over Public and Private Social Benefits in the United States*. New York: Cambridge University Press.
- Hacker, Jacob S. 2005. "Policy Drift: The Hidden Politics of US Welfare State Retrenchment." In *Beyond Continuity: Institutional Change in Advanced Political Economies*, edited by Wolfgang Streeck and Kathleen Thelen, 40-82. Oxford and New York: Oxford University Press.

- Hacker, Jacob S., and Paul Pierson. 2006. *Off Centre: The Republican Revolution and the Erosion of American Democracy*. New Haven, CT: Yale University Press.
- Hacker, Jacob S. and Paul Pierson. 2007. "Tax Politics and the Struggle over Activist Government." In *The Transformation of American Politics: Activist Government and the Rise of Conservatism*, edited by Paul Pierson and Theda Skocpol. Princeton and Oxford: Princeton University Press.
- Hacker, Jacob S., and Paul Pierson. 2010. *Winner-Take-All-Politics: How Washington Made the Rich Richer – and Abandoned the Middle Class*. New York: Simon and Schuster.
- Hall, Peter A. 1986. *Governing the Economy: The Politics of State Intervention in Britain and France*. New York: Oxford University Press.
- Hall, Peter A. 2015. "The Changing Role of the State in Liberal Market Economies." In *The Oxford Handbook of Transformations of the State*, edited by Stephen Leibfried, Evelyn Huber, Matthew Lange, Jonah D. Levy, Frank Nullmeier and John D. Stephens, 427-444. Oxford: Oxford University Press.
- Hall, Peter A. 2016. "Politics as a Process Structured in Space and Time." In *The Oxford Handbook of Historical Institutionalism*, edited by Orfeo Fioretos, Tulia G. Falletti and Adam Sheingate, 31-50. Oxford: Oxford University Press.
- Hall, Peter A., and Daniel W. Gingerich. 2009. "Varieties of Capitalism and Institutional Complementarities in the Political Economy: An Empirical Analysis." *British Journal of Political Science* 39 (3) July : 449-482.
- Hall, Peter A., and David Soskice. 2001. "An Introduction to Varieties of Capitalism." In *Varieties of Capitalism: The Institutional Foundations of Comparative Advantage*, edited by Peter A. Hall and David Soskice, 1-68. Oxford: Oxford University Press.
- Hall, Peter A., and Kathleen Thelen. 2009. "Institutional Change in Varieties of Capitalism." *Socio-Economic Review* 7: 7-34.
- Hansen, Ronald W. 1979. "The pharmaceutical development process: estimates of current development costs and times and the effects of regulatory changes." In *Issues in Pharmaceutical Economics*, edited by R.I. Chien. Lexington, MA: Lexington Books.

- Hargadon, Andrew. 2003. *How Breakthroughs Happen: The Surprising Truth about How Companies Innovate*. Boston: Harvard Business School Press.
- Harrison, Christopher Scott. 2001. "Protection of Pharmaceuticals as Foreign Policy: The Canada-U.S. Trade Agreement and Bill C-22 Versus the North American Free Trade Agreement and Bill C-91." *North Carolina Journal of International Law and Commercial Regulation* 26 (2): 457- 525.
- Harrison, R.K. 2016. "Phase II and phase III failures: 2013-2015." *Nature Reviews /Drug Discovery* 15 December: 817-818.
- Hay, Colin. 2020. "Does capitalism (still) come in varieties?" *Review of International Political Economy* 27 (2): 302-319.
- Henry, Nicholas. 1975. "Paradigms of Public Administration." *Public Administration Review*. 35 (4) July-August: 378-386.
- Herweg, Nicole, Nikolaos Zahariadis, and Reimut Zohlnhöfer. 2018. "The Multiple Streams Framework: Foundations, Refinements, and Empirical Applications." In *Theories of the Policy Process*, edited by Christopher M. Weible and Paul A. Sabatier, 17-53. 4th ed. New York: Westview Press.
- Howlett, Michael, Allan McConnell, and Anthony Perl. 2015. "Streams and stages: Reconciling Kingdon and policy process theory." *European Journal of Political Research* 54: 419-434.
- Hubbard, Ruth, and Gilles Paquet. 2010. *The Black Hole of Public Administration*. Ottawa: University of Ottawa Press.
- Hubbard, Ruth, and Gilles Paquet. 2013. *Innovation as redesign*. 21 August. Ottawa: Centre on Governance, University of Ottawa <http://www.gouvernance.ca/publications/13-08.pdf>
- Hurt, Shelley L. 2011. Reprinted 2016. "The Military's Hidden Hand: Examining the Dual-Use Origins of Biotechnology in the American Context, 1969-72." In *State of Innovation: The U.S. Government's Role in Technology Development*, edited by Fred Block and Matthew Keller, 31-56. New York: Routledge.
- Jackson, Gregory and Richard Deeg. 2006. "How Many Varieties of Capitalism: Comparing the Comparative Institutional Analyses of Capitalist Diversity." MplfG Discussion

- Paper 06/2/, April. Cologne, Germany: Max Planck Institute für Gesellschaftsforschung/ Max Planck Institute for the Study of Societies.
- Jacobson, David, ed. 2013. *The Nuts and Bolts of Innovation: New Perspectives on Irish Industry Policy*. Dublin: Glasnevin Publishing.
- Jessop, Bob. 1999. "The Changing Governance of Welfare: Recent Trends in its Primary Functions, Scale, and Modes of Coordination." *Social Policy and Administration* 33 (4) December: 348-359.
- Kattel, Rainer, and Mariana Mazzucato. 2018. "Mission-oriented innovation policy and dynamic capabilities in the public sector." *Industrial and Corporate Change* 27 (5): 787-801.
- Katzenstein, Peter J. 1985a. *Small States in World Markets: Industrial Policy in Europe*. Ithaca, New York: Cornell University Press.
- Katzenstein, Peter J. 1985b. "Small Nations in an Open International Economy: The Converging Balance of State and Society in Switzerland and Austria." In *Bringing the State Back In*, edited by Peter B. Evans, Dietrich Rueschemeyer and Theda Skocpol, 227-251. Cambridge: Cambridge University Press.
- Katzenstein, Peter J. 1987. *Policy and Politics in West Germany: The Growth of a Semisovereign State*. Philadelphia: Temple University Press.
- Keck, Otto. 1993. "The National System for Technical Innovation in Germany." In *National Innovation Systems: A Comparative Analysis*, edited by Richard R. Nelson, 115-157. Oxford: Oxford University Press.
- Keller, Matthew R. 2011. Reprinted 2016. "The CIA's Pioneering Role in Public Venture Capital Initiatives." In *State of Innovation: The U.S. Government's Role in Technology Development*, edited by Fred Block and Matthew R. Keller, 109-132. New York: Routledge.
- Keller, Matthew R., Fred Block, and Marian Negoita. 2017. "How does innovation work within the developmental network state: New data on public-private agreements in a U.S. Department of Energy Laboratory." *Sociologias* 19 (46): 136-164.
- Kelly, Josie, and Anneliese Dodds. 2012. "Public Administration in an age of austerity: the future of the discipline." *Public Policy and Administration* 27 (3): 199-211.

- Kettl, Donald F. 2000a. "Public Administration at the Millennium: The State of the Field." *Journal of Public Administration Research and Theory* 10 (1): 7-34.
- Kettl, Donald F. 2000b. *The Global Public Management Revolution: A Report on the Transformation of Governance*. Washington, D.C.: Brookings Institution Press.
- Kinder, Jeff, and Paul Dufour, eds. 2018. *A Lantern on the Bow: A History of The Science Council of Canada and Its Contributions to The Science and Innovation Policy Debate*. Ottawa: Invenire.
- King, Gary, Robert O. Keohane, and Sidney Verba. 1994. *Designing Social Inquiry: Scientific Inference in Qualitative Research*. Princeton, NJ: Princeton University Press.
- King, Gary, Robert O. Keohane, and Sidney Verba. 1995. "The Importance of Research Design in Political Science." *American Political Science Review* 89 (2) June: 475-481.
- Kingdon, John W. 2011 [1984]. *Agendas, Alternatives and Public Policies*. 2nd ed. Boston: Boston, Brown and Company.
- Klepper, Steven. 2016. *Experimental Capitalism: The Nanoeconomics of American High-Tech Industries*. Princeton: Princeton University Press.
- Knopf, Howard P. 2018. "Canada's Role in the Relationship of Trade and Intellectual Property." In *Reflections on Canada's past, present and future in international law = Réflexions sur le passé, le présent et l'avenir du Canada en droit international*, edited by Oonagh E. Fitzgerald, Valerie Hughes and Mark Jewett, 361-379. Centre for International Governance Innovation.
- Kohli, Atul. 2016. "States and Economic Development." In *The Oxford Handbook of Historical Institutionalism*, edited by Orfeo Fioretos, Tulia G. Falletti and Adam Sheingate, 167-180. Oxford: Oxford University Press.
- Kondratiev, Nikoloi. 1984. *The Long Wave Cycle*. Translated by Guy Daniels. New York: Richardson and Snyder.
- Kuhn, Thomas S. 2012 [1962]. *The Structure of Scientific Revolutions*, 4th ed., 50th Anniversary Edition. Chicago and London: The University of Chicago Press.

- Kwong, Elizabeth. 2015. "Advancing Drug Discovery: A Pharmaceutical Perspective." *Journal of Pharmaceutical Sciences* 104: 865-871.
- Lalitha, N. 2005. "Review of the Pharmaceutical Industry of Canada." *Economic and Political Weekly* 40 (13) 26 March - 1 April: 1355-1362.
- Lash, Scott and John Urry. 1987. *The End of Organized Capitalism*. Madison, Wisconsin: The University of Wisconsin Press.
- Latouche, Daniel. 1998. "Do Regions Make a Difference? The Case of Science and Technology Policies in Quebec." In *Regional Innovation Systems: The Role of Governances in a Globalized World*, edited by H.J. Braczyk, P. N. Cooke, and M. Heidenreich, 319-344. London: Routledge.
- Lazonick, William. 2005. "The Innovative Firm." In *Innovation Studies: Evolution & Future Challenges*, edited by Jan Fagerberg, Ben R. Martin and Esben Sloth Andersen, 29-55. Oxford: Oxford University Press.
- Laitin, David D. 1995. "Disciplining Political Science." *American Political Science Review* 89 (2) June: 454-456.
- Lecours, André. 2002. "L'approche néo-institutionnaliste en science politique : unité ou diversité?" *Politique et Sociétés* 21 (3) : 91-112.
- Lecours, André, ed. 2005. *New Institutionalism: Theory and Analysis*. Toronto: University of Toronto Press.
- LeCun, Yann, Yoshua Bengio and Geoffrey Hinton. 2015. *Nature* (521) 28 May: 436 – 444.
- Lerner, Josh. 2009. "The Empirical Impact of Intellectual Property Rights on Innovation: Puzzles and Clues." *American Economic Review*, 99 (2): 343-48.
- Lester, Richard K., and Michael Piore. 2004. *Innovation: The Missing Dimension*. Cambridge, Mass.: Harvard University Press.
- Levy, Charles S. and Stuart M. Weiser. 1993. "The NAFTA: A Watershed for Protection of Intellectual Property." *The International Lawyer* 27 (3) Fall: 671-689.
- Levy, Jonah D. 2005. "Redeploying the State: Liberalization and Social Policy in France." In *Beyond Continuity: Institutional Change in Advanced Political Economies*, edited by

- Wolfgang Streeck and Kathleen Thelen, 103-126. Oxford and New York: Oxford University Press.
- Levy, Jonah D., ed. 2006. *The State after Statism: New State Activities in the Age of Liberalization*. Cambridge and London: Harvard University Press.
- Levy, Jonah D. 2015. "The Transformations of the Statist Model." In *The Oxford Handbook of Transformations of the State*, edited by Stephen Leibfried, Evelyne Huber, Matthew Lange, Jonah D. Levy, Frank Nullmeier and John D. Stephens, 394-409. Oxford: Oxford University Press.
- Lexchin, Joel. 2016. *Private Profits versus Public Policy: The Pharmaceutical Industry and the Canadian State*. Toronto, Buffalo, London: University of Toronto Press.
- Lindgart, Z., M. Reeves and J. Wallenstein. 2008. "Waking the giant: the business model innovation in the drug industry." *In Vivo* 26: 1- 6.
- Lipietz, Alain. 1987. *Mirages and Miracles: The Crisis of Global Fordism*. London: Verso.
- Lockwood, Matthew. 2013. "The political sustainability of climate policy: The Case of the UK Climate Change Act." *Global Environmental Change* 23: 1339-1348.
- Lowi, Theodore H. 2019 [1979]. *The End of Liberalism: The Second Republic of the United States*. 2nd ed. 40th Anniversary Edition. New York and London: W.W. Norton & Company, Inc.
- Lundvall, Bengt-Åke. 1988. "Innovation as an interactive process: from user-producer interaction to the national system of innovation." In *Technical Change and Economic Theory*, edited by Giovanni Dosi, Christopher Freeman, Richard Nelson, Gerald Silverberg and Luc Soete. London and New York: Pinter Publishers Limited.
- Lundvall, Bengt-Ake, ed. 1992. *National Systems of Innovation: Towards a Theory of Innovation and Interactive Learning*. London: Pinter Publishers.
- Lundvall, Bengt-Åke. 2013. "An Agenda for Future Research." In *Innovation Studies: Evolution & Future Challenges*, edited by Jan Fagerberg, Ben R. Martin and Esben Sloth Andersen, 203-209. Oxford: Oxford University Press.

- Lundvall, Bengt-Åke, and Susana Borrás. 2005. "Science, Technology, and Innovation Policy." In *The Oxford Handbook of Innovation*, edited by Jan Fagerberg, David C. Mowery, and Richard R. Nelson, 599-631. Oxford: Oxford University Press.
- Luton, Larry S. 2010. *Qualitative Research Approaches for Public Administration*. Armonk, New York: M.E. Sharpe.
- Lynch, Julia. 2006. *Age in the Welfare State: The Origins of Social Spending on Pensioners, Workers and Children*. Cambridge and New York: Cambridge University Press.
- Lynch, Julia, and Martin Rhodes. 2016. "Historical Institutionalism and the Welfare State." In *The Oxford Handbook of Historical Institutionalism*, edited by Orfeo Fioretos, Tulia G. Falletti and Adam Sheingate, 417-437. Oxford: Oxford University Press.
- Mainzer, Lewis C. 1994. "Public Administration in Search of a Theory: The Interdisciplinary Delusion." *Administration & Society*. November 26 (3): 359-394.
- Mahoney, James. 2003. "Strategies of Causal Assessment in Comparative Historical Analysis." In *Comparative Historical Analysis in the Social Sciences*, edited by James Mahoney and Dietrich Rueschemeyer, 337-372. Cambridge: Cambridge University Press.
- Mahoney, James and Dietrich Rueschemeyer. 2003. "Comparative Historical Analysis: Achievements and Agendas." In *Comparative Historical Analysis in the Social Sciences*, edited by James Mahoney and Dietrich Rueschemeyer, 3-40. Cambridge: Cambridge University Press.
- Mahoney, James, and Kathleen Thelen. 2010. "A Theory of Gradual Institutional Change." In *Explaining Institutional Change: Ambiguity, Agency and Power*, edited by James Mahoney and Kathleen Thelen, 1-37. Cambridge: Cambridge University Press.
- Malerba, Franco. 2005. "Sectoral Systems and Why Innovation Differs across Sectors." In *The Oxford Handbook of Innovation*, edited by Jan Fagerberg, David C. Mowery, and Richard R. Nelson, 380-406. Oxford: Oxford University Press.
- Malerba, Franco, Richard R. Nelson, Luigi Orsenigo and Sidney G. Winter. 2016. *Innovation and the Evolution of Industries: History-Friendly Models*. Cambridge, U.K.: Cambridge University Press.

- Malerba, Franco, and Luigi Orsenigo. 2002. "Innovation and market structure in the dynamics of the pharmaceutical industry and biotechnology: towards a history-friendly model." *Industrial and Corporate Change* 11 (4): 667-703.
- Malerba, Franco, and Luigi Orsenigo. 2015. "The evolution of the pharmaceutical industry." *Business History* 57 (5): 664-687.
- Martin, Ben R. 2013. "Innovation Studies: An Emerging Agenda." In *Innovation Studies: Evolution & Future Challenges*, edited by Jan Fagerberg, Ben R. Martin and Esben Sloth Andersen, 169-186. Oxford: Oxford University Press.
- Mazzoleni, Roberto, and Richard R. Nelson. 1998. "Economic Theories about the Benefits and Costs of Patents." *Journal of Economic Issues* 32 (4) December: 1031-1052.
- Mazzucato, Mariana. 2013. "Smart and Inclusive Growth: Rethinking the State's Role and the Risk-Reward Relationship." In *Innovation Studies: Evolution & Future Challenges*, edited by Jan Fagerberg, Ben R. Martin and Esben Sloth Andersen, 195-201. Oxford: Oxford University Press.
- Mazzucato, Mariana. 2015a. "Conclusion: Beyond Market Failures: Shaping and Creating Markets for Innovation-Led Growth." In *Mission-oriented finance for innovation: New Ideas for Investment-led Growth*, edited by Mariana Mazzucato and C.C. R. Penna, 147-159. London: Policy Network.
- Mazzucato, Mariana. 2015b [2013]. *The Entrepreneurial State: Debunking Public vs. Private Sector Myths*. New York: Public Affairs.
- Mazzucato, Mariana, 2018. "Mission-oriented innovation policies: challenges and opportunities." *Industrial and Corporate Change* 27 (5): 803-815.
- Mazzucato, Mariana, and G. Diosi, eds. 2006. *Knowledge Accumulation and Industry Evolution: The Case of Pharma-Biotech*. Cambridge: Cambridge University Press.
- Mazzucato, Mariana, and Caetano C.R. Penna. 2015a. "Introduction: Mission-oriented Finance for Innovation." In *Mission-oriented Finance for Innovation: New Ideas for Investment-led Growth*, edited by Mariana Mazzucato and C.C. R. Penna, 1-10. London: Policy Network.

- Mazzucato, Mariana, and Caetano C.R. Penna, eds. 2015b. *Mission-oriented Finance for Innovation: New Ideas for Investment-led Growth*. London: Rowman & Littlefield International, Ltd.
- Mazzucato, Mariana, and Caetano C.R. Penna. 2016. “Beyond market failures: the market creating and shaping roles of state investment banks.” *Journal of Economic Policy Reform* 19 (4): 305-326.
- Mazzucato, Mariana, and Victory Roy. 2018. “Rethinking value in health innovation: *from mystifications towards prescriptions*.” *Journal of Economic Policy Reform* 22 (2): 101-119.
- Mazzucato, Mariana, and Gregor Semieniuk. 2017. “Public Financing of Innovation: New Questions.” *Oxford Review of Economic Policy* 33 (1): 24-48.
- McCurdy, Howard.E, and Robert E. Cleary. 1984. “Why can’t we resolve the research issue in public administration?” *Public Administration Review* 44 (1): 49-55.
- McFetridge, Donald G. 1993. “The Canadian System of Industrial Innovation.” In *National Innovation Systems: A Comparative Analysis*, edited by Richard R. Nelson, 299-323. Oxford: Oxford University Press.
- Mettler, Suzanne. 2007. “The Transformed Welfare State and the Redistribution of Political Voice.” In *The Transformation of American Politics: Activist Government and the Rise of Conservatism*, edited by Paul Pierson and Theda Skocpol. Princeton and Oxford: Princeton University Press.
- Mettler, Suzanne. 2011. *The Submerged State: How Invisible Government Policies Undermine American Democracy*. Chicago: The University of Chicago Press.
- Morgan, Paul, Dean G. Brown, Simon Lennard, Mark J. Anderton et al. 2018. “Impact of a five-dimensional framework on R&D productivity at AstraZeneca.” *Nature Reviews/ Drug Discovery* 17, January: 167-181.
- Motoyama, Y., R. Appelbaum, and R. Parker. 2011. “The National Nanotechnology Initiative: Federal Support for Science and Technology, or Hidden Industrial Policy?” *Technology in Society* 33 (1-2): 109-18.

- Mowery, David C. 2009. “*Plus ça change*: Industrial R&D in the ‘third industrial revolution’.” *Industrial and Corporate Change* 18 (1): 1-50.
- Mowery, David C. 2010. “Military R&D and Innovation.” In *Handbook of the Economics of Innovation*, edited by Bronwyn N. Hall and Nathan Rosenberg. Vol. 2. Amsterdam and Boston: Elsevier.
- Mowery, David C., Richard R. Nelson, Bhaven N. Sampat, and Arvids A. Ziedonis. 2004. *Ivory Tower and Industrial Innovation: University-Industry Technology Transfer Before and After the Bayh-Dole Act in the United States*. Stanford: Stanford University Press.
- Mowery, David C., Richard R. Nelson, and Ben R. Martin. 2010. “Technology policy and global warming: Why new policy models are needed (or why putting new wine in old bottles won’t work).” *Research Policy* 39: 1011-1023.
- Mowery, David C., and Nathan Rosenberg. 1993. “The U.S. National Innovation System.” In *National Innovation Systems: A Comparative Analysis*, edited by Richard R. Nelson, 29-75. Oxford: Oxford University Press.
- Mowery, David C., and Bhaven N. Sampat. 2005. “Universities in National Innovation Systems.” In *The Oxford Handbook of Innovation*, edited by Jan Fagerberg, David C. Mowery, and Richard R. Nelson, 209-239. Oxford: Oxford University Press.
- Mowery, David C., and Timothy Simcoe 2005, “The Internet.” In *The Limits of Market Organization*, edited by Richard R. Nelson. New York: Russell Sage Foundation.
- Munos, Bernard. 2009. “Lessons from 60 years of pharmaceutical innovation.” *Nature Reviews/Drug Discovery* 8 (12): 959-968.
- Negoita, Marian, and Fred Block. 2012. “Networks and Public Policies in the Global South: The Chilean Case and the Future of the Developmental Network State.” *Studies in Comparative International Development* 47: 1-22.
- Nelson, Richard R. 1988. “Institutions Supporting Technical Change in the United States.” In *Technical Change and Economic Theory*, edited by Giovanni Dosi, Christopher Freeman, Richard Nelson, Gerald Silverberg and Luc Soete. London and New York: Pinter Publishers Limited.

- Nelson, Richard R., ed. 1993a. *National Innovation Systems: A Comparative Analysis*. Oxford: Oxford University Press.
- Nelson, Richard R. ed., 1993b. “A Retrospective.” In *National Innovation Systems: A Comparative Analysis*, edited by Richard.R. Nelson, 505-523. Oxford: Oxford University Press.
- Nelson, Richard R. 2005a. “Basic Scientific Research.” In *The Limits of Market Organization*, edited by Richard R. Nelson., 233-258. New York: Russell Sage Foundation.
- Nelson, Richard R., ed. 2005b. *The Limits of Market Organization*. New York: Russell Sage Foundation.
- Nelson, Richard R. 2000c. *Technology, Institutions and Economic Growth*. Cambridge, MA: Harvard University Press.
- Nelson, Richard R. 2008. “Factors Affecting the Power of Technological Paradigms.” *Industrial and Corporate Change* 17 (3): 485-497.
- Nelson, Richard R. 2013. “Reflections on the Study of Innovation and on Those Who Study It.” In *Innovation Studies: Evolution & Future Challenges*, edited by Jan Fagerberg, Ben R. Martin and Esben Sloth Andersen, 188-193. Oxford: Oxford University Press.
- Nelson, Richard R. 2020. “A Perspective on the Evolution of Evolutionary Economics.” *Industrial and Corporate Change* 29 (5): 1101-1118.
- Nelson, Richard R. and Nathan Rosenberg. 1993. “Technical Innovation and National Systems.” In *National Innovation Systems: A Comparative Analysis*, edited by Richard R. Nelson, 3-21. Oxford: Oxford University Press.
- Nelson, Richard R., and Sidney G. Winter. 1982. *An Evolutionary Theory of Economic Change*. Cambridge, MA and London, England: The Belknap Press of Harvard University Press.
- Newfield, Christopher. 2011. (Reprinted 2016.) “Avoiding Network Failure: The Case of the National Nanotechnology Initiative.” In *State of Innovation: The U.S. Government’s Role in Technology Development*, edited by Fred Block and Matthew R. Keller, 282-299. New York: Routledge.

- Nicholson, Peter. 2016. "Canada's Low-Innovation Equilibrium: Why It Has Been Sustained and How It Will Be Disrupted." *Canadian Public Policy* 42 (Supplement 1) November: S39 – S45.
- Niosi, Jorge. 1998. "Canada's National R&D System." In *Innovation Systems in a Global Context: The North American Experience*, edited by Robert Anderson, Theodore Cohn, Chad Day, Michael Howlett, & Catherine Murray, 91-107. Montreal & Kingston: McGill-Queen's University Press.
- Niosi, Jorge. 2003. "Alliances are not enough explaining rapid growth in biotechnology firms." *Research Policy* 32: 737-750.
- Niosi, Jorge. 2010. *Building National and Regional Innovation Systems: Institutions for Economic Development*. Northampton Mass: Edward Elgar Publishing Limited.
- Niosi, Jorge. 2018a. "Introduction: Institution Systems, Policies and Management." In *Innovation Systems, Policy and Management*, edited by Jorge Niosi, 1-24. Cambridge: Cambridge University Press.
- Niosi, Jorge, ed. 2018b. *Innovation Systems, Policy and Management*. Cambridge: Cambridge University Press.
- Niosi, Jorge and Tomas Gabriel Bas. 2001. "The Competencies of Regions : Canada's Clusters in Biotechnology." *Small Business Economics* 17: 31-42.
- Niosi, Jorge, with Tomas Gabriel Bas, and Majlinda Zhegu. 2014. *Canada's Regional Innovation Systems: The Science-based Industries*. Montreal, Kingston, London and Ithaca: McGill-Queen's University Press.
- Niosi, Jorge, with André Manseau, and Benoît Godin. 2000. *Canada's National System of Innovation*. Montreal and Kingston: Mc-Gill-Queen's University Press.
- Ó Riain, Seán. 2004. *The Politics of High-Tech Growth: Developmental Network States in the Global Economy*. Cambridge: Cambridge University Press.
- Ó Riain, Seán. 2011. Reprinted 2016. "From Developmental Network State to Market Managerialism in Ireland." In *State of Innovation: The U.S. Government's Role in Technology Development*, edited by Fred Block and Matthew R. Keller, 196-216. New York: Routledge.

- Ó Riain, Seán. 2013. "Ireland's Industrial Policy Challenge." In *The Nuts and Bolts of Innovation: New Perspectives on Irish Industrial Policy*, edited by David Jacobson, 15-36. Dublin: Glasnevin Publishing.
- Orloff, Ann Shola. 1988. "The Political Origins of America's Belated Welfare State." In *The Politics of Social Policy in the United States*, edited by Margaret Weir, Ann Shola Orloff and Theda Skocpol, 37-80. Princeton: Princeton University Press.
- Orloff, Ann Shola. 1993. *The Politics of Pensions: A Comparative Analysis of Britain, Canada and the United States 1880-1940*. Madison, WI: University of Wisconsin Press.
- Orloff, Ann Shola, and Theda Skocpol. 1984. Why Not Equal Protection? Explaining the Politics of Public Social Spending in Britain, 1900-1911, and the United States, 1880s-1920." *American Sociological Review* 49 (6) December: 726-250.
- Ostrom, Vincent. 2008. *The Intellectual Crisis in American Public Administration*, 3rd ed. Tuscaloosa, Alabama: The University of Alabama Press.
- Pammolli, Fabio, Laura Magazzini and Massimo Riccaboni. 2011. "The productivity crisis in pharmaceutical R&D." *Nature Reviews/ Drug Discovery* 10, June: 428-438.
- Paquet, Gilles. 1998. "Techno-nationalism and Meso Innovation Systems." In *Innovation Systems in a Global Context: The North American Experience*, edited by Robert Anderson, Theodore Cohn, Chad Day, Michael Howlett, & Catherine Murray, 58-75. Montreal & Kingston: McGill-Queen's University Press.
- Paquet, Gilles. 1999. "Tectonic Changes in Canadian Governance." In *How Ottawa Spends: 1999-2000: Shape Shifting: Canadian Governance Toward the 21st Century*, edited by Leslie A. Pal, 75-111. Oxford, New York, Toronto: Oxford University Press Canada.
- Paquet, Gilles, and Jeffrey Roy. 1995. "Prosperity through Networks: The Bottom-Up Strategy That Might Have Been." In *How Ottawa Spends: 1995-1996*, edited by S. Phillips, 137-158. Ottawa: Carleton University Press.
- Patashnik, Eric. 2003. "After the public interest prevails: the political sustainability of policy reform." *Governance* 16: 203-234.
- Patashnik, Eric M. 2008. *Reforms at Risk: What Happens After Major Policy Changes are Enacted*. Princeton: Princeton University Press.

- Paul, Steven M., Daniel S. Mytelka, Christopher T. Dunwiddie, Charles C. Persinger, Bernard H. Munos, Stacy R. Lindborg, and Aaron L. Schacht. 2010. "How to improve R&D productivity: the pharmaceutical industry's grand challenge." *Nature Reviews/ Drug Discovery* 9, March: 203-214.
- Pavitt, Keith. 2005. "Innovation Processes." In *The Oxford Handbook of Innovation*, edited by Jan Fagerberg, David C. Mowery, and Richard R. Nelson, 86-114. Oxford: Oxford University Press.
- Phillips, Peter W.B., and David Castle. 2010. "Science and Technology Spending: Still No Viable Federal Innovation Agenda." In *How Ottawa Spends, 2010 – 2011: Recession, Realignment, and the New Deficit Era*, edited by G. Bruce Doern and Christopher Stoney, 168-186. Montreal & Kingston: McGill – Queen's University Press.
- Phillips, Peter W.B. and David Castle. 2012. "Science and Technology in Canada: Government Investment at a Crossroad?" In *How Ottawa Spends, 2012-2013: The Harper Majority, Budget Cuts, and the New Opposition*, edited by G. Bruce Doern and Christopher Stoney, 89-105. Montreal & Kingston: McGill – Queen's University Press.
- Phillips, Peter W.B., Graeme Jobe, Aditya Das Gupta, Sarah Juma, Paul Trujillo Jacome, Samuel Kanyoro Karba, Achint Rastogi and Michael Horvath. 2017. "Science and Innovation Policy for Canada's Next 150 Years." In *How Ottawa Spends, 2017-2018: Canada@150*, edited by Katherine A.H. Graham, and Allan M. Maslove, 46-58. <https://carleton.ca/hos/wp-content/uploads/How-Ottawa-Spends-2017-2018-Ottawa-@150.pdf>.
- Phillips, Peter W.B. and Aaron Hertes. 2018. "Implementing the New Innovation Agenda." In *How Ottawa Spends, 2018-2019: Next?*, edited by Katherine Graham and Allan M. Maslove, 129-139. <https://carleton.ca/sppa/2018/now-available-how-ottawa-spends-2018-2019-next/>.
- Pierson, Paul. 1994. *Dismantling the Welfare State? Reagan, Thatcher, and the Politics of Retrenchment*. Cambridge: Cambridge University Press.
- Pierson, Paul, ed. 2001. *The New Politics of the Welfare State*. Oxford: Oxford University Press.

- Pierson, Paul. 2003. "Big, Slow-Moving, and ... Invisible: Macro-Social Processes in the Study of Comparative Politics." In *Comparative Historical Analysis in the Social Sciences*, edited by Dietrich Rueschemeyer and James Mahoney, 177-207. Cambridge and New York: Cambridge University Press.
- Pierson, Paul. 2004. *Politics in Time: History, Institutions, and Social Analysis*. Princeton and Oxford: Princeton University Press.
- Pierson, Paul. 2016. "Power in Historical Institutionalism." In *The Oxford Handbook of Historical Institutionalism*, edited by Orfeo Fioretos, Tulia G. Falletti and Adam Sheingate, 124-141. Oxford: Oxford University Press.
- Pierson, Paul, and Theda Skocpol. 2007. "American Politics in the Long Run." In *The Transformation of American Politics: Activist Government and the Rise of Conservatism*, edited by Paul Pierson and Theda Skocpol, 3-16. Princeton and Oxford: Princeton University Press.
- Piore, Michael, and Charles F. Sable. 1984. *The Second Industrial Divide: Possibilities for Prosperity*. New York: Basic Books.
- Polanyi, Karl. 1957 [1944]. *The Great Transformation: The Political and Economic Origins of Our Time*. Beacon Hill and Boston: Beacon Press.
- Polanyi, Michael. 1966. *The Tacit Dimension*. Garden City, N.Y.: Doubleday.
- Popper, Karl. 1959. *The Logic of Scientific Discovery*. London: Routledge Classics.
- Porter, Michael, E. 1990. *The Competitive Advantage of Nations*. New York: The Free Press.
- Powell, Walter W., and Stine Grodal. 2005. "Networks of Innovators." In *The Oxford Handbook of Innovation*, edited by Jan Fagerberg, David C. Mowery and Richard R. Nelson, 56-85. Oxford: Oxford University Press.
- Powell, Walter W., Kenneth W. Koput, and Laurel Smith-Doerr. 1996. "Interorganizational Collaboration and the Locus of Innovation in Biotechnology." *Administrative Science Quarterly* 41(1): 116-145.
- Quirion, Remi, Arthur Carty, Paul Dufour, and Ramia Jabr. 2016. "Reflections on science advisory systems in Canada." *Palgrave Communications*. <https://doi.org/10.1057/palcomms.2016.48>.

- Raadschelders, Jos. C.N. 1999. "A Coherent Framework for the Study of Public Administration." *Journal of Public Administration and Research Theory* 9 (2): 281-303.
- Raadschelders, Jos C.N. 2011a. *Public Administration: The Interdisciplinary Study of Government*. Oxford: Oxford University Press.
- Raadschelders, Jos. C.N. 2011b. "The Future of the Study of Public Administration: Embedding Research Object and Methodology in Epistemology and Ontology." *Public Administration Review*. November/December: 71 (6): 916-924.
- Raadschelders, Jos C.N. 2011. "The Study of Public Administration in the United States." *Public Administration* 89 (1): 140-155.
- Raadschelders, Jos C.N. 2019. "The State of Theory in the Study of Public Administration in the United States: Balancing Evidence-Based, Usable Knowledge, and Conceptual Understanding." *Administrative Theory & Praxis* 41: 79-98.
- Rhodes, R.A.W. 1996. "The New Governance: Governing without Government." *Political Studies* XLIV: 652-667.
- Ragin, Charles C. 2008. *Redesigning Social Inquiry: Fuzzy Sets and Beyond*. Chicago and London: University of Chicago Press.
- Riccucci, Norma M. 2010. *Public Administration: Traditions of Inquiry and Philosophies of Knowledge*. Washington: Georgetown University Press.
- Rittel, Horst W. and Melvin M. Webber. 1973. "Dilemmas in a General Theory of Planning." *Policy Sciences* 4 (2) June: 155-169.
- Rogowski, Ronald. 1995. "The Role of Theory and Anomaly in Social Scientific Inference." *American Political Science Review* 89 (2) June : 467-470.
- Rosenberg, Nathan. 1982. *Inside the Black Box: Technology and Economics*. Cambridge: Cambridge University Press.
- Rosenberg, Nathan. 1994. *Exploring the Black Box*. Cambridge: Cambridge University Press.
- Rueschemeyer, Dietrich. 2003. "Can One or a Few Cases Yield Theoretical Gains?" In *Comparative Historical Analysis in the Social Sciences*, edited by James Mahoney and Dietrich Rueschemeyer, 305-336. Cambridge: Cambridge University Press.

- Rusu, Alexandru, Katja Kuokkanen, and Annabell Heier. 2011. "Current Trends in the pharmaceutical industry – A case study approach." *European Journal of Pharmaceutical Sciences* 44: 437-440.
- Rutgers, Mark R. 1994. "Can the Study of Public Administration Do Without a Concept of the State: Reflections on the Work of Lorenz Von Stein." *Administration & Society* 26 (3) November: 395-412.
- Sabatier, Paul A., and Hank C. Jenkins-Smith. 1993. *Policy Change and Learning: An Advocacy Coalition Approach*. Boulder, CO: Westview Press.
- Sabatier, Paul A., and Hank C. Jenkins-Smith. 1999. "The Advocacy Coalition Framework: An Assessment." In *Theories of the Policy Process*, edited by Paul A. Sabatier and Hank C. Jenkins-Smith, 117-166. Boulder, CO: Westview Press.
- Sabatier, Paul A., and Christopher M. Weible. 2007. "The Advocacy Coalition Framework: Innovations and Clarifications." In *Theories of the Policy Process*, edited by Paul Sabatier. 2nd ed., 189-220. Boulder, Colorado: Westview Press.
- Saxenian, AnnaLee. 1994. *Regional Advantage: Culture and Competition in Silicon Valley and Route 128*. Cambridge, Mass.: Harvard University Press.
- Scannell, Jack W., Alex Blanckley, Helen Boldon and Brian Warrington. 2012. "Perspectives." *Nature Reviews/ Drug Discovery* 11, March: 191-200.
- Schumpeter, Joseph A. 1934. *The Theory of Economic Development*. Cambridge, Mass.: Harvard University Press.
- Schumpeter, Joseph. 1950 [1942]. *Capitalism, Socialism and Democracy*. 3rd ed. New York: Harper & Row, Publishers.
- Schumpeter, Joseph A. 2017 [1939]. *Business Cycles: A Theoretical, Historical, and Statistical Analysis of the Capitalist Process: Volume Two*. Eastford, CT: Martino Fine Books.
- Schrank, Andrew. 2011. (Reprinted 2016.) "Green Capitalists in a Purple State: Sandia National Laboratories and the Renewable Energy Industry in New Mexico." In *State of Innovation: The U.S. Government's Role in Technology Development*, edited by Fred Block and Matthew R. Keller, 96-108. New York: Routledge, 96-108.

- Schrank, Andrew, and John Whitford. 2009. "Industrial Policy in the United States: A Neo-Polanyian Interpretation." *Politics & Society* 37 (4): 521-553.
- Schmidt, Vivien A. 2010. "Taking ideas and discourse seriously: explaining change through discursive institutionalism as the fourth 'new institutionalism'." *European Political Science Review* 2 (1): 1-25.
- Shih, Hsin-Pei, Xiaodan Zhang, and Alex M. Aronov. 2018. "Drug discovery effectiveness from the standpoint of therapeutic mechanisms and indicators." *Nature Reviews/Drug Discovery* 17, January: 19-33.
- Shonfield, Andrew. 1965. Reprinted 1969. *Modern Capitalism: The Changing Balance of Public and Private Power*. Oxford: Oxford University Press.
- Simon, Herbert A. 1946. "The Proverbs of Administration." *Public Administration Review* 6 (1) 53-67.
- Skocpol, Theda. 1973. "A Critical Review of Barrington Moore's Social Origins of Dictatorship and Democracy." *Politics and Society* 4 (1): 1 – 34.
- Skocpol, Theda. 1979. *States and Social Revolutions: A Comparative Analysis of France, Russia and China*. Cambridge: Cambridge University Press.
- Skocpol, Theda. 1980. "Political Response to Capitalist Crisis: Neo-Marxist Theories of the State and the Case of the New Deal." *Politics and Society* 10 (2): 155-201.
- Skocpol, Theda. 1985. "Bringing the State Back In: Strategies of Analysis in Current Research." In *Bringing the State Back In*, edited by Peter B. Evans, Dietrich Rueschemeyer and Theda Skocpol, 3-37. Cambridge: Cambridge University Press.
- Skocpol, Theda. 1988. "The Limits of the New Deal System and the Roots of Contemporary Welfare Dilemmas." In *The Politics of Social Policy in the United States*, edited by Margaret Weir, Ann Shola Orloff and Theda Skocpol, 293-311. Princeton: Princeton University Press.
- Skocpol, Theda. 1992. *Protecting Soldiers and Mothers: The Political Origins of Social Policy in the United States*. Cambridge, Mass. and London, England: The Belknap Press of Harvard University Press.
- Skocpol, Theda. 1995. "Why I am an Historical Institutional." *Polity* 28 (1): 103-106.

- Skocpol, Theda. 1996. *Boomerang: Clinton's Health Security Effort and the Turn against Government in U.S. Politics*. New York and London: W.W. Norton & Company.
- Skocpol, Theda. 2003a. *Diminished Democracy: From Membership to Management in American Civic Life*. University of Oklahoma Press: Norman.
- Skocpol, Theda. 2003b. "Doubly Engaged Social Science: The Promise of Comparative Historical Analysis." In *Comparative Historical Analysis in the Social Sciences*, edited by James Mahoney and Dietrich Rueschemeyer, 407-428. Cambridge: Cambridge University Press.
- Skocpol, Theda. 2011. "Government Activism and the Reorganization of American Civic Democracy." In *The Transformation of American Politics: Activist Government and the Rise of Conservatism*, edited by Paul Pierson and Theda Skocpol. Princeton: Princeton University Press.
- Skocpol, Theda and Edwin Amenta. 1985. "Did Capitalists Shape Social Security?" *American Sociological Review* 50 (4): 572-575.
- Skocpol, Theda and Edwin Amenta. 1986. "States and Social Policies." *Annual Review of Sociology* 12: 131-157.
- Skocpol, Theda, and Kenneth Finegold. 1982. "State Capacity and Economic Intervention in the Early New Deal." *Political Science Quarterly* 97 (2) Summer: 255-278.
- Skocpol, Theda, and John Ikenberry. 1983. "The Political Formation of the American Welfare State in Historical and Comparative Perspective." *Comparative Social Research* 6 (1): 5-87.
- Skocpol, Theda and Paul Pierson. 2002. "Historical Institutionalism in Contemporary Political Science." In *Political Science: State of the Discipline*, edited by Ira Katznelson and H.V. Milner, 693-721. New York: W.W. Norton
- Smith, Margaret. 1993. "Patent Protection for Pharmaceutical Products." Law and Government Division, Library of Parliament. November: BP-354E.
- Smiley, Donald V. 1976. *Federalism in Question: Federalism in the Seventies*. 2nd ed. Toronto: McGraw- Hill Ryerson.

- Steinmo, Sven. 2008. "Historical Institutionalism." In *Approaches and Methodologies in the Social Sciences: A Pluralist Perspective*, edited by Donatella della Porta and Michael Keating, 118-138. Cambridge: Cambridge University Press.
- Steinmo, Sven, Kathleen Thelen, and Frank Longstreth, eds. 1992. *Structuring Politics: Historical Institutionalism in Comparative Analysis*. Cambridge: Cambridge University Press.
- Stepan, Alfred. 1971. *The Military in Politics: Changing Patterns in Brazil*. Princeton, NJ: Princeton University Press.
- Stepan, Alfred. 1985. "State Power and the Strength of Civil Society in the Southern Cone of Latin America." In *Bringing the State Back In*, edited by Peter B. Evans, Dietrich and Theda Skocpol, 317-343. Cambridge: Cambridge University Press.
- Stepan, Alfred. 1988. *Rethinking Military Politics: Brazil and the Southern Cone*. Princeton: Princeton University Press.
- Strange, Susan. 1997. "The Future of Global Capitalism; or, Will Divergence Persist Forever?" In *Political Economy of Modern Capitalism: Mapping Convergence and Diversity*, edited by Colin Crouch and Wolfgang Streeck. London: SAGE Publications Ltd.
- Streeck, Wolfgang. 2016. *How Will Capitalism End?* London: Verso.
- Streeck, Wolfgang, and Kathleen Thelen. 2005. "Introduction: Institutional Change in Advanced Political Economies." In *Beyond Continuity: Institutional Change in Advanced Political Economies*, edited by Wolfgang Streeck and Kathleen Thelen, 1-39. Oxford and New York: Oxford University Press.
- Tang, Jianmin, and Someshwar Rao. 2003. "Are Foreign-Controlled Manufacturing Firms Less R&D-Intensive than Canadian-Controlled Firms?" *Canadian Public Policy* 29 (1). March: 111-117.
- Tancer, Robert S. 1997. "Foreign Investment in North America and the Pharmaceutical Industry in Canada." *The International Executive* 39(2) March/April: 283-297.
- Tarrow, Sidney. 1995 "Bridging the Quantitative-Qualitative Divide in Political Science." *American Political Science Review* 89 (2) June: 471-474.

- Thelen, Kathleen. 2003. "How Institutions Evolve: Insights from Comparative Historical Analysis." In *Comparative Historical Analysis in the Social Sciences*, edited by James Mahoney and Dietrich Rueschemeyer, 208-240. Cambridge: Cambridge University Press.
- Thelen, Kathleen. 2004. *How Institutions Evolve: The Political Economy of Skills in Germany, Britain, the United States and Japan*. Oxford: Oxford University Press.
- Thelen, Kathleen. 2014. *Varieties of Liberalization and the New Politics of Social Solidarity*. New York: Cambridge University Press.
- Thelen, Kathleen and James Mahoney. 2015. "Comparative-historical analysis in contemporary political science." In *Advances in Comparative-Historical Analysis*, edited by James Mahoney and Kathleen Thelen, 3-36.
- Thelen, Kathleen and Sven Steinmo. 1992. "Historical institutionalism in comparative politics." In *Structuring Politics: Historical Institutionalism in Comparative Analysis*, edited by Sven Steinmo, Kathleen Thelen and Frank Longstreth, 1-32. Cambridge: Cambridge University Press.
- Tilly, Charles. 1984. *Big Structures, Large Processes, Huge Comparisons*. New York: Russell Sage Foundation.
- Tilly, Charles. 1985. "War Making and State Making as Organized Crime." In Peter B. Evans, Dietrich Rueschemeyer and Theda Skocpol (eds.), *Bringing the State Back In*. Cambridge: Cambridge University Press.
- Tosun, Jale, and Samuel Workman. 2018. "Struggle and Triumph in Fusing Policy Process and Comparative Research." In *Theories of the Policy Process*, edited by Christopher M. Weible and Paul A. Sabatier, 329-362. 4th ed. New York, Westview Press.
- Trimberger, Ellen Kay. 1978. *Revolution from Above: Military Bureaucrats and Development in Japan, Turkey, Egypt and Peru*. New Brunswick, NJ: Transaction Books.
- Vallas, Steven P., Daniel Lee Kleinman, and Dina Biscotti. 2011. (Reprinted 2016.) "Political Structure and the Making of U.S. Biotechnology." In *State of Innovation: The U.S. Government's Role in Technology Development*, edited by Fred Block and Matthew R. Keller, 57-76. London and New York: Routledge.

- Van Atta, Richard H., Project Leader, Michael J. Lippitz with Jasper C. Lupo, Rob Mahoney, and Jack H. Nunn. 2003. *Transformation and Transition: DARPA's Role in Fostering an Emerging Revolution in Military Affairs: Volume 1 – Overall Assessment*. Alexandria, Virginia: Institute for Defense Analyses.
- Verspagen, Bart. 2005. "Innovation and Economic Growth." In *The Oxford Handbook of Innovation*, edited by Jan Fagerberg, David C. Mowery and Richard R. Nelson, 487-513. Oxford: Oxford University Press.
- Walker, William. 1993. "National Innovation Systems: Britain." In *National Innovation Systems: A Comparative Analysis*, edited by Richard R. Nelson, 158-191. Oxford: Oxford University Press..
- Wallerstein, Immanuel. 1974. *The Modern World-System I: Capitalist Agriculture and the Origins of the European World-Economy in the Sixteenth Century*. San Diego, New York, Berkeley, Boston, London: Academic Press, Inc., Harcourt Brace Jovanovich, Publishers.
- Weber, K.M., and B. Truffer. 2017. "Moving Innovation Systems Research to the Next Level: Towards an Integrative Agenda." *Oxford Review of Economic Policy* 33 (1): 101-121.
- Weible, Christopher M. 2018. "Moving Forward and Climbing Upward: Advancing policy Process Research." In *Theories of the Policy Process*, edited by Christopher M. Weible and Paul A. Sabatier, 363-378 4th ed. New York: Westview Press.
- Weir, Margaret. 1988. "The Federal Government and Unemployment: The Frustration of Policy Innovation from the New Deal to the Great Society." In *The Politics of Social Policy in the United States*, edited by Margaret Weir, Ann Shola Orloff and Theda Skocpol, 149-190. Princeton: Princeton University Press.
- Weir, Margaret. 1992a. "Ideas and the Politics of Bounded Innovation." In *Structuring Politics: Historical Institutionalism in Comparative Analysis*, edited by Sven Steinmo, Kathleen Thelen and Frank Longstreth, 188-216. Cambridge: Cambridge University Press.
- Weir, Margaret. 1992b. *Politics and Jobs: The Boundaries of Employment Policy in the United States*. Princeton, New Jersey: Princeton University Press.

- Weir Margaret, Ann Shola Orloff, and Theda Skocpol, eds. 1988. *The Politics of Social Policy in the United States*. Princeton: Princeton University Press.
- Weir, Margaret, and Theda Skocpol. 1985. "State Structures and the Possibilities for 'Keynesian' Responses to the Great Depression in Sweden, Britain, and the United States." In *Bringing the State Back*, edited by Peter B. Evans, Dietrich Rueschemeyer and Theda Skocpol, 107-163. Cambridge: Cambridge University Press.
- Weiss, Linda. 1997. "Globalization and the Myth of the Powerless State." *New Left Review* 225 September-October: 3-27.
- Whetsell, Travis A., and Patricia M. Shields. 2015. "The Dynamics of Positivism in the Study of Public Administration: A Brief Intellectual History and Reappraisal." *Administration and Society* 47 (4): 416-446.
- Whitford, Josh. 2005. *The New Old Economy: Networks, Institutions and the Organizational Transformation of American Manufacturing*. Oxford: Oxford University Press.
- Whitford, Josh, and Andrew Schrank. 2011. Reprinted 2016. "The Paradox of the Weak State Revisited: Industrial, Policy, Network Governance, and Political Decentralization." In *State of Innovation: The U.S. Government's Role in Technology Development*, edited by Fred Block and Matthew R. Keller, 261-281. London and New York: Routledge.
- Whitford, Josh and Jonathan Zeitlin. 2004. "Governing Decentralized Production: Institutions, Public Policy , and the Prospects for Inter-Firm Collaboration in U.S. Manufacturing." *Industry and Innovation* 11 (1-2): 11-44.
- Wilson, Woodrow. 1887. "The Study of Public Administration" *Political Science Quarterly* 2 June: 197-222.
- Witt, Michael A., and Gregory Jackson. 2016. "Varieties of Capitalism and institutional comparative advantage: A test and reinterpretation." *Journal of International Business Studies* 47 (7): 778-806.
- Wolfe, David A. 1998. "Ontario's Regional System: The Evolution of Knowledge-based Institutions." In *Regional Innovation Systems: The Role of Governances in a Globalized World*, 2nd ed., edited by Hans-Joachim Braczyk, Phillip Cooke, and Martin Heidenreich. London: Routledge.

- Wolfe, David A. 2002a. "Innovation Policy for the Knowledge-Based Economy: From the Red Book to the White Paper." In *How Ottawa Spends: 2002-2003: The Security Aftermath and National Priorities*, edited by G. Bruce Doern, 137-156. Oxford: Oxford University Press.
- Wolfe, David A. 2002b. "Social Capital and Cluster Development in Learning Regions." In J. Adam Holbrook and David A. Wolfe, eds. *Knowledge, Clusters and Learning Regions: Economic Development in Canada*, 11-38. Kingston: School of Policy Studies, Queen's University, 2002.
- Wolfe, David A. 2009. "Introduction: Embedded Clusters in the Global Economy." *European Planning Studies* 17 (2) February: 179-187.
- Wolfe, David A., and Meric C. Gertler, eds. 2016a. *Growing Urban Economies: Innovation, Creativity, and Governance in Canadian City-Regions*. Toronto: University of Toronto Press.
- Wolfe, David A. and Meric C. Gertler. 2016b. "Innovation, Creativity, and Governance in Canadian City-Regions." In *Growing Urban Economies: Innovation, Creativity, and Governance in Canadian City-Regions*, edited by David A. Wolfe and Meric C. Gertler, 5-47. Toronto: University of Toronto Press.
- Wolfe, David A, and M. Lucas, eds. 2005. *Global Networks and Local Linkages: The Paradox of Cluster Development in an Open Economy*. Montreal and Kingston: McGill-Queen's University Press.
- Wolfe, David A., and Allison Bramwell. 2016. "Toronto's Fourth Era: An Emerging Cognitive-Cultural Economy." In *Growing Urban Economies: Innovation, Creativity, and Governance in Canada City-Regions.*, edited by David A. Wolfe and Meric S. Gertler. Toronto, Buffalo, London: University of Toronto Press.
- Wolfe, David A., and Jen Nelles. 2008. "The Role of Civic Capital and Civic Associations in Cluster Policies." In *Handbook of Research on Innovation and Cluster Policies*, ed. Charlie Karlsson. Cheltenham, UK: Edward Elgar Publishers.

- Zittoun, Philippe, and Benoît Demongeot. 2009. "Debates in French policy studies: from cognitive to discursive approaches." *Critical Policy Studies*. 3 (3-4) October-December: 391-406.
- Zachary Taylor, Mark. 2004. "Empirical Evidence Against Variety of Capitalism's Theory of Technical Innovation." *International Organization*. 58: 601-603.
- Zalmanovitch, Yal. 2014. "Don't reinvent the wheel: the search for an identity for public administration." *International Review of Administrative Sciences* 80 (4): 808 - 826
- Zuijdewijk, Ton. 2018. "Integrating the Rules of International Intellectual Property Law into the Body of International Trade Law." In *Reflections on Canada's Past, Present and Future in International Law = Réflexions sur le passé, le présent et l'avenir du Canada en droit international*, edited by Oonagh E. Fitzgerald, Valerie Hughes and Mark Jewett, 381-399. Centre for International Governance Innovation.
- Zysman, John. 1983. *Governments, Markets, and Growth: Financial Systems and the Politics of Industrial Change*. Ithaca and London: Cornell University Press.

Government Documents, Commissions and International Agency Reports

- Advisory Council on Economic Growth (ACEG). 2017. *Unlocking Innovation to Drive Scale and Growth*. 6 February. Ottawa: Advisory Council on Economic Growth.
- Advisory Council on Science and Technology (ACST). 1999a. *Public Investments in University Research: Reaping the Benefits: Report of the Expert Panel on the Commercialization of University Research*. May 4. Ottawa: Her Majesty the Queen in Right of Canada (Industry Canada).
- , 1999b. *Stepping Up: Skills and Opportunities in the Knowledge Economy. Report of the Expert Panel on Skills*. October. Ottawa: Her Majesty the Queen in Right of Canada (Industry Canada).
- , 2000. *Reaching Out: Canada, International Science and Technology and the Knowledge-based Economy. Report of the Expert Panel on Canada's Role in International Science and Technology*. June. Ottawa: Industry Canada.

- , 2001. *Creating a Sustainable University Research Environment in Canada*. September. Ottawa: Industry Canada.
- Advisory Panel for the Review of Federal Support for Fundamental Science (Naylor Report). 2017. *Investing in Canada's Future: Strengthening the Foundations of Canadian Research*. Ottawa: Advisory Panel.
- Belloni, Annalisa, David Morgan and Valérie Paris. 2016. "OECD Health Working Paper no. 87: Pharmaceutical Expenditures And Policies; Past Trends And Future Challenges." <https://dx.doi.org/10.1787/5jm0q1f4cdq7-en>.
- Boekholt, Patries and Ben Thuriaux. 1999. "Public Policies to Facilitate Clusters: Background, Rational and Policy Practices in International Perspective in *OECD, Boosting Innovation: The Cluster Approach*. Paris: OECD Proceedings.
- Business Development Bank of Canada. 2017. *Canada's Venture Capital Landscape: Challenges and Opportunities*. June. Ottawa: BDC.
- Canada. 2003. *Biotechnology Transforming Society: Creating an Innovative Economy and a Higher Quality of Life: Report on Biotechnology (1998-2003)*. Ottawa: Public Works and Government Services Canada.
- Canada. Canadian Biotechnology Advisory Committee (CBAC). 2006. *Toward a Canadian Action Agenda for Biotechnology: A Report from the Canadian Biotechnology Advisory Committee*. September. Ottawa: Government of Canada.
- Canada. Canadian Biotechnology Advisory Committee (CBAC). 2007. *Annual Report 2006*. Ottawa: Government of Canada (Canadian Biotechnology Advisory Committee).
- Canada. Canadian Institutes of Health Research. 2007, 2008, 2009, 2010, 2011, 2012, 2013, 2014, 2015, 2016. *Departmental Performance Report*. <https://cihr-irsc.gc.ca/e/22978.html#a2>.
- , -----, 2017, 2018, 2019. *Departmental Results Report*. Ottawa. Her Majesty the Queen in Right of Canada. <https://cihr-irsc.gc.ca/e/22978.html#a2>.

- Canada. External Advisory Committee on Smart Regulation. September 2004. *Smart Regulation: A Regulatory Strategy for Canada*. Ottawa: Library and Archives Canada Cataloguing in Publication.
- Canada. External Affairs Canada. 1987. *The Canada-U.S. Free Trade Agreement*. Ottawa: External Affairs Canada.
- Canada. Finance Canada. 1994. *The Budget Plan*. February. Ottawa: Her Majesty the Queen in Right of Canada (1994.).
- , -----, 1995. *Budget Plan*. 27 February. Ottawa: Her Majesty the Queen in Right of Canada (1995).
- , -----, 1996. *Budget Plan*. 6 March. Ottawa: Her Majesty the Queen in Right of Canada (1996).
- , -----, 1997. *Budget Plan*. 18 February. Ottawa: Her Majesty the Queen in Right of Canada (1997).
- , -----, 1998. *The Budget Plan 1998: Strong Economy & Secure Society*. 24 February 1998. Ottawa: Her Majesty the Queen in Right of Canada (1999).
- , -----, 1999. *The Budget Plan 1999: Building today for a better tomorrow*. 16 February. Ottawa: Her Majesty the Queen in Right of Canada (1999).
- , -----, 2000a. *The Budget Plan 2000*. 28 February. Ottawa: Her Majesty the Queen in Right of Canada (2000).
- , -----, 2000b. *Economic Statement and Budget Update*. 18 October. Ottawa: Her Majesty the Queen in Right of Canada (2001).
- , -----, 2001. *The Budget Plan 2001*. Ottawa: Her Majesty the Queen in Right of Canada.
- , -----, 2003. *The Budget Plan 2003*. Ottawa: Her Majesty the Queen in Right of Canada (2003).
- , -----, 2004. *The Budget Plan 2004*. Ottawa: Her Majesty the Queen in Right of Canada.(2004).
- , -----, 2005. *The Budget Plan 2005*. Ottawa: Her Majesty the Queen in Right of Canada (2005).

- , -----, 2006a. *Advantage Canada: Building a Strong Economy for Canadians*. Ottawa: Her Majesty the Queen in Right of Canada (2006).
- , -----, 2006b. *Focusing on Priorities. Canada's New Government Turning a New Leaf. The Budget Plan 2006*. Ottawa: Her Majesty the Queen in Right of Canada (2006).
- , -----, 2007. *ASPIRE to a Stronger, Safer, Better Canada. Canada's New Government. The Budget Plan 2007*. 19 March. Ottawa: Her Majesty the Queen in Right of Canada (2007).
- , -----, 2008. *Responsible Leadership. The Budget Plan 2008*. 26 February. Ottawa: Her Majesty the Queen in Right of Canada (2008).
- , -----, 2009. *Canada's Economic Action Plan. Budget 2009*. 27 January. Ottawa: Her Majesty the Queen in Right of Canada (2009).
- , -----, 2010. *Leading the Way on Jobs and Growth.: Canada's Economic Action Plan Year 2. Budget 2010*. 4 March. Ottawa: Her Majesty the Queen in Right of Canada (2010).
- , -----, 2011. *A Low-Tax Plan for Jobs and Growth: The Next Phase of Canada's Economic Action Plan*. 6 June. Ottawa: Her Majesty the Queen in Right of Canada (2011).
- , -----, 2012. *Jobs Growth and Long-Term Prosperity. Economic Action Plan 2012*. 29 March. Ottawa: Her Majesty the Queen in Right of Canada (2012).
- , -----, 2013. *Jobs Growth and Long-Term Prosperity. Economic Action Plan 2013*. 21 March 2013. Ottawa: Her Majesty the Queen in Right of Canada.
- , -----, 2014. *The Road to Balance: Creating Jobs and Opportunities*. 11 February. Ottawa: Her Majesty the Queen in Right of Canada (2014).
- , -----, 2015. *Strong Leadership: A Balanced-Budget, Low-Tax Plan for Jobs, Growth and Security*. 21 April. Ottawa: Her Majesty the Queen in Right of Canada (2014) [sic].
- , -----, 2016. *Growing the Middle Class*. 22 March. Ottawa: Her Majesty the Queen in Right of Canada (2016).

- , -----, 2017. *Building a Strong Middle Class: Budget 2017*. 22 March. Ottawa: Her Majesty the Queen in Right of Canada (2017).
- , -----, 2018a. *Equality and Growth: A Strong Middle Class*. 27 February. Ottawa: Her Majesty the Queen in Right of Canada (2018).
- , -----, 2018b. *Investing in Middle Class Jobs: Fall Economic Statement 2018*. Ottawa: Her Majesty the Queen in Right of Canada (2018).
- , -----, 2019. *Investing in the Middle Class. Budget 2019*. 19 March. Ottawa: Her Majesty the Queen in Right of Canada (2019).
- , -----, 2020. *Supporting Canadians and Fighting COVID-10: Fall Economic Statement 2020*. Her Majesty the Queen in Right of Canada (2020).
- , -----, 2021. *A Recovery Plan for Jobs, Growth, and Resilience. Budget 2021*. Ottawa: Her Majesty the Queen in Right of Canada (2021).
- Canada. Department of Justice. 1963. Restrictive Trade Practices Commission. *Report Concerning the Manufacture, Distribution and Sale of Drugs*. Ottawa: Queen's Printer.
- Canada. Human Resources Development Canada and Industry Canada. 2002. *Knowledge Matters: Skills and Learning for Canadians*. Ottawa: Her Majesty the Queen in Right of Canada.
- Canada. Industry Canada. 1996. *Science and Technology for the New Century. Summary*. Ottawa: Minister of Supply and Services Canada.
- Canada. Industry Canada. 1998. *The 1998 Canadian Biotechnology Strategy: An Ongoing Renewal Process*. Ottawa: Her Majesty the Queen in Right of Canada (Industry Canada) 1998.
- , -----, 2000. *Government Response to the Fourth Report of the Standing Committee on Industry: Productivity and Innovation: A Competitive and Prosperous Canada*. Ottawa. Industry Canada.
- , -----, 2001a. *Achieving Excellence, Investing in People, Knowledge and Opportunity: Canada's Innovation Strategy. Executive Summary*. Ottawa: Industry Canada

- , -----, 2001b. *Achieving Excellence, Investing in People, Knowledge and Opportunity: Canada's Innovation Strategy*. Ottawa: Industry Canada.
- , -----, 2001c. *Investing in Excellence, 1996-2001: A Report on Federal Science and Technology – 2001*. Ottawa: Industry Canada.
- , -----, 2002a. *Government Response to the Tenth Report of the Standing Committee on Industry, Science and Technology: Canada's Innovation Strategy: Peer Review and the Allocation of Research Funds*. November. Ottawa: Industry Canada.
- , -----, 2002b. *Science and Technology Advice: A Framework to Build On: A Report on Federal Science and Technology – 2002*. Ottawa: Industry Canada.
- , -----, 2005. *In the Service of Canadians. A Framework for Science and Technology*. Prepared by the Interdepartmental Working Group on Federal Science and Technology Framework. Ottawa: Industry Canada.
- , -----, 2006. *Telecommunications Policy Review Panel: Final Report*. Ottawa: Public Works and Government Services Canada .
- , -----, 2007a. *Government Response to the Fifth Report of the House of Commons Standing Committee on Industry, Science and Technology: Manufacturing: Moving Forward – Rising to the Challenge*. May. Ottawa: Industry Canada.
- , -----, 2007b. *Mobilizing Science and Technology to Canada's Advantage*. Ottawa: Public Works and Government Services Canada.
- , -----, 2009a. *Government Response to the Fifth Report of the Standing Committee on Industry, Science and Technology: A Study of the Crisis Faced by Certain Industrial Sectors in Canada*. October. <https://www.ourcommons.ca/DocumentViewer/en/40-2/INDU/report-5/response-8512-402-104>.
- , -----, 2009b. *Mobilizing Science and Technology to Canada's Advantage: Progress Report*. Ottawa: Public Works and Government Services Canada.
- , -----, 2013. *Canada's Pharmaceutical Industry and Prospects*. Ottawa: Her Majesty the Queen in Right of Canada, represented by the Minister of Industry, 2013.

- , -----, 2013a. *Evaluation of the Canadian Institute for Advanced Research*. Ottawa: Industry Canada.
- , -----, 2013b. *Government Response to the Third Report of the House of Commons Standing Committee on Industry, Science and Technology: Intellectual Property Regime in Canada*. June. <https://www.ourcommons.ca/DocumentViewer/en/41-1/INDU/report-3/response-8512-411-200>.
- , -----, 2014a. *Seizing Canada's Moment: Moving Forward in Science, Technology and Innovation 2014*. Ottawa: Her Majesty the Queen in Right of Canada, as represented by the Minister of Industry.
- , -----, 2014b. *Seizing Canada's Moment: Moving Forward in Science, Technology and Innovation 2014. Summary*. Ottawa: Her Majesty the Queen in Right of Canada, represented by the Minister of Industry.
- , -----, 2015: *Evaluation of Industry Canada's Contribution to Genome Canada: Final Report*. 18 March. Ottawa: Industry Canada.
- Canada. Industry Canada. (DPR). 2000. *Industry Canada Performance Report for the period ending March 31, 2000*. Ottawa: Minister of Public Works and Government Services Canada.
- , -----, (DPR). 2001. *Industry Canada Performance Report for the period ending March 31, 2001*. Ottawa: Minister of Public Works and Government Services Canada.
- , -----, (DPR). 2002. *Industry Canada Performance Report for the period ending March 31, 2002*. Ottawa: Minister of Public Works and Government Services Canada.
- , -----, (DPR). 2003. *Industry Canada Performance Report for the period ending March 31, 2003*. Ottawa: Minister of Public Works and Government Services Canada.
- , -----, (DPR). 2004. *Industry Canada Performance Report for the period ending March 31, 2004*. Ottawa: Minister of Public Works and Government Services Canada.

- , -----, (DPR). 2005. *Industry Canada Performance Report for the period ending March 31, 2005*. Ottawa: Minister of Public Works and Government Services Canada.
- , -----, (DPR). 2006. *Industry Canada Performance Report for the period ending March 31, 2006*. Ottawa: Minister of Public Works and Government Services Canada
- , -----, (DPR). 2007. *Industry Canada Performance Report for the period ending March 31, 2007*. Ottawa: Minister of Public Works and Government Services Canada
- , -----, (DPR). 2008. *Industry Canada Performance Report for the period ending March 31, 2008*. Ottawa: Minister of Public Works and Government Services Canada.
- , -----, (DPR). 2009. *Industry Canada Performance Report for the period ending March 31, 2009*. Ottawa: Minister of Public Works and Government Services Canada
- , -----, (DPR). 2010. *Industry Canada Performance Report for the period ending March 31, 2010*. Ottawa: Minister of Public Works and Government Services Canada.
- , -----, (DPR). 2011. *Industry Canada Performance Report for the period ending March 31, 2011*. Ottawa: Minister of Public Works and Government Services Canada.
- , -----, (DPR). 2012. *Industry Canada Performance Report for the period ending March 31, 2012*. Ottawa: Minister of Public Works and Government Services Canada.
- , -----, (DPR). 2013. *Industry Canada Performance Report for the period ending March 31, 2013*. Ottawa: Minister of Public Works and Government Services Canada.

- , -----, (DPR). 2014. *Industry Canada 2013-14 Departmental Performance Report*. Ottawa: Her Majesty the Queen in Right of Canada, represented by the Minister of Industry, 2014.
- , -----, (DPR). 2015. *Industry Canada 2014-15 Departmental Performance Report*. Ottawa: Her Majesty the Queen in Right of Canada, as represented by the Minister of Innovation, Science and Economic Development, 2016 [sic].
- Canada. Industry Canada. National Biotechnology Advisory Committee (NBAC). 1998. *National Biotechnology Advisory Committee Sixth Report 1998: Leading in the next millennium*. Ottawa: Her Majesty the Queen in Right of Canada (Industry Canada) 1998.
- Canada. Industry Canada. Natural Sciences and Engineering Research Council of Canada. 2001. *Natural Sciences and Engineering Research Council of Canada Departmental Performance Report for the period ending March 31, 2001*. Ottawa: Minister of Public Works and Government Services Canada – 2001.
- , -----, -----, 2002.
- Departmental Performance Report for the period ending March 31, 2002*.
<https://www.canada.ca/en/treasury-board-secretariat/services/departmental-performance-reports.html>.⁵
- , -----, -----, 2003.
- Departmental Performance Report for the period ending March 31, 2003*.
<https://www.canada.ca/en/treasury-board-secretariat/services/departmental-performance-reports.html>.
- , -----, -----, 2004.
- Departmental Performance Report for the period ending March 31, 2004*.
<https://www.canada.ca/en/treasury-board-secretariat/services/departmental-performance-reports.html>.
- , -----, -----, 2005.
- Departmental Performance Report for the period ending March 31, 2005*.

⁵ At the time of writing, the TBS archived website was not fully operational for all reporting years.

<https://www.canada.ca/en/treasury-board-secretariat/services/departmental-performance-reports.html>.

-----, -----, -----, 2006.

Departmental Performance Report for the period ending March 31, 2006.

<https://www.canada.ca/en/treasury-board-secretariat/services/departmental-performance-reports.html>.

-----, -----, -----, 2007.

Departmental Performance Report for the period ending March 31, 2007.

<https://www.canada.ca/en/treasury-board-secretariat/services/departmental-performance-reports.html>.

-----, -----, -----, 2008.

Departmental Performance Report for the period ending March 31, 2008.

<https://www.canada.ca/en/treasury-board-secretariat/services/departmental-performance-reports.html>

-----, -----, -----, 2009.

Departmental Performance Report for the period ending March 31, 2009.

<https://www.canada.ca/en/treasury-board-secretariat/services/departmental-performance-reports.html>.

-----, -----, -----, 2010.

Departmental Performance Report for the period ending March 31, 2010.

<https://www.canada.ca/en/treasury-board-secretariat/services/departmental-performance-reports.html>

, -----, -----, -----, 2012.

2011-2012 Departmental Performance Report. <https://www.canada.ca/en/treasury-board-secretariat/services/departmental-performance-reports.html>.

-----, -----, -----, 2013.

2012-2013 Departmental Performance Report. <https://www.canada.ca/en/treasury-board-secretariat/services/departmental-performance-reports.html>.

- , -----, -----, 2014.
2013-2014 Departmental Performance Report. <https://www.canada.ca/en/treasury-board-secretariat/services/departmental-performance-reports.html>.
- , -----, -----, 2015.
2014-2015 Departmental Performance Report. <https://www.canada.ca/en/treasury-board-secretariat/services/departmental-performance-reports.html>.
- , -----, -----, 2016.
2015-2016 Departmental Performance Report. <https://www.canada.ca/en/treasury-board-secretariat/services/departmental-performance-reports.html>.
- , -----, -----, 2017.
2016-2017 Departmental Results Report. <https://www.canada.ca/en/treasury-board-secretariat/services/departmental-performance-reports.html>.
- , -----, -----, 2018.
2017-2018 Departmental Results Report. Ottawa: Her Majesty the Queen in Right of Canada, as represented by the Minister of Industry, 2018.
- , -----, -----, 2020.
2018-2019 Departmental Results Report. Ottawa: Her Majesty the Queen in Right of Canada, as represented by the Minister of Industry, 2020 [sic].
- , -----, -----, 2020.
2019-2020 Departmental Results Report. Ottawa: Her Majesty the Queen in Right of Canada, as represented by the Minister of Industry, 2020.
- , -----, -----, 2006. *People and Excellence: The Heart of Successful Commercialization. Volume 1: Final Report of the Expert Panel on Commercialization. Ottawa: Public Works and Government Services Canada*
- , -----, -----, Social Sciences and Humanities Research Council. 2018.
2017-2018 Departmental Results Report. Ottawa: Her Majesty the Queen in Right of Canada as represented by the Minister of Industry, 2018.

- ⁶While Industry Canada was changed to Innovation, Science and Economic Development Canada in 2015, legally the Department remains the Department of Industry as governed by the Department of Industry Act, S.C. 1995, c.1. As such, publication is still in the name of Industry Canada.

Ottawa: Her Majesty the Queen in Right of Canada, as represented by the Minister of Industry, 2017.

-----, -----, (DRR). 2018. *Innovation, Science and Economic Development Canada 2017-18 Departmental Results Report*.

Ottawa: Her Majesty the Queen in Right of Canada, as represented by the Minister of Industry, 2018.

-----, -----, (DRR). 2020. *Innovation, Science and Economic Development Canada 2018-19 Departmental Results Report*.

Ottawa: Her Majesty the Queen in Right of Canada, as represented by the Minister of Industry, 2020 [sic].

-----, -----, (DRR). 2020. *Innovation, Science and Economic Development Canada 2019-20 Departmental Results Report*.

Ottawa: Her Majesty the Queen in Right of Canada, as represented by the Minister of Industry, 2020.

Canada. National Research Council Canada. 2017. *Annual Report 2016-2017*. Ottawa. National Research Council Canada.

-----, -----, 2018a. *A Platform for Innovation/ Annual Report 2017-2018*. Ottawa. National Research Council Canada.

-----, -----, 2020a. *From Dialogue to Action, Excellence to Impact : NRC Strategic Plan 2019-2024*. Ottawa: Her Majesty the Queen in Right of Canada, as represented by the National Research Council of Canada.

-----, -----, 2020b. *National Research Council Canada 2020-21 Departmental Plan*. Ottawa. Her Majesty the Queen in Right of Canada, as represented by the Minister of Industry. 2020.

-----, -----, *National Research Council Canada Departmental Performance Report For the period ending 31 March 2007*. <https://www.tbs-sct.gc.ca/dpr-rmr/2006-2007/inst/nrc/nrc-eng.pdf>.

- , -----, *National Research Council Canada Departmental Performance Report For the period ending 31 March 2008*. <https://www.tbs-sct.gc.ca/dpr-rmr/2007-2008/inst/nrc/nrc-eng.pdf>.
- , -----, *National Research Council Canada 2008-2009 Departmental Performance Report*. <https://www.tbs-sct.gc.ca/dpr-rmr/2008-2009/inst/nrc/nrc-eng.pdf>.
- , -----, *National Research Council Canada 2009-2010. Departmental Performance Report*. <https://www.tbs-sct.gc.ca/dpr-rmr/2009-2010/inst/nrc/nrc-eng.pdf>.
- , -----, *National Research Council Canada 2010-11 Departmental Performance Report*. <https://www.tbs-sct.gc.ca/dpr-rmr/2010-2011/inst/NRC/nrc-eng.pdf>.
- , -----, *National Research Council Canada Departmental Performance Report 2011-2012*. https://www.nrc-cnrc.gc.ca/obj/images/reports-rapports/NRC_2011-12_DPR_FINAL_2012-10-05_English.pdf.
- , -----, *National Research Council Canada Departmental Performance Report 2012-2013*. https://www.nrc-cnrc.gc.ca/obj/doc/reports-rapports/nrc-cnrc_dpr-rmr_2012_2013_eng.pdf.
- , -----, *National Research Council Canada Departmental Performance Report 2013-2014*. https://www.nrc-cnrc.gc.ca/obj/doc/reports-rapports/2013-2014_dpr-rmr_en.pdf.
- , -----, *National Research Council Canada Departmental Performance Report 2014-15*. https://www.nrc-cnrc.gc.ca/obj/doc/reports-rapports/2014-2015_dpr-rmr_en.pdf.
- , -----, 2016. *National Research Council Canada 2015-2016 Departmental Performance Report*. Ottawa: National Research Council Canada, 2016.

- , -----, *National Research Council Canada Departmental Results Report 2016-2017*. <https://nrc.canada.ca/en/corporate/planning-reporting/departmental-results-report-2016-17>.
- , -----, 2018b. *National Research Council Canada 2017-18 Departmental Results Report*. Ottawa: Her Majesty the Queen in Right of Canada, as represented by the Minister of Industry, 2018.
- , -----, 2020c. *National Research Council Canada 2018-19 Departmental Results Report*. Ottawa: Her Majesty the Queen in Right of Canada, as represented by the Minister of Industry, 2020 [sic].
- , -----, 2020d. *National Research Council Canada 2019-20 Departmental Results Report*. Ottawa: Her Majesty the Queen in Right of Canada, as represented by the Minister of Industry, 2020.
- , -----, 2020e. *Re-imagining the National Research Council of Canada: Final report on the NRC Dialogue 2016 to 2020*. Ottawa: National Research Council Canada.
- Canada. Networks of Centres of Excellence (NCE). 2017. *Evaluation of Commercialization of Research: Centres of Excellence for Commercialization and Research*. September. Ottawa: Networks of Centres of Excellence.
- Canada. 1992. *North American Free Trade Agreement between the Government of Canada, the Government of the United Mexican States and the Government of the United States of America*. Ottawa: Minister of Supply and Services 1992.
- Canada. Parliament. House of Commons. 1997. *Fifth Report of the Standing Committee on Industry*. https://www.ourcommons.ca/Content/Archives/Committee/352/indu/reports/05_1997-04/indu-05-cov-e.html.
- Canada. Parliament. House of Commons. 1999. *Speech from the Throne*, 12 October 1999. 36th Parliament. 2nd Session. Ottawa: Her Majesty the Queen in Right of Canada.
- , -----, 2001. *Speech from the Throne*, 30 January 2001. 37th Parliament. 1st Session. Ottawa. Her Majesty the Queen in Right of Canada.

-----, -----, 2002. *Speech from the Throne*, 30 September 2002. 37th Parliament. 2nd Session. Ottawa. Her Majesty the Queen in Right of Canada.

-----, -----, 2004a. *Speech from the Throne*, 2 February 2004. 37th Parliament. 3rd Session. Ottawa. Her Majesty the Queen in Right of Canada.

-----, -----, 2004b. *Speech from the Throne*, 5 October 2004. 38th Parliament. 1st Session. Ottawa. Her Majesty the Queen in Right of Canada.

-----, -----, 2006. *Speech from the Throne*, 4 April 2006. 39th Parliament, 1st Session. Ottawa. Her Majesty the Queen in Right of Canada.

-----, -----, 2007. *Speech from the Throne*, 16 October 2007. 39th Parliament, 2nd Session. Ottawa. Her Majesty the Queen in Right of Canada.

-----, -----, 2008. *Speech from the Throne*, 19 November 2008. 40th Parliament. 1st Session. Ottawa. Her Majesty the Queen in Right of Canada.

-----, -----, 2009. *Speech from the Throne*, 26 January 2009. 40th Parliament. 2nd Session. Ottawa: Her Majesty the Queen in Right of Canada.

-----, -----, 2010. *Speech from the Throne*. 3 March 2010. 40th Parliament. 3rd Session. Ottawa: Her Majesty the Queen in Right of Canada.

-----, -----, 2011. *Speech from the Throne*, 3 June 2011. 41st Parliament. 1st Session. Ottawa: Her Majesty the Queen in Right of Canada.

-----, -----, 2013. *Speech from the Throne*, 16 October 2013. 41st Parliament. 2nd Session. Ottawa: Her Majesty the Queen in Right of Canada.

-----, -----, 2015. *Speech from the Throne*, 4 December 2015. 42nd Parliament. Ottawa: Her Majesty the Queen in Right of Canada.

-----, -----, 2019. *Speech from the Throne*, 5 December 2019. 43rd Parliament. Ottawa: Her Majesty the Queen in Right of Canada.

-----, -----, 2020. *Speech from the Throne*, 23 September 2020. 43rd Parliament. Ottawa: Her Majesty the Queen in Right of Canada.

-----, -----, Senate, Special Committee on Science Policy. Lamontagne Report. 1970. *Science Policy for Canada*. Ottawa: Information Canada.

Canada. Patented Medicine Prices Review Board. (PMPRB). *Patented Medicine Prices Review Board Annual Report 2003*. <https://www.canada.ca/en/patented-medicine-prices-review/services/annual-reports.html>.

-----, -----, -----, *Patented Medicine Prices Review Board Annual Report 2004*. <https://www.canada.ca/en/patented-medicine-prices-review/services/annual-reports.html>.

-----, -----, -----, *Patented Medicine Prices Review Board Annual Report 2005*. <https://www.canada.ca/en/patented-medicine-prices-review/services/annual-reports.html>.

-----, -----, -----, *Patented Medicine Prices Review Board Annual Report 2006*. <https://www.canada.ca/en/patented-medicine-prices-review/services/annual-reports.html>.

-----, -----, -----, *Patented Medicine Prices Review Board Annual Report 2007*. <https://www.canada.ca/en/patented-medicine-prices-review/services/annual-reports.html>.

-----, -----, -----, *Patented Medicine Prices Review Board Annual Report 2008*. <https://www.canada.ca/en/patented-medicine-prices-review/services/annual-reports.html>.

-----, -----, -----, *Patented Medicine Prices Review Board Annual Report 2009*. <https://www.canada.ca/en/patented-medicine-prices-review/services/annual-reports.html>.

-----, -----, -----, *Patented Medicine Prices Review Board Annual Report 2010*. <https://www.canada.ca/en/patented-medicine-prices-review/services/annual-reports.html>.

-----, -----, -----, *Patented Medicine Prices Review Board Annual Report 2011*. <https://www.canada.ca/en/patented-medicine-prices-review/services/annual-reports.html>.

- , -----, -----, *Patented Medicine Prices Review Board Annual Report 2012*. <https://www.canada.ca/en/patented-medicine-prices-review/services/annual-reports.html>.
- , -----, -----, *Patented Medicine Prices Review Board Annual Report 2013*. <https://www.canada.ca/en/patented-medicine-prices-review/services/annual-reports.html>.
- , -----, -----, *Patented Medicine Prices Review Board Annual Report 2014*. <https://www.canada.ca/en/patented-medicine-prices-review/services/annual-reports.html>.
- , -----, -----, *Patented Medicine Prices Review Board Annual Report 2015*. <https://www.canada.ca/en/patented-medicine-prices-review/services/annual-reports.html>.
- , -----, -----, *Patented Medicine Prices Review Board Annual Report 2016*. <https://www.canada.ca/en/patented-medicine-prices-review/services/annual-reports.html>.
- , -----, -----, *Patented Medicine Prices Review Board Annual Report 2017*. <https://www.canada.ca/en/patented-medicine-prices-review/services/annual-reports.html>.
- , -----, -----, *Patented Medicine Prices Review Board Annual Report 2018*. <https://www.canada.ca/en/patented-medicine-prices-review/services/annual-reports.html>.
- , -----, -----, *Patented Medicine Prices Review Board Annual Report 2019*. <https://www.canada.ca/en/patented-medicine-prices-review/services/annual-reports.html>.
- , -----, -----, 2016. *PMPRB Guidelines Modernization Discussion Paper*. June. Ottawa: The Patented Medicine Prices Review Board.
- , -----, -----, 2015. *Strategic Plan 2015-2018*. Ottawa: The Patented Medicine Prices Review Board.

- , Receiver General for Canada (RGC). 1986. *Public Accounts of Canada 1986. Volume II, Part I: Details of Expenses and Revenues*. Prepared by the Receiver General for Canada. Ottawa: Minister of Public Works and Government Services Canada 1986.
- , -----, 1987. *Public Accounts of Canada 1987. Volume II, Part I: Details of Expenses and Revenues*. Prepared by the Receiver General for Canada. Ottawa: Minister of Public Works and Government Services Canada 1987.
- , -----, 1988. *Public Accounts of Canada 1988. Volume II, Part I: Details of Expenses and Revenues*. Prepared by the Receiver General for Canada. Ottawa: Minister of Public Works and Government Services Canada 1988..
- , -----, 1989. *Public Accounts of Canada 1989. Volume II, Part I: Details of Expenses and Revenues*. Prepared by the Receiver General for Canada. Ottawa: Minister of Public Works and Government Services Canada 1989.
- , -----, 1990. *Public Accounts of Canada 1990. Volume II, Part I: Details of Expenses and Revenues*. Prepared by the Receiver General for Canada. Ottawa: Minister of Public Works and Government Services Canada 1990.
- , -----, 1991. *Public Accounts of Canada 1991. Volume II, Part I: Details of Expenses and Revenues*. Prepared by the Receiver General for Canada. Ottawa: Minister of Public Works and Government Services Canada 1991.
- , -----, 1992. *Public Accounts of Canada 1992. Volume II, Part I: Details of Expenses and Revenues*. Prepared by the Receiver General for Canada. Ottawa: Minister of Public Works and Government Services Canada 1992.
- , -----, 1993. *Public Accounts of Canada 1993. Volume II, Part I: Details of Expenses and Revenues*. Prepared by the Receiver General for Canada. Ottawa: Minister of Public Works and Government Services Canada 1993.
- , -----, 1994. *Public Accounts of Canada 1994. Volume II, Part I: Details of Expenses and Revenues*. Prepared by the Receiver General for Canada. Ottawa: Minister of Public Works and Government Services Canada 1994.

- , ----- 1995. *Public Accounts of Canada 1995. Volume II, Part I: Details of Expenses and Revenues.* Prepared by the Receiver General for Canada.
Ottawa: Minister of Public Works and Government Services Canada 1995.
- , ----- 1996. *Public Accounts of Canada 1996. Volume II, Part I: Details of Expenses and Revenues.* Prepared by the Receiver General for Canada.
Ottawa: Minister of Public Works and Government Services Canada 1996.
- , ----- 1997. *Public Accounts of Canada 1997. Volume II, Part I: Details of Expenses and Revenues.* Prepared by the Receiver General for Canada.
Ottawa: Minister of Public Works and Government Services Canada 1997.
- , ----- 1998. *Public Accounts of Canada 1998. Volume II, Part I: Details of Expenses and Revenues.* Prepared by the Receiver General for Canada.
Ottawa: Minister of Public Works and Government Services Canada 1998.
- , ----- 1999. *Public Accounts of Canada 1999. Volume II, Part I: Details of Expenses and Revenues.* Prepared by the Receiver General for Canada.
Ottawa: Minister of Public Works and Government Services Canada 1999.
- , ----- 2000. *Public Accounts of Canada 2000. Volume II, Part I: Details of Expenses and Revenues.* Prepared by the Receiver General for Canada.
Ottawa: Minister of Public Works and Government Services Canada 2000.
- , ----- 2001. *Public Accounts of Canada 2001. Volume II, Part I: Details of Expenses and Revenues.* Prepared by the Receiver General for Canada.
Ottawa: Minister of Public Works and Government Services Canada 2001.
- , ----- 2002. *Public Accounts of Canada 2002. Volume II, Part I: Details of Expenses and Revenues.* Prepared by the Receiver General for Canada.
Ottawa: Minister of Public Works and Government Services Canada 2002.
- , ----- 2003. *Public Accounts of Canada 2003. Volume II, Part I: Details of Expenses and Revenues.* Prepared by the Receiver General for Canada.
Ottawa: Minister of Public Works and Government Services Canada 2003.

- , -----, 2004. *Public Accounts of Canada 2004. Volume II: Details of Expenses and Revenues*. Prepared by the Receiver General for Canada. Ottawa: Minister of Public Works and Government Services Canada 2004.
- , -----, 2005. *Public Accounts of Canada 2006. Volume II: Details of Expenses and Revenues*. Prepared by the Receiver General for Canada. Ottawa: Minister of Public Works and Government Services Canada 2005.
- , -----, 2006. *Public Accounts of Canada 2006. Volume II: Details of Expenses and Revenues*. Prepared by the Receiver General for Canada. Ottawa: Minister of Public Works and Government Services Canada 2006.
- , -----, 2007. *Public Accounts of Canada 2007. Volume II: Details of Expenses and Revenues*. Prepared by the Receiver General for Canada. Ottawa: Minister of Public Works and Government Services Canada 2007.
- , -----, 2008. *Public Accounts of Canada 2008. Volume II: Details of Expenses and Revenues*. Prepared by the Receiver General for Canada. Ottawa: Minister of Public Works and Government Services Canada 2008.
- , -----, 2009. *Public Accounts of Canada 2009. Volume II: Details of Expenses and Revenues*. Prepared by the Receiver General for Canada. Ottawa: Minister of Public Works and Government Services Canada 2009.
- , -----, 2010. *Public Accounts of Canada 2010. Volume II: Details of Expenses and Revenues*. Prepared by the Receiver General for Canada. Ottawa: Minister of Public Works and Government Services Canada 2010.
- , -----, 2011. *Public Accounts of Canada 2011. Volume II: Details of Expenses and Revenues*. Prepared by the Receiver General for Canada. Ottawa: Minister of Public Works and Government Services Canada 2011.
- , -----, 2012. *Public Accounts of Canada 2012. Volume II: Details of Expenses and Revenues*. Prepared by the Receiver General for Canada. Ottawa: Minister of Public Works and Government Services Canada 2012.

- , -----, 2013. *Public Accounts of Canada 2013. Volume II: Details of Expenses and Revenues*. Prepared by the Receiver General for Canada. Ottawa: Minister of Public Works and Government Services Canada 2013.
- , -----, 2014. *Public Accounts of Canada 2014. Volume II: Details of Expenses and Revenues*. Prepared by the Receiver General for Canada. Ottawa: Minister of Public Works and Government Services Canada 2014.
- , -----, 2015. *Public Accounts of Canada 2015. Volume II: Details of Expenses and Revenues*. Prepared by the Receiver General for Canada. Ottawa: Minister of Public Services and Procurement 2015.
- , -----, 2016. *Public Accounts of Canada 2016. Volume II: Details of Expenses and Revenues*. Prepared by the Receiver General for Canada. Ottawa: Minister of Public Services and Procurement 2016.
- , -----, 2017. *Public Accounts of Canada 2017. Volume II: Details of Expenses and Revenues*. Prepared by the Receiver General for Canada. Ottawa: Minister of Public Services and Procurement 2017.
- , -----, 2018. *Public Accounts of Canada 2018. Volume II: Details of Expenses and Revenues*. Prepared by the Receiver General for Canada. Ottawa: Minister of Public Services and Procurement 2018.
- , -----, 2019. *Public Accounts of Canada 2019. Volume II: Details of Expenses and Revenues*. Prepared by the Receiver General for Canada. Ottawa: Minister of Public Services and Procurement 2019.
- , -----, 2020. *Public Accounts of Canada 2020. Volume II: Details of Expenses and Revenues*. Prepared by the Receiver General for Canada. Ottawa: Minister of Public Services and Procurement 2020.
- Canada. 1985. *Report of the Commission of Inquiry on the Pharmaceutical Industry*. (Eastman Commission). Ottawa: Minister of Supply and Services Canada 1985.
- Canada. 1964. Royal Commission on Health Services (Hall Commission). Volume 1. Ottawa: Queen's Printer.
- Canada. Statistics Canada. 2000. *Survey of Innovation 1999*: 31 January. Ottawa: Statistics Canada,

- , 2004. *Survey of Innovation 2003*. 31 March. Ottawa: Statistics Canada.
- , 2006. *Survey of Innovation 2005*. 2 June. DOI: <https://doi.org/10.25318/2710024001>.
- , 2015. *Gross Domestic Expenditures on Research and Development in Canada (GERD), the Provinces and Territories: National estimates 2005 to 2015; Provincial and Territorial estimates 2009 to 2013*. October. Catalogue no. 88-221-X. Ottawa: Published by the authority of the Minister responsible for Statistics Canada; Minister of Industry 2015.
- , 2015. *Survey of Advanced Technology, 2014*. 11 December. DOI: <https://doi.org/10.25318/2710031601-eng>.
- , 2019. *Survey of Innovation and Business Strategy – January 1, 2015 to December 31, 2017*. 26 March. DOI: <https://doi.org/10.25318/2710017801-eng>.
- , 2021. *Survey of Innovation and Business Strategy – January 1, 2017 to December 31, 2019*. 26 April. DOI: <https://doi.org/10.25318/2710017801-eng>
- Canada's Economic Strategy Tables (EST). 2018a. *The Innovation and Competitiveness Imperative: Seizing Opportunities for Growth. A Report from Canada's Economic Strategy Tables*. September. Ottawa: Canada's Economic Strategy Tables.
- , 2018b. *The Innovation and Competitiveness Imperative: Seizing Opportunities for Growth. Report of Canada's Economic Strategy Tables: Advanced Manufacturing*. September. Ottawa: Canada's Economic Strategy Tables.
- , 2018c. *The Innovation and Competitiveness Imperative: Seizing Opportunities for Growth. Report of Canada's Economic Strategy Tables: Agri-Food*. September. Ottawa: Canada's Economic Strategy Tables.
- , 2018d. *The Innovation and Competitiveness Imperative: Seizing Opportunities for Growth. Report of Canada's Economic Strategy Tables: Clean Technology*. September. Ottawa: Canada's Economic Strategy Tables.
- , 2018e. *The Innovation and Competitiveness Imperative: Seizing Opportunities for Growth. Report of Canada's Economic Strategy Tables: Digital Industries*. September. Ottawa: Canada's Economic Strategy Tables.

- , 2018f. *The Innovation and Competitiveness Imperative: Seizing Opportunities for Growth. Report of Canada's Economic Strategy Tables: Health and Biosciences*. September. Ottawa: Canada's Economic Strategy Tables.
- , 2018g. *The Innovation and Competitiveness Imperative: Seizing Opportunities for Growth. Report of Canada's Economic Strategy Tables: Resources of the Future*. September. Ottawa: Canada's Economic Strategy Tables.
- CIFAR 2015: *2014-2015: Annual Performance Report*. Toronto: CIFAR
- CIFAR. 2017. *Annual Report 2016-2017: Increasing Impact*. Toronto: CIFAR.
- CIFAR. 2018. *Annual Report: 2017- 2018: Convening Great Minds*. Toronto: CIFAR.
- , 2019a. *AICan 2019: Annual Report of the CIFAR Pan-Canadian Strategy*. Toronto: CIFAR.
- , 2019b. *Annual Report: 2018-2019*. Toronto: CIFAR.
- , 2020. Financial Statements of the Canadian Institute for Advanced Research – L'Institut Canadien de Recherches Avancées and Independent Auditors' Report thereon: Year ended June 30, 2020. Toronto: CIFAR.
- Competition Policy Review Panel. 2008. *Compete to Win*. Ottawa: Public Works and Government Services Canada.
- Council of Canadian Academies (CCA), The Committee on The State of Science & Technology in Canada. 2006. *The State of Science & Technology in Canada*. Ottawa: CCA.
- , The Expert Panel on Business Innovation. 2009. *Innovation and Business Strategy: Why Canada Falls Short*. Ottawa: CCA.
- , The Expert Panel on the State of Science & Technology in Canada, 2012. *The State of Science and Technology in Canada, 2012*. Ottawa: CCA
- , 2013a., The Expert Panel on the State of Industrial R&D in Canada. *The State of Industrial R&D in Canada*. Ottawa: CCA.
- 2013b. *Paradox Lost: Explaining Canada's Research Strength and Innovation Weakness*. Ottawa: CCA.

- , Expert Panel on the State of Science and Technology and Industrial Research and Development in Canada. 2018. *Competing in a Global Innovation Economy: The Current State of R&D in Canada*. Ottawa: CCA.
- Council of Science and Technology Advisors (CSTA). 1999. *Science Advice for Government Effectiveness (SAGE): A Report of the Council of Science and Technology Advisors*. May. Ottawa: CSTA.
- , 2000. *Building Excellence in Science and Technology (BEST): The Federal Roles in Performing S&T. A Report of the Council of Science and Technology Advisors*. March. Ottawa: CSTA.
- , 2001a. *Reinforcing External Advice to Departments (READ): A Report of the Council of Science and Technology Advisors (CSTA)*. May. Ottawa: CSTA
- , 2001b. *Science and Technology Excellence in the Public Service (STEPS): A Report of the Council of Science and Technology Advisors*. August. Ottawa: CSTA.
- , 2005. *Linkages in the National Knowledge System: Fostering a Linked Federal S&T Enterprise. A Report to the Government of Canada*. February. Ottawa: CSTA.
- Dernis, Hélène and Dominique Guellec. 2001. “Using Patent Counts for Cross-country Comparisons of Technology Output.” *OECD STI Science Technology Industry Review*. Paris: OECD Publishing.
- Gouvernement du Québec (GQ). n/d. *Plan Budgétaire : 2000-2001*. Québec: Gouvernement du Québec.⁷
- , 2001. *Plan Budgétaire : Budget 2001-2002*. Mars. Québec: Gouvernement du Québec.
- , 2001. *Plan Budgétaire : Budget 2002-2003*. Novembre. Québec: Gouvernement du Québec.

⁷ Le Plan Budgétaire for 2000-2001 does not provide a date; however, an associated website “Discours sur le budget 2000-2001” provides the date of le 14 mars 2000 (<http://www.budget.finances.gouv.qc.ca/budget/2000-2001/fr/pdf/pfa-fra.pdf>).

- , 2003. *Plan Budgétaire : Budget 2003-2004*. Mars. Québec: Gouvernement du Québec.
- , 2004. *Plan Budgétaire : Budget 2004-2005*. Mars. Québec: Gouvernement du Québec.
- , 2005. *Plan Budgétaire : Budget 2005-2006*. Avril. Québec: Gouvernement du Québec.
- , 2006. *Plan Budgétaire : Budget 2006-2007*. Avril. Québec: Gouvernement du Québec.
- , 2007. *Plan Budgétaire : Budget 2007-2008*. Février. Québec: Gouvernement du Québec.
- , 2008. *Plan Budgétaire : Budget 2008-2009*. Mars. Québec: Gouvernement du Québec.
- , 2009. *Plan Budgétaire : Budget 2009-2010*. Mars. Québec: Gouvernement du Québec.
- , 2010. *Plan Budgétaire : Budget 2010-2011*. Mars. Québec: Gouvernement du Québec.
- , 2011. *Plan Budgétaire : Budget 2011-2012*. Mars. Québec: Gouvernement du Québec.
- , 2012. *Plan Budgétaire : Budget 2012-2013*. Mars. Québec: Gouvernement du Québec.
- , 2013. *Plan Budgétaire : Budget 2013-2014*. Novembre. Québec: Gouvernement du Québec.
- , 2014. *Plan Budgétaire : Budget 2014-2015*. Février 2014. Québec: Gouvernement du Québec.
- , 2015. *Le Plan économique du Québec : Budget 2015-2016 – Mars 2015*. Québec : Gouvernement du Québec.
- , 2016. *Le Plan économique du Québec : Budget 2016-2017 – Mars 2016*. Québec : Gouvernement du Québec.

- , 2017a. *Le Plan économique du Québec : Budget 2017-2018 – Mars 2017*. Québec : Gouvernement du Québec.
- , 2017b. *The Québec Economic Plan : Budget 2017-2018 – March 2017*. Québec : Gouvernement du Québec.
- , 2018. *Le Plan économique du Québec : Budget 2018-2019 – Mars 2018*. Québec : Gouvernement du Québec.
- , 2019. *Budget 2019-2020 – Mars 2019. Vos Priorités. Votre Budget*. Québec : Gouvernement du Québec.
- , 2019. *Budget 2019-2020 – March 2019. Your Priorities. Your Budget*. Québec : Gouvernement du Québec.
- , Économie, Science et Innovation (ESI). Comité d'orientation de la grappe en intelligence artificielle (IA Comité). 2018a. *Stratégie pour l'essor de l'écosystème québécois en intelligence artificielle*. Mai. Québec : Économie, Science et Innovation.
- Independent Panel on Federal Support to Research and Development. 2011. *Innovation Canada: A Call to Action; Review of Federal Support to Research and Development – Expert Panel Report*. (Jenkins Report). Ottawa: Public Works and Government Services Canada.
- , Économie, Science et Innovation (ESI). Artificial Intelligence Cluster Steering Committee (AI SC). *Strategy for the Development of Quebec's Artificial Intelligence Ecosystem*. 2018b. May. Québec : Économie, Science et Innovation.
- OECD. 1999. *Boosting Innovation: The Cluster Approach*. Paris: OECD Publishing.
- , 2003. *Information and Communications Technologies. ICT and Economic Growth: Evidence from OECD Countries, Industries and Firms*. Paris: OECD Publications Service.
- , 2007a. *Glossary of Statistical Terms*. Paris: OECD Publications Service.
- , 2007b. *Science, Technology and Industry Scoreboard: Innovation and Performance in the Global Economy*. Paris: OECD Publishing.
- , 2009. *Science, Technology and Industry Scoreboard: Innovation and Performance in the Global Economy*. Paris: OECD Publishing.

- , 2011a. *Financing High-Growth Firms: The Role of Angel Investors*. Paris: OECD Publishing.
- , 2011b. *Science, Technology and Industry Scoreboard: Innovation and Performance in the Global Economy*. Paris: OECD Publishing.
- , 2015a. *Frascati Manual: Guidelines for Collecting and Reporting Data on Research and Experimental Development, The Measurement of Scientific, Technological and Innovation Activities*. 7th ed. Paris: OECD Publishing.
- , 2015b. *Science, Technology and Industry Scoreboard: Innovation and Performance in the Global Economy*. Paris: OECD Publishing.
- , 2015c. *The Innovation Imperative: Contributing to Productivity, Growth and Well-Being*. Paris: OECD Publishing.
- , 2016a. *OECD Reviews of Innovation Policy: Sweden 2016*. Paris: OECD Publishing.
- OECD, 2016b. *OECD Economic Surveys: Canada 2016*. Paris: OECD Publishing.
- , 2017a. *Key Issues for Digital Transformation in the G20: Report prepared for a joint G20 Germany Presidency/ OECD conference*. 12 January, Berlin, Germany. Paris: OECD Publishing.
- , 2017b. *Science, Technology and Industry Scoreboard: Innovation and Performance in the Global Economy*. Paris: OECD Publishing.
- , 2017c. *The Next Production Revolution: A Report for the G20*. Paris: OECD Publishing.
- , 2018a. *OECD Economic Surveys: Canada 2016*. Paris: OECD Publishing.
- , 2018b. *Oslo Manual: Guidelines for Collecting, Reporting and Using Data on Innovation, The Measurement of Scientific, Technological and Innovation Activities*. 4th ed. Paris/ Eurostat, Luxembourg: OECD Publishing.
- , 2018c. *Pharmaceutical Innovation and Access to Medicines, OECD Health Policy Studies*. Paris: OECD Publishing.
- , 2019. *Measuring the Digital Transformation: A Roadmap for the Future*. Paris: OECD. Publishing.<https://doi.org/10.1787/9789264311992-en>.

Performance Management Network Inc. (PMN). 2012. *Evaluation of the Business-Led Networks of Centres of Excellence (BL-NCE) Program: Final Report*. Submitted to the Natural Sciences and Engineering Research Council (NSERC). 2 March. Ottawa: Science, Technology and Innovation Council (STIC). Advisory Council to the Government of Canada. 2009. *State of the Nation 2008: Canada's Science, Technology and Innovation System*. Ottawa: STIC.

-----, 2011. *State of the Nation 2010: Imagination to Innovation: Building Canadian Paths to Prosperity*. Ottawa: STIC.

-----, 2013. *State of the Nation 2012: Canada's Science, Technology and Innovation System: Aspiring to Global Leadership*. Ottawa: STIC

-----, 2015. *State of the Nation 2014: Canada's Innovation Challenges and Opportunities*. Ottawa: STIC.

The Conference Board of Canada. 2017. *Lessons Learned from a World Innovation Leader: Understanding Israel's Innovation Ecosystem*. Ottawa: The Conference Board of Canada.

World Economic Forum (WEF). 2006. *The Global Competitiveness Report 2006-2007*. Geneva: World Economic Forum.

-----, 2008. *The Global Competitiveness Report 2008-2009*. Geneva: World Economic Forum.

-----, 2009. *The Global Competitiveness Report 2009-2010*. Geneva: World Economic Forum.

-----, 2010. *The Global Competitiveness Report 2010-2011*. Geneva: World Economic Forum.

-----, 2012. *The Global Competitiveness Report 2012-2013*. Geneva: World Economic Forum.

-----, 2013. *The Global Competitiveness Report 2013-2014*. Geneva: World Economic Forum.

-----, 2014. *The Global Competitiveness Report 2014-2015*.

Geneva: World Economic Forum.

-----, 2015. *The Global Competitiveness Report 2015-2016*.

Geneva: World Economic Forum.

-----, 2016. *The Global Competitiveness Report 2016-2017*.

Geneva: World Economic Forum.

-----, 2017. *The Global Competitiveness Report 2017-2018*.

Geneva: World Economic Forum.

-----, 2018. *The Global Competitiveness Report 2018*.

Geneva: World Economic Forum.

-----, 2019. *The Global Competitiveness Report 2019*.

Geneva: World Economic Forum.

News Articles and Releases

Allen, Glen. 1992. "Strong Medicine." *Maclean's*. 21 December.

Bernstein, Alan. 2018. "Canada's AI Success must inform our innovators." *The Globe and Mail*. 15 May.

Bury, Scott. 1999. "PRECARN and IRIS: building innovation infrastructure." *Silicon Valley North* 3 (2) April: 15-17.

Canada. Canada Economic Development for Quebec Regions (CEDQ). 2018. "Government of Canada invests in artificial intelligence and creates close to 1,000 middle-class jobs" [news release]. 5 December.

Canada. Innovation, Science and Economic Development (ISED). 2018. "News Release. Government of Canada's new innovation program expected to create tens of thousands of middle-class jobs." February 15.

-----, 2018. "News Release: Government of Canada invests in artificial intelligence and start-up innovation across Canada." 9 October.

-----, 2019. "News Release; Government of Canada creates Advisory Council on Artificial Intelligence." 14 May.

- , -----, 2019. “Backgrounder (BK) Draft for Discussion. International Panel on Artificial Intelligence.” 16 May 2019.
- , -----, 2019. “Canada and France work with international community to support responsible use of artificial intelligence.” 16 May.
- , -----, 2019. “News Release: Canada and EU collaborate on supercluster.” 6 June.
- , -----, 2019. “News Release: Minister Bains and MP McGuinty announce investment in Canadian artificial intelligence company.” 12 June.
- , -----, 2019. “News Release. SCALE.AI starts off with first projects. Projects aim to improve efficiencies in consumer goods, farming, telecom and shipping sectors.” 27 June.
- , -----, 2019. “News Release. Government of Canada and Government of Quebec announce the creation of an international centre of expertise in Montreal for the advancement of artificial intelligence.” 6 September.
- , -----, 2020. “News Release: Supercluster invests in AI’s economic potential for Canadians.” 14 January.
- , -----, 2020. “News Release: Government of Canada announces major steps in treating and preventing COVID-19 through vaccines and therapies.” 5 August.
- , -----, 2021. “Backgrounder (BK) Updated list of Government of Canada investments in COVID-19 vaccines and biomanufacturing capacity.” 2 February 2021
- , -----, 2021 “News Release Government of Canada investments will help advance made-in-Canada vaccines and therapeutics for COVID-19.” 16 March.
- Canada. Prime Minister’s Office. 2018. “Prime Minister announces even closer collaboration with France.” [News Release]. 7 June.

-----, -----, 2018. "Prime Minister announces investment in artificial intelligence to create over 16,000 jobs for Canadians." [News Release] 6 December.

-----, -----, 2020. "Prime Minister announces Canada's Plan to Mobilize Industry to fight COVID-19." [News Release] 20 March.

-----, -----, 2020. "Canada's plan to mobilize science to fight COVID-19." [News Release] 23 March.

-----, -----, 2021. "New support to produce COVID-19 vaccines and treatments in Canada." [News Release] 2 February.

Québec. Fonds de recherche Santé. 2018. « Les fonds de recherche du Québec lancent un Observatoire internationale sur les impacts sociétaux de l'intelligence artificielle et du numérique » [communiqué de presse]. 3 décembre 2018.

Crann, Gord. 1986. "Patent Act could be Mulroney's undoing." *The Globe and Mail*. 30 November.

Cyr, Dianne. 1999. "Industry Minister John Manley on technology and competitiveness." *The Academy of Management Executive; Briarcliff Manor* 13 (2) May: 8-12.

Delean, Paul. 1987. Projects worth \$315 million await bill's OK. *The Gazette*. 27 August.

Eklove, Debra J. 1987. "Drug bill a bitter pill to swallow." *The Globe and Mail*. 21 October.

Erola, Judy. 1987. "Bill C-22's benefits." *The Globe and Mail*. 28 September.

Fagan, Drew. 1992. "Liberals spoil for drug fight: Senators' plan for lengthy hearings may delay start for new legislation." *The Globe and Mail*. 11 December.

Freeman, Alan. 1992. "Drug Firms promise to invest \$400 million: Extended patent protection prompts payoff by brand-name manufacturers." *Toronto Star*. 24 June.

Forsey, Eugene. 1987. "Senate within its rights over Bill C-22 revisions." *The Globe and Mail*. 7 November.

Gibbens, Robert 1984. "Generic drug licence delay sought." *The Globe and Mail*. 5 June.

Gibbon, Ann. 1993. "BioChem warns Liberals about changing patent act." *The Globe and Mail*. 27 October.

Hall, Sally. 1986. "Drug bill is beyond repair, no incentive to research." *The Globe and Mail*. 26 November.

- Ham, James. 1985. "Space Station role a boon for Canada." *The Globe and Mail*. 12 December: A7.
- Hyman, Solomon. 1989. "Research may no longer be industry stepchild." 29 June: 13. [Daily Edition].
- Immen, Wallace. 1985. "Building 'world-class' research team in Canada." 28 January: 13.
- Kapica, Jack. 2004. "Ottawa bolsters centres of excellence." *The Globe and Mail*. 5 November: on-line.
- Kennedy, Peter. 2006. "Working to bridge the development gap." *The Globe and Mail*. 28 November: B10.
- Lewington, Jennifer and Christopher Waddell. 1987. *The Globe and Mail*. "Ottawa made drug bill pledge in trade pact: Offer to change law later cut out of text." 9 October.
- Lynn, Robert. 1984. "Research Institute launches artificial intelligence program." *The Globe and Mail*. 27 July: T1.
- McKenna, Barrie. 2011. "John McDougall: Hungry for better 'return' on research. *The Globe and Mail*. 5 August.
- McKenna, Barrie and Ivan Semeniuk. 2013. "Research council's makeover leaves Canadian industry setting the agenda." *The Globe and Mail*. 7 May.
- O'Donnell, Joe. "Ottawa denies link to drug bill." *Toronto Star*. 10 October.
- Orr, John L. 1987. "Drug bill no cure for research ailments." *The Globe and Mail*. 24 September.
- RESEARCH MONEY . 2017. "Precarn Inc taking different tact to realize enhanced business plan." 3 July: 4.
- Rimkus, Algis. 1987. "Technology: Artificial intelligence game has long way to go." 19 May: B22.
- Ross, Howard, and Patricia Poirier. 1987. "PCs reject compromise in fight over drug bill." *The Globe and Mail*. 4 November 1987.
- Scale AI. 2019, "News Release: SCALE.AI starts off with first projects." 27 June 2019.
- Scale AI. 2020. "Investments of \$75 million: Scale AI propels 10 AI projects." 14 January.

- Silcoff, Sean. 2021. "Pfizer to buy Canadian cancer drug developer Trillium." *The Globe and Mail*. 24 August.
- Silcoff, Sean. 2021. "Trillium shareholders approve Pfizer takeover." *The Globe and Mail*. 28 October: B8.
- Silversides, Ann. 1986. "Cheap generic drug law under fire." *The Globe and Mail*. 23 January.
- Silversides, Ann. 1986. "Drug manufacturers seek changes to Patent Act." *The Globe and Mail*. 20 February.
- Semeniuk, Ivan. 2016. "Ottawa names new president of National Research Council." *The Globe and Mail*. 28 July.
- Spears, Tom. 2011. "NRC boss orders scientists to focus on 'market drivers.'" *Ottawa Citizen*. 20 March.
- Spears, Tom. 2013. "NRC pure science research plummets." *Ottawa Citizen*. 8 May: A1 and A4.
- Spears, Tom. 2018. "NRC re-imagines itself with aid of bigger budget." *Ottawa Citizen*. 9 March: A4.
- Taylor-Valsey Nick. 2013. "The Conservative love affair with targeted research." *Maclean's*. 8 May.
- The Economist*. 2017. "The founding of Maple Valley; Innovation in Canada." 425 (9065) 4 November: 46.
- , 2018. "The Unexamined Mind." 426 (9079) 17 February: 78-80.
- The Globe and Mail (G&M)*. 1986. "The Canadian Institute for Advanced Research." 4 February: B10.
- , 1991. "The Canadian Institute for Advanced Research." 7 February: B4.
- , 1996. "The Canadian Institute for Advanced Research (CIAR)." 18 April: B9.
- , 2001. "R&D funding needs boost, says tech group chairman." 7 June: B15.
- , 2003. "Grants to boost robot research." 26 March: online.

- , 2004. "The Canadian Institute for Advanced Research." 13 October: B10.
- , 2006a. "Precarn to offer funding in pilot program." 21 February: on-line.
- , 2006b. "Precarn Associates Inc." 28 November: B10.
- , 2010a. "Allan MacDonald: Next Big Question discussion." 12 May: online.
- , 2010b. "Canadian Institute for Advanced Research." 1 December 2010: B3
- , 2012. "Canadian Institute for Advanced Research." 1 May: B3.
- , 2012. "Lack of drug R&D tough to swallow." 8 June.
- , 2017. "Canada counters Silicon Valley talent raid with fresh funding for AI." 29 March: A1.
- , 2017. "Government, business leaders launch AI initiative." 31 March: A4.
- , 2017. "French tech giant Thales joins Montreal AI rush." 10 October: B1-2.
- , 2018. "Quebec urged to boost AI funding or risk losing edge." 15 February: B9.
- , 2018. "Goggle's Clips camera uses AI to take pictures." 28 February.
- , 2018. "Interested in AI? Why Montreal is where you need to be." 26 April: B7.
- , 2018. "Samsung to open AI research lab in Toronto." 24 May: B3
- , 2018. "Canada's AI success must inform our innovators: Artificial Intelligence, and the way Canada treats it, should inform most other approaches." 15 May: B4.
- , 2019. "Canada's AI dream." 20 June: B6-7.

The Ottawa Citizen. 1989. "Government gives Precarn \$10 M." 29 June: E2. [Final Edition].

Waddell, Christopher. 1987. "Ministers differ on linking of trade, drugs." *The Globe and Mail*.
10 October.