

Green Productivity, Sustainability, and the Law

Incorporating green productivity into the policy cycle and legal instrument choice frameworks to
address legal commitments to sustainability

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TABLE OF CONTENTS

Table of Contents	ii
List of Tables	vi
List of Figures	vii
Abstract	viii
Acknowledgements	ix
1. Introduction	1
1.1 Research Question	9
1.2 Contributions to Knowledge.....	10
1.3 Structure of Thesis	12
Part One: Theory, Methods, Concepts & Terminology	16
2. Legal Foundations and Methodology.....	17
2.1 Introduction	17
2.2 Legal Foundations	17
2.2.1 Canadian Legal Commitments.....	17
2.2.1.1 Intergenerational Equity & Sustainability.....	24
2.2.1.1.1 A Note on Discount Rates	26
2.2.1.1.2 Sustainability – Weak v. Strong	27
2.2.2 Section summary.....	36
2.3 Research Methodology	37
2.3.1 Law and Economics.....	37
2.3.1.1 Theories of Efficiency.....	40
2.3.1.2 Categories of Efficiency.....	48
2.3.1.2.1 Efficiently using Renewable and Non-Renewable Resources	51
2.3.2 Interdisciplinary Research Methodology	54
2.4 Conclusion	59
3. Policy Cycle and Legal Instrument Choice Frameworks.....	63
3.1 Introduction	63
3.2 The Policy Cycle	63
3.2.1 Stage One: Agenda-Setting.....	67
3.2.2 Stage Two: Policy-Formulation.....	70

3.2.3 Stage Three: Decision Making.....	71
3.2.4 Stage Four: Implementation.....	72
3.2.5 Stage Five: Evaluation	72
3.3 Instrument Choice.....	75
3.3.1 Frameworks – the “how” of Instrument Choice	76
3.3.2 Normative Criteria for Successful Choice – the “what” of Instrument Choice	81
3.4 Chapter Summary	86
4. Concepts and Terminology	88
4.1 Introduction	88
4.2 Capital and Natural Capital	89
4.2.1 Natural Capital	91
4.3 Conventional Productivity and Green Productivity.....	95
4.3.1 Conventional Productivity	96
4.3.2 Green Productivity	101
4.3.2.1 Natural Resource Productivity	103
4.3.2.1.1 Natural Resource Productivity Terminology.....	103
4.3.2.1.2 Natural Resource Productivity Framework	107
4.3.2.1.3 Conceptual Arguments for Measurement of Natural Resource Productivity	110
4.3.2.2 Environmentally Adjusted Productivity.....	116
4.3.2.2.1 Terminology	117
4.3.2.2.2 Environmentally Adjusted Productivity Framework.....	126
4.3.2.2.2.1 A note on how to model undesirables	131
4.3.2.2.3 Conceptual Arguments for Improving and Measuring Environmentally Adjusted Productivity	133
4.3.2.2.4 Past Research.....	135
4.3.2.3 Natural Capital & the Multifactor Productivity Residual	146
4.3.2.3.1 Conceptual Framework.....	147
4.4 Chapter Summary	153
Part Two: Application of Green Productivity to Law & Policy	155
5. Green Productivity and the Policy Cycle	156

5.1 Introduction	156
5.2 Green Productivity <i>Should</i> be a Public Policy Goal.....	157
5.3 Green Productivity and Agenda-Setting.....	158
5.3.1 The Broad Appeal of Green Productivity to Policy Actors	159
5.3.2 Determinates of the Adoption of Green Productivity.....	163
5.4 The Influence of Natural Capital and the Residual (NCR) on the Policy Cycle	170
5.5 Measures of Green Productivity and Evaluation.....	172
5.6 Chapter Summary	174
6. Green productivity as a new tool for legal instrument choice.....	176
6.1 Introduction	176
6.2 Green Productivity Can Help Target Goals for Instrument Choice	179
6.3 Green Productivity Measures Can Improve the Design of Legal Instrument Options..	184
6.4 Ex-Ante Evaluation of Legal Instruments Using Measures of Green Productivity	186
6.4.1 Natural Resource Productivity and Legal Instrument Options.....	188
6.4.2 Environmentally Adjusted Productivity and Legal Instrument Options.....	194
6.5 Chapter Summary	196
7. Application of Natural Resource Productivity: A Water Productivity Case Study of the Canadian Manufacturing Sector.....	198
7.1 Introduction	198
7.2 Past Research & Context.....	198
7.2.1 Importance of Water Productivity as an Indicator.....	198
7.2.2 Past Research on Water Productivity.....	200
7.3 Hypothesis & Data.....	204
7.3.1 Implications of Hypotheses.....	204
7.3.2 Data	205
7.4 Method.....	209
7.5 Analysis	210
7.5.1 Testing H_1	210
7.5.2 Testing H_2	216
7.5.2.1 Bivariate Regression Analysis	216
7.5.2.2 Multivariate Regression Analysis	220

7.6 Discussion.....	224
7.7 A Note on Modelling Other Green Productivity Measures	233
7.8 Chapter Summary	235
8. Conclusion.....	238
8.1 Introduction	238
8.2 Contributions	239
8.3 Other Notable Points	244
8.4 Limitations.....	247
8.5 Directions for Future Research.....	248
8.6 Moving Toward a Green, Sustainable Economy.....	249
Bibliography	251
Appendix A: Case Study Details	269
Municipal and Self-Supply Bivariate Results	270
National Sub-sector Water Productivities	273
Labour Compensation and Capital Costs.....	275
Table of Data for Case Study – Water Intake	277
Table of Data for Case Study – Water Acquisition Costs & Sub-Sector Percentage of Provincial Manufacturing Sales	279

LIST OF TABLES

Table 3.1- Analysis of Generalized Policy Cycle and Instrument Choice Framework to Treasury Board Analytical Framework.....	81
Table 3.2 - Instrument Choice Evaluative Criteria	82
Table 4.1 - Definitions of Capital	89
Table 4.2 - Definitions of Natural Capital	92
Table 4.3–Terms Used to Indicate Outputs Not Currently Included in Productivity Frameworks	118
Table 4.4–Terms Used to Indicate Outputs Currently Included in Productivity Frameworks ...	120
Table 4.5 - Terms Used to Describe Productivity Which Considers Desirable and Undesirable Outputs.....	122
Table 7.1 - Results of Bivariate Analysis of Water Productivity and Water Price.....	217
Table 7.2 - Results of Multivariate Analysis of Water Productivity and Water Price.....	221
Table 7.3 - Results of Multivariate Analysis of Municipal Water Productivity and Municipal Water Price with Logged Variables	224

LIST OF FIGURES

Figure 2.1 - Scale of Sustainability Concepts	28
Figure 2.2 – Productive Efficiency and the Production Possibilities Frontier.....	49
Figure 2.3 – Change in Allocative Efficiency	51
Figure 2.4 – Interdisciplinary versus Multidisciplinary Approaches.....	56
Figure 3.1 – The Policy Cycle with Imbedded Instrument Choice Framework	66
Figure 3.2 – Instrument Choice Framework	77
Figure 3.3 – Analytical Framework for Selecting Instruments.....	78
Figure 4.1 – Changes in Multifactor Productivity and Labour Productivity	101
Figure 6.1 – Instrument Choice Framework	177
Figure 7.1 - Total Manufacturing Sector Water Productivity, by Province (2005-2011).....	211
Figure 7.2- Total Water Productivity - 2011	212
Figure 7.3 - Manufacturing Sub-sectors by Percentage of Total Provincial Manufacturing Sales (2011).....	214

ABSTRACT

Over the past number of decades, Canadian governments (both federal and provincial) have made commitments to preserving and protecting the natural environment and to using its components efficiently in order to benefit both current and future generations. These commitments, this thesis argues, translate into duties to strive for sustainable economic growth and intergenerational equity. One of the key challenges is to figure out which are the best policy tools and legal instruments that are capable of leading Canada towards these goals. Unfortunately, the economic measures typically employed by decision makers (GDP, GNP, productivity) tend to exclude or under represent natural capital, which may lead to decisions which actually degrade and deplete the natural environment and therefore violate the aforementioned legal commitments. One clear strategy to help Canada meet its commitments to sustainable economic growth and intergenerational equity is to ensure it uses its natural capital as efficiently as possible. This thesis proposes that green productivity is a useful tool for improving decision making because it considers the efficiency of use of natural capital a criteria important to helping achieve both sustainable economic growth and intergenerational equity.

Green productivity is presented in this thesis as an umbrella term for productivity measures which include or account for, in some way, the (mis)use of natural capital. Specifically, the dissertation discusses three measures of green productivity used within economics: natural resource productivity, environmentally adjusted productivity, and natural capital and the residual. In addition to exploring the differences between these three measures of green productivity, the dissertation shows that they can be used to improve decision making in a number of ways, including as a broader public policy agenda item used by the government to target sustainability objectives. Additionally, measures of green productivity can be used to identify more specific policy and legal instrument goals, in designing and evaluating legal instruments, and in stakeholder consultation. For example, natural resource productivity can help identify leaders and laggards, thereby allowing decision makers to target certain industries or areas which are lagging. It can also help decision makers learn from leading jurisdictions which may ultimately lead to the implementation of new ideas in legal instrument design. The dissertation concludes with a case study of one type of green productivity measure (water productivity) in order to illustrate how the information it produces could be applied by decision makers.

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1. Introduction

The development of modern industrial economies has greatly improved the lives of citizens in material terms, but the impact of this economic model on the environment is becoming increasingly apparent. It is becoming clear that the number and severity of environmental problems is increasing – parts per million of carbon dioxide in the atmosphere continue to increase, biodiversity loss is above its suggested planetary boundary, and other earth system boundaries are nearing their limits as well.¹ While environmental challenges are well documented by the scientific community, their implications tend to be poorly translated into economic measures, which often means that decision makers are not well informed. This is because, when making choices about law and policy, decision makers are using flawed economic measures – flawed because they fail (for the most part) to account for impacts on the natural environment. While these shortcomings are widely recognized, solutions are not easy to come by. This dissertation aims to contribute to this discussion by considering green productivity (an economic measure adjusted to be more inclusive of natural capital). Specifically, the dissertation focuses on analysing how green productivity can be used in the policy cycle and as a tool for instrument choice so that decisions made better align with Canada’s commitments to sustainable economic growth and intergenerational equity.²

While the indivisibility between the economy and natural capital has been recognized at an international level,³ progress in ensuring law makers and industry make this connection has lagged.⁴ If these links are not recognized and accounted for, it seems likely that economic

¹ Johan Rockström et al., “A safe operating space for humanity” (2009) 461 Nature 472 [Rockström et al] at 473.

² See Chapter 2 for a more detailed explanation of these commitments.

³ *Natural Capital Declaration*, UNEPFI, June 2012 online: <http://www.unepfi.org/> [NCD].

⁴ Though in some places the Canadian federal government has indicated a belief that “economic prosperity and environmental protection are not mutually exclusive goals” (Government of Canada, Enhancing Environmental Protection, Online: <http://actionplan.gc.ca/en/backgrounder/r2d-dr2/enhancing-environmental-protection>) other

development will continue at the expense of the quality and quantity of the world's natural capital. Further, over time, the impacts of this degradation will likely begin to show up on the balance sheet of companies, and in the lowered productive capacity passed along to those in the future. At present, environmental costs are often not incorporated into standard economic measures such as productivity. In turn, this leads to poor decision making with regards to the use and preservation of natural capital. If these exclusions continue, eventually clear impacts on production from overuse, degradation, and destruction of natural capital stocks and flows will increasingly appear as additional costs. Adjusting current measurement practices, decision making cycles, and evaluative frameworks may in fact be cheaper now than in the long term.

Productivity is one of a suite of key economic measures which helps to determine economic success and progress. Measures of productivity are well known to be directly linked, over the long run, to standards of living⁵ as well as gross domestic product (GDP) per capita, wages, and wealth.⁶ These strong connections are most prominent with labour productivity, but multifactor productivity (MFP) is also an important measure. There are several types of

actions have proved that an understanding of the indivisibility between the economy and the environment is not entrenched in how decisions are made. For example, consider the change in environmental assessment, which some commentators believe weakened the environmental protection aspect of this process in favour of more streamlined approval for economic projects [Ecojustice, Legal Backgrounder – Canadian Environmental Assessment Act, 2012 – Regulations (August 2012) online: <http://www.ecojjustice.ca/wp-content/uploads/2015/03/August-2012_FINAL_Ecojustice-CEAA-Regulations-Backgrounder.pdf>]. Also, the repeated lack of action on reducing GHG emissions which has led Canada to be considered a laggard in climate change action and which shows the lack of understanding of how natural capital and the economy are linked. Canada, in fact, received the “Fossil” award at the Rio+20 Talks on Sustainable Development (Heather Scofield “Canada Wins 'Fossil' Award at Rio+20 Talks on Sustainable Development” Huff Post (15 June 2012) Canada Politics Section online: http://www.huffingtonpost.ca/2012/06/15/canada-fossil-award-rio-20_n_1600627.html.

⁵ Andrew Sharpe, “Three Policies to Increase Productivity Growth in Canada” (2008) Canadian Priorities Agenda, at 4, online: <<http://irpp.org/wp-content/uploads/assets/research/canadian-priorities-agenda/productivity-growth-in-canada/sharpe-sept-2008.pdf>> [Sharpe, “Three Policies”].

⁶ TD Bank Economics, *The Productivity Puzzle: Why is the Canadian Record so Poor and What can be done about it?* (Toronto: TD Bank Financial Group, 2010) at 1 online: <http://www.td.com/document/PDF/economics/special/td-economics-special-ab0610-productivity.pdf> [TD, “The Productivity Puzzle”].

productivity, including partial measures of productivity and, as noted, MFP.⁷ Labour productivity is the most well-known type of partial (or single factor) productivity measure which “relates output to one particular type of input.”⁸ Partial productivity measures provide an estimate of the efficiency of use of a single input, such as labour or capital. This kind of measure can also be constructed for natural resources, such as water, which is discussed at length in Chapters 4 and 7. These measures are termed partial because they are not comprehensive in their inputs -they do not use all inputs, but rather focus on only one. Still, they are considered a very important measure by decision makers in Canada and around the world. MFP (or total factor productivity),⁹ on the other hand, is a more comprehensive measure and “relates a change in output to several types of inputs.”¹⁰ Typically, MFP is understood as representing technology change, better management, or other factors not accounted for in standard inputs of, for example, labour and capital.¹¹ MFP is often considered to be a good indicator of innovation – it “captures increases in productivity from utilizing a given set of resources more efficiently.”¹²

Measures of productivity are used in a number of ways, including to compare the success of one nation to another and to analyse the impacts of legal instruments and government policies. Further, rising productivity has increasingly become a government priority in Canada. Many, if not most, studies which compare Canada to other countries have concluded that Canada is slipping in terms of productivity growth as compared to foreign jurisdictions.¹³ This decline that

⁷ These two concepts will be explored in more depth in Chapter 4, but are presented here as part of a preview of green productivity.

⁸ OECD, “Labour Productivity” in *Statistics Definitions*, online:
<<https://stats.oecd.org/glossary/detail.asp?ID=2463>>

⁹ MFP and total factor productivity are often used interchangeably. In this thesis, MFP is the term used.

¹⁰ OECD, “Multifactor Productivity” in *Statistics Definitions*, online:
<https://stats.oecd.org/glossary/detail.asp?ID=1698> relates a change in output to several types of inputs

¹¹ Robert Solow, “A Contribution to the Theory of Economic Growth” (1956) 70:1 *The Quarterly Journal of Economics* 65 [Solow, “A Contribution”].

¹² TD, “The Productivity Puzzle”, *supra* note 6 at 1.

¹³ *Ibid.*

has led decision makers and commentators alike to increasingly focus on ways which Canada's productivity can be improved.

Despite the emphasis on conventional productivity estimates, there has been little focus on the part natural capital may play in Canada's productivity agenda. Though European countries and organizations such as the Organization for Economic Cooperation and Development (OECD) have shown increasing interest in measuring forms of productivity that are more inclusive of natural capital, what is termed in this thesis 'green productivity' has so far had limited (if any) application in decision making processes here in Canada. Though this may seem surprising given the emphasis that various actors in Canada have placed on productivity growth, the lack of resonance that green productivity has had may be due to a lack of knowledge of the topic by decision makers who have the capacity for such a proposal and the fact that, as discussed in Chapter 4, research on green productivity has tended to be fragmented. Further, the lack of attention paid to green productivity by Canadian decision makers may be exacerbated by the fact that even green GDP (a more well-known and studied environmentally adjusted economic measure) has not been included in Statistics Canada's standard set of measures.¹⁴

Defined, green productivity is a 'greened' measure which is part of a broader movement towards more inclusive types of economic measures. This approach to adjusting economic measures has been termed by the United Nations Industrial Development Organization (UNIDO) as "green initiatives".¹⁵ In the past few decades, there have been a number of 'green' or more

¹⁴ Statistics Canada, *Environmental and Resource Accounts: Frequently Asked Questions*, online: <http://www.statcan.gc.ca/eng/nea/faq/env#q2>.

¹⁵ Frederick Hinterberger et al. *Green Growth: From Labour to Resource Productivity* (Vienna: United Nations Industrial Development Organization, 2013) at 30-31[Hinterberger et al, "Green Growth"].

environmentally inclusive economic measures explored, including, green GDP,¹⁶ green (or environmental) national accounting,¹⁷ and the genuine progress index,¹⁸ among others. Green productivity is another addition to this family of more inclusive and ‘greened’ economic measures, but until now, has tended to be the focus of less attention, especially in law and policy realms.

Green productivity, in this thesis, is used as an umbrella term to include conventional measures of productivity adjusted or altered, in some way, to account for the (mis)use of natural capital in production. Within green productivity, the thesis considers three specific measures – natural resource productivity (NRP), environmentally adjusted productivity (EAP), and natural capital and the residual (NCR). Each of these measures is discussed conceptually with reference to previous research (Chapter 4), and is then considered in relation to the policy cycle (Chapter 5) and legal instrument choice frameworks (Chapter 6). While measures of green productivity are discussed in detail in Chapter 4, some basic definitions may be useful here.

Natural resource productivity is a partial productivity measure (like labour productivity) which compares total output to the input of natural resources (either one type – water, for example, as is done in Chapter 7’s case study – or total natural resources). The result is a measure of how efficiently natural resources are used in production – how much output is gained per unit of natural resource used. This measure is similar to resource productivity which is a

¹⁶ Discussion and explanations of green GDP can be found in, among others: James Boyd, *The Nonmarket Benefits of Nature: What Should be Counted in Green GDP?* (Washington, DC: Resources for the Future, 2006) [Boyd, “Nonmarket Benefits”]; John Talbert & Alok K. Bohara, “Openness and Green GDP” (2006) 58 *Ecological Economics* 743 at 743-744; James Boyd, *Don’t Measure, Don’t Manage: GDP and the Missing Economy of Nature* RFF Issue Brief 08-01. (Washington, DCL Resources for the Future, 2008) [Boyd, “Don’t Measure”]; EPA, *Green Accounting*, Online: EPA <<http://www.epa.gov/sustainability/analytics/green-accounting.htm>>; and Geir B. Asheim, “Green national accounting: why and how?” (2000) 5 *Environment and Development Economics* 25-48.

¹⁷ Joy E. Hecht, “Environmental Accounting: Where we are now, Where we are heading” (1999) Spring: 35 *Resources* 14-17 online: <http://www.rff.org/rff/Documents/RFF-Resources-135-enviroaccount.pdf>.

¹⁸ Genuine Progress Indicator, online: <http://genuineprogress.net/genuine-progress-indicator/>.

current focus area of the European Union and the OECD.¹⁹ NRP, then, is not an adjustment to methodology, but rather an alteration in what is measured – instead of considering inputs of labour to outputs, it considers inputs of natural resources.

Environmentally adjusted productivity is an adjustment to the methodology of conventional MFP in that it changes what outputs are included. Conventional MFP considers the ratio of total inputs to total desirable outputs (typically GDP or another value of products). The results are called the residual. EAP takes into account undesirable outputs which are externalities – pollution, waste, ecosystem degradation – that are produced alongside profit, products, and services but are not typically included in MFP measures. Rather than assuming all outputs are positive, EAP includes the value of harmful outputs alongside conventional outputs. Thus, total output is desirable outputs combined with undesirable outputs (the latter having a negative impact on the productivity equation) and changes in this are equated to changes in a combination of inputs. Essentially EAP is a “corrected” version of MFP.

Natural capital and the residual also builds on conventional MFP, but in this case is concerned with the impact that changes in the quality and quantity of natural capital have on the residual. Typically changes in the residual (which represents the changes in output not accounted for by changes in inputs) are considered to be a function of innovations in technology, managerial operations, or organizational behaviour.²⁰ It is entirely possible, though, that some of

¹⁹ For example, Recommendation of the Council on Resource Productivity, Meeting of the Environment Policy Committee (EPOC) at Ministerial Level Environment and Global Competitiveness 28-29 April 2008 Adopted by the OECD Council on 28 March 2008 [Recommendation of the Council]; EC, European Resource Efficiency Platform, *Manifesto & Policy Recommendations* (17 December 2012) online: http://ec.europa.eu/environment/resource_efficiency/documents/erep_manifesto_and_policy_recommendations_31-03-2014.pdf [EC, Manifesto].

²⁰ Tarek M. Harchaoui, Mustapha Kaci & Jean-Pierre Maynard, *Appendix 1 – The Statistics Canada Productivity Program: Concepts and Methods* (Ottawa: Statistics Canada: 2001) [Harchaoui et al, “Appendix 1”] at 144; Charles R. Hulten, “Total Factor Productivity: A Short Biography. In Charles R. Hulten, Edwin R. Dean and Michael J. Harper (Eds.) *New Developments in Productivity Analysis* (Chicago: University of Chicago Press, 2001) at 8.

the residual comes from changes in the quality and/or quantity of natural capital being used by production processes. This is especially so for aspects of natural capital which are excluded as inputs from the MFP calculation –for example, the variability of rainfall, and the potential for that to impact agricultural productivity.

Without including natural capital in conventional productivity, the results reported and used to make decisions about designing and evaluating law and policy are incomplete. The decisions which result have the potential to cause significant long term impacts for the quality and quantity of natural capital as well as the productive capacity of the economy, not to mention limiting the potential to reach broad sustainability goals. This dissertation sets out a suite of measures of green productivity and analyses their usefulness in broader policy discussions and instrument choice decision making. Ultimately, recommendations are provided as to how these measures (and green productivity as a broad concept) can help decision makers make better choices which align with sustainable economic growth and intergenerational equity goals. It should be made clear, though, that while the use of green productivity measures is an important step forward, and as is argued in this thesis, a new tool for decision makers designing and choosing legal instruments and policy targets, it cannot be thought of as “the” answer and be used as a stand-alone tool. Importantly, it is certainly possible for growth in green productivity to result in improvements in efficiency of use of natural capital, but that increases in economic growth could be higher, which would likely lead to overall increases in use of natural capital thereby impacting the natural environment but also the long-term capacity of the economy which relies, in many ways, on the use of natural capital. The risk of such a situation leads to the understanding that, coupled with green productivity, limits or caps on overall use of the natural

environment are important to ensure both sustainable economic growth and intergenerational equity.

In addition, it is important to note that though this dissertation is focused on sustainable economic growth (to which, it is argued, the government has a commitment), there are also other ideas of growth espoused by proponents of green legal theory²¹ and green economics.²² These agendas of no-growth or de-growth, though certainly different in their perspective on how the economy should proceed, can still benefit from the information provided by measures of green productivity. For example, aiming for a no-growth society today which also takes into consideration future generations would almost certainly require improvements in the efficiency with which we use natural capital. That is, aiming to reduce the amount of natural capital used while keeping output the same would mean more natural capital left for future generations than a business as usual scenario. Further, regardless of whether the ultimate government goal is to increase sustainable economic growth, pursue a no-growth agenda, or aim for de-growth, it is inevitable that some natural capital will be used. It only makes sense, then, to get the most output per unit of input (natural resources, for example) and therefore to improve the efficiency of use of natural capital by eliminating any deadweight loss and by encouraging substitution, where

²¹ See generally, Michael M’Gongile, “Green Legal Theory: A new approach to the concept of environmental law” (2008) *Ökologisches Wirtschaften* 4, 34-38; Michael M’Gongile & Louise Takeda, “The Liberal Limits of Environmental Law: A Green Legal Critique” (2013) 30:4 *Pace Environmental Law Review* 1005-1113; R. Michael M’Gonigle & Paula Ramsay, “Greening Environmental Law: From Sectoral Reform to Systemic Reformation” (2004) 14 *J. Env’tl. L. & Prac.* 342

²² For example, the work by: Molly Scott Cato, *Green Economics: An Introduction to Theory, Policy and Practice* (London: Earthscan, 2009); David Pearce, “Green Economics” (1992) 1:1 *Environmental Values* 3-13; Robin Hahnel, *Green Economics: Confronting the Ecological Crisis* (Armonk, NY, London UK: M.E. Sharpe, 2011) [Hahnel, “Green Economics”]; Miriam Kennet & Volker Heinemann, “Green Economics: setting the scene. Aims, context, and philosophical underpinning of the distinctive new solutions offered by Green Economics” (2006) 1:1/2 *International Journal of Green Economics*, 68; Derek Wall, “Green Economics: An Introduction and Research Agenda” (2006) 1:1/2 *International Journal of Green Economics*, 201.

possible. Again, this shows that measures of green productivity are useful information sources and targets for decision makers regardless of their ultimate economic growth objective.

To examine the possible benefits of incorporating green productivity into law and policy development, this dissertation relies on three important concepts which cut across several different disciplines. The first is sustainability, and in particular the principle of intergenerational equity. The Canadian government has a legal obligation to intergenerational equity and sustainability because of its statements and commitments at both the national and international level.²³ The second concept is flawed measurement and the critiques that standard economic measures, such as GDP or productivity, do not accurately measure the impact of economic activity on the environment. These criticisms show how using only standard economic measures make it difficult to meet the government's commitments to sustainability and intergenerational equity. Finally, the concept of efficiency will be discussed, both in a broad context as well as with specific reference to the efficient use of (natural) capital.

1.1 Research Question

Given the legal commitments to sustainable economic growth and intergenerational equity made by the Canadian government, this research proposes that the use of green productivity measures can improve decision making in the policy cycle and instrument choice frameworks so that better progress can be made towards their achievement. The key research question is: *“in what way(s) can green productivity measures be used in the policy cycle and to improve instrument choice decision making?”* More specifically, this thesis will examine how the broad concept of green productivity and the measure of NCR can be applied in the policy cycle and how NRP and EAP

²³ See Chapter 2, section 2.2.

can be tools to improve decision making about instrument choice goals, design, and evaluation.

The dissertation will proceed in four stages:

- i. Establishing the legal foundations of Canada's sustainability commitments;
- ii. Exploring the different types of green productivity measures, and developing a set of consistent concepts and terminology;
- iii. Examining how and where in the policy cycle and legal instrument choice framework green productivity measures can be used; and
- iv. Testing a case study of one green productivity measure – water productivity – to illustrate both the usefulness to instrument choice decision making and the need for improvements in data collection.

1.2 Contributions to Knowledge

In exploring the relationship between green productivity and law and policy, this thesis makes a number of important contributions, primarily in law and policy, but also to economics and interdisciplinary research.

This thesis takes three environmentally inclusive economic measures of productivity – NRP, EAP, and NCR – and frames them as measures under the broad umbrella of 'green productivity'. The main contribution here is the presentation of a cohesive and coherent suite of green productivity measures, which should allow better diffusion of research and a more unified and informed field of work. A further, related, contribution is the clarification of terminology and meanings of green productivity, NRP, and EAP. Crucially, in terms of interdisciplinary research, this dissertation is important as it draws together two complementary, disciplinary ideas – green productivity and instrument choice. Further, the thesis provides an extensive synthesis of research related to EAP, a useful contribution given that this is a rather disjointed literature in need of more cohesion.²⁴

²⁴ This is done, but only to a modest extent quite briefly, by Nicola Brandt, Paul Schreyer & Vera Zipperer, "'A Green Productivity Measure'" (2012) Draft OECD Paper [Brandt et al., "A Green Productivity Measure"] at 20-22,

Further, the analysis of what these green productivity measures can provide to decision makers, distinct from information already provided from economic measures such as GDP (or green GDP), cost benefit analysis, and environmental accounts, is a significant contribution. Though these measures may use the same data as green productivity does, the latter presents results in terms of efficiency – how much output is being produced per unit of an input or combined inputs. In the same way that labour productivity and MFP measures provide decision makers with information distinct from GDP or cost benefit analysis, so too do green measures of productivity.

Recommendations for how green productivity can improve law and policy decision making are made at a general level as well as with specific reference to the federal government of Canada's *Analytical Framework for Instrument Choice*.²⁵ NRP as a measure is discussed as being able to: i) provide decision makers with information about where to target new instruments and what goals to set; ii) help identify leaders and laggards and consequently identify ways which improvements can be made as well as point to ideas about what could be incorporated into the design of legal instruments; and iii) evaluate legal instruments either *ex-ante* (as part of the instrument choice framework) or *ex-post* (as part of the broader policy cycle). EAP can be used to evaluate instruments (*ex-ante* and *ex-poste*), in particular with regards to their relationship to innovation. NCR is shown to be most likely useful in the broader policy cycle, especially with regards to providing additional information to decision makers about unmeasured impacts of changing quantities and qualities of natural capital.

and some time ago by David Tyteca, "On the Measurement of the Environmental Performance of Firms—A Literature Review and a Productive Efficiency Perspective" (1996) 46 *Journal of Environmental Management* 281-308 [Tyteca, "On the Measurement"] at 289-296.

²⁵ Treasury Board of Canada, *Assessing, Selecting, and Implementing Instruments for Government Action* (Ottawa: Government of Canada, 2007) [Treasury Board, "Assessing, Selecting"] at 10.

The role of green productivity as a broad concept in the policy cycle is also discussed, specifically with regards to where and when green productivity can and should be introduced to improve decision making. Green productivity, it is argued, would be most successful if introduced at the agenda setting phase of the policy cycle. One reason for this is that green productivity has characteristics which make it likely to appeal to decision makers with diverse backgrounds. Further, the successful implementation of green productivity needs a variety of expertise, from a broad array of decision makers (environmental and economic) who are more likely to all be part of the discussion at the agenda-setting phase of the policy cycle. Given current emphasis on similar measures of productivity in other jurisdictions, the conclusion here is that it is plausible that green productivity could emerge in Canada as a consequence of policy diffusion.

Finally, this thesis presents a case study of water productivity (a measure of NRP) and demonstrates how such measures can, in practice, be used by decision makers. It does so by showing that water productivity comparisons can highlight leaders and laggards. It also illustrates the relationship between water productivity and water prices (a proxy for a pricing instrument). This comparison is an example of how measures of NRP can be used to evaluate legal instruments. Conclusions from the case study are preliminary, in large part due to data restrictions, but, on a whole, they provide a practical demonstration of the usefulness of a measure of green productivity.

1.3 Structure of Thesis

This dissertation is primarily laid out in two parts. Part one is entitled ‘Theory, Methods, Concepts & Terminology’ and presents the legal, economic, and environmental foundations of this research. The first chapter in Part One – Chapter 2 – introduces the legal foundations of this

dissertation. Specifically, through evidence of international, national, and provincial legal commitments, it demonstrates Canada's responsibility to sustainable economic growth and intergenerational equity. These concepts are instrumental to the remainder of the dissertation. Chapter 2 also presents the methodologies used in this research – notably law and economics as well as interdisciplinary research (IDR) methodology. The focus in the law and economics section is on the idea of efficiency. IDR is discussed as it is relevant to how this research was completed.

Chapter 3 presents an overview of the policy cycle and instrument choice. It lays the foundation for later chapters (5, 6 and 7) which explore the application of green productivity in the policy cycle and instrument choice frameworks. The focus in the policy cycle is on agenda-setting and in the instrument choice framework on design and evaluation. The instrument choice discussion includes a comparison between a generalized instrument choice framework and the Canadian federal government's instrument selection framework.²⁶

Chapter 4 presents the economic concepts and terminology used throughout the thesis. It begins with a brief discussion of capital and natural capital, since this is an important part of the various green productivity measures. Green productivity as a whole, and its more specialized measures, are the focus of the majority of this chapter. Specifically, terminology recommendations are made for each measure, frameworks are laid out and existing literature is reviewed. The three measures of focus are natural resource productivity, environmentally adjusted productivity, and natural capital and the residual.

²⁶ *Ibid.*

Part two of this dissertation is about application – specifically the application of green productivity within the policy cycle and legal instrument choice frameworks. Chapter 5 focuses on where in the policy cycle green productivity is likely to have influence. The chapter begins by reiterating the important role green productivity can play in moving towards the commitments discussed in Chapter 2, though the bulk of chapter considers where in the policy cycle the adoption of green productivity as a broad concept is most likely to gain traction. Specifically, the chapter argues that the nature of green productivity is especially well suited to the broad policy debate and cross-departmental engagement at the agenda-setting level. Further, the chapter discusses some factors which make adoption in Canada plausible. This chapter also briefly discusses how NCR information can be used at different policy cycle stages, and specifically how it aligns with the government of Canada’s consultation requirement in its instrument selection framework.²⁷ Further, this chapter highlights that the green productivity measures of NRP and EAP can provide useful information during the evaluation stage of the policy cycle.

Chapter 6 focuses on instrument choice frameworks, and the application of two green productivity measures – NRP and EAP – as tools for setting goals, as well as designing and evaluating legal instruments. In particular, NRP, it is argued, can identify leaders and laggards in efficiency and provide information which can be useful for choosing appropriate goals for instruments as well as for identifying innovative ideas for use in new instrument design. Both NRP and EAP can also be important in evaluating, and ultimately choosing, the instrument(s) that best align with commitments to sustainable economic growth and intergenerational equity.

²⁷ *Ibid* at 10 and 26.

Chapter 7 is a proof-of-concept case study about water productivity in the Canadian manufacturing sector. The case study demonstrates that measures of green productivity can actually be calculated and can provide useful information to decision makers. This chapter presents results that show a measure of NRP can identify leaders and laggards (provinces which have substantially higher or lower water productivity) in the manufacturing sector. In addition, the case study demonstrates that water productivity is positively correlated with water price – but only for municipally supplied water (not for self-supplied water). This is important information for decision makers considering a pricing instrument. Despite these preliminary findings, the case study suffers from data challenges. This too is an important consideration for future research and for the implementation of green productivity measures into decision making processes.

Chapter 8 – the concluding chapter – wraps up the dissertation by summarizing the main goals and research question asked. It also provides a detailed discussion of the contributions made throughout the thesis. Further, this chapter highlights some future research directions as well as the limitations of this work.

PART ONE: THEORY, METHODS, CONCEPTS & TERMINOLOGY

2. Legal Foundations and Methodology

2.1 Introduction

This chapter introduces the legal and theoretical arguments that underpin the use of green productivity in law and policy contexts. The central argument of the chapter is that Canada has legal commitments to sustainable economic growth and intergenerational equity which require preserving natural capital, in part, through improving how efficiently it is used. This chapter is divided into two parts. The first presents the legal foundations of this research. Specifically, it begins by describing Canada's legal commitments to sustainable economic growth, resource use efficiency, and intergenerational equity. Following this, a discussion about the underlying concepts and theories of these commitments is presented - notably sustainability and intergenerational equity are discussed. Taking Canada's legal commitments together with an understanding of sustainability and intergenerational equity, it is argued, means that Canada has legal commitments to conserve and increase how efficiently natural capital is used.

The second part of this chapter sets out the research methodology employed throughout the dissertation. It begins by presenting 'law and economics' as the primary method employed and discusses some of the key theories that inform this dissertation. A detailed description of different conceptions of efficiency is also presented. Finally a brief overview of interdisciplinary research (IDR) methodology concludes the chapter, since much of this research relies on understanding how, in a research methodology, different disciplinary perspectives can be combined.

2.2 Legal Foundations

2.2.1 Canadian Legal Commitments

Over the past few decades, Canada and the international community have made strong statements and have legal commitments and obligations²⁸ to the protection and sustainable use of the natural environment. Most well-known, perhaps, are the commitments laid out in the principles of the *Rio Declaration on Environment and Development*, specifically, Principles 4, 7, and 8, which state that:

In order to achieve sustainable development, environmental protection shall constitute an integral part of the development process and cannot be considered in isolation from it [Principle 4]

States shall cooperate in a spirit of global partnership to conserve, protect and restore the health and integrity of the Earth's ecosystem [Principle 7]

To achieve sustainable development and a higher quality of life for all people, States should reduce and eliminate unsustainable patterns of production and consumption and promote appropriate demographic policies [Principle 8]²⁹

²⁸ In this thesis, the terms legal obligation and legal commitment have different meanings. Legal obligations are considered to be those which have stronger legal force – those which can be categorized as ‘hard’ law - while legal commitments are considered less binding, legally, but still important from the perspective of understanding the perspectives and goals of a government. They can be categorized as ‘soft’ law. As Currie states, hard law (*lex lata*) only includes “the products of the traditional, formal sources of international law ... (namely, treaties, customary international law, general principles of law, and perhaps unilateral declarations).” He goes on to note that even though the specific details of what comprises soft law (*lex ferenda*) is not unanimously agreed upon, “some authors...consider it to be a reservoir of *evidence* of state practice, *opinion juris*, or general principles, rather than a formal source of law in itself” (emphasis in original). [John H. Currie, *Public International Law*, 2nd Ed. (Irwin Law Inc.: Toronto, 2008) at 118]. In the case of this thesis, the commitments made in the *Rio Declaration* would be considered soft law while those made within the *Convention on Biological Diversity (CBD)* would constitute hard law obligations. This is because while the *Rio Declaration* emerged from a major international conference, which, as Currie notes “can at least state broad agreements of principle where the participants have been otherwise unable to agree on legally binding obligations enshrined in a convention” [Currie at 119], the *CBD* is an international legally binding agreement. While these distinctions are perhaps most obvious with regards to international law, they also exist at a domestic level, perhaps most easily recognizable as the distinction between laws, regulations and jurisprudence in contrast to government priorities, policies and guidelines. In summary, the conclusions of this dissertation are that legal obligations do exist to protect the natural environment and to consider future generations, but that legal commitments to both areas, as well as to sustainable economic growth are more numerous, yet nonetheless, important. Together it is argued that legal commitments to sustainable economic growth and intergenerational equity do exist and that they also imply commitments to the efficient use of natural capital.

²⁹ While these statements do not directly refer to the sustainable use and protection of natural capital, their frequent reference to the use of the natural environment within production processes (whether by direct use or assimilative capacity) makes it clear that natural capital use is very much included. (See 1992 *Rio Declaration on Environment and Development (Rio Declaration)*, 14 June 1992, 31 ILM 874, UN Doc. A/CONF.151/26 (vol. I) [Rio Declaration]).

Canada was a significant part of the round of negotiations during which the *Rio Declaration* was drafted. The *Convention on Biological Diversity (CBD)* was also concluded at this international meeting and Canada was one of the first to sign and ratify it. The *CBD* is explicit about sustainable use and protection commitments. Article 1 of the *CBD* states that the objectives are “...the conservation of biological diversity, the sustainable use of its components ...”³⁰ Article 6 of the *CBD* requires Contracting Parties (Nation-States) to

in accordance with its particular conditions and capabilities:

(a) *Develop national strategies, plans or programmes for the conservation and sustainable use of biological diversity* or adapt for this purpose existing strategies, plans or programmes which shall reflect, inter alia, the measures set out in this Convention relevant to the Contracting Party concerned; and

(b) *Integrate, as far as possible and as appropriate, the conservation and sustainable use of biological diversity into relevant sectoral or cross-sectoral plans, programmes and policies.*³¹ [emphasis added]

More recent international commitments echo these statements, including the final document “The Future We Want” released after the Rio + 20 meetings in 2012. Specifically, paragraph 61 of this document indicates that the international community

...recognize[s] that urgent action on unsustainable patterns of production and consumption where they occur remains fundamental in addressing environmental sustainability and promoting conservation and sustainable use of biodiversity and ecosystems, regeneration of natural resources and the promotion of sustained, inclusive and equitable global growth³²

This statement echoes but expands upon the standard definition of sustainable development from the 1987 World Commission on Environment and Economy (otherwise known as the *Brundtland*

³⁰ *Convention on Biological Diversity*, 6 May 1992, 1760 UNTS art 1 (entered into force 29 December 1992) [CBD].

³¹ *Ibid* at art. 6.

³² UNCSO, *The Future We Want*, 22 June 2012 online: <http://sustainabledevelopment.un.org/futurewewant.html> [UNCSO] at para 61.

Report) which defined the concept as “development that meets the needs of the present generation without compromising the ability of future generations to meet their own needs.”³³

The OECD Council has also released recommendations indicating the importance of using natural capital efficiently, specifically noting that they

Recommend[], with regard to the policies concerning the improvement of resource productivity, that Member countries: Take appropriate actions to *improve resource productivity* and reduce negative environmental impacts of materials and product use, by *encouraging environmentally effective and economically efficient uses of natural resources* and materials at the macro, sectoral and micro levels and by involving all relevant ministries and departments of government as well as research and other non-governmental organisations.³⁴ [*emphasis added*]

While some of these statements (e.g. The Future We Want) have little true legal force, others are much stronger (e.g. the *CBD*). Taken together, they make clear that while economic growth is still a goal, it must be done in a way which promotes sustainable use, conservation and regeneration of the environment. This type of growth can be defined as ‘sustainable economic growth.’ The Canadian government has also indicated that sustainable economic growth is one of three ‘priority themes’ in its international development and assistance work.³⁵ It is a reasonable conclusion, then, that Canadian economic growth should, itself, also be sustainable.

Aside from the international commitments already presented, the Canadian federal government has obligations which stem from national legislation which encourage focus to be

³³ World Commission on Environment and Development, *Our Common Future* (Oxford: Oxford University Press, 1987) [Brundtland] at 8.

³⁴ Recommendation of the Council, *supra* note 19 at II.

³⁵ Government of Canada, *CIDA's Sustainable Economic Growth Strategy* online: <http://www.acdi-cida.gc.ca/acdi-cida/acdi-cida.nsf/eng/NAD-9241625-RHC> [CIDA].

placed on the efficient use of natural resources. The *Federal Sustainable Development Act*, s. 5 states that

accept[ing] the basic principle that sustainable development is based on an ecologically efficient use of natural, social and economic resources and acknowledges the need to integrate environmental, economic and social factors in the making of all decisions by government.³⁶

In the same vein, commitments made in the *Canadian Environmental Protection Act, 1999* recognize that

seek[ing] to achieve sustainable development that is based on an ecologically efficient use of natural, social and economic resources and acknowledges the need to integrate environmental, economic and social factors in the making of all decisions by government and private entities.³⁷

Section 2 of the *Canadian Environmental Protection Act, 1999* also commits the government to take into consideration the environment when social and economic decisions are made, as well as to facilitate “preventative and remedial measures to protect, enhance, and restore the environment.”³⁸

In addition to conserving and efficiently using the natural environment, Canada also has made legal commitments to intergenerational equity. More specifically, ensuring a healthy and productive environment for future generations has been a component of international agreements, national law, and Canadian jurisprudence. The *CBD*, in its preamble, makes it very clear that the *Convention* was drafted with nations “[d]etermined to conserve and sustainably use biological diversity for the benefit of present and future generations.”³⁹ The Supreme Court of Canada, in *Imperial Oil Ltd. v. Quebec (Minister of the Environment)*,⁴⁰ refers to a duty to future

³⁶ *Federal Sustainable Development Act*, SC 2008, c33 s 5 [FSDA].

³⁷ *Canadian Environmental Protection Act, 1999*, SC 1999, c 33, preamble [CEPA].

³⁸ *Ibid* at s 2.

³⁹ *CBD*, *supra* note 30 at preamble.

⁴⁰ *Imperial Oil Ltd. v. Quebec (Minister of the Environment)*, 2003 SCC 58, [2003] 2 SCR 624.

generations through their statement that there may well be “an emerging sense of inter-generational solidarity and acknowledgement of an environmental debt to humanity and to the world of tomorrow.”⁴¹ The Court, in *Spraytech*, also identified that “[t]he context of this appeal includes the realization that our common future, that of every Canadian community, depends on a healthy environment.”⁴² Further, many pieces of federal legislation make commitments to intergenerational equity as well.⁴³

Given the jurisdictional challenges surrounding the environment (as a consequence of the lack of specific control given through the Canadian constitution’s division of powers),⁴⁴ consideration of legal commitments to sustainable economic growth and intergenerational equity made by both levels of government are important for a comprehensive overview. That said, those provided here are not exhaustive, but illustrative of the fact that Canada’s federal and provincial governments have committed themselves to moving in a more sustainable direction

⁴¹ *Ibid* at para 19.

⁴² *114957 Canada Ltée (Spraytech, Société d'arrosage) v. Hudson (Town)* 2001 SCC 40, [2001] 2 SCR 241, 2001 SCC 40 at para 1.

⁴³ *Canada National Marine Conservation Areas Act*, SC 2002, c 18 s 4(3) which states “Marine conservation areas shall be managed and used in a sustainable manner that meets the needs of present and future generations without compromising the structure and function of the ecosystems, including the submerged lands and water column, with which they are associated”; *Saguenay-St. Lawrence Marine Park Act*, SC 1997, c 37 s 4 which states “The purpose of this Act is to increase, for the benefit of the present and future generations, the level of protection of the ecosystems of a representative portion of the Saguenay River and the St. Lawrence estuary for conservation purposes, while encouraging its use for educational, recreational and scientific purposes.”

⁴⁴ This challenge is highlighted in most legal articles dealing with the environment in Canada. See, for example, David R. Boyd, *Unnatural Law* (Vancouver: UBC Press, 2003) at 10-12 and Kathryn Harrison, *Passing the Buck: Federalism and Canadian Environmental Policy* (Vancouver: UBC Press, 1996) which provide broad overviews of the challenge. Peter Hogg, “Constitutional Authority over Greenhouse Gas Emissions” (2009) 46.2 *Alberta Law Review* 507-520 discusses the constitutionality of greenhouse gas emissions, and Stewart Elgie, “Kyoto, the Constitution, and Carbon Trading: Waking a Sleeping *BNA* Bear (or Two)” (2007-2008) 13 *Rev. Const. Stud.* 67 also considers greenhouse gas emissions in particular with regards to the *Kyoto Protocol Implementation Act*. Brenda Heelen Powell, “Environmental Assessment & the Canadian Constitution: Substitution and Equivalency” (2014) *Environmental Law Center* at 10-12 discusses the environmental challenges with regards to environmental assessment.

and to considering both the current and future generations' need for natural capital and productive capacity in their decision making.

From a provincial perspective, Nova Scotia's *Environmental Goals and Sustainable Prosperity Act*⁴⁵ provides a number of clear statements of sustainability commitments, including a guiding principle which states

environmentally sustainable economic development that recognizes the economic value of the Province's environmental assets is essential to the long-term prosperity of the Province.⁴⁶

Further, this Act is guided by the principle that "the environment and economy must be managed for the benefit of present and future generations ..."⁴⁷

Similarly, Quebec's *Sustainable Development Act*⁴⁸ provides that sustainable development in the province be carried out consistent with 16 principles, including: "Social equity and solidarity" which is described to encompass inter and intragenerational equity⁴⁹ and "Economic efficiency" which describes that

[t]he economy of Québec and its regions must be effective, geared toward innovation and economic prosperity that is conducive to social progress and respectful of the environment.⁵⁰

In sum, Canadian governments have made commitments to, or been charged with the responsibility to, conserve⁵¹ the natural environment and to ensure whatever use is made is done

⁴⁵ *Environmental Goals and Sustainable Prosperity Act*, SNS 2007, c7 (as amended by 2012, c. 42)

⁴⁶ *Ibid* at s 3 (2) (b).

⁴⁷ *Ibid* at s 3 (2) (D).

⁴⁸ *Sustainable Development Act*, CQLR c – D-8.1.1 [SDA].

⁴⁹ *Ibid* at s 6 (b).

⁵⁰ *Ibid* at s 6 (d).

⁵¹ For example, the Rio Declaration principle 4 notes protection of the environment and principle 7 insists on conservation, protection, and restoration of the Earth's ecosystem, Rio Declaration, *supra* note 29; the *CBD Articles*

efficiently,⁵² in part, as a consequence of commitments to intergenerational equity. Further, commitments towards sustainable economic growth have been noted.⁵³ Of course, the precise intention of the drafters of these commitments is not known, nor is how they intended to define sustainability. Therefore, having established that there are legal commitments to sustainable economic growth and intergenerational equity, the next step is to consider which of the possible ways of interpreting sustainability is most appropriate.

In addition to these specific legal commitments, author Edith Brown Weiss argues that current generations have a fiduciary duty or ‘primordial social value’ to future generations which means caring about the sustained welfare of those not yet born.⁵⁴ If this is accepted, it becomes clear that Canada has legal commitments, both nationally and internationally, to pursue sustainable economic growth and intergenerational equity but also that moral obligations to future generations exist. When such commitments are made, decision makers are charged with implementing laws, regulations, policies, and guidelines which align with and move the country towards compliance.

2.2.1.1 Intergenerational Equity & Sustainability

Having established Canadian and international legal commitments to sustainability and intergenerational equity, a more detailed examination of these concepts is necessary to understand their implications for decision making. Intergenerational equity emerged perhaps

1 and 6 indicate a requirement to conserve and sustainability use biological diversity, CBD, *supra* note 30; CEPA s. 2 requires protection, enhancement and restoration of the environment, CEPA, *supra* note 37.

⁵² See, for example, the preamble of CEPA, CEPA, *supra* note 37; and s. 5 of the *Federal Sustainable Development Act*, FSDA, *supra* note 36, require ecologically efficient use, Quebec’s *Sustainable Development Act* indicates the importance of economic efficiency, SDA, *supra* note 48.

⁵³ CIDA, *supra* note 35.

⁵⁴ Edith Brown Weiss, “The Planetary Trust: Conservation and Intergenerational Equity” (1984) 11:4 Ecology LQ 495 [Brown Weiss, “The Planetary Trust”] at 498, 501 and 508; Edith Brown Weiss, “In Fairness to Future Generations and Sustainable Development” (1992) 8:1 American University International Law Review 19 – 26 [Brown Weiss, “In Fairness”].

most prominently in the 1987 publication by the United Nations of *Our Common Future*, better known as *The Bruntland Report*.⁵⁵ The most well-known definition of sustainable development is taken from this report and emphasizes intergenerational equity in stating that sustainable development should “meet the needs and aspirations of the present without compromising the ability to meet those of the future.”⁵⁶ One justification for this duty can be found by looking at John Rawls’ ‘veil of ignorance’ which essentially charges decision makers to operate as if they knew nothing about their personal, social or historical circumstances – thus, they would treat all people and generations equally well.⁵⁷

For natural capital, the principle of intergenerational equity implies a requirement to leave a stock for future generations so that they are just as well off as past generations. As Birnie and Boyle state, in reference to Brown Weiss’ seminal work on intergenerational equity, it “requires each generation to use and develop its natural ... heritage in such a manner that it can be passed on to future generations in no worse condition than it was received.”⁵⁸ While fully achieving this standard is difficult, some say “essentially unfeasible,”⁵⁹ it does not, then, follow that the spirit of the ambition is also undesirable. The key insight is in recognizing the need to ensure options for future use and that the quality and quantity of the natural environment is not severely diminished.⁶⁰ An alternate perspective on sustainability is presented by Solow who states that current generations have “an obligation to conduct ourselves so that we leave to the

⁵⁵ Bruntland, *supra* note 33.

⁵⁶ *Ibid* at para 49.

⁵⁷ John Rawls, *The Theory of Justice* (Cambridge, Ma: Harvard University Press, 1971).

⁵⁸ Patricia Birnie & Alan Boyle, *International Law & The Environment*, 2nd ed (Oxford: Oxford University Press, 2002) [Birnie & Boyle] at 89.

⁵⁹ Robert M. Solow, “Sustainability: An economist’s perspective” in R. Dorfman and N. Dorfman, eds, *Economics of the environment: Selected readings* (New York: W.W. Norton and Company, 1993) [Solow, “Sustainability”] at 180.

⁶⁰ Birnie & Boyle, *supra* note 58 at 84-85.

future the option or the capacity to be as well off as we are.”⁶¹ Solow’s definition does not specifically include reference to the necessity of preserving parts of the environment or stocks of natural capital, but he does recognize the preservation of overall capital, of productive capacity, as an obligation to future generations. Solow’s perspective on sustainability can be considered ‘weak’ sustainability while that put forth by Brown Weiss⁶² aligns with ‘strong’ sustainability. These concepts will be elaborated on in the next section.

2.2.1.1.1 A Note on Discount Rates

The use of discount rates can affect whether and how a legal commitment to intergenerational equity is achieved. The use of a discount rate informs the balancing of the use of natural capital between current and future generations. While determining the ‘right’ rate is not necessary to answer the research question in this dissertation, it is still useful to briefly consider the general outcomes associated with the use of different discount rates. If the goal is to maximize the utility of present and future generations when making policy decisions, the general assumption is that the future can be somewhat discounted because those generations will be better off.

The net effect of discount rates is that, as Newell & Pizer indicate, “positive discount rates lead us to place very little weight on events in the distant future.”⁶³ In this case of this dissertation, the key events are the intergenerational impacts of current degradation and depletion of natural capital. That is, the higher the discount rate, the less value is placed on future use of natural capital, and hence that it has a higher value in the present. The result is that increased use (or degradation) of natural capital in the present can be justified. Conversely, with a lower

⁶¹ Solow, “Sustainability”, *supra* note 59 at 181.

⁶² See her seminal article Brown Weiss “In Fairness”, *supra* note 54.

⁶³ Richard G. Newell & William A. Pizer, “Discounting the distant future: how much do uncertain rates increase valuations?” (2003) 46 *Journal of Environmental Economics and Management* 52 [Newell & Pizer] at 52.

discount rate, the future value of natural capital use is closer to present value, and therefore the allocation of natural capital use needs to be more equal.

There is great deal of debate over what the appropriate discount rate(s) should be, especially when dealing with environmental considerations.⁶⁴ While there are various approaches for setting the appropriate discount rate (declining or uncertain rates⁶⁵ and dual rates,⁶⁶ for example), their detailed arguments are beyond the scope of this thesis. While policy making generally involves the use of some discount rate, defining the precise rate is not essential here, since any reasonable discount rate would still be consistent with the need to improve the efficiency with which natural capital is currently being used.

2.2.1.1.2 Sustainability – Weak v. Strong

One conceptual difficulty with intergenerational equity is that its demands can seem excessive. If, as suggested by some definitions of strong sustainability, we are to leave natural resources in the state in which they were received, this suggests current generations may not be able to make much, or any use of them. If an infinite number of future generations have equal status to the current one, then even a very limited use of non-renewable resources seems to violate the principle of intergenerational equity. This problem has been a matter of longstanding debate between the proponents of strong versus weak sustainability. Importantly, the degree of sustainability adopted has significant implications for the responsibilities of government in

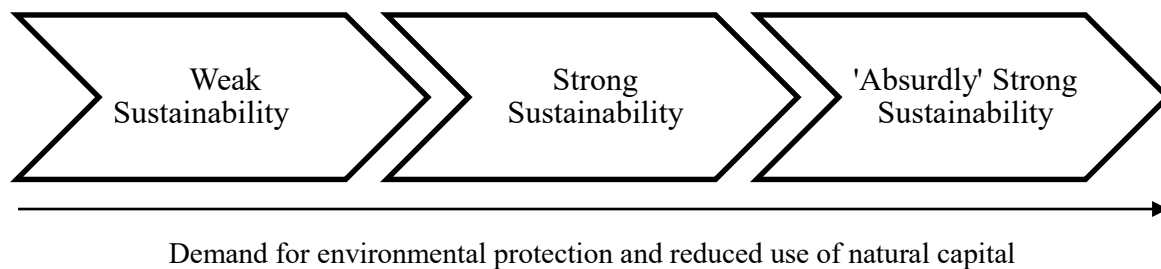
⁶⁴ Martin L. Weitzman, “Gamma Discounting” (2001) 91(1) *The American Economic Review* 260 provides an insightful discussion of some of the disagreements amongst economists coming up with discount rates and an interesting experiment through which the variety of discount rates used by economists is provided.

⁶⁵ Newell & Pizer, *supra* note 63 discuss these different perspectives and, in their work, consider an uncertain discount rate.

⁶⁶ Hans-Peter Weikard & Xueqin Zhu, “Discounting and Environmental Quality: When Should Dual Rates be Used?” (2005) 22 *Economic Modelling* 868.

regulating the use of natural capital. In discussing the various levels of sustainability, it may be useful to consider them as being on a spectrum which increases (from left to right) in demands and stringency of requirements.

Figure 2.1 - Scale of Sustainability Concepts



Weak sustainability is a concept coined originally by economists Robert Solow⁶⁷ and John Hartwick.⁶⁸ It has been adopted, expanded and used by many others from a variety of disciplines, and perhaps can be considered the dominant interpretation of sustainability among economists.⁶⁹ It is based on the premise that current generations should pass along to future generations a total aggregate stock of capital (including ‘human-made’, human, social, and natural capital, etc.) but that the composition of the stock is less important than the amount of well-being it can provide.⁷⁰ According to Solow, “earlier generations are entitled to draw down the pool (optimally of course!) so long as they add (optimally of course!) to the stock of

⁶⁷ Robert Solow, “Intergenerational Equity and exhaustible resources” (1974) 41 Review of Economic Studies 29 [Solow, “Intergenerational Equity”]; Robert Solow, “On the Intergenerational Allocation of Natural Resources” (1986) 88:1 Scand. J. of Economics 141 [Solow, “On the Intergenerational Allocation”].

⁶⁸ John M. Hartwick, “Intergenerational Equity and the Investing of Rents from Exhaustible Resources” (1977) 67:5 The American Economic Review 972; John M. Hartwick, “Investing Returns from Depleting Renewable Resource Stocks and Intergenerational Equity (1978) 1 Economic Letters 85-88.

⁶⁹ K.A. Brekke, *Economic Growth and the Environment: On the Measurement of Income and Welfare* (Edward Elgar: Cheltenham, 1997) at 91.

⁷⁰ Eric Neumayer, *Weak versus Strong Sustainability: Exploring the Limits of Two Opposing Paradigms* (Cheltenham, UK: Edward Elgar Publishing Limited, 2003) [Neumayer, “Weak versus Strong”] at 1.

reproducible capital.”⁷¹ The composition - that is, the mix of different types of capital - is not important because the various forms of capital are considered to be substitutable in the production of goods and as forms of direct utility providers. As Neumayer notes, the assumption that ‘perfect substitutability’ is valid is the “centre of the paradigm of weak sustainability.”⁷² Thus, for example, it would be acceptable for future generations to have less natural capital but more built capital, so long as the amount of well-being provided is equal. It is the lack of weight attached to the composition of the stock of capital passed to future generations, which turns on the idea of perfect substitutability, and which distinguishes weak sustainability from stronger forms of sustainability. For the latter, the maintenance of an equivalent stock of natural capital is specifically important. One of the ways that weak sustainability proponents justify this substitutability is through the emphasis on technology – that progress in technology will be able to overcome any constraints from the loss of natural capital.⁷³ Therefore, even though, in many cases, there are not currently anthropogenically reproducible forms of capital that can substitute for natural capital stocks and flows, it is assumed this substitution will be possible in the future.

Strong sustainability is premised on the need for future generations to inherit a stock of natural capital - often stated to be one which has a value at least as high as the current natural capital stock.⁷⁴ The key difference is that, unlike weak sustainability, the composition of the stock of capital passed along *does* matter, and specifically, the proportion of natural capital is important. The reason for this is differences in the underlying assumptions of perfect substitutability versus complementarity between natural capital and other forms of capital (weak

⁷¹ Solow, “Intergenerational equity”, *supra* note 67 at 41.

⁷² As Neumayer notes, the assumption that ‘perfect substitutability’ is valid is the “centre of the paradigm of weak sustainability” Eric Neumayer, ‘Global Warming: discounting is not the issue, but substitutability is’ (1999) 27 Energy Policy 33-43 [Neumayer, “Global Warming”] at 35.

⁷³ Neumayer, “Weak versus Strong”, *supra* note 70 at 23.

⁷⁴ Hahnel, “Green Economics”, *supra* note 22 at 42.

sustainability assumes the former and strong sustainability the latter) which, as Neumayer argues, “is the real disagreement” between advocates of the two parameters of sustainability.⁷⁵ The requirement for a given stock of natural capital to be passed along to future generations is based on a belief that natural capital is non-substitutable, and is complementary to other types of capital. This means that in the context of the production of goods and the capacity to act as a sink for pollution as well as providing utility from environmental amenities, natural capital works with other forms of capital, but its functions are not substitutable.⁷⁶ To be clear, substitution is certainly possible sometimes - in fact Chapter 7 highlights apparent substitution of other inputs (labour, capital, for example) for water. Importantly, though, substitution between natural capital and other forms of capital is not always possible. Weak sustainability, however, assumes perfect substitutability.

Further, there are differing interpretations of what preserving a stock of natural capital actually means. That is, there are differing ideas of what exactly strong sustainability requires be preserved for future generations. The difference here turns on whether the *value* of natural capital needs to be preserved or whether there are certain *types* of natural capital (‘critical natural capital’) which must have their physical stock remain intact.⁷⁷ Those who focus on maintaining the value of natural capital are not stringent on the use of non-renewables, instead they demand re-investment of profits from their use into the development of, for example, renewable energy sources.⁷⁸ For example, the Norwegian government might direct revenue from oil extraction into a dedicated research and development fund for renewable energy instead of, as it currently

⁷⁵ Neumayer, “Global Warming”, *supra* note 72 at 35.

⁷⁶ Neumayer, “Weak versus Strong”, *supra* note 70 at 2.

⁷⁷ *Ibid* at 26.

⁷⁸ *Ibid*.

does, using the money to create a sovereign wealth fund.⁷⁹ Notably, strong sustainability which focuses on the preservation of the value of natural capital, allows for unconstrained substitution between different forms of natural capital, which, as Neumayer notes, is one of the problems of this interpretation since, “it would be strange to assume that more [hu]man-made capital cannot substitute for a bigger hole in the ozone layer, but an increased number of whales can.”⁸⁰

The second interpretation of strong sustainability requires the preservation of the physical stock of critical natural capital, and therefore does not allow for substitution between forms of critical natural capital. The idea is that the essential functions (life support for the planet, waste assimilation, etc.) that critical natural capital performs need to be maintained, not that the natural world must be kept exactly as it is.⁸¹ This also means that forms of renewable natural capital should be used at the level of natural regeneration and sinks should be used to the extent that they do not become degraded over time – these tenets are consistent with the natural limits of natural capital.

Environmental sustainability is, in some ways, a compromise between the two interpretations of strong sustainability. While not specifically referring to the way other types of capital interact with natural capital (and therefore not presented in *Figure 2.1*), environmental sustainability considers how natural capital should be used. Its goal is the maintenance of ecosystem sinks (for waste, emissions etc.) and a physical stock of major natural resource

⁷⁹ Barrie McKenna, “Norway proves oil-rich nations can be both green and prosperous” 9 November 2004 Globe and Mail online: <http://www.theglobeandmail.com/report-on-business/international-business/european-business/norway-proves-oil-rich-nations-can-be-both-green-and-prosperous/article21514455/>

⁸⁰ Neumayer, “Weak versus Strong”, *supra* note 70 at 25-26.

⁸¹ *Ibid* at 26.

categories.⁸² The limits of using natural capital, as espoused by definitions of environmental sustainability, are “holding waste emissions within the assimilation capacity of the environment without impairing it” and “keeping harvest rates of renewable within regeneration rates.”⁸³ For non-renewables, the rate of use should equal or be exceeded by the creation of substitutes which are renewable.⁸⁴

When looking at the sustainability spectrum (*Figure 2.1*) you will notice that weak and strong sustainability are not at opposing ends. This is because some authors do not consider strong sustainability to be the most ambitious form, but they instead introduce the idea of ‘absurdly’ strong sustainability.⁸⁵ This form of sustainability is more stringent than even strong sustainability in that it requires non-use of non-renewable resources and for renewable resources, all that can be used are the “net annual growth increments.”⁸⁶

Given the discussion in section 2.1 of this chapter, it is clear that Canada’s commitment to the principles of sustainability implies a requirement to maintain an equivalent stock of natural capital for future generations. This is in part because of commitments to sustainable economic

⁸² David Pearce, *Public Policy and Natural Resources Management* (Brussels: GXI, European Commission, 2000) at 42; Robert Goodland, “The Concept of Environmental Sustainability” (1995) 26 *Annual Review of Ecology and Systematic* 1 [Goodland, “The Concept”] at 6.

⁸³ Robert Goodland & Herman Daly, “Environmental Sustainability: Universal and Non-negotiable” (1996) 6:4 *Ecological Applications* 1002 at 1003.

⁸⁴ Robert Costanza, Herman E. Daly & Joy A Bartholemew, “Goals, Agenda and Policy Recommendations for Ecological Economics” in Robert Costanza, ed, *Ecological Economics: The Science and Management of Sustainability* (New York: Columbia University Press, 1991) at 16; Herman E. Daly, “Elements of Environmental Macroeconomics” in Robert Costanza, ed, *Ecological Economics: The Science and Management of Sustainability* (New York: Columbia University Press, 1991) at 45.

⁸⁵ The literature does indeed refer to “absurdly” strong sustainability. The term seems to stem back to Herman Daly’s response to Wilfred Beckerman’s critique of sustainable development. Here Daly uses the label of “absurdly strong sustainability” to describe a type of sustainability which does not allow anything ever to go extinct and advocates non-use of renewable resources – no matter the situation. He uses the ‘absurdly strong’ label because he is trying to illustrate that Beckerman is missing the fact that there is a middle ground between weak and (absurdly) strong sustainability – this middle ground is what Daly is an advocate for. See Herman E. Daly, “On Wilfred Beckerman’s Critique of Sustainable Development” (1995) 4 *Environmental Values* 49 at 49.

⁸⁶ Goodland, “The Concept”, *supra* note 82 at 16.

growth and the knowledge that most, if not all, types of capital which are anthropogenically reproducible rely on some aspect of natural capital for production (whether that be as an input or as assimilative capacity for undesirable outputs). On the other hand, aspects of natural capital are also substitutable – for example, investing in more efficient machinery could mean less use of a natural resource. For many functions of natural capital, however, only partial substitution is plausible.

Even if it was acknowledged that some, even most, aspects of natural capital can be substituted for, there are some natural functions which are irreplaceable and substitutions for them are either (near) impossible to find or prohibitively expensive.⁸⁷ This lack of substitutability is perhaps best illustrated by considering ecosystem services such as those which assimilate waste or regulate climate.⁸⁸ The failed Biosphere II project is an excellent example of the problems which arise when attempting to replicate ecosystem services.⁸⁹ Another example is the earth's freshwater hydrological system which is finite, and if it were to be used up, or degraded to the point it was unusable, what other type of capital could take its place? Freshwater is considered 'largely nonsubstitutable,'⁹⁰ and really the only viable (but very costly) substitution for fresh water is the desalinization of salt water. Even then, this is really only a substitution option for human consumption of water it and would be much more difficult, if not impossible, to do so in the context of freshwater ecosystem services, such as filtration, waste assimilation, or

⁸⁷ James Salzman, "Valuing Ecosystem Services" (1997) 24 Ecology LQ 887 [Salzman] at 887-888

⁸⁸ See Gretchen Daily, "Introduction: What are Ecosystem Services" in Gretchen Daily, ed, *Nature's Services: Societal Dependence on Natural Ecosystems* (Washington D.C.: Island Press, 1997) at 6, for a discussion on some of these services

⁸⁹ Salzman, *supra* note 87 at 887-888 which discusses the failed Biosphere II project; an excellent example of the problems with attempting to replicate ecosystem services

⁹⁰ Sandra Postel & Stephen Carpenter, "Freshwater Ecosystem Services" in Gretchen Daily, ed, *Nature's Services: Societal Dependence on Natural Ecosystems* (Washington D.C.: Island Press, 1997) [Postel & Carpenter] at 197.

habitat.⁹¹ Certainly these difficulties with substitution do not apply to all forms of natural capital, but, nonetheless, if natural capital is only partly substitutable, this is still a serious difficulty for weak sustainability.

Generally speaking, natural capital cannot be created anthropogenically once it is gone (at least with current science). That means, if current generations were to use up significant amounts of natural capital, but it turns out that future generations in fact need natural capital in order to achieve the same level of well-being, they would be unable to produce it. As Piketty notes “if natural capital is destroyed, consuming fewer iPhones in the future will not be enough to repair the damage.”⁹² In contrast, producing more built capital is something which can be done anthropogenically.

This dissertation, therefore, argues that weak sustainability, because it does not require a maintained stock of natural capital, is not well aligned to help Canada meet its commitments. Further, since some of Canada’s legal commitments are specifically to conserve natural capital for future generations, converting these to financial or other kinds of capital seems to violate this commitment. As a result, weak sustainability principles are inconsistent with Canada’s commitment in the *Convention on Biological Diversity* to “conserve and sustainably use biological diversity for the benefit of present and future generations”⁹³ because this requires preservation of aspects of natural capital and not just a total stock of overall capital.

⁹¹*Ibid* at 197-198.

⁹² Thomas Piketty, *Capital in the Twenty-first Century* (Cambridge: The Belknap Press of Harvard University Press, 2014) at 654.

⁹³ *CBD*, *supra* note 30 at preamble.

Although weak sustainability seems inadequate, on the other hand, strong sustainability, taken at its most rigid (‘absurdly’ strong sustainability), effectively means current generations must drastically reduce the use of natural capital today (including perhaps stopping the use of non-renewable resources) to ensure future generations have a natural capital stock which is at least as valuable as it is at present. Regardless of other merits it may have, this is politically implausible, and therefore is unlikely to prove useful for decision makers. ‘Absurdly’ strong sustainability with its requirements for essential non-use of non-renewable resources also misses the mark with regards to what the Canadian government’s commitments mean in terms of sustainability approaches. That is, the commitment to sustainable economic growth means that immediately halting the use of non-renewables is not practical.

Based on Canada’s commitments to sustainable economic growth, intergenerational equity, and more generally to conserve and efficiently use the natural environment, the principles espoused by regular strong sustainability seem most appropriate for fulfilling these commitments. Unlike absurdly strong sustainability, implementing them is plausible, if difficult, and can be consistent with other commitments to economic growth. Unlike weak sustainability, it avoids assuming perfect substitutability between types of capital, which is both a fragile assumption (at least for some types of natural capital), and may well violate commitments to preserve the natural environment, in general, and certain parts in particular. Nonetheless, strong sustainability allows for substitution in some situations – which, as will be demonstrated in Chapter 7, is by no means a bad thing. These substitutions should allow economic growth to continue but in a sustainable way, especially if the principles of environmental sustainability are also respected.

2.2.2 Section summary

This section sets out Canada's legal obligation to sustainable development and intergenerational equity. As noted earlier in this chapter, the demands of 'absurdly' strong sustainability seem excessive as they would essentially require the ending of current economic production processes. On the other hand, weak sustainability assumes perfect substitutability between natural capital and other forms of capital, which seems implausible, at least for some forms of natural capital. Therefore, two related version of sustainability were proposed as aligning well with Canada's commitments - strong sustainability and environmental sustainability. These versions of sustainability likely still require a reduction in use of natural capital given that the present rate and type of use is known to be unsustainable.⁹⁴

Further, given the reliance on natural capital for economic production, a required reduction of use could put governments in a difficult situation, where they are required to reduce economic production and as a consequence, very likely, the standard of living of their citizens. Obviously, this is politically difficult. Governments normally want to improve (or at least maintain) the economic well-being of their people. The solution to this conundrum, this thesis suggests, is the idea of productivity – of improving efficiency. That is, by improving the efficiency of use of natural capital, governments could potentially move toward meeting their legal commitments to sustainable economic growth and intergenerational equity. This will be discussed at greater length at the end of the chapter and introduced more completely in Chapter 4 in the context of green productivity measures. Before turning to these concepts, though, an important methodological framework, law and economics, is laid out.

⁹⁴ NCD, *supra* note 3; J. Aronson *et al.*, "Natural Capital: The Limiting Factor" (2006) 28 Ecological Engineering 1-5 at 1.

2.3 Research Methodology

This dissertation is undertaken primarily using a ‘law and economics’ methodology. It also draws on different disciplinary perspectives and therefore uses an interdisciplinary research (IDR) methodology. This initial section explores one of the key aspects of law and economics methodology – the application of efficiency to the analysis of law, and lays out the various ways efficiency is defined. The thesis also employs a more specific empirical methodology which will be explained in Chapter 7.

2.3.1 Law and Economics

Law and economics methodology is, broadly, based upon the application of the rational choice approach to law and legal decision making.⁹⁵ Moreover, this method of research uses economic concepts to analyse the “formation, structure, processes and economic impacts”⁹⁶ of laws, legal institutions, judicial judgements and other aspects of the law and legal system. As Tunick explains, “law and economics theories treat legal issues as economic problems.”⁹⁷ Yet the law and economics literature addresses many issues and there are many schools of thought, leading to a diversity of approaches. This thesis employs both positive and normative methods of law and economics. Though to some, normative approaches are inappropriate for economic analysis,

⁹⁵ H. Kerkmeester, “Methodology: in General” in B. Bouckaert & G. De Geest, eds, *Encyclopedia of Law and Economics, Volume I: History and Methodology of Law and Economics* (Cheltenham: Edward Elgar, 2000) [Kerkmeester] at 384; Thomas Ulen, (2000), ‘Rational Choice Theory in Law and Economics’, in: Boudewijn Bouckaert and Gerrit De Geest (eds.), *Encyclopedia of Law and Economics. Volume I. The History and Methodology of Law and Economics* (Cheltenham: Edward Elgar), 790- 818 at 797; Francesco Parisi, “Positive, Normative and Functional Schools in Law and Economics” (2004) 18(3) *Eur J L & Econ* at 262.

⁹⁶ Nicholas Mercuro & Steven Medena, *Economics and the Law: From Posner to Post-Modernism and Beyond*, 2nd ed, (Princeton, NJ: Princeton University Press, 2006) [Mercuro & Medena] at 1.

⁹⁷ Mark Tunick, “Efficiency, Practices and the Moral Point of View: Limits of Economic Interpretations of Law” in Marc D. White, ed, *Theoretical Foundations of Law and Economics* (New York: Cambridge University Press, 2009) [Tunick] at 77.

or cannot be combined with positive analysis,⁹⁸ much of law and economics research has traditionally been normative.⁹⁹

The case study undertaken in Chapter 7 is a positive law and economics analysis given that it uses data to consider responses to price changes and consequently predicts what similar changes associated with legal instruments could be. Specifically, this case study uses already available data to show the relationship between water productivity and water acquisition costs in order to demonstrate the potential effects of pricing instruments. As is common in law and economics research, the results of this positive analysis are also used to provide normative suggestions of what *ought* to be¹⁰⁰—that is, whether instruments align with the normative goals and therefore should be recommended.

Normative analyses are about providing recommendations of what *should* or what *ought* (to) be done. In this case, this research explores how green productivity measures should be used as decision making tools to successfully meet Canada’s legal commitments to sustainable development and intergenerational equity. Generally, research using the law and economics methodology derives its framework for determining what law and policy should be (sometimes also considered its normative goal) based on the criteria of efficiency.¹⁰¹

Efficiency as a normative aim is also major goal of this research, because increased efficiency of natural capital use can help meet legal commitments to sustainability. Though efficiency in law and economics typically refers to allocative efficiency, other types of efficiency

⁹⁸ Kerkmeester, *supra* note 95 at 390 provides a brief overview of this debate.

⁹⁹ Eli M Salzberger, “The Economic Analysis of Law – The Dominant Methodology for Legal Research?!” (2007) 8 SSRN Electronic Journal [Salzberger] at 23.

¹⁰⁰ Mercurio & Medena, *supra* note 96 at 390.

¹⁰¹ Alessio M. Paccès & Lovis Visscher, “Methodology of Law & Economics” in Bart van Klink and Sanne Taekema (eds) *Law and Method: Interdisciplinary Research into Law* (Tübingen: Mohr Siebeck, 2011) [Paccès & Visscher]; Salzberger, *supra* note 99 at 17.

are also important to this dissertation and will be discussed in due course. As discussed elsewhere, there are a number of key factors that link sustainability to the need to efficiently use natural capital. The first is the under-pricing of natural capital, both in general and due to intergenerational equity. As will be discussed in section 2.3.1.2.1, natural capital is often not priced, and if it is, it tends to be priced very low. In addition, as the discussion of intergenerational equity suggests, markets are unlikely to account for future generations in pricing. Effectively, this underestimates demand, and results in prices that are too low and as a consequence, use is too high. Setting “correct” prices for natural capital is very difficult, both politically and because of valuation challenges. Nonetheless, society must make choices about the relative value of (and substitutability between) natural capital and other forms of capital, such as labour. NRP (which is discussed at length in Chapters 4, 6, and 7) is an important way to consider this kind of substitution.

A second factor which illustrates why the efficiency of use of natural capital is important given sustainability requirements is a pragmatic compromise: recognizing that reducing natural capital use is an important end, but also that improving efficiency of use may currently be the best means. Some proponents of strong sustainability argue for ceasing all non-renewable resource use, while others state that a "critical" level of natural capital must be preserved. Increasing efficiency does not necessarily result in reduced usage, but it is at least a step toward it. The difficulty with hard limits on use is that they often imply significant economic costs which are politically unfeasible, and therefore are unlikely to be implemented (at least in the short to medium term). Improving the efficiency of use of natural capital may be a second best option, but it is one which is more likely to be implemented at present.

Finally, recall that Canada's legal commitments specifically include using natural capital efficiently, in addition to the requirements for preservation and conservation, so efficiency of use is a legally relevant goal.

Though law and economic scholars typically focus on efficiency, other principles are also used. New Haven Scholars, for example, accept the basic principles of law and economics methodology, but also take into account justice and distribution.¹⁰² Given the dual commitments (sustainable economic growth and intergenerational equity) for which this dissertation makes recommendations, and in order to assist decision makers in successfully moving towards compliance with them, here it is proposed that policy goals and legal instruments should be evaluated not solely based on efficiency, but also with consideration for two other important normative factors – namely effectiveness and equity. These will be discussed further in Chapter 3.

2.3.1.1 Theories of Efficiency

Theories of efficiency, a key part of the law and economics methodology, are fundamentally about scarce resources. Specifically, efficiency is used to evaluate laws, because governments (and societies) have scarce resources and should devote them to goals in the most efficient way¹⁰³ – be they legislative, military etc. Thus, when recommendations are made for a given law, legal instrument, etc to be implemented, the decision is based primarily on which makes the most efficient use of government resources. Often the scarce resources being referred to are financial, but natural capital is also becoming increasingly scarce,¹⁰⁴ and importantly, is difficult

¹⁰²Mercurio & Medena, *supra* note 96 at 287.

¹⁰³ Tunick, *supra* note 97 at 77.

¹⁰⁴ Herman E. Daly, “Operationalising Sustainable Development by Investing in Natural Capital” in Nirmal Chandra Saher & Amita Kumari Choudhury, eds, *Dimensions of Environmental and Ecological Economics* (Hyderabad,

to anthropogenically reproduce, if it can be replicated at all.¹⁰⁵ In the case of this dissertation, the scarce resource being considered is natural capital and decisions should therefore be based on improving the efficiency of its use.

Defining efficiency, however, is complex. In law and economics, efficiency is typically about societal welfare and can be defined as meaning that “given the resources initially available and their allocation, the members of a society have achieved the highest possible level of utility.”¹⁰⁶ Of course, deciding when members of society have achieved the highest possible level of utility is not straightforward. In fact, there are several well established theories of efficiency each with different criteria. Below, each will briefly be described, along with important caveats. To summarize, Coase efficiency essentially defines rationality as efficient, but is less useful in situations with multiple parties and transaction costs. Kaldor-Hicks efficiency is the most commonly used in the economic analysis of law,¹⁰⁷ though it runs into difficulty in intergenerational settings. Pareto efficiency is a better standard in these cases, but its requirements can be extremely difficult to satisfy.

Classifications of the different efficiency theories used by law and economics scholars typically begin with the Coase Theorem. Coase argues, in the absence of transaction costs, an efficient solution will be obtained regardless of the initial distribution of resources or property through negotiations between party ‘A’ and party ‘B.’¹⁰⁸ He argues that individuals, amongst

India: Universities Press (India) Private Limited, 2005) [Daly, “Operationalising Sustainable Development] at 481-482.

¹⁰⁵ We know that once non-renewable resources are used up they are gone – they cannot be reproduced. The same can be said of renewable resources if they are used wastefully and are depleted beyond the point of regeneration rates. This idea is present within Gretchen C Daily, ed. *Nature’s Services: Societal Dependence on Natural Ecosystems* (Island Press: Washington, DC, 1997)

¹⁰⁶ Hans-Bernd Schäfer & Claus Ott, *The Economic Analysis of Civil Law* (Cheltenham: Edward Elgar, 2004) at 8.

¹⁰⁷ Paces & Visscher, *supra* note 101.

¹⁰⁸ R.H. Coase, “The Problem of Social Cost” (1960) III JL & Econ 1 [Coase] at 2-6.

themselves, will come to the most efficient solution simply through bartering and considering their own marginal profit and cost. In essence, Coase is describing a situation (under specific circumstances) where actors are acting rationally – therefore “to act rationally ... is to promote allocative efficiency.”¹⁰⁹ Further, in these situations, there is no information failure – each of the parties is assumed to know the other very well and that no private information is withheld.¹¹⁰ Further, since negotiation between rational actors will necessarily come to the most efficient solution (as per this theorem), government intervention is unnecessary.

The Coase Theorem, though, struggles with two quite significant restrictions– that the aforementioned efficient solution can only emerge in the absence of transaction costs,¹¹¹ in two-party situations,¹¹² and with perfect information.¹¹³ In practice there is almost always some level of transaction cost, usually more than two parties are involved, and imperfect information is the norm. Therefore the Coase Theorem’s form of efficiency is rarely sufficient. A further challenge, especially when considering environmental issues, is the idea which is at the center of Coase’s theorem - that no “natural” state of affairs is assumed. This leads to a rejection of the usual standards of blame for undesirable states. Consider the following example. ‘A’ lives in a neighbourhood which is located beside ‘B’. B is a factory that causes air pollution. Generally speaking, B would be considered to be harming A. Coase suggests, though, that while this is one way to look at it, if A did not reside in that location, B would not be causing “harm” and therefore it cannot be said that one is necessarily harming the other and not vice versa.¹¹⁴ This

¹⁰⁹ Jules L. Coleman, “Efficiency, Exchange and Auction: Philosophic Aspects of the Economic Approach to Law” (1980) 68:2 Cal L Rev 221 [Coleman] at 225.

¹¹⁰ Joseph Farrell, “Information and the Coase Theorem” (1987) 1:2 The Journal of Economic Perspectives 113.

¹¹¹ Coase, *supra* note 108 at 10, 15.

¹¹² Coleman, *supra* note 109 at 222.

¹¹³ Donald H Regan, “The Problem of Social Cost Revisited” (1972) 15 Journal of Law and Economics, 427-437 at 427.

¹¹⁴ Mercuro & Medena, *supra* note 96 at 107-108.

idea challenges many of the key considerations in much of tort and natural law,¹¹⁵ and causes problems in achieving sustainability, in particular the polluter pays principle which states that “the polluter should, in principle, bear the cost of pollution.”¹¹⁶

Since real-world scenarios do not tend to lend themselves to Coase efficiency, it normally is not the appropriate form for decision makers and/or academics to use when making recommendations and decisions about how to distribute societal wealth.

Pareto efficiency is an alternative theory of efficiency, though not one without its own challenges. A Pareto improvement, or a Pareto superior shift in allocation, occurs when, from a variety of allocation scenarios, the solution that is chosen is the one which makes at least one person better off but does not make anyone worse off.¹¹⁷ As a principle applied to instrument choice, the Pareto tenet would indicate that the most efficient solution is the one which shows benefit to one (or some) but no harm to anyone. Pareto efficiency, unlike the Coase Theorem, does not require that there be an absence of transaction costs, nor does it suppose that government intervention is unnecessary. While an efficient result according to Coase may also be Pareto efficient, this is not necessarily the case - they have different criteria for achieving efficiency. While most, if not all results which are Coase efficient will be Pareto efficient (since no rational party would willingly agree to a solution which reduced their welfare), not all Pareto efficient solutions align with the Coase Theorem (many solutions considered to be Pareto efficient include government intervention and transaction costs).

¹¹⁵*Ibid* at 108

¹¹⁶ Rio Declaration, *supra* note 29 at Principle 16.

¹¹⁷ Richard Posner, “The Ethical and Political Basis of the Efficiency Norm in Common Law Adjudication” (1979) 8 Hofstra L Rev 487 at 488.

One of the major problems with Pareto efficiency is that it is difficult to rank different potential allocations of resources. Think, for example, of a situation where decision makers are considering where to install public use bicycle repair stations (as is currently being done by Steamwhistle, a Toronto-based brewery).¹¹⁸ These self-service bike repair stations are not making anyone less well off, but they do improve the welfare of those who live, work, or play nearby and can make use of the facilities. How do decision-makers choose where to locate these facilities? That is, which people should be made better off? As in most cases, the allocation of these new resources is particularly difficult because one allocation could be better for certain people while a different one would benefit a separate group.¹¹⁹ In other words, using the Pareto efficiency criteria, the different scenarios would be considered equal, because in both cases groups are being made better off by the same amount – and nobody is worse off. The difference is in the people getting the benefit in the different scenarios – it is a case of distributional choice, something which is often not brought into the analyses of efficiency.¹²⁰ Thus, Pareto efficiency does not necessarily prescribe a single distribution (and hence legal and policy structure), but rather there could be multiple equally desirable options.

More seriously, there is no particular reason espoused by Pareto efficiency to favour the current distribution. Herein a challenge is raised with simply focusing on efficiency to choose allocations and in designing legal instruments to achieve them – there is no guidance on what or whom should be given priority or from what point or distribution to begin. Further, it is generally understood that there are very few allocative scenarios which leave nobody worse off

¹¹⁸ Kendra, “Steam Whistle Brewing’s Bike Repair Stations” (1 June 2015) Steamwhistle Blog, <online: <http://www.steamwhistle.ca/blog/2015/06/01/steam-whistle-brewings-public-bike-repair-stations/>>

¹¹⁹ C. Edwin Baker, “Starting Points in Economic Analysis of Law” (1979) 8 Hofstra L Rev 939 at 950.

¹²⁰ Jeffrey L. Harrison & Jules Theeuwes, *Law and Economics* (New York: W.W. Norton & Company, 2008) at 9.

and therefore if Pareto criteria were used as a precondition for instituting new law and policy, the status quo would almost always prevail.¹²¹ For example, almost all legal instruments for environmental protection leave someone worse off (often, the polluter) because they require a change in behaviour which typically means extra costs are incurred. Technology standards typically require companies to introduce a new technology which means, at least initially, they must spend more money than they had been in their status quo situation. Taxes require polluters to pay for the impact their processes are having on the natural environment – again, a cost which would not have existed in a business as usual scenario. Pareto efficiency would restrict the use of these legal instruments because their implementation would make the polluters worse off. In a way, then, this preference for the status quo could limit innovation, new policy initiatives, and shifts toward intergenerational equity. If it is accepted that the current status quo is *not* aligned with sustainable economic growth and intergenerational equity, then Pareto efficiency is likely incompatible with moves toward achieving Canada’s commitment to these goals.

The Kaldor-Hicks perspective on efficiency is distinct from the ‘do no harm to others’ principle of Pareto and instead states that so long as the gains are larger than the losses (so that the losers could be compensated by the winners), an efficient solution has been achieved.¹²² In this way, Kaldor-Hicks efficiency is more about society as a whole and not the individual. This perspective builds on an older tradition – Marshall-Pigou – which said that an increase in efficiency meant an increased in the size of the ‘pie’ (not the distribution)¹²³: the pie being social wealth, net social benefits, GNP/GDP etc.¹²⁴ By this it is meant that even if one section of the

¹²¹ Mercuro & Medena, *supra* note 96 at 26; Jeffrey L. Harrison, *Law and Economics* (St. Paul, MN: Thomson/West, 1995) at 36.

¹²² Coleman, *supra* note 109 at 239.

¹²³ David Ellerman, “Numeraire Illusion: The Final Demise of the Kaldor-Hicks Principle” in Marc D. White, ed, *Theoretical Foundations of Law and Economics* (New York: Cambridge University Press, 2009) at 97.

¹²⁴ *Ibid* at 96.

population sees a huge increase while another sees a decrease, so long as the ratio of benefits to losses rises overall, a gain in efficiency is achieved. Kaldor-Hicks uses the same definition, but adds the tenet that the losers must be able to be compensated by the winners – that is there must be an improvement in overall social wealth in order for an increase in efficiency to arise.¹²⁵

Interestingly, as the Kaldor-Hicks efficiency principle was developed, there was no requirement for actual compensation on the part of the winners towards the losers, it was enough that the gains would be sufficient to cover the losses in a balance sheet perspective.¹²⁶ If the rule was that compensation had to be paid out, then it could be said that the result was also Pareto superior. Further, Kaldor-Hicks efficiency can be seen as the starting point, the theoretical framework if you will, for the well-known idea of cost-benefit analysis.¹²⁷

In summary, there are multiple theories of efficiency in the law and economics literature, and these different definitions of efficiency would provide different suggestions for instrument choice and therefore it is important to consider them carefully. Typically Kaldor-Hicks efficiency is employed by decision makers¹²⁸ – in part because Pareto is extremely difficult to achieve and Coase is unrealistic in most real-world situations. When considering the intergenerational commitments which governments such as Canada have made, Pareto improvements become extremely difficult, if not impossible, especially when dealing with non-renewable forms of natural capital, because use necessarily disadvantages later generations. That said, intergenerational equity is also challenged from the perspective of Kaldor-Hicks because,

¹²⁵ *Ibid* at 97.

¹²⁶ The actual compensation of the losers has no bearing on the efficiency of the measure, but rather is a separate issue. So long as the resources to do so exist, then the solution is considered more efficient – see Mercuro & Medena, *supra* note 96 at 27.

¹²⁷ Cento Veljanovski, *Economic Principles of Law* (Cambridge, UK: Cambridge University Press, 2007) at 33.

¹²⁸ Paces & Visscher, *supra* note 101.

theoretically, one generation could use up all the natural capital so long as their gains were equal to or more than the losses of future generations. It seems, therefore that a compromise is needed and decision makers ultimately will have to choose which form of allocative efficiency to emphasize in their law and policy choices. That is, it is probably more realistic to *minimize*, rather than *avoid* outright, damage to the environment and others. Part of this compromise may be to acknowledge that efficiency theories should not be the only criterion used when evaluating legal instruments and policy proposals. In situations where intergenerational equity commitments have been made, using a second decision making criterion – one which focuses on equity (as is proposed in Chapter 3) – would be important. Taken in this light, defining allocative efficiency as Kaldor-Hicks should allow decision makers to choose options which alter the current situation while also considering the impact on future generations by applying the equity criterion.

Using law and economics methodology in this thesis is appropriate given that the goal of the economic analysis of law is the maximization of social welfare through efficiency.¹²⁹ This maximization of social welfare, of both current and future generations, demands the protection and efficient use of natural capital, as required by Canada's legal commitments to sustainable economic growth and intergenerational equity. Throughout this dissertation, the principle of efficiency is included by using measures of green productivity— since these are, in effect, measures of efficient use of different parts of natural capital. As will be described below, though, there are different types of efficiency so not all of these measures represent allocative efficiency and societal welfare in the same way. Still, the overall goal of sustainable economic growth through resource efficient use requires a normative application of efficiency to recommendations for decision makers. That is, in order to have both economic growth while at

¹²⁹ *Ibid.*

the same time ensuring it is sustainable and people are not being made worse off, on a whole, because of declining natural capital, efficient allocations are necessary.

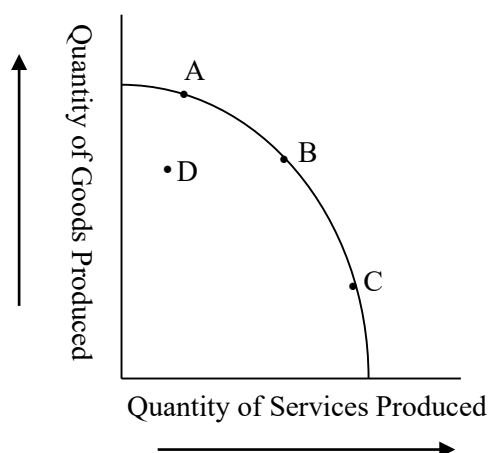
2.3.1.2 Categories of Efficiency

Generally speaking, the theories of efficiency espoused by law and economics scholars and utilized as part of the law and economics methodology are about allocative efficiency - that is overall societal welfare. Allocative efficiency is how resources can be employed to produce goods and services society demands in the way that maximizes overall societal welfare. Both Pareto and Kaldor-Hicks efficiency theories are forms of allocative efficiency.

In addition, though, there are other types of efficiency which are important to this research; namely productive and technical efficiency. Instead of focusing on the welfare of society, productive efficiency is about different ways to produce outputs. Of course, the same inputs can produce different mixes of goods and services (outputs). The main point is that a process is productively efficient when it reaches the point where it is impossible to produce one more unit of a given output without producing less of another type of output (typically this is portrayed as goods versus services) as is shown in *Figure 2.2*.

Essentially this means that the economy can produce different combinations of the same outputs and so long as that combination falls on the production possibility frontier. A, B, and C, in *Figure 2.2* are equally productively efficient. Point 'D' in *Figure 2.2* is productively inefficient.

Figure 2.2 – Productive Efficiency and the Production Possibilities Frontier



Technical efficiency is directly related to productive efficiency. In order to be productively efficient, the inputs must be used in the best way technically possible – that is, there must be no deadweight loss – no direct waste of the inputs used. Importantly, often discussions focus around allocative efficiency, as was the earlier focus in this chapter, but it is necessary to have both productive and technical efficiency in production processes in order to achieve maximum allocative efficiency in society.

To clarify this relationship, an example from a recent article on health care in the United States, may be useful:

productive efficiency, mean[s] that health care resources are put to the best use possible and produce as much health as they can, and allocative efficiency, mean[s] that the right share of resources is being devoted to health care versus other goods in the economy.¹³⁰

Though they are discussing financial resources, if considering this statement with regards to natural capital and substitute “the economy” and “current and future generations” for “health”

¹³⁰ Katherine Baicker and Amitabh Chandra, *Aspirin, Angioplasty, and Proton Beam Therapy: The Economics of Smarter Healthcare Spending* (2011) Federal Reserve Bank of Kansas City Proceedings - Economic Policy Symposium online <http://www.kc.frb.org/publicat/sympos/2011/2011.BaickerandChandra.paper.pdf> at 2.

and “other sectors”, respectively, a picture emerges of how these concepts apply to this dissertation and why green productivity measures are important. Consider the following:

productive efficiency, mean[s] that [natural capital] resources are put to the best use possible and produce as much [utility] as they can, and allocative efficiency, mean[s] that the right share of [natural capital]resources is being devoted to [current] versus [future generations].¹³¹

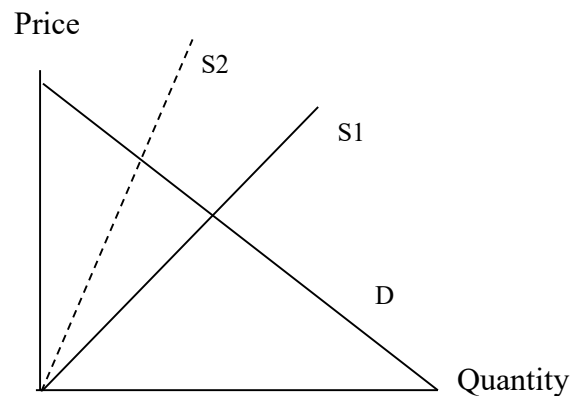
An important insight from this is that the market forces determine the presumed point of allocative efficiency. That is, the market, shaped by consumer demand (and influenced by government regulations), determines the mix of goods the economy produces. Companies will produce more, until supply meets demand. Crucially, taking into account the commitments to sustainable economic growth and intergenerational efficiency might lead to a quite different allocative efficiency point. That is, the allocative (social welfare maximizing) point would seem to be quite different if the cost of damage to ecosystem services is taken into account than if it is not. Similarly, the point of allocative efficiency for just the current generation would likely be quite different than the allocative efficiency point taking into account future generations. In both cases, the most efficient mix of inputs, outputs, and production would be quite different once the environment and sustainability is taken into consideration.

The shift in allocative efficiency is illustrated in *Figure 2.3*, where the supply of goods (S1) increases until it meets the demand curve (D). This is the point of allocative efficiency – where the amount consumers are willing to pay equals the price of the resources needed to produce it. That is, where marginal cost meets marginal benefits. However, what happens if prices are artificially low? In the case presented here, allocating natural capital use entirely to the

¹³¹ Based on the relationship described in *ibid*.

current generation, rather than to future generations, probably under prices natural capital. As the S2 line indicates, when the unit price of a good increases, the point at which the supply and demand curves meet also changes. In other words, the allocative efficiency point changes. The implication is that in order to maintain a supply of natural capital, its price should be increased, and thus its current use reduced. However, this may be extraordinarily difficult from a political standpoint, since it likely implies a reduction in production which would probably also negatively impact economic growth and (it is often presumed) standards of living. One solution, as discussed in the following section, is to focus on the efficiency of use of natural capital.

Figure 2.3 – Change in Allocative Efficiency



2.3.1.2.1 Efficiently using Renewable and Non-Renewable Resources

The efficient use of natural capital is important for several interrelated reasons. Many of these have already been discussed, but summarizing them here may be useful. First, natural capital is generally not anthropogenically reproducible, unlike built capital. This means that problems of scarcity can become more severe because the supply cannot be easily increased (if at all).

Second, natural capital, at least in part, is also non-substitutable. That is, it cannot be replaced by other forms of capital. This is especially so when critical natural capital, which provides services such as air filtration, water filtration, and climate regulation, is considered. In addition, natural capital is generally not priced correctly (and often not at all) by the market. This is true generally, but especially so because the market does not typically take use by future generations into account. In other words, the market is unlikely to allocate natural capital in a way that aligns with intergenerational equity.

A simple moratorium on use of natural capital, or a hard limit on the amount used, might solve intergenerational problems (i.e. that an intact stock of natural capital would be passed along). However, this could have drastic effects on current economic production (therefore violating commitments to sustainable economic growth) and so seems quite politically unacceptable. For this reason, the efficient use of natural capital is also important to align with commitments to sustainable economic growth.

One complicating factor is that natural capital used in and by production processes take the form of renewable and non-renewable resources as well as ecosystem goods and services. All might be scarce resources at any given time, but some have natural regeneration capacity and others do not. This might lead some to think that efficiency issues are only related to non-renewable resources (those without such regenerative capacity), but this is not the case. Even those with regenerative capacity can themselves be degraded to the point where they can no longer regenerate and therefore they may also become non-renewable. A classic example is that of fisheries. Fisheries are a renewable resource – they repopulate – but if they are harvested faster than their rate of regeneration, their ability to repopulate can become severely damaged. Similarly, while natural capital has assimilative ecosystem services, they are only effective to a

point – if they receive too many undesirable outputs, their capacity to absorb and process the waste or pollution will be reduced. For example, a wetland that is excessively polluted may become incapable of filtering water thereby losing its capacity as a provider of renewable ecosystem services.

Non-renewable resources – those without regenerative capacity - such as minerals and oil, for example, are perhaps the most obvious place to focus on scarcity. Once these resources are used up, they are effectively gone – irreplaceable at any plausible timescale¹³² and no longer available for use by current or future generations. In a sense, there is no truly sustainable use of these resources, because by definition they cannot both be used, and also preserved, for future generations. Nonetheless, a society without use of any non-renewable resources requires a massive transformation, and is not a useful proposal for decision makers. As such, it seems likely that a discount rate in some form will be applied to the use of non-renewable natural resources meaning current generations can continue to use them. The greater the discount applied to the future, the greater share of resources that can be used in the present (for a brief overview of discount rates, see section 2.2.2.2.1).

In sum, increasing the efficiency with which natural capital is used is important and necessary to meet Canada's legal commitments to sustainability and intergenerational equity because it is, for the most part, non-anthropogenically reproducible, only partially substitutable, and typically not priced with reference to intergenerational use. All of these factors suggest that natural capital is severely underpriced, and should be used more efficiently than it is. The fact that natural capital is partially substitutable is important – indeed, using it more efficiently often

¹³² Recycling and waste mining can help offset this problem (see Robert U. Ayres, “The second law, the fourth law, recycling and limits to growth” (1999) 29 Ecological Economics 473-483), to a certain extent, but could not be exclusively relied upon to solve this problem.

means substituting other forms of capital, such as built capital, for natural capital. This need for efficiency applies to both renewable and non-renewable natural capital, because even renewable and substitutable aspects of natural capital can themselves be so negatively impacted by over or misuse that they become themselves non-renewable.

2.3.2 Interdisciplinary Research Methodology

Though the primary methodology employed in this dissertation is that of law and economics, this research is not limited to the field of law and/or law and economics, but rather it touches on and draws from other disciplinary traditions key among them are policy studies, environmental sciences and the literature surrounding sustainability studies. Undertaking research which has this characteristic – that it integrates ideas, theories and methodologies from different academic areas - means that the researcher must be cognisant of the challenges and opportunities presented and must utilize somewhat different research methods. Thankfully, interdisciplinary research (IDR) has recently become a more applied approach and offers important methodological insights developed for just such projects.

Like many terms, IDR has a variety of definitions, but one of the most all-encompassing ones comes from the Committee on Facilitating Interdisciplinary Research and the Committee on Science, Engineering and Public Policy. They define IDR as

a mode of research by teams or individuals that integrates information, data, techniques, tools, perspectives, concepts and or theories from two or more disciplines or bodies of specialized knowledge to advance fundamental understanding or to solve problems whose solutions are beyond the scope of a single discipline or area or research practices.¹³³

¹³³ Committee on Facilitating Interdisciplinary Research and the Committee on Science, Engineering and Public Policy, *Facilitating Interdisciplinary Research* (Washington, D.C.: National Academies Press, 2005) at 2.

This definition highlights perhaps the key point which distinguishes IDR from other types of joint research such as multi-disciplinary (MDR) - *integration*. The idea is that when undertaking IDR, the integration of concepts from different fields is so fundamental to the research being undertaken it is not possible to step back into an individual discipline again without being impacted by the knowledge gained. MDR, on the other hand, is sometimes termed “additive” and often is undertaken by a group of academics who have come together to solve a common problem but, once the research project is completed, split apart and emerge unchanged.¹³⁴ Put another way, IDR changes the way academics view future research whereas MDR does not necessarily have this effect. Consider the following graphical depiction (*Figure 2.3*) of the difference between IDR and MDR¹³⁵

¹³⁴ *Ibid* at 29.

¹³⁵ This diagram is adapted taken from *ibid* at 29 which is based on a presentation: L. Tabak, Address (Convocation on Facilitating IDR, Washington, 29 January 2004).

Figure 2.4 – Interdisciplinary versus Multidisciplinary Approaches

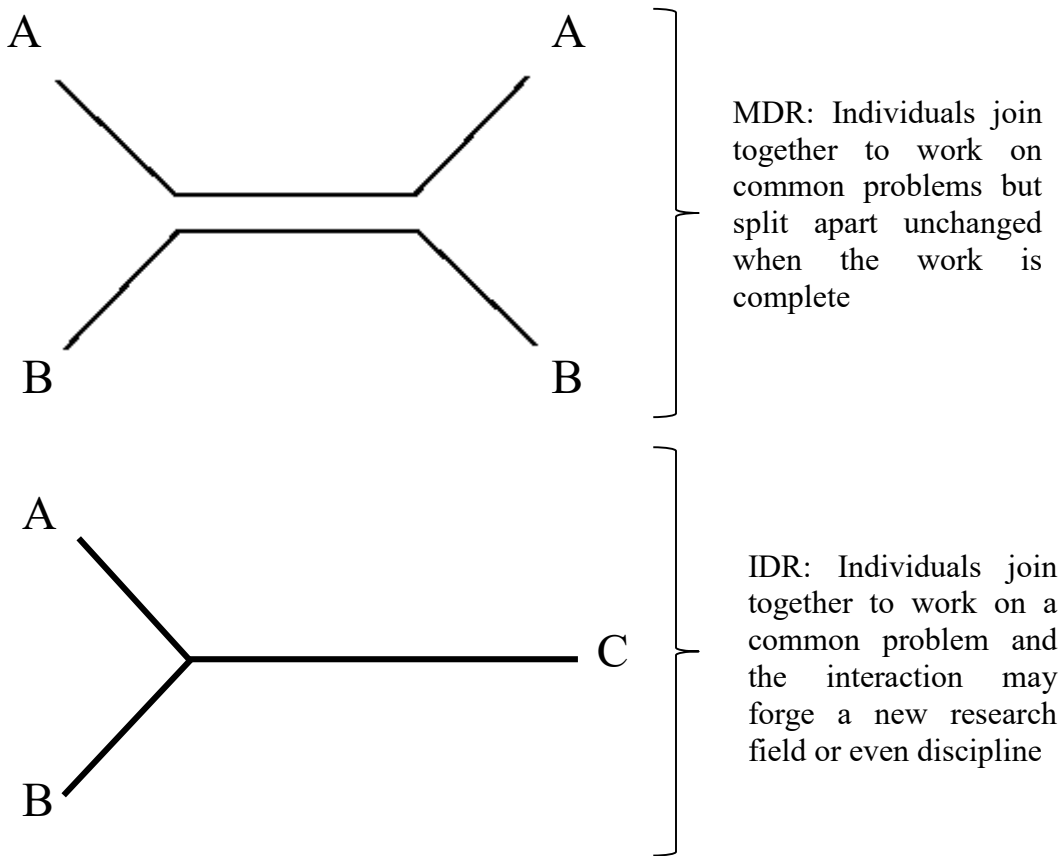


Diagram Adapted from: L. Tabak, Director, NINDS, NIH. Presentation at Convocation on Facilitating Interdisciplinary Research, Washington DC, January 29, 2004

While this diagram speaks specifically to multiple scholars working together, IDR in particular is also often undertaken by a single researcher.¹³⁶

IDR requires thinking outside traditional disciplinary boundaries – whether that be comprehending what experts in other fields are saying and seeing application to other research

¹³⁶ Conceivably MDR could also be undertaken by a single researcher, but MDR research tends to focus on multiple academics working together.

agendas, or simply putting aside preconceptions that you hold as an individual and forcing yourself to think about ways different disciplinary theories, methods, and ideas can be combined to create a more robust solution. The skill and method to do this offers many opportunities and is applied throughout this research.

One of the major challenges which arise in IDR is presented by language and the ability (or lack thereof) to communicate across disciplinary boundaries.¹³⁷ The terminology challenge may occur due to a complete lack of understanding of what is being said or because different disciplines use the same words but in different ways and with different meanings.¹³⁸ Even more challenging is the fact that language and understanding is often invisible and therefore it is difficult to know whether others understand what is being said in the context it is intended.¹³⁹ In fact, the issue of terminology is a major challenge in this research, as will be discussed in more detail in Chapter 4.

When research is undertaken primarily using an IDR methodology, this methodology itself can be a stumbling block. Thankfully, there is relative agreement between most natural and social scientists about basic methodological issues – that “research carried out in a scientific way is systematic, skeptical, analytical and ethical”¹⁴⁰ Even still, there are challenges, especially when combining disciplines with rigid methodologies – such as general science and the scientific method – with those such as law which use terms and methods strategically to advance their

¹³⁷ John Mixon, “Linguistic Silos as Barriers to Sustainable Environment” (2010) 44 Tulsa L Rev 7 [Mixon]; Julie Thompson Klein, “Interdisciplinary Teamwork: The Dynamics of Collaboration and Integration” in Sharon Derry, Christian D Schunn & Mortan Ann Gernsbacher, eds, *Interdisciplinary Collaboration: An Emerging Cognitive Science* (London: Lawrence Erlbaum Associates Publishers, 2005) at 29; J. R. Davis, *Interdisciplinary Courses and Team Teaching: New Arrangements for Learning* (Phoenix, AZ: American Council on Education and Oryx Press, 1995) at 50.

¹³⁸ Mixon, *ibid* at 7.

¹³⁹ *Ibid* at 11.

¹⁴⁰ Denise Lach, “Challenges of Interdisciplinary Research: Reconciling Qualitative and Quantitative Methods for Understanding Human-Landscape Systems” (2014) 53 Environmental Management 88 [Lach] at 88.

cause when it is reasonable to do so.¹⁴¹ This research uses the law and economics methodology as the groundwork and then draws on other disciplinary methodologies – both qualitative and quantitative – to improve the robustness of the research and recommendations. Of course there are situations where these methodologies differ, but careful examination, qualifications and explanations, in many cases, can help. Therefore, throughout this dissertation there are times when methodological or theoretical concepts familiar to one discipline – economics for example – are explained at length due to the relative unfamiliarity of other scholars to the idea (such as those who study law).

Despite these challenges, IDR offers many opportunities for those who are willing to pursue it. Many of the challenges to IDR can be overcome and when considered in a different light become opportunities. For example, those performing research using an IDR methodology are perhaps better able to tackle global issues which are ever-increasing in complexity. Environmental challenges such as climate change or urban sprawl are very clearly not issues which can be solved by the work of a single discipline but require the integration of ideas from numerous fields to begin to form plausible solutions. Often times these issues are the same ones which are growing in importance, are globally recognized and require innovative and unique solutions. Further, IDR methodologies develop skills which help researchers more effectively pose questions and analyse results.¹⁴² These new skills, the mental ability to think outside the box, and the innovative combination of ideas and methodologies, offer those involved in IDR the capacity to strengthen the larger academy with integrated thinking, approaches, and ideas. At the researcher level, such skills help make connections between different areas of research not

¹⁴¹ Mixon, *supra* note 137 at 24.

¹⁴² Lach, *supra* note 140 at 90.

traditionally aligned and bring unique aspects from one discipline to another – sometimes solving issues within a discipline that even a disciplinary perspective itself cannot fully resolve, or sometimes helping refine a position or theory that is clarified by perspectives from outside the discipline.¹⁴³ For example, for years, researchers in political science suggested that voters used heuristics - mental shortcuts such as using a candidate's race or gender to guess what their policy position were likely to be.¹⁴⁴ Dual process theory, from psychology, has shown that the same piece of information can influence people in different ways (i.e. a rational, cognitive evaluation versus an unconscious reaction) which helps better understand the actual motivations for these political behaviours.¹⁴⁵ Here psychology has clarified a theory in political science.¹⁴⁶

2.4 Conclusion

This chapter has presented the legal and methodological foundation for this dissertation. It has done so, first, by identifying legal commitments to sustainable economic growth and intergenerational equity. Second, it presented the methods which are used to undertake and present the research in this dissertation– ‘law and economics’ as well as IDR.

Legal commitments made by the Canadian government and its provinces through international agreements, legislation, and jurisprudence,¹⁴⁷ it was argued, lead to a duty¹⁴⁸ to

¹⁴³ John T. Bruer, “Cognitive Science: Interdisciplinary and Intradisiplinary Collaboration in Sharon Derry, Christian D Schunn & Mortan Ann Gernsbacher, eds, *Interdisciplinary Collaboration: An Emerging Cognitive Science* (London: Lawrence Erlbaum Associates Publishers, 2005) [Bruer] at 223.

¹⁴⁴ Samuel L. Popkin, *The Reasoning Voter* (Chicago University Press: Chicago, 1991)

¹⁴⁵ Richard E. Petty and John T. Cacioppo, “The effects of involvement on responses to argument quantity and quality: Central and peripheral routes to persuasion: Central and Peripheral Routes to Persuasion” (1984) 46(1) *Journal of Personal and Social Psychology* 69-81.

¹⁴⁶ Dennis Chong & James N. Druckman. “A Theory of Framing and Opinion Formation in Competitive Elite Environments” (2007) 57 *Journal of Communication* 99-118 integrates psychology and political science heuristics

¹⁴⁷ See detailed discussion and references in the first section of this chapter (2.2)

¹⁴⁸ Though international agreements are included in this list, the author is well aware they are “soft” and are rarely enforceable. Still, these commitments provide insights into the positions national governments are willing to take or at least to what they want the international community to see as their priorities. See footnote 28 for a longer discussion on this.

make policy and legal decisions aligned with moving towards sustainable economic growth and intergenerational equity. To achieve this means, among other things, improvements in the efficiency of use of natural capital so that economic growth may continue but without being at the expense of future generations' ability to enjoy and use the natural environment.

Natural capital is scarce, just like other forms of capital. Importantly, however, many forms of natural capital are non-reproducible by humans, unlike built or other kinds of capital, which makes the problem of scarcity and management all the more severe. While substitution is sometimes possible, this is not always the case, and often only with difficulty and at higher costs. For this reason, using efficiency as a criterion for choosing and designing legal instruments and public policy goals is important to achieve Canada's sustainability goals.

The process of designing, evaluating and implementing these various legal and policy tools is a complex one which relies on many different sources of information.¹⁴⁹ One important set of tools is economic indicators, which include commonly used measures such as GDP and productivity. Unfortunately, most of these measures fail to accurately include or consider aspects of natural capital, meaning that they are inadequate, alone, as indicators to inform decision makers charged with developing new instruments aimed at sustainable economic growth and intergenerational equity. In fact, the concluding document published from the Rio +20 meeting in 2012, *The Future We Want*, indicated that the Nation-States assembled at the meeting "... recognize the need for broader measures of progress to complement gross domestic product in order to better inform policy decisions."¹⁵⁰ This research aims to help fill this gap.

¹⁴⁹ Treasury Board, "Assessing, Selecting", *supra* note 25 at 18.

¹⁵⁰ UNCSO, *supra* note 32 at para 38.

The law and economics methodology is an obvious choice for research concerned with how efficiently the economy uses resources, and in particular, research such as this which considers how to use measures of efficiency when choosing policy goals and legal instruments. Through both normative and positive law and economics methodologies, this thesis presents how decision makers *should* use measures which highlight the efficiency of use of natural capital (green productivity measures) and what studies employing them actually *can* illustrate. This research is concerned with technical (using inputs without waste), productive (where no more of one type of output can be produced without producing less of another output) and allocative (the ‘ideal’ distribution of outputs that society desires) efficiency. The ‘ideal’ distribution can (and has) been defined in a number of ways, but this research, aligned with much current practice, proposes Kaldor-Hicks distribution, though considerations of equity are also important to ensure intergenerational obligations are met.

Finally, this chapter has presented a brief overview of IDR, an important methodological consideration in research (such as this) which combines ideas from various disciplines. Research questions such as the one asked in this research “in what way(s) can green productivity measures be used in the policy cycle and to improve instrument choice evaluation and decision making?” require a knowledge and use of IDR to provide a robust answer.

This chapter set out the legal framework justifying a focus on sustainable economic growth and intergenerational equity. These principles, it was argued, require policy emphasis and legal instrument choices to focus on the efficiency of use of natural capital. In later chapters (Chapter 4, in particular) the focus turns to a key way of measuring that efficiency of use – green productivity – and how it can be integrated into the policy making cycle and instrument choice

frameworks. First, however, the foundations of the policy cycle and instrument choice are introduced.

3. Policy Cycle and Legal Instrument Choice Frameworks

3.1 Introduction

Determining how to implement government goals and commitments involves a large and complex set of decisions. As was established in Chapter 2, the responsibility to efficiently use natural capital, and more broadly, to strive for sustainable economic growth and intergenerational equity, has a clear foundation in Canada's legal commitments (national, provincial and international) as well as in statements by various levels of government. But even given broad principles of sustainability, decision makers must determine more specific policy goals and establish appropriate legal instruments needed in order to ensure compliance. To that end, this chapter details both the policy cycle and the instrument choice decision making process – both key pieces in decision making - in order to set up discussion in later chapters about the possible role of green productivity in these frameworks.

Though clearly a part of the policy cycle (see *Figure 3.1*), instrument choice decision making also has its own body of literature which includes not just public policy research but research from legal, economic, and other areas as well. This dissertation emphasizes the instrument choice part of the policy cycle (specifically a more detailed examination of how green productivity can be incorporated into Stages 2 and 3 – policy formulation and decision making) but also analyses green productivity in Stages 1 (agenda-setting) and 5 (evaluation).

3.2 The Policy Cycle

The standard way to understand the development of policy is to view its creation as an inter-related process or a cycle. That is not to say this process is simple to define (nor is this standard

process without its critics),¹⁵¹ but perhaps the most appropriate approach for this research identifies five stages which compose the framework for policy development.¹⁵² As Howlett *et al* state, this development “flow[s] in a more or less sequential fashion from ‘inputs’ (problems) to ‘outputs’ (policies),¹⁵³ though certainly it is true that this cycle fluctuates and interactions between the different stages is commonplace thereby significantly increasing the complexity of the process.¹⁵⁴ It is at this point that most scholars who use the policy cycle as the base for research qualify its use by stating that there are flaws in the approach, but that it proves useful for clearly presenting results about the policy process.¹⁵⁵ This argument is echoed here in that for the purposes of describing how and when green productivity can and should be used by decision makers, the policy cycle is valuable despite its challenges. Further, the process described here, which follows Howlett *et al*,¹⁵⁶ is transferrable to different jurisdictional contexts and is not specific to Canada.

Over the years there has been much research which has presented the stages of the policy cycle. The pioneer in this area – breaking down policy making into specific, differentiated stages – was Harold Lasswell who considered the process to have seven stages.¹⁵⁷ Since then a variety of authors have proposed modifications and changes to the policy cycle.¹⁵⁸ While

¹⁵¹ Paul A. Sabatier, “The Need for Better Theories” in Paul A. Sabatier, ed, *Theories of the Policy Process* (Boulder, Co: Westview Press, 2014) [Sabatier] at 6-7.

¹⁵² A sixth stage – termination/renewal - can be added, but in our case it is included within evaluation as it is, essentially, the outcome of that stage. See Garry D. Brewer “The Policy Sciences Emerge: To Nurture and Structure a Discipline” (1974) 5 *Policy Sciences* 239-44 [Brewer] at 240; Peter deLeon, “A Theory of Policy Termination,” in *The Policy Cycle*, ed. Judith V. May and Aaron B. Wildavsky (Beverly Hills: Sage Publications, 1978) at 294.

¹⁵³ Michael Howlett, M. Ramesh & Anthony Perl, *Studying Public Policy: Policy Cycles & Policy Subsystems* (Oxford: Don Mills, 2009) [Howlett et al] at 10.

¹⁵⁴ Sabatier, *supra* note 151 at 7.

¹⁵⁵ Thomas A. Birkland, *An Introduction to the Policy Process: Theories, Concepts, and Models of Public Policy Making* (M.E. Sharpe, Inc.: New York, 2001) at 223

¹⁵⁶ Howlett et al, *supra* note 153 at 10.

¹⁵⁷ Harold Lasswell, *A Pre-view of the Policy Sciences* (New York: Elsevier, 1971)

¹⁵⁸ For example, Brewer, *supra* note 152; Charles O. Jones, *An Introduction to the Study of Public Policy* (Brooks/Cole Publishing Company: Pacific Grove, CA, 1984)

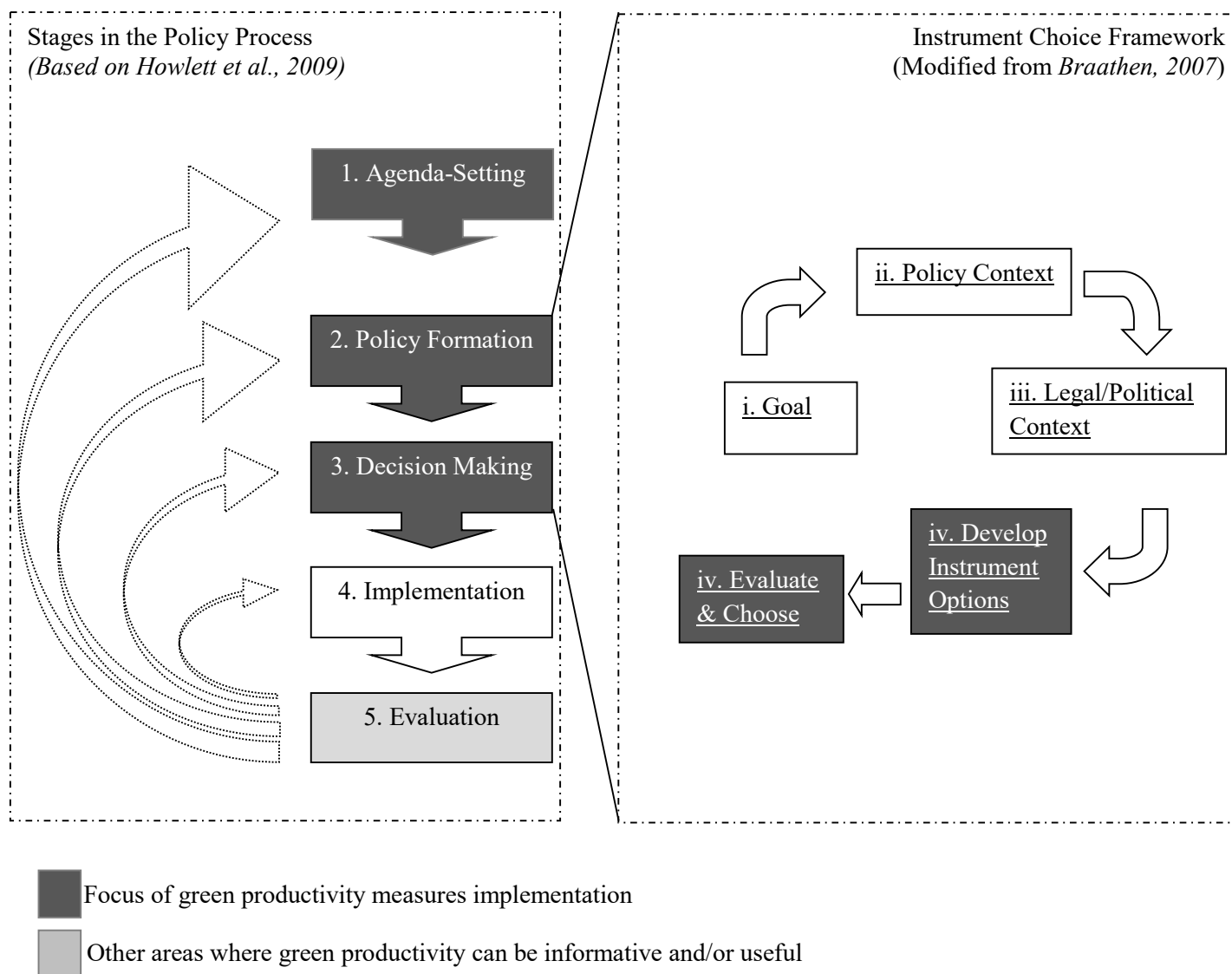
interesting in their own right, these advances are not central to the purpose of this chapter which is to lay out the stages of the policy cycle so measures of green productivity can be applied. Therefore, a discussion of the different versions of the policy cycle is not necessary, and instead the general policy process and its five stages, as presented by Howlett *et al* are used.¹⁵⁹ This simplified policy cycle is widely accepted, and for the purpose of this research is sufficient to show how incorporating measures of green productivity can lead to better decision making. Specifically, in order for this research to constitute a broader contribution, a simplified policy cycle is important so that the transferability of the conclusions to different jurisdictions (in Canada and elsewhere) is made easier. To demonstrate the applicability of the conclusions to real world processes, this thesis compares the simplified policy cycle and instrument choice framework to the Canadian government's guiding document for selecting instruments. It is unlikely that governments in different jurisdictions have identical processes which they follow, but they are likely to all have some similarities many of which can be found in this simplified cycle.

Figure 3.1 illustrates the basic policy cycle. This diagram displays the connection between the overall policy cycle and its stages, with the more detailed examination of the instrument choice framework. As can be seen, the instrument choice framework fits within the policy cycle Stages 2 and 3, but can also be considered a process all its own. The policy cycle is made up of five distinct, but often interconnected, stages and will be discussed in the first part of this chapter and in Chapter 5. The focus is on Stage 1 (agenda-setting) and Stage 5 (evaluation). Stages 2 (policy formation) and 3 (decision making) are primarily about instrument choice and will be discussed in the second part of this chapter and in Chapter 6. Though Figure 3.1 is

¹⁵⁹ Howlett et al, *supra* note 153.

presented as linear, a series of arrows represent the potential for the process to become cyclical (which it frequently does).

Figure 3.1 – The Policy Cycle with Imbedded Instrument Choice Framework



The different shading presented in *Figure 3.1* shows where the emphasis will be placed in the upcoming chapters as they present detailed arguments for where and how green productivity as a whole, and more specifically its detailed measures, can and should be used.

Briefly, the first stage of the policy cycle – agenda-setting – will dominate much of the recommendations which discuss green productivity’s potential to become a policy priority. Further, Stages 2 and 3 – policy formulation and decision making – will be expanded on through an in-depth consideration of the processes involved in choosing the appropriate legal instrument. Stage 5 – evaluation – will also be discussed in the context of green productivity measures and can be found in Chapter 5. The remainder of this chapter lays out the structure of, and considerations in, both the policy cycle broadly, and more specifically the instrument choice framework. This is necessary in order to be able to apply green productivity measures within these constructs in the following chapters. What follows begins by describing the policy cycle stages, following which a detailed discussion of instrument choice is presented.

3.2.1 Stage One: Agenda-Setting

Being the first stage in the policy process, agenda-setting takes place at the broadest level, with the most diverse set of actors and the widest set of considerations. This stage is about determining which issues get addressed and which are ignored - it is about “the recognition of some subject as a problem requiring further government action.”¹⁶⁰ Oftentimes, what distinguishes one subject from another – what pushes something into the category where government action may be taken – has to do with threats or challenges, though potentially also opportunities.¹⁶¹ Other authors define these potential agenda items as being foreign or domestic, new or grown out of a previous policy item, and differing in scope.¹⁶² This thesis also adds broad legal commitments, such as international obligations, to this list of stimulants for policy agenda items. Though one could consider the process of being bound by an international agreement as

¹⁶⁰ *Ibid* at 92.

¹⁶¹ *Ibid* at 93.

¹⁶² James E. Anderson, *Public Policymaking*, 5th ed. (Houghton Mifflin Company: Boston, 2003) at 81.

going through the various policy stages as one large agenda item, in reality, this is not necessarily the case, and certainly the full cycle is rarely implemented until after ratification. Often such commitments are quite broad and therefore various agenda items are needed to deal with and satisfy the requirements.

The agenda-setting stage can be broken into two quite distinct phases. It is here suggested that the influence of external actors in raising the profile of a particular issue (be that the situation of sweeping legal commitments or public pressure) is different than how governments choose to define agenda items. This idea is aligned with Dery's differentiation of initial agenda-setting (getting the attention of the government) and the actual definition of the problem which becomes the government agenda item.¹⁶³ External pressure from legal commitments made, for example, by previous governments, or broad societal interest in an issue, are different from how that problem or solution is defined by the government in power as a policy priority. These phases can be classified as 1A and 1B in the policy cycle. There are a number of reasons for this, including that "legitimizing an issue is not the same as legitimizing demands."¹⁶⁴ While external factors have more power to draw attention to an issue (1A) the government is often able to define it in a particular way (1B) which sets up the remainder of the policy cycle to be better aligned to their ideals.¹⁶⁵

The distinction between 1A and 1B may become clearer with an example. Consider the Millennium Development Goals (MDGs). External forces (the commitment to achieving these goals and public pressure associated with hosting the G8 summit, for example) seemed to force the attention of the Canadian government. They chose to address the broad goal of the MDGs by

¹⁶³ David Dery, "Agenda Setting and Problem Definition" (2000) 21:1 Policy Studies 37-47 [Dery].

¹⁶⁴ *Ibid* at 38.

¹⁶⁵ *Ibid* at 40, 46.

making maternal health (goal #5) an item on their national government agenda.¹⁶⁶ Here, it is clear that the societal pressure and previous commitments to achieving these goals can be considered 1A (drawing attention to the issue) and the choice made by the government to focus on maternal health is 1B. Though both parts of the agenda-setting process are important, in Chapter 5 where green productivity is considered, the focus is almost exclusively on 1B – how the government defines the problem or solution as its own policy priority.

Green productivity has distinct implications for these different phases of agenda-setting. This thesis suggests that in the case of green productivity the broad legal commitments laid out in Chapter 2 along with societal concern for sustainable actions are relevant to Stage 1A. That is, they are the external factors which influence the government to take the sustainable economic growth and intergenerational equity commitments seriously. However, the way this issue is defined is likely to be determined by internal government actors and this is how green productivity may find prominence (a further discussion of this can be found in Chapter 5).

In understanding why, and when, governments adopt items as policy priorities there has been an increased focus on the idea of policy diffusion and innovation at the agenda-setting phase.¹⁶⁷ Policy innovation, though somewhat hard to define – when is a policy *really* new? – has been accepted “as a program that is new to the government adopting it.”¹⁶⁸ It is this “new to the government adopting it” which allows policy diffusion to be considered as part of the agenda-setting phase of the policy cycle. Diffusion is one of two main theories which explain policy

¹⁶⁶ Government of Canada, *The Muskoka Initiative: Background*, online
<http://mnch.international.gc.ca/en/topics/leadership-muskoka_background.html>

¹⁶⁷ Michael Mintrom, “Policy entrepreneurs and the diffusion of innovation” (1997) 41 *American Journal of Political Science* 738-770

¹⁶⁸ Jack Walker, “The Diffusion of Innovations among the American States” (1969) 63 *American Political Science Review* at 880-889 at 881.

innovation (the other being internal determinants, such as interest groups or partisan control of government).¹⁶⁹ While diffusion has historically tended to be considered at the policy formulation and decision making stages,¹⁷⁰ it is becoming more recognized as contributing to agenda-setting as well. This is an important development especially when considering the latter of the two phases of Stage 1 – problem definition. It is at the agenda-setting stage where policy actors are the most stretched for time and resources¹⁷¹ and therefore more likely to adopt the definition of a problem already used (and proven successful) elsewhere. These complementary ideas of political innovation and policy diffusion directly influence the argument made in Chapter 5 - that green productivity has the characteristics to become a government priority at the agenda-setting stage.

3.2.2 Stage Two: Policy-Formulation

Stage 2 is the first of two stages in the policy cycle which encompasses instrument choice decision making frameworks. A brief description of this stage – policy formulation – will be presented, but more detailed analysis is reserved for the second part of this chapter on instrument choice. The same is done for Stage 3 of the policy cycle – decision making.

The policy formulation stage can be extensive, and includes collecting options, instruments, and ideas about how to deal with and or solve the problem identified in Stage 1. This may involve narrowing down ideas to those deemed to be, broadly, acceptable,¹⁷² but final

¹⁶⁹ Frances Stokes Berry & William D Berry, “Innovation and Diffusion Models in Policy Research” in Paul A Sabatier & Christopher Weible, eds, *Theories of the Policy Process* (Westview Press, Boulder, Co: 2014) [Berry & Berry] at 310.

¹⁷⁰ Andrew Karsh, *Democratic Laboratories: Policy Diffusion Among the American States* (University of Michigan Press: Ann Arbor, 2007) [Karsh] at 67

¹⁷¹ *Ibid* at 4.

¹⁷² Howlett et al, *supra* note 153 at 110.

decisions are not made at this stage. Often ideas are “floated” but not discarded until the decision making stage.

It may be easier to understand the policy formulation process as first deciding which instrument can be employed to deliver the desired results based on the new goal on the government agenda. Then, decision makers must consider the technical, political, legal and administrative feasibility of these potential instruments and provide recommendations of serious options to be studied in the decision making stage. In Chapter 6, this process is discussed in the context of green productivity and what its various measures can provide with regards to information for the design and evaluation of potential instruments.

3.2.3 Stage Three: Decision Making

At the decision making stage of the policy process the options discussed in the policy formulation stage are debated, evaluated and chosen or discarded as the official government action towards the public policy agenda item determined in Stage 1. Decision making is the second part of the instrument choice framework discussed in the second part of this chapter (Section 3.3) and emphasised with relation to green productivity measures in Chapter 6. Because it is discussed in depth in the following section on instrument choice, very little will be said here except to highlight that the decision making process does not always end up with a positive choice (where an option is chosen which changes the status quo). Sometimes the choice is negative (to maintain the status quo) or there is no agreement on what to do.¹⁷³ Further, once an instrument, or suite of instruments, is chosen (again criteria for how this choice is made are

¹⁷³ *Ibid* at 81 and 102.

discussed later in this chapter in the context of legal instrument choice) they will be implemented. Implementation is presented as the next stage in the policy cycle.

3.2.4 Stage Four: Implementation

The implementation stage of the policy process is often undertaken by bureaucrats who have been empowered through statutes or regulations to apply the option chosen in the decision making stage.¹⁷⁴ That said, at times, non-governmental organizations are also charged with implementing programs or instruments decided on by policy actors.¹⁷⁵ Though historically viewed as the “easy” stage in the policy cycle¹⁷⁶, increasingly a realisation about difficulties in implementation has emerged, and scholars have debated and researched various models of public policy implementation.¹⁷⁷ This is often a stage where a relatively small part of the policy universe, perhaps a single empowered bureaucrat or an individual department, is active. Interestingly, though lobbying has traditionally occurred in earlier stages of the policy cycle – agenda setting, policy formulation, or decision making - outside stakeholders have recently shifted some of their attention to implementation. In particular, efforts have been focused on timing or the order of implementation of instruments in a bundle.¹⁷⁸ Though an important part of the policy cycle, here the implementation stage is not the focus of the application of green productivity and therefore is not a significant part of this thesis.

3.2.5 Stage Five: Evaluation

¹⁷⁴ *Ibid* at 161.

¹⁷⁵ *Ibid*.

¹⁷⁶ E.C Hargrove, *The Missing Link: The Study of Implementation of Social Policy* (Washington, D.C.: Urban Institute, 1975).

¹⁷⁷ Howlett et al, *supra* note 153 at 161-168.

¹⁷⁸ Kevin Young, “Financial industry groups’ adaptation to the post-crisis regulatory environment: Changing approaches to the policy cycle” (2013) 7 *Regulation & Governance* 460-480 at 472-473.

The fifth and final stage of the policy cycle – evaluation - is critical in that it determines how effective the option chosen in Stage 3 has been as well as how well implementation has been carried out. It may be judged successful and therefore continued unchanged, it may be judged as wanting in some respect and therefore revisions are needed, or it may be judged a complete failure and terminated.¹⁷⁹ Perhaps the most common situation is the second, that the implemented policy option is not producing outcomes exactly as desired and therefore policy actors may return to any of the previous stages of the policy cycle (forming an evaluation-amendment loop) to set a new agenda, reformulate, make a different decision, or implement differently, in order to get better results. Though seemingly a straight-forward process, policy evaluation has been shown to be contentious, politically motivated and certainly not always about trying to improve a policy.¹⁸⁰ Policy evaluation can be administrative, judicial, or political. Think for example of the review processes built into several pieces of Canada’s environmental legislation. The *Species at Risk Act* requires the review of the classification of species’ “at least once every 10 years, or at any time if it has reason to believe that the status of the species has changed significantly.”¹⁸¹ Similarly, the *Canada National Parks Act* requires a review of each park management plan, by the Minister, at least every ten years.¹⁸² While many kinds of review can be important – including judicial review based on the constitutionality of environmental instruments – here the focus is on administrative policy evaluation.

¹⁷⁹ Howlett et al, *supra* note 153 at 191.

¹⁸⁰ *Ibid* at 179.

¹⁸¹ *Species at Risk Act*, SC 2002, c 29 at s.24.

¹⁸² *Canada National Parks Act*, SC 2000, c 32 at s. 11(2).

Further, policy making can, and should, have both retrospective and prospective evaluation components.¹⁸³ That is, typically evaluation is considered only after implementation, but there is increasingly a trend towards *ex-ante* assessment (evaluation of various instrument options done before implementation).¹⁸⁴ Most often this assessment is done within Stages 2 and 3 of the policy cycle which have already been identified as being part of instrument choice. In contrast to *ex-post* evaluation (that which is done after implementation and based on what has occurred) *ex-ante* assessment considers the different instrument options proposed and provides recommendations for which instrument(s) should be implemented. One well known type of *ex-ante* evaluation is cost-benefit analysis which “compares the values of all benefits from the action under consideration and the costs associated with it.”¹⁸⁵ Chapter 5 and 6 show that green productivity measures are also useful in both types of evaluation processes.

The discussion of the policy cycle presented here sets up the analysis of green productivity in Chapters 5 and 6 as well as leads directly into the next section of this chapter (section 3.3) which is on instrument choice. This discussion has emphasized Stage 1 – agenda setting – as it is most relevant to the application of green productivity in Chapter 5. Brief discussions of the other phases (2-5) have also been presented. Instrument choice, as is illustrated in *Figure 3.1*, is embedded in the policy cycle and can be seen as a magnification of what happens during Stage 2 (policy formulation) and Stage 3 (decision making) of the policy

¹⁸³ Ray C. Rist, “Choosing the Right Policy Instrument at the Right Time: The Contextual Challenges of Selection and Implementation” in Marie-Louise Bemelmans-Videc, Ray C Rist & Evert Vedung, eds, *Carrots, Sticks & Sermons: Policy Instruments & Their Evaluation* (New Brunswick, NJ: Transaction Publishers, 1998) at 154.

¹⁸⁴ Peter Teirlink et al., “Closing the policy cycle: Increasing the utilization of evaluation findings in research, technological development and innovation policy design” (2013) 40 *Science and Public Policy* 366-377 at 366

¹⁸⁵ OECD, *Cost Benefit Analysis*, in Glossary of Statistics Online: <https://stats.oecd.org/glossary/detail.asp?ID=6377>.

cycle. For this reason, very little of these two phases was discussed above given the in-depth discussion of instrument choice provided below.

3.3 Instrument Choice

To begin a discussion of instrument choice it seems reasonable to discuss what the real, underlying goals of these frameworks are. Taylor *et al* put it nicely when they said instrument choice frameworks they are about answering “what instruments work, when and with whom, and why?”¹⁸⁶ If these are the questions to answer, how do they fit more broadly into the legal and policy process? As was illustrated in *Figure 3.1* (in section 3.2 of this chapter), choosing and eventually deciding on an instrument to implement is part of the broader policy cycle. This section lays out a more detailed framework of how this is done and some key characteristics that are used. The focus here is on instrument choice decision making from a legal and policy perspective, though contributions from other disciplines will certainly be presented when appropriate.

Wide arrays of different ideas, guidelines and criteria have been proposed for instrument choice. One useful distinction is dividing the instrument choice task into two sections - first the decision of *how* to make the choice and then the decision of *what* to choose.¹⁸⁷ This section begins by considering the question of *how* by discussing the instrument choice framework presented in *Figure 3.1* and comparing it to the Treasury Board of Canada’s ‘Analytical Framework for Selecting Instruments.’ Both will be further elaborated on with regards to green productivity in Chapter 6. Considering both a general and more specific instrument choice

¹⁸⁶ Christopher Taylor, et al., “Selecting Policy Instruments for Better Environmental Regulation: a Critique and Future Research Agenda” (2012) *Environmental Policy and Governance* 22, 268-292 at 272.

¹⁸⁷ Government of Canada, *Smart Regulation – a Regulatory Strategy for Canada* (Ottawa: Government of Canada, 2004) at 38.

framework demonstrates that the instrument choice discussion and recommendations provided in Chapter 6 are directly applicable to the Canadian federal government's framework, but also widely applicable and easily interpretable for other countries and contexts. Following the discussion of instrument choice frameworks, the 'what' to choose question is considered by analysing research which proposes various normative criteria for decision making. Ultimately, three normative criteria are presented, each which is aligned with the goals of sustainable economic growth and intergenerational equity.

3.3.1 Frameworks – the “how” of Instrument Choice

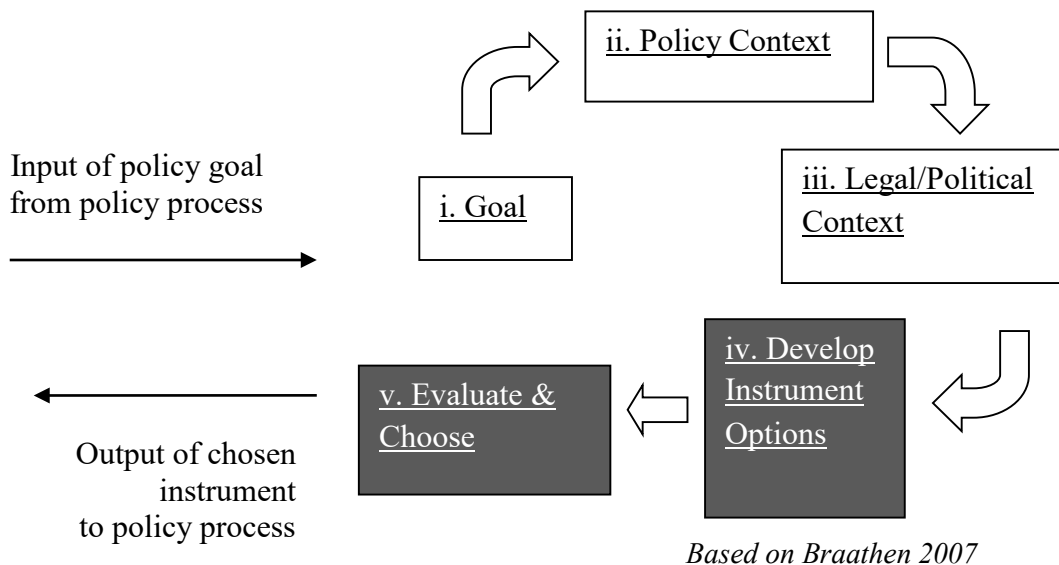
Though there are a large number of instrument choice frameworks presented and used by academics, government officials, and others, this research has chosen to focus on one widely used generic framework, and another which is specific to Canada. These two frameworks are discussed in general terms in this chapter and then, in Chapter 6, considered alongside green productivity measures, with particular attention paid to how green productivity can improve the decision making which occurs at the different steps of the frameworks.

The more generalized instrument choice framework – *Figure 3.2* – is based on work done by Nils Axel Braathen,¹⁸⁸ though expanded to include a step where various instrument options are presented and more detailed evaluative criteria for the actual choice of instrument. Braathen specifically highlights Steps i to iii (presented in *Figure 3.2*). The framework used in this thesis has taken these considerations as the starting point but then added two other critical steps (iv and

¹⁸⁸ Nils Axel Braathen, “Instrument Mixes for Environmental Policy: How Many Stones Should be used to Kill a Bird?” (2007) 1 *International Review of Environmental and Resource Economics* 185-235[Braathen].

v)¹⁸⁹ which allow decisions to be made and ultimately fed back into the broader policy cycle for implementation.

Figure 3.2 – Instrument Choice Framework



The first step in determining instruments that could successfully implement a new agenda item is to ensure the decision makers fully understand the goal – that is, that they are clear about what the legal instrument is supposed to achieve.¹⁹⁰ This is followed by Steps ii and iii which consider the different contexts relevant to the instruments proposed. These contexts include: policy (other instruments which have been implemented and may impact – positively or negatively on the effectiveness of the new instrument), legal (constitutional issues are key here

¹⁸⁹ These steps are common in instrument choice frameworks including those presented in Gretchen C. Daily and Katherine Ellison, *The New Economy of Nature – the Quest to Make Conservation Profitable* 226–227 (2002); Stratos Inc., *Economic Instruments for Environmental Protection and Conservation: Lessons for Canada* (2003) 21 [Stratos]; OECD, *Environmentally Related Taxes in OECD Countries: Issues and Strategies* 21 (Paris: OECD, 2001) [OECD, “Environmentally Related”] at 10.

¹⁹⁰ This step is laid out in Braathen, *supra* note 188 as well as in other instrument choice discussions, for example, in OECD, “Environmentally Related”, *ibid* at 10.

for environmental issues in Canada) and political (the [lack of] political will for certain goals, instruments, etc). Consideration of context is a key feature of many instrument choice frameworks.¹⁹¹ Step iv is where a selection of legal instruments are proposed and Step v where one or more are chosen using various criteria – in this dissertation the focus is on efficiency, effectiveness and equity (3Es).

Comparing the general instrument choice framework presented in *Figure 3.2* with the ‘Analytical Framework for Selecting Instruments’ produced by the Treasury Board of Canada,¹⁹² (*Figure 3.3*) many similarities emerge.

Figure 3.3 – Analytical Framework for Selecting Instruments

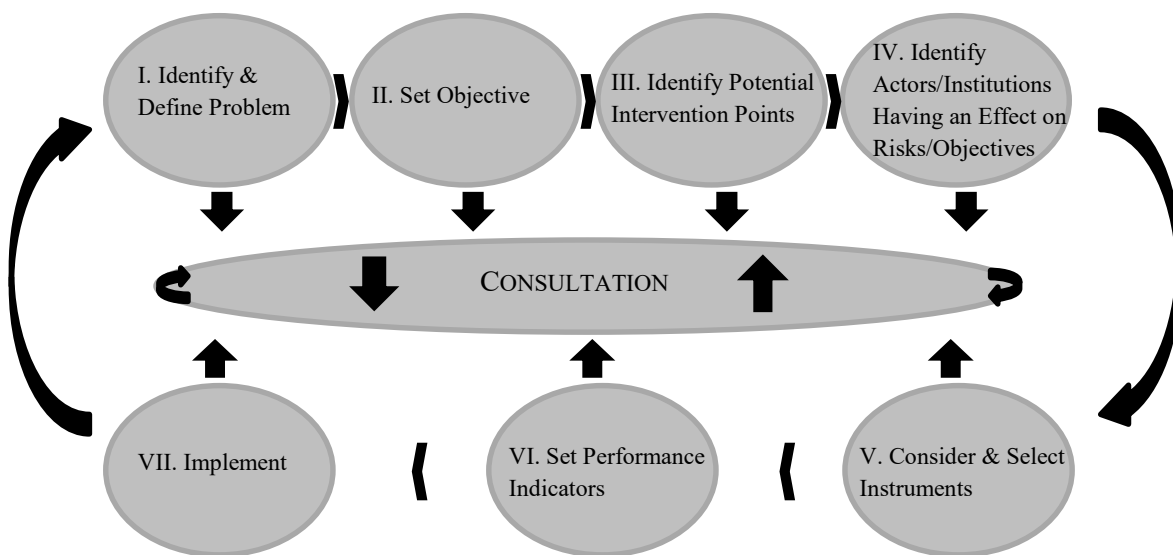


Figure based upon Treasury Board of Canada Secretariat, 2007, p. 10

¹⁹¹ Peter Bohm & Clifford S. Russell, “Comparative Analysis of Alternative Policy Instruments” in Allen V. Kneese & J. Sweeney, eds, *Handbook of Natural Resource and Energy Economics* (North Holland Publishing: Amsterdam, 1993) at 401-402

¹⁹² Treasury Board, “Assessing & Selecting, *supra* note 25 at 10.

What is particularly interesting in comparing these two instrument choice frameworks is that, though the Treasury Board's is more detailed and includes more steps, it is fairly easy to see how it fits within the more generalized framework based on Braathen's work. There are two exceptions to this and both center on the fact that the Treasury Board framework seems to be addressing broader policy cycle stages itself, instead of fitting within the policy cycle. That is, the first step of the Treasury Board framework is "Identify & Define the Problem" and is meant "to identify and define the key features and sources of the problem."¹⁹³ Further investigation of this framework finds that the authors discuss many of the same aspects as being important to this step as are highlighted in the agenda-setting stage of the policy cycle (discussed in section 3.2). Specifically, the Treasury Board framework discusses the importance of how a problem is defined¹⁹⁴ as do some authors writing about agenda-setting.¹⁹⁵ It seems plausible, then, that the first step in the Treasury Board framework takes a broader perspective than the general instrument choice framework presented in this thesis, but that this same step aligns well with agenda-setting in the policy cycle. A similar comparison can be made between Step VI in the Treasury Board framework and Stage 4 of the policy cycle – both are about implementation. Again, the general use instrument choice framework presented in this dissertation does not include an implementation stage because it is incorporated within the broader policy cycle.

Step II in the Treasury Board framework is labeled 'Set Objective' but refers, in actuality, to policy goals and outcomes.¹⁹⁶ Therefore, this step is well aligned with Step i in the generalized instrument choice framework which refers also to goals and the importance of ensuring decision

¹⁹³ *Ibid* at 12.

¹⁹⁴ *Ibid*.

¹⁹⁵ Dery, *supra* note 163.

¹⁹⁶ Treasury Board, "Assessing, Selecting", *supra* note 25 at 14.

makers are aware of what the goal is that the legal instrument chosen is trying to achieve. Further, an important part of the generalized instrument choice framework is context – it represents Steps ii and iii. The Treasury Board framework also considers context, although not explicitly. While policy, political, and legal contexts are well defined in the generalized framework as being important considerations when choosing an instrument for implementation, the Treasury Board identifies these in a slightly different way – through highlighting intervention points (Step III) and actors and institutions that can affect risks or objectives (Step IV). Though slightly different in their lay out, both frameworks consider the effect that factors external to the direct goal and instrument could have on the ultimate outcome of implementation.

In some ways, the contexts which Steps ii and iii in the general framework present can also be addressed in the considerations laid out in the Treasury Board's Step V. More specifically though, Step V of the Treasury Board framework (Consider and Select Instruments) aligns nicely with Steps iv and v in the general framework in that they are all about considering and evaluating instrument options as well as making the final selection. It is at this point in the general framework, after Step v (evaluate and choose) that instrument choice decision making is complete and the results are then fed back into the broader policy cycle for implementation (Stage 5 of the policy cycle).

The Treasury Board, as discussed above, includes implementation in its instrument choice framework (as Step VI) but prior to this it includes a step not found in either the general policy cycle or general instrument choice framework presented in this work. Step V in the Treasury Board framework is about setting performance indicators intended to help evaluate the

success of the chosen instrument(s) at achieving the desired outcome.¹⁹⁷ This is quite interesting and aligns well with both *ex-ante* and *ex-post* evaluation, briefly presented in section 3.2, and elaborated on in Chapters 5 and 6.

Table 3.1- Analysis of Generalized Policy Cycle and Instrument Choice Framework to Treasury Board Analytical Framework

<i>Generalized Policy Cycle</i>	<i>Generalized Instrument Choice Framework</i>	<i>Treasury Board Analytical Framework</i>
Stage 1: Agenda-Setting (specifically 1B)		Step I: Identify & Define Problem
Stage 2: Policy Formulation	Step i: Goal	Step II: Set Objective
	Step ii & iii: Policy, Legal/Political Context	Step III: Identify Potential Intervention Points
		Step IV: Identify Actors/Institutions Having an Effect on Risks/Objectives
	Step iv: Develop Instrument Options	Step V: Consider & Select Instruments
Stage 3: Decision Making	Step v: Evaluation & Choose	
Stage 4: Implementation		Step VI: Implement
Stage 5: Evaluation		Step VII: Set Performance Indicators (related in a way to Stage 5)

In summary, though the Treasury Board’s analytical framework differs slightly from the general instrument choice framework presented in this dissertation, and includes aspects of the broader policy cycle, the steps presented are very closely related and therefore findings presented in Chapters 5 and 6 can be also applied to the Canadian federal decision making context. Some examples of this will be shown throughout to strengthen this conclusion.

3.3.2 Normative Criteria for Successful Choice – the “what” of Instrument Choice

¹⁹⁷ *Ibid* at 22.

This research is interested in considering the criteria used to choose instruments and illustrating how green productivity measures can improve the decision making process and aid in making choices better aligned with broader government commitments to sustainable economic growth and intergenerational equity. As such, this section focuses on *what* to choose by discussing research which proposes various normative criteria for decision making. The section concludes with a discussion of those criteria which are most useful given Canadian legal commitments to sustainable economic growth and intergenerational equity. The focus of the discussion is on the criteria of efficiency, equity, and effectiveness – the 3E’s.

Perhaps the best way to begin this discussion is to present some of the commonly emphasized criteria for instrument choice. Table 3.2 gives an overview of what some authors have proposed as key criteria to evaluate the potential options.

Table 3.2 - Instrument Choice Evaluative Criteria

<i>Evaluative Criteria</i>	<i>Reference</i>
Environmental Effectiveness, Economic Efficiency, Distributional Impact; Political and Public Acceptability and Jurisdictional Compatibility; Trade and Investment Obligations ¹⁹⁸	Environment Canada’s Qualitative Screening of Management Tools, 2004-2005
Effectiveness of instrument in meeting environmental objective ¹⁹⁹	Hahn & Stavins, 1992
Instrument must address an incentive objective (efficient deterrence of environmental degradation) and a remedy objective (efficient clean-up of damages and proper compensation of victims) ²⁰⁰	Boyer & Porrini, 2002

¹⁹⁸ See *ibid* at 26-31; Environment Canada, 2004-2005 *Departmental Performance Report* (Ottawa: Government of Canada, 2005) online: http://publications.gc.ca/collections/collection_2012/sct-tbs/BT31-4-3-2005-eng.pdf at 115.

¹⁹⁹ Robert W. Hahn and Robert N. Stavins “Economic Incentives for Environmental Protection: Integrating Theory and Practice” (1992) Prepared for Presentation at the 1992 Meetings of the American Economic Association, New Orleans, Louisiana, January 5, 1992

²⁰⁰ Marcel Boyer and Donatella Porrini, “The Choice of Instruments for Environmental Policy: Liability or Regulation” in eds, Timoty Swanson *An Introduction to the Law and Economics of Environmental Policy: Issues in Intuitional Design, Volume 20* (Oxford: Elsevier Science Ltd, 2002) at 245- 267.

Economic efficiency, distributional impacts, flexibility, political acceptability ²⁰¹	Stratos Inc., 2003
Sustainable scale (biospheres finite limits), Just distribution (inter- and intra-generational equity), Efficient allocation (classic goal of economics) ²⁰²	Daly & Farley, 2004
Economists will argue that a direct price on the pollutant is the most efficient incentive for developing less emitting technologies (tax or trading) but, given the range of policies in place, other forces are obviously relevant (political appeal, distribution/equity, credibility problems with achieving goal – spillover, not actually inducing innovation etc.) ²⁰³	Fischer & Newell, 2008
Effective, efficient, politically acceptable ²⁰⁴	Gunningham, 2009
Effectiveness and efficiency ²⁰⁵	Gunningham & Sinclair, 1999
Though economic efficiency should be the goal, there may be important practical reasons for choosing between price or quantity based planning instruments, including: ideological, political, legal, social, historical, administrative, motivational, informational, monitoring, enforcing or others ²⁰⁶	Weitzman, 1974

While this is just a very small sample of the literature on instrument choice, common criteria clearly stand out. Perhaps the most widely proposed criteria are that the chosen instrument should be effective and efficient. Recall that Chapter 2 pointed out that though law and economics normative frameworks often focus solely (or at least heavily) on efficiency, this research is also interested in other normative goals – effectiveness of the instrument at achieving

²⁰¹ Stratos, *supra* note 189.

²⁰² Herman E. Daly & Joshua Farley, *Ecological Economics: Principles and Applications* (2004) [Daly & Farley] at 360.

²⁰³ Carolyn Fischer & Richard Newell, “Environmental and Technology Policies for Climate Mitigation” (2008) 55 *Journal of Environmental Economics and Management* 142-162 at 143.

²⁰⁴ Neil Gunningham, “Environment Law, Regulation and Governance: Shifting Architectures” (2009) 23: 2 *Journal of Environmental Law* 179-212 at 179.

²⁰⁵ Neil Gunningham & Darren Sinclair, “Integrative regulation: a principle-based approach to environmental policy” (1999) 24:4 *Law and Social Inquiry* 853-896.

²⁰⁶ Martin L. Weitzman, “Prices vs. Quantities” (1974) *Review of Economic studies* 477-491 at 479.

the policy goal is one of them. After all, an ineffective instrument cannot produce the desired policy aim, regardless of how efficient it is in theory. It seems realistic, then, that there is a hierarchy of criteria – without meeting at least a minimum level of effectiveness, efficiency and equity are unimportant. Further, since measuring effectiveness is sometimes difficult to gauge – as Chapter 7 will illustrate, it is here that green productivity measures can provide innovative advances.

Note that efficiency as the aim of an instrument, and efficiency as instrument selection criteria, can easily become confused. The argument about sustainability and intergenerational equity in Chapter 2 leads to a requirement for using natural capital efficiently (both eliminating dead-weight loss and encouraging substitution) so that the allocative efficiency of natural capital between generations is possible. In contrast, efficiency as an evaluation criterion for legal instruments is about achieving goals as cost-effectively as possible. Therefore, the aim of legal instruments is to increase efficiency of use of natural capital. However, in choosing instruments, how efficiently (cost-effectively) they achieve their aims is also important. That is, they should achieve their aims without using more resources than necessary. Therefore, an instrument might both increase natural capital efficiency, and do so efficiently.

Though not mentioned in all criteria lists, the idea of equity or distributional issues is also central to meeting Canadian commitments to intergenerational equity and therefore is a third normative criteria for instrument choice.²⁰⁷ Recall that in Chapter 2, one of the problems with Kaldor-Hick's efficiency was its focus on overall societal welfare, while ignoring the distribution of such welfare between individuals or generations. Often these principles may conflict – a more

²⁰⁷ Daly & Farley, *supra* note 202 at 360 include just distribution (relating to equity) as a goal for instrument choice; distributional impacts are one of five criteria proposed by Stratos to guide the process of selecting amongst instruments, see: Stratos, *supra* note 189 at 21.

equitable distribution may imply a solution that is less efficient at an aggregate level. Balancing these principles is a decision that needs to be made with reference to the specific context. Nonetheless, the same legal commitments to sustainability which motivate the focus on efficiency of use of natural capital also require that equity issues be taken into account. Therefore, equity is an important criterion in instrument choice.

Finally, a criterion often listed is political will or the political context. That is, the likelihood that an instrument will be implemented given the political impacts, popularity, or ideological considerations. This criterion is different than the others discussed, in that it is not a measure of how “objectively” desirable a policy is, but of how likely it is to be implemented. This is, of course, crucial – a policy which is not implemented will certainly fail in achieving its objectives. Though it may be the best option in terms of other criteria, having the instruments implementation stalled because of political pressure is not benefiting anyone or anything and therefore the ‘second best’ option is likely better to pursue. The most ‘effective’ way to undertake the legal instrument choice process may be to not propose options for the final decision making phase which have to be thrown out for political will reasons. In a sense, this is different than other criteria in that it is a veto – policies which fail the political will test may not be worth evaluating in terms of efficiency, effectiveness, and equality. While certainly important, in this framework the concerns about the political context are placed at an earlier stage in the instrument choice cycle (Step ‘ii’ in *Figure 3.1*) and not involved in the final decision making process where the normative criteria are applied.

Taking into consideration this discussion of instrument choice criteria, three are proposed for use where green productivity is applied in an instrument choice framework. Throughout this thesis, these criteria will be termed the 3E’s - efficiency, effectiveness, and equity. Further, it is

suggested here that they be the normative goals by which legal instruments should be judged when seeking to achieve overall goals of sustainable economic growth and intergenerational equity. Two things should stand out about these criteria – first, that they are reminiscent of principles 8/16, 11, and 3, respectively of the *Rio Declaration*.²⁰⁸ Secondly, that measures of green productivity are able to provide information that address all three. Using these three criteria as a set is not a new proposal; certainly it has been done (alone or with other criteria) by a number of authors in the past.²⁰⁹ In this situation, though, their use is proposed because they are the most appropriate for analysing legal instruments to improve sustainable economic growth and achieve intergenerational equity.

3.4 Chapter Summary

In this chapter two different, but connected, frameworks were presented. They structure and inform the application of green productivity into law and public policy decision making. A general policy cycle was detailed along with a broadly applicable version of an instrument choice framework. The Canadian government Treasury Board's 'Analytical Framework for Selecting

²⁰⁸ Rio Declaration, *supra* note 29 at Principle 8, 16, 11, and 3. Principle 8 states "To achieve sustainable development and a higher quality of life for all people, States should reduce and eliminate unsustainable patterns of production and consumption and promote appropriate demographic policies," Principle 16 that "National authorities should endeavour to promote the internalization of environmental costs and the use of economic instruments, taking into account the approach that the polluter should, in principle, bear the cost of pollution, with due regard to the public interest and without distorting international trade and investment," Principle 11 notes that "States shall enact effective environmental legislation. Environmental standards, management objectives and priorities should reflect the environmental and developmental context to which they apply. Standards applied by some countries may be inappropriate and of unwarranted economic and social cost to other countries, in particular developing countries," and Principle 3 states that "The right to development must be fulfilled so as to equitably meet developmental and environmental needs of present and future generations."

²⁰⁹ Mark Winfield, "Policy Instruments in Canadian Environmental Policy" in Debora L. VanNijnatten & Robert Boardman, eds., *Canadian Environmental Policy and Politics: Prospects for Leadership and Innovation* (Don Mills, Ontario: Oxford University Press, 2009) at 53-54; Lori Snyder Bennear & Robert.N. Stavins "Second-Best Theory and the Use of Multiple Policy Instruments" (2007) 37(1) *Environ Resource Econ* 111 at 112; Stephen Dovers & Robin Connor, "Institutions and Policy Change for Sustainability" in Benjamin J. Richardson & Stephan Wood, eds., *Environmental Law for Sustainability* (Portland: Hart Publishing, 2006) at 29-30; Nathalie Chalifour, "Ecological Economics, Sustainable Land Use and Policy Changes" in Nathalie Chalifour *et al.* eds., *Land Use for Sustainable Development* (New York: Cambridge University Press, 2007) at 548.

Instruments' was compared, primarily, to the instrument choice framework (though, as was shown, there is also small overlap with the broader policy cycle). While some differences were found between the general framework and the Treasury Board framework, an integration of steps was not difficult and will be useful in discussing the application of green productivity for both the Canadian federal government, as well as a wide array of other governments and actors.

Having examined the various policy cycle stages, the main application of green productivity measures is argued to be in the design and evaluation of legal instrument options (found as part of the instrument choice framework and within Stages 2 and 3 of the policy cycle). This will be discussed further in Chapter 6. Chapter 5 will discuss the application of green productivity as a broad concept in Stage 1 of the policy cycle – agenda-setting - and some connections are also made to green productivity measures in the *ex-post* evaluation stage (5).

Instrument choice was also discussed in this chapter, with a particular focus on criteria for evaluating and choosing instruments. Three specific criteria were suggested – efficiency, effectiveness, and equity – as most appropriate for achieving government commitments to sustainable economic growth and intergenerational equity. Throughout the remainder of this dissertation, it is these three evaluative criteria (the 3E's) which will be used in discussions of instrument choice. It is also in this context that measures of green productivity will be proposed as useful to decision makers. That is, the additional information provided by the various measures will be considered with regards to what they can add to furthering the evaluation of efficient, effective and equitable.

4. Concepts and Terminology

4.1 Introduction

This chapter lays out the economic concepts – primarily green productivity - which will be used throughout the remainder of the thesis. It goes beyond defining these concepts, though, and also develops a standardized terminology for green productivity research which is based on an extensive literature review and the criteria of consistency, conceptual accuracy, and broad acceptance.²¹⁰ Given the inconsistencies and conceptual discrepancies across disciplines, this set of ‘best practice’ terminology is crucial²¹¹ and is one contribution that this dissertation makes to the literature.

This chapter begins by discussing the concepts of capital and natural capital. This is important given that the focus of green productivity measures is the inclusion of natural capital within conventional calculations. The second half of the chapter presents conventional measures of productivity and introduces their ‘greened’ counterparts. Three green productivity measures are presented, including natural resource productivity (NRP) (a partial productivity measure), environmentally adjusted productivity (EAP) (MFP adjusted to include both desirable and undesirable outputs), and the impact that natural capital has on the MFP (NCR). NRP and EAP are presented as important alternatives to more conventional productivity measurement, given the need for accurate information about the efficiency with which natural capital is being used.

²¹⁰ F. García, *et al.*, “Towards a consistent terminology for software measurement” (2006) 48:8 Information and Software Technology 631–644 at 632; R. Garcia & R. Calantone, “A critical look at technological innovation typology and innovativeness terminology: a literature review” (2002) 19:2 The Journal of Product Innovation Management 110–132 at 111.

²¹¹ This research has been published in Laurel Besco, “Green Productivity: Clarifying Terminology and Concepts” (2014) 6:4 International Journal of Sustainable Economy 406–425.

Further, a comprehensive survey of studies related to EAP is also presented – perhaps the first time this rather disparate research has been brought together.²¹²

4.2 Capital and Natural Capital

Capital is central to measures of productivity; therefore defining natural capital is a key part of the discussion about green productivity. Since at least the mid 1850's, there has been discussion about the challenges posed by the many definitions of capital.²¹³ Over the years, different academics have noted the difficulty in defining capital: Irving Fisher, in 1896, said that “of economic conceptions few are more fundamental and none more obscure than capital.”²¹⁴ More than a century later Peter Victor echoed this sentiment noting the problem still existed and that “there is no single theory of capital to which all economists subscribe.”²¹⁵ *Table 4.1* demonstrates some differing views of what capital is or is not, how it is formed, and how it can be used.

Table 4.1 - Definitions of Capital

Definition	Author/Citation
“The capital of an economy is its stock of real goods, with power of producing further goods (or utilities) in the future” ²¹⁶	El Serafy, 2013
capital is “anything that permits people to work more productivity than they otherwise might” ²¹⁷	Hahnel, 2011
“capital is to be regarded as a stock of goods which are left over from or cannot be	Knies, 1885

²¹² Through reviewing this literature, the author has been unable to find a recent place where a similar comprehensive review has been presented. Tyteca, *supra* note 24 provides a brief overview but this is now almost 20 years out of date.

²¹³ Nassau William Senior, *Political Economy Encyclopedia Metropolitana*, vol. vi. (Glasgow: J. J. Griffin & co., 1850) [Senior] at 153.

²¹⁴ Irving Fisher, “What is Capital?” (1896) 6:24 *The Economic Journal* 509 [Fisher] at 509.

²¹⁵ Peter Allen Victor, “Indicators of Sustainable Development: Some Lessons from Capital Theory” (1991) 4 *Ecological Economics* 191 at 192.

²¹⁶ Salah El Serafy, *Macroeconomics and the Environment: Essays on Green Accounting* (Cheltenham, UK: Edward Elgar Publishing, 2013) [El Serafy] at 43.

²¹⁷ Hahnel, “Green Economics”, *supra* note 22 at 41.

employed for the satisfaction of current present wants and therefore are free to be applied to economic employment at another time” ²¹⁸	
Capital is “all things other than land, which yield income...” ²¹⁹	Marshall, 1961
“the capital of a country consists of those portions of the produce of industry existing in it, which may be directly employed either to support human beings or to facilitate production” ²²⁰	McCulloch, 1849
“capital is defined as the sum total of nonhuman assets that can be owned and exchanged on some market” ²²¹	Piketty, 2014
“capital is that part of the wealth of a country which is employed in production and consists of food, clothing, raw materials, machinery, &c. necessary to give effect to labour” ²²²	Ricardo, 1817
Capital is “essentially monetary, meaning either actual money, or claims to money, or some goods evaluated in money” ²²³	Schumpeter, 1954
“Capital is an article of wealth, the result of human exertion, employed in the production or distribution of Wealth” ²²⁴	Senior, 1849

The above *Table 4.1* demonstrates the very fragmented nature of capital definitions and illustrates some of the challenges with extending the concept to *natural* capital. Certain definitions leave no room for natural capital’s inclusion while others are more broadly defined and it is clear that their framework is more flexible. For example, that “capital is that part of the wealth of a country which is employed in production”²²⁵ allows a place for natural capital to be seen. On the other

²¹⁸ Karl Knies, *Das Geld*, 2nd ed, (Berlin: Weidmann, 1885) at 68070.

²¹⁹ Alfred Marshall, *Principles of Economics*, 9th ed (London: Macmillian, 1961) at 56.

²²⁰ J.R. McCulloch, *The Principles of Political Economy*, 4th ed, (Edinburgh: William Blackwood and Sons, 1849) at 100.

²²¹ Piketty, *supra* note 92 at 46.

²²² David Ricardo, *On the Principles of Political Economy and Taxation*, 2nd ed, (London: John Murray, 1817) [Ricardo] at 93-94.

²²³ Joseph A. Schumpeter, *History of Economic Analysis* (Oxford and New York: Oxford University Press, 1954) [Schumpeter] at 322-323.

²²⁴ Senior, *supra* note 213 at 89.

²²⁵ Ricardo, *supra* note 222 at ss. 37.

hand, the requirement for human reproducibility, laid out in many definitions of capital,²²⁶ is one of the biggest stumbling blocks for the general acceptance of the term ‘natural capital.’

Interestingly, natural capital is not the only type of capital which has been challenged by definitional issues. As is illustrated above, there are some definitions which preclude anything but financial capital²²⁷ while others include physical materials that are produced or used to produce.²²⁸ Clearly these different definitions are not completely compatible and yet they are both widely accepted as definitions of capital. So, the fact that natural capital does not fit the criteria of every definition need not be seen as a fatal problem. Further, the concept of natural capital can fit into many other assumptions and requirements of capital. For example, natural capital aligns with the basic assumptions about capital stock and flows as well as with the Hicksian definition of income,²²⁹ the concept of reduction in stock reducing productive capacity,²³⁰ and with the central idea that capital is “anything that permits people to work more productively than they otherwise might.”²³¹

4.2.1 Natural Capital

A number of leading scholars distinguish between different types of capital, and natural capital is now a relatively common classification.²³² Ekins, for example, divides capital into manufactured,

²²⁶As discussed in Friedrich Hinterberger, Fred Luks & Friedrich Schmidt-Bleek, “Material flows vs. ‘natural capital’ What makes an economy sustainable?” (1997) 23 *Ecological Economics* 1 [Hinterberger et al, “Material flows”] at 7; Senior, *supra* note 213 at 153.

²²⁷Schumpeter, *supra* note 223 at 322-323.

²²⁸Hinterberger et al, “Material flows”, *supra* note 226 at 6.

²²⁹The Hicksian idea of income, as described by Hinterberger et al, “Material flows”, *supra* note 226 at 2 is the idea that “non-declining capital [i]s a precondition for maintaining positive income flows over time.” Hicks himself spends a section of his 1946 *Value and Capital* publication describing this concept. J.R. Hicks, *Value and Capital: An Inquiry into some Fundamental Principles of Economic Theory*, 2nd ed, (Oxford: Oxford University Press, 1946) at 171-181.

²³⁰Hinterberger et al, “Material flows”, *supra* note 226 at 2.

²³¹Hahnel, “Green Economics”, *supra* note 22 at 41.

²³²Paul Ekins, “A four-capital model of wealth creation” in Paul Ekins & M. Max-Neef, eds, *Real-Life Economics: Understanding Wealth Creation* (London/New York: Routledge, 1992) [Ekins, “A four-capital”] at 147-155;

human, social/organisational and natural.²³³ The UNIDO provides two definitions of what capital includes which are quite useful for linking traditional measures of capital to measures of natural capital. They indicate that from an economics perspective, capital is defined quite narrowly to include only manufactured or physical capital and human-made capital-, while on the other hand, from a sustainability perspective, capital is broadly defined to include not only manufactured, physical and financial but also human, social and natural capital.²³⁴ Nonetheless, the term is somewhat recent, perhaps used most prominently in 1990 by Pearce and Turner's book called *Economics of Natural Resources and the Environment*.²³⁵ Like its parent term 'capital', natural capital too has a variety of definitions (see *Table 4.2*).

Table 4.2 - Definitions of Natural Capital

Definition	Author/Citation
"Natural Capital comprises Earth's natural assets (soil, air, water, flora and fauna), and the ecosystem services resulting from them, which make human life possible" ²³⁶	Mulder <i>et al.</i> , 2012 (The Natural Capital Declaration Roadmap)
Natural capital is "the stock of natural and environmental resources" ²³⁷	Olewiler, 2002
Natural capital is "an economic metaphor for the limited stocks of	The Economics of Ecosystems and Biodiversity

Hinterberger et al, "Green growth", *supra* note 15 at 24, 65; Fikret Berkes & Carl Folke, "A systems perspective on the interrelations between natural, human-made and cultural capital " (1992) 5 *Ecological Economics* 1-8.

²³³ Ekins, "A four-capital", *supra* note 232 at 147-155.

²³⁴ Hinterberger et al, "Green growth", *supra* note 15 at 24, 65.

²³⁵ Pearce and Turner "Economics of Natural Resources and the Environment" (London: Harvester Wheatsheaf, 1990).

²³⁶ I. Mulder et al., *The NCD roadmap: 4 steps to implement the Natural Capital Declaration for the financial Industry* (Geneva: UNEP FI, Global Canopy Programme, and FGVces, 2012) online: <http://www.naturalcapitaldeclaration.org/wp-content/uploads/2012/04/NaturalCapitalDeclaration.pdf> [Mulder *et al*] at 1.

²³⁷ Nancy Olewiler, "Natural Capital, Sustainability and Productivity: An Exploration of the Linkages" in Keith Banting, Andrew Sharpe and France St-Hilaire, eds, *The Review of Economic Performance and Social Progress* (Montreal: Institute for Research on Public Policy, 2002) [Olewiler] at 118.

physical and biological resources found on earth” ²³⁸	
Natural capital is “natural assets in their role of providing natural resource inputs and environmental services for economic production” ²³⁹	United Nations, 1997
Natural capital is “the parts of the natural environment that produce value to people” ²⁴⁰	United Kingdom Natural Capital Committee

While the phrasing of these definitions are all slightly different, generally speaking, they conclude that natural capital is the stock of natural and environmental resources or natural and environmental assets, which produce beneficial and valuable (directly or indirectly) goods and services for the economy or humanity in general. This is the understanding which will guide discussions of natural capital in the remainder of this thesis. To improve how the understanding of this concept, it is also helpful to lay out those specific aspects which comprise natural capital. Olewiler states that natural capital is made up of

natural resource capital (stocks of renewable and non-renewable resources); ecosystems or environmental capital (systems that provide essential goods and services); and land (the space in which human activities take place)²⁴¹

These specific aspects are fairly well accepted; the OECD in their description of natural capital makes a very similar statement – that it is comprised of natural resource stocks, land and ecosystems.²⁴²

²³⁸ Glossary of Terms, The Economics of Ecosystems and Biodiversity, online: <<http://www.teebweb.org/resources/glossary-of-terms/>>

²³⁹ *Glossary of Environment Statistics*, Studies in Methods, Series F, No. 67 (New York: United Nations, 1997).

²⁴⁰ *Natural Capital Committee*, Online: UK Department for Environment, Food and Agriculture <<http://www.naturalcapitalcommittee.org/natural-capital.html>>.

²⁴¹ Olewiler, *supra* note 237 at 118.

²⁴² *Supra* note 239.

In addition to the core definitions of capital and natural capital, there are several key conceptual aspects of capital which have implications for green productivity measures (and what they measure) and therefore must be addressed before moving to a discussion about green productivity. The first is the distinction between stock and flows. It is widely accepted that capital is a stock which “possesses the capacity of giving rise to flows of goods and/or services.”²⁴³ Fisher’s distinction allows an understanding of how these ideas are relevant to the natural world. He notes “the understanding we have of traditional capital is that the overall stock of wealth is considered the capital and the income which this capital produces is the flow of wealth.”²⁴⁴ So, stock is considered capital and the flows produced by the stock are considered income. When referring to human capital, labour is the flow, which is typically measured as number of hours worked. In the environmental sense the stock of natural capital is made up of the stocks of natural resources, ecosystems, and land. The flows of wealth are the aspects of the resource stocks, for example, which are extracted and used to improve human well-being through their employment in economic production, waste assimilation, or aesthetics (think timber or wetland filtration services).

The recent *Natural Capital Declaration* furthered this discussion and compared profits from financial capital in a more traditional capital framework to future flows of timber from a stock of forest.²⁴⁵ The clear cohesiveness of natural capital and the framework of stock and flows has been the focus of Herman Daly’s pressure to convey that natural capital should be treated in the same way as produced capital.²⁴⁶ The purpose behind this drive is very much at the centre of

²⁴³ Paul Ekins et al., “A framework for the practical application of the concepts of critical natural capital and strong sustainability” (2003) 44:2-3 *Ecological Economics* 165 at 166.

²⁴⁴ Fisher, *supra* note 214.

²⁴⁵ Mulder et al, *supra* note 236 at 5.

²⁴⁶ Hahnel, “Green Economics”, *supra* note 22 at 38.

this research as well – so that natural capital can be included in economic measures across the board – in this case, specifically, in productivity measurement. The different green productivity measures (discussed below) incorporate different aspects of natural capital so this distinction between stocks and flows is important. Specifically, NRP considers flows as inputs into production and EAP uses changes in undesirable outputs as proxies for changing impacts on the stock of natural capital.

As has been illustrated in this section, there are difficulties in extending the definition of capital to include natural capital, but these are not insurmountable. The biggest challenge is that many traditional definitions of capital include a requirement for human reproducibility which is not a characteristic of natural capital. That said, other definitions do not have such a requirement - natural capital fits well, for example, with El Serafy's definition of capital as the "stock of real goods, with power of producing further goods (or utilities) in the future."²⁴⁷ Further, the term natural capital has been accepted by many academics from the economics field and beyond, international organizations such as the OECD and the United Nations, and by a variety of governments around the world. As well, natural capital fits the characterization of a stock which produces flows, something which is fundamental to capital definitions. As will become clear in the second section of this chapter, the distinction between stock and flow is important for correctly conceptualizing productivity measures.

4.3 Conventional Productivity and Green Productivity

If natural capital can be understood as a type of capital, then it should be able to be incorporated into productivity measures. The first step, though, is to understand conventional productivity.

²⁴⁷ El Serafy, *supra* note 216 at 43.

This section will first provide a concise description of productivity, how it has developed over time, and its importance in economic forecasting and policy setting. Next, three measures of green productivity will be presented. Each sub-section (based on one measure of green productivity) will present a framework for a different type of green productivity, provide terminology recommendations, and discuss the connections between the measure and the dual goals of sustainable economic growth and intergenerational equity, as well as provide an overview of past research and/or policy work in the sub-field.

4.3.1 Conventional Productivity

The economic measure of productivity, at its most basic, estimates the “efficiency with which the economy transforms inputs into outputs”²⁴⁸ or “how effectively the economies[’] resources are translated into the production of goods and services.”²⁴⁹ In its simplest form, productivity can be represented as is shown in *Equation 4.1*.

Equation 4.1 – Generic Productivity

$$Productivity = \frac{Y}{X}$$

where Y is output and X is input.

In productivity measurement, outputs can be represented as the number of units of a good or service produced or as the GDP produced from the sale of these goods and services. Generally

²⁴⁸ Tarek M. Harchaoui, Dmitry Kabrelyan & Rob Smith, *Accounting for Greenhouse Gases in the Standard Productivity Framework* (Ottawa: Statistics Canada, 2002) at 1.

²⁴⁹ Richard G. Harris, “Determinants of Canadian Productivity Growth: Issues and Prospects” (Delivered at the CSLS-Industry Canada Conference on Canada in the 21st Century: A Time for Vision, Ottawa, 17-18 September 1999) (September 17-18, 1999) online: Centre for the Study of Living Standards < <http://www.csls.ca/events/sept1999/harre.pdf> > at 2.

speaking, inputs are typically one or more of labour, capital, energy, materials, services and/or intermediates.²⁵⁰

Productivity can be calculated as a single, or partial, productivity measure (Equation 4.2), which uses only one input against total output, or as a more complex measure which includes more inputs against total output, otherwise known as total or multifactor productivity (Equation 4.4).

Equation 4.2 – Basic Partial Productivity

$$PP = \frac{Y}{\text{Specified Input}}$$

Equation 4.3 – Labour Productivity

$$LP = \frac{Y}{\text{Labour Input}}$$

where PP is partial productivity, LP is labour productivity and Y is output.

Equation 4.4 – Multifactor Productivity

$$Y = AF(K, L)$$

$$A = \frac{Y}{F(K, L)}$$

²⁵⁰ Anthony D. Apostolides, *A Primer on Multifactor Productivity: Description, Benefits and Uses. Research and Innovative Technology* (Washington D.C.: Administration Bureau of Transportation Statistics, 2008) [Apostolides].

Where Y represents output, A is the residual, F is the production function, K is capital and L is labour.²⁵¹

In the Canadian context, productivity measurement has evolved over the decades, in part due to changing ideas in the economics literature, data availability and demand for different types of information.²⁵² Labour productivity (calculated as output over labour input) began as a table for Statistics Canada not long after the Second World War.²⁵³ For decades productivity was reported solely as labour productivity which is still the most widely reported measure today.²⁵⁴ More recent developments have included the publication of MFP estimates – in Canada the MFP program was launched in 1987.²⁵⁵

Labour productivity is measured as output produced per unit of a given input. Generally speaking, this is calculated using hours worked (see *Equation 4.3*). Partial productivity measures, though, suffer from one main challenge – they do not provide a complete picture of the production process since their framework only places part of the total production inputs (for example, labour) against total outputs.²⁵⁶ And since labour (or any other single input type) is not the sole input of a production process which has an impact on output variation, there is a limit to what results can tell us. From an analytical sense, it is important to understand that the results of

²⁵¹ Depending on the circumstances of the calculation, other inputs are also included (for example, energy, services and intermediates).

²⁵² Harchaoui et al, “Appendix 1”, *supra* note 20 at 143.

²⁵³ *Ibid.*

²⁵⁴ This is obvious if one looks at national data as well as numbers produced by international organizations (for example, the OECD) which still report both labour and multifactor productivity numbers. See also, Gordon Theissen, “*The Canadian Economy, Productivity and the Standard of Living*” (Remarks delivered to the Fraser Institute, Vancouver, 6 December 1999) at 3.

²⁵⁵ John R. Baldwin & Wulong Gu, *Multifactor Productivity Measurement at Statistics Canada* (Ottawa: Statistics Canada Economic Analysis Division Ottawa, 2013) at 5; Charles R. Hulten, “Total Factor Productivity: A Short Biography” in Charles R. Hulten, Edwin R. Dean & Michael J. Harper, eds, *New Developments in Productivity Analysis* (Chicago: University of Chicago Press, 2001) [Hulten] at 21.

²⁵⁶ Vivian Chen et al., “Recent Productivity Developments in the World Economy: An Overview From the Conference Board Total Economy Database” (2010) 19 *International Productivity Monitor* 6 [Chen et al].

a partial productivity measure (such as labour productivity) reflect not only the change in how efficiently the input being measured (for example, labour) is used, but also changes in other inputs which are not the focus of measurement.²⁵⁷ For example, changes in labour productivity may be a consequence of increased capital per worker,²⁵⁸ but the source of these changes would be unclear because capital is not the factor of production studied. For this reason, labour productivity (and others which measure one input against total output) is termed a partial (or single-factor) productivity measure. Despite the challenges to labour productivity, many still consider it the “preferred productivity measure” as it requires less data than the alternative measure of MFP²⁵⁹ and it has the status as “one of the most fundamental measures of economic success.”²⁶⁰

MFP is a more comprehensive measure of productivity and, unlike partial measures, it incorporates a bundle of inputs (labour, capital, energy, services etc.) and compares them against total economic outputs to get a measure which provides more detail (*Equation 4.4* presents the MFP equation). A production function is used to “show[] how the inputs are combined to produce output.”²⁶¹

Once the change in inputs is compared against the change in outputs, any leftover increase/decrease in outputs (that is, a change in outputs not accounted for by the change in inputs) is defined as the change in MFP (either growth or decline) and is called the residual.²⁶²

²⁵⁷ Harchaoui et al, “Appendix 1”, *supra* note 20 at 144.

²⁵⁸ Apostolides, *supra* note 250.

²⁵⁹ Barbara M. Fraumeni, “Human Capital Productivity: A New Concept for Productivity Analysis” (2012) 20 International Productivity Monitor 20 at 21.

²⁶⁰ Tim Jackson & Peter Victor, “Productivity and work in the ‘green economy’ some theoretical reflections and empirical tests” (2011) 1 Environmental Innovation and Societal Transitions 101 at 101.

²⁶¹ N. Gregory Mankiw, *Principles of Macroeconomics*, 6th ed (South-Western Cengage Learning: Mason, OH, 2012) at 243.

²⁶² Robert Repetto, “Measuring the True Productivity Gains from Environmental Technology Improvements” in Dora Marinova, David Annandale & John Phillimore, eds, *The International Handbook on Environmental*

This residual is generally considered to be a consequence of technological progress which shifts the production function (see *Figure 4.1*).²⁶³ More recent research has indicated that the changes in residual are not limited to technological progress²⁶⁴ and things such as organizational innovation,²⁶⁵ market power, increasing returns, external technical complementarities, chronic excess capacity, unmeasured fluctuations in work effort and hours, errors in measuring capital or output, and monopsony power in the labour market can also impact the shift.²⁶⁶

MFP can also be presented graphically (*Figure 4.1*). A shift from isoquant A to isoquant B represents an increase in the amount of output being produced with the same amount of inputs. This shift represents a change in MFP. Importantly, this is different than a change in partial productivity, which is illustrated by movement from point 'I' to 'II' on isoquant B. Although increases in MFP might lead to changes in partial productivity, those changes also might simply involve substituting one kind of input for another. As will become clear later, these different measures of productivity are useful in different ways, depending on the kind of information and analysis that is needed.

Technology Management (Cheltenham, UK: Edward Elgar Publishing, 2006) [Repetto, "Measuring the True Productivity"] at 293

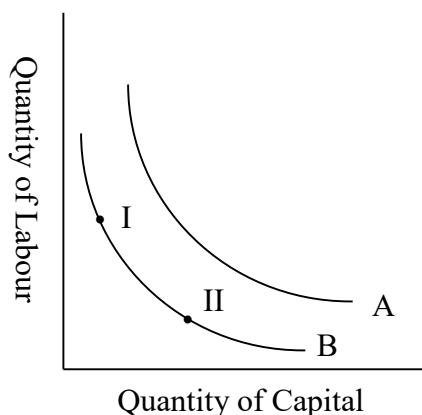
²⁶³ Harchaoui et al, "Appendix 1", *supra* note 20 at 144.

²⁶⁴ Hulten, *supra* note 255 at 8.

²⁶⁵ Repetto, "Measuring the True Productivity", *supra* note 262; Harchaoui et al, "Appendix 1", *supra* note 20 at 144-45.

²⁶⁶ Robert. E. Hall, "Market Structure and macroeconomic fluctuations" (1986) 2 Brookings Papers on Economic Activity 265.

Figure 4.1 – Changes in Multifactor Productivity and Labour Productivity



While not the only factor impacting the economic growth and welfare of a nation, productivity estimates and analyses help with understanding things such as standard of living, economic prosperity, and how competitive a country may or may not be.²⁶⁷ As discussed in Chapter 1, these characteristics represent many of the reasons why productivity is an important economic measure and continues to be a priority for many governments.²⁶⁸ Crucially, the different types of productivity measures provide related, but distinct, pieces of information about efficiency of use, and the economic effects of other factors, such as innovation and technological improvements, and therefore are useful at different stages of the policy process.

4.3.2 Green Productivity

Having set out conventional measures of productivity, the focus now turns to the ways these can be adapted to include or account for natural capital. Green economic and accounting measures have gained prominence over the past few decades as there is an increasing understanding that by largely ignoring natural capital, conventional measures are incomplete.²⁶⁹ This includes a

²⁶⁷ Sushma Kumar, “Environmentally Sensitive Productivity Growth: A Global Analysis using Malmquist-Luenberger Index (2006) 56 *Ecological Economics* 280 [Kumar] at 282.

²⁶⁸ See Chapter 1 for more background on the importance of productivity.

²⁶⁹ Robert Repetto et al., *Wasting Assets: Natural Resources in the National Income Accounts* (Washington D.C.: World Resources Institute, 1989) [Repetto, “Wasting Assets”] at 2.

substantial literature on environmentally adjusted accounting and other economic measures, such as green GDP and green national accounts. Green productivity is a more recent development in this area of research, one which aims to better understand and account for the role of the natural environment in production processes.

In this thesis, the term ‘green productivity’ is used to indicate all productivity measures which incorporate natural capital. The main justification for this terminology is that it is a natural extension of terms such as green accounting and green GDP, which are two commonly used and accepted phrases indicating work that integrates natural capital into accounting and economic measures.²⁷⁰ The UNIDO specifically defines ‘green’ concepts as promoting the idea that “economic development can progress with lower resource use and environmental impacts while increasing human well-being through providing new job opportunities, strengthening social cohesion and reducing inequalities.”²⁷¹ It seems clear that green productivity measures have the same goals.

Green productivity, as a term, seems to have made its initial appearance at the 1992 Rio Earth Summit where it was presented as a strategy by the Asian Productivity Organization (APO).²⁷² While the specific definition and goals of green productivity espoused by the APO are not explicit in indicating the same things this paper classifies as aspects of green productivity research, the APO definition and strategy is sufficiently broad for the use of the term to be considered in a similar line of thought.²⁷³ A paper by Mohanty and Deshmukh further indicates the broad nature of the term when they note that “green productivity signifies ... the need for

²⁷⁰ Kumar, *supra* note 267.

²⁷¹ Hinterberger et al, “Green Growth”, *supra* note 15.

²⁷² Tom Tuttle & John Heap, “Green Productivity: Moving the Agenda” (2008) 57:1 International Journal of Productivity and Performance Management 93.

²⁷³ *Ibid.*

higher output with the mandate to protect the environment.”²⁷⁴ This definition is sufficiently wide and it is therefore easy to see how a variety of research looking at partial and MFP measures, which consider inputs and outputs related to natural capital, could be included. Further, the OECD has begun to use the term ‘green productivity’ in its research on productivity and the natural environment.²⁷⁵

4.3.2.1 Natural Resource Productivity

Having defined green productivity as the general term for measures of productivity adjusted to include or account for natural capital in some form, the focus shifts next to more specific measures. The first measure uses partial productivity frameworks as a base and substitutes natural resource flows as the inputs of the production processes which are measured. This section begins by clarifying terminological inconsistencies, introduces the idea of natural resource productivity (NRP), and provides some examples of past research which uses similar methodologies. Two key arguments are made about the importance of measuring NRP and its connection to sustainable economic growth and intergenerational equity. Specifically, discussion will center, first, on how the shift in understanding of natural capital as scarce makes using it efficiently an important goal, and, second, on the relationship between NRP and long term living standards. This section concludes with a discussion about the work that the OECD and the European Union have been doing, and continue to do, on the topic of resource productivity.

4.3.2.1.1 Natural Resource Productivity Terminology

²⁷⁴R.P Mohanty & S.G Deshmukh, “Managing Green Productivity: A Case Study” (1999) 48:5 Work Study 165 [Mohanty & Deshmukh] at 165.

²⁷⁵ Nicola Brandt, “Green Productivity” (Presentation delivered at the OECD Green Growth and Sustainable Development Forum, Paris, France, 23 November 2012).

Natural resource productivity is the term used throughout this dissertation for partial productivity measures focused on natural capital. While there are many possible versions of this measure, they all evaluate the efficiency with which natural resources (single or total) are used as inputs in production processes. The focus is on the extraction and use of virgin natural resources and does not consider recycled materials, primarily, because policy and legal instrument implications may be quite different and therefore need to target different areas of focus.

NRP is similar to, but more specific than, resource productivity which is well accepted and acknowledged in the economics field as “describe[ing] the relation between economic outputs in monetary terms (Y, numerator) and a physical indicator (M, denominator) for material or resource input.”²⁷⁶ Resource productivity as a term is also used by several large research and policy organizations, such as the OECD and the European Union, but sometimes the boundaries of these frameworks are inconsistent. For example, the OECD’s 2011 publication entitled “Material Resources, Productivity and the Environment” defined resource productivity in a somewhat broad sense. They stated that resource productivity “is understood to contain both a *quantitative* dimension (e.g. the quantity of output produced with a given input of natural resources) and a *qualitative* dimension (e.g. the environmental impacts per unit of output produced with a given natural resource input)”.²⁷⁷ The first part of this definition – the ‘quantitative dimension’ - is in line with what is well known as resource productivity. The second, though, seems to introduce another dimension to this term, which requires a quite different methodological approach. While important in its own right, this element is more in line with the second type of green productivity measure presented in this dissertation – EAP - which

²⁷⁶ Sören Steger & Raimund Bleischwitz, “Decoupling GDP from resource use, resource productivity and competitiveness: a cross-country comparison”, in Raimund Bleischwitz, Paul Welfens & Zhong Xiang Zhang, eds, *Sustainable Growth and Resource Productivity*, (Sheffield: Greenleaf Publishing, 2009) 172 at 173.

²⁷⁷ *Ibid.*

modifies the numerator to include undesirable outputs. The main difference identified in this dissertation between NRP and resource productivity is that the latter includes all material use (virgin, recycled, etc.) and the former does not.

In providing recommendations for consistent terminology, it is important to look at other terms which have been used to describe partial productivity frameworks that measure the use of natural capital flows, and therefore which may confuse academics and decision makers. The term ‘natural capital productivity’ has also been employed to describe how efficiently the flow material from natural capital is being used as an input.²⁷⁸ This term, however, is misleading, and from a purely economic perspective, is not accurate. This inaccuracy stems from the use of “natural *capital*” as the object of the productivity calculation. Consider the following. The total accumulated capital at a point in time is called the *stock* of capital - from which comes goods and services, the *flows*.²⁷⁹ It is these flows which are used as inputs in economic production and which are measured by partial productivity. For example, human capital is the stock from which labour flows and therefore the partial productivity measure which looks at the amount of economic output per unit of labour input is called labour productivity. Natural capital, then, is the stock from which natural resources and ecosystem goods and services flow, and so the partial productivity term used should refer to the flows from natural capital, such as natural resources or ecosystem goods and services, and not the overall stock (natural capital). There are many individual and more general terms which can be used for these partial productivity measures –

²⁷⁸ For example, David Batker et al., *A New View of the Puget Sound Economy: The Economic Value of Nature's Services in the Puget Sound Basin* (Seattle: Earth Economics, 2008) online: Earth Economics <http://www.floods.org/ace-files/documentlibrary/committees/A_New_View_of_the_Puget_Sound_Economy.pdf>; Daly, “Operationalising Sustainable Development”, *supra* note 104; Bruce Ledewitz, “The Constitutions of Sustainable Capitalism and Beyond” (2002) 29:2 BC Env'tl Aff L Rev 229; Yan-ying & Yi-jun Yuan, “Conditions of Sustainable Economic Growth Based on Natural Capital” (2003-2004) *Modern Economic Science* [Yan-ying & Yi-jun].

²⁷⁹ Fisher, *supra* note 214.

water productivity, ecosystem services productivity, or natural resource productivity – but the term natural capital productivity is not one of them as it is inconsistent with the standard conceptions of capital stock and flows.

In addition to the term ‘natural capital productivity’ being problematic from the perspective of economic concepts, there is one further challenge – it has also been used to describe other processes. Specifically, ‘natural capital productivity’ has been used to refer to the biological functions and processes which occur within the stock of natural capital – that is, as an ecological and not economic concept.²⁸⁰ In these situations, natural capital productivity would refer to things such as the reproduction rate of a species. While, from a biological perspective, this may be accurate and seem clear, when crossing disciplinary boundaries, as this research does, it is important to use terms which are acceptable to all those working on the research (if at all possible). In this case, using a term such as “ecological productivity”²⁸¹ or the phrase “physical productivity of nature”²⁸² might eliminate confusion.

NRP, then, is the general term recommended in this thesis to describe research which measures the efficiency of use of natural resource flows in production processes. This term (and its parent term of ‘resource productivity’) meet the criteria of clarity, provide an accurate description of the action being undertaken, and are broadly accepted by the academic and international policy community. For more flow-specific partial productivity measures, the input

²⁸⁰ Robert Costanza et al., *An Introduction to Ecological Economics* (Boca Raton, FL: CRC Press, 1997); Economic Commission for Latin America and the Caribbean, *Handbook for Estimating the Socio-economic and Environmental Effects of Disasters* (Chile: Economic Commission for Latin America and the Caribbean, 2003).

²⁸¹ Giles Atkinson, *Environmental Valuation and Greening the National Accounts: Challenges and Initial Practical Steps* (Washington, D.C.: The World Bank, 2010) at 14.

²⁸² Raimund Bleischwitz, “Rethinking Productivity: Why has Productivity Focussed on Labour Instead of Natural Resources?” (2001) 19 *Environmental and Resource Economics* 23 [Bleischwitz, “Rethinking”] at 27.

of interest should be named and therefore the terms used should be, for example, water productivity or timber productivity.

4.3.2.1.2 Natural Resource Productivity Framework

Before moving into a discussion which connects NRP with overall sustainability goals, its measurement framework is first presented. The formula(s) which can be used to calculate this measure are shown below. *Equation 4.5* provides an example of NRP calculated for a single resource (here, timber) while *Equation 4.6* shows NRP which combines the various types of natural resource inputs used in production.

Equation 4.5 – Timber Productivity

$$TP = \frac{Y}{\text{Timber Input}}$$

Equation 4.6 – Natural Resource Productivity

$$NRP = \frac{Y}{F(\text{timber, water, minerals, other natural resource flow inputs})}$$

Where Y is output, F is the function which aggregates the different natural resource flows,²⁸³ NRP is total natural resource productivity and TP is timber productivity - the measure which looks solely at the use of timber in production.

²⁸³ There are many suggestions as to how this aggregation can be done. Some literature simply adds together the materials so that one tonne of timber and one tonne of sand equal two tonnes of resource material (A. Adriaanse *et al.*, *Resource Flows: The Material Basis of Industrial Economies* (Washington DC: World Resources Institute, 1997). Another suggestion for how aggregation should be done is to weight each tonne of natural resource used based on a toxicity factor (David Pearce, *measuring resource productivity*, presented at the Department of Trade and

As previously discussed, partial productivity measures are calculated by taking total output (usually reported in GDP) and dividing it by the relevant input. For example, to get a measure of labour productivity, total output is divided by total labour input (for a given company, industry, country).²⁸⁴ As demonstrated above, this basic formula can be used for other inputs as well. In the case of NRP, one could determine a productivity estimate for total natural resource use. This would require the combination of all the different natural resource flow inputs into one type of unit (for example: value, weight, or volume).²⁸⁵ Alternatively, if interest is more in a specific resource flow, for example timber, one would simply divide total output by the total input of timber. The results, in this case, indicate how much GDP is produced per unit of combined natural resources or per unit of timber input. Undertaking these studies could tell us different and interesting information relevant to legal instrument design and evaluation – ideas which will be explored at length in Chapter 6. Of course, in comparing partial productivity measures it is important to compare similar situations – comparisons between countries or sectors with very different kinds of outputs is not useful. Nonetheless, partial productivity measures can be quite useful if when examining widely used inputs, or restricting the comparators to relatively similar production processes

For example, in Canada, numerous provinces (British Columbia, Ontario, etc.) use forest resources (timber) to produce output. It may well be that one of these provinces produces more output per unit of timber input (that is, they have higher timber productivity). Given that past harvesting techniques have damaged forests (and therefore supply of timber may be more

Industry and Green Alliance Conference, 14 February 2001, London, UK. Online: http://www.green-alliance.org.uk/page_263.php).

²⁸⁴ See section 4.3.1 for more discussion about labour productivity.

²⁸⁵ In their calculation of MFA, the OECD often uses physical mass units (metric tonnes, for example) to calculate a variety of indicators. See OECD, *Measuring Material Flows and Resource Productivity – Volume I. The OECD Guide* (OECD: Paris, 2008) at 69.

limited) the provinces may want to maximize the output they can get from one unit of timber input. In this situation, looking to the province with the highest timber productivity may yield transferrable information about best practices, new technologies or legal instrument implementation. Similar comparisons could be undertaken across countries which are heavily reliant on timber (i.e. Brazil, Russia, United States).

It is important to note that, like other partial productivity measures, changes in the ratio of total output to one type of input may be a consequence of other factors such as changes in other inputs or technological improvements.²⁸⁶ Still, these measures provide valuable information. For example, partial productivity measures such as labour productivity make comparison amongst different countries, and over time, relatively simple since the collection and analysis of input data is done in a standardized way. A NRP program could provide similar benefits at both the national and global scale; in fact similar measures are already been used and promoted by different jurisdictions and organizations.²⁸⁷ While comparing results of individual NRP measures (such as timber or mineral productivity) might only be useful between jurisdictions which are heavy users of such resources, more inclusive measures of NRP or even water productivity could be compared on a much more global scale.

Measures of NRP are important because the stock of natural capital produces flows of natural resources which are often used in production processes²⁸⁸ and which, for many

²⁸⁶ Statistics Canada, *Productivity Performance in Canada, 1961 to 2005* (Ottawa: Statistics Canada, 2007) online: Statistics Canada <<http://www.statcan.gc.ca/pub/15-206-x/15-206-x2007011-eng.pdf>> at 10-11.

²⁸⁷ For example, in the EU, resource productivity (GDP/domestic material consumption) is used to measure “whether decoupling between the use of natural resources and economic growth is taking place” and as an “EU sustainable development indicator for policy evaluation”. Domestic material consumption is defined as “the annual quantity of raw materials extracted from the domestic territory, plus all physical imports and minus all physical exports”. See, Eurostat, *Material Flows and Resource Productivity*, online: <http://ec.europa.eu/eurostat/web/environment/material-flows-and-resource-productivity>

²⁸⁸ Ida Kubiszewski et al., “Beyond GDP: Measuring and Achieving Global Genuine Progress” (2013) 93 *Ecological Economics* 57-68 at 58.

economies, are critical for economic growth.²⁸⁹ However, often how efficiently these resources are being used and what effect their current employment of them might have on their potential for future use is not known. Importantly, because often these resources are not fully valued or are considered to be free of charge, there is good reason to think they may be inefficiently used.

4.3.2.1.3 Conceptual Arguments for Measurement of Natural Resource Productivity

Having reviewed the concept of NRP, the following section will discuss its connection to the goals of sustainable economic growth and intergenerational equity. Using the partial productivity methodology to consider how aspects of natural capital are used in economic production can provide important insights for decision makers both at a conceptual and practical level. Chapters 5 and 6 present a more concrete discussion of its role in the policy cycle and instrument choice decision making, but here some general conceptual arguments about the importance of NRP are set out.

This section argues there are two main reasons to develop and use measures of NRP. In brief, the first argument has to do with scarcity. Traditionally, natural capital has been considered essentially infinite in quantity,²⁹⁰ and therefore not a limiting factor of production. Instead, the focus has been on improving the efficiency of use of the much more scarce human capital and its associated flows of labour. Today, it is widely accepted that this is not still the case, but that both the quantity and quality of natural capital is limited. The second argument deals with the link between NRP and the measure of standards of living, which is one of the main justifications for the continued focus on the labour productivity framework. This thesis

²⁸⁹ Robert Costanza et al., “Changes in the global value of ecosystem services” (2014) 26 *Global Environmental Change* 152-158 at 152.

²⁹⁰ Repetto, “Wasting Assets”, *supra* note 269 at 2.

presents the argument that total NRP (GDP per combined unit of natural resources) can also be an indicator of long term living standards as well as the broader measure of quality of life, and therefore should be considered important by governments who aim to improve one or both of these measures.

The somewhat single-minded pursuit of increased labour productivity, which has been the focus of many governments in the recent past, is blind to the fact that human capital (from which flows labour inputs) may well no longer be the limiting factor for economic production, but that natural capital may be moving into that place (or may have already taken its place).²⁹¹ When faced with a limiting factor it is important to attempt to increase both its supply and the efficiency of its use in order to ensure continued productivity.²⁹²

Historically, it makes sense that labour productivity was the focus and considered a key limiting factor because in the twentieth century, as industrialization took hold of the western world, labour was very much in demand as factories built increasingly more products, cities expanded, and the globalized economy began to take root.²⁹³ During this time, the fruits of natural capital were used in a way which indicated the belief that they were unlimited, or at least in no danger of being depleted.²⁹⁴ The focus during this time was on improving the efficiency of use of labour that flowed from the scarce form of human capital. The effect of improving this

²⁹¹ This is a belief espoused by a number of very reputable academics from various disciplines, though there are others who question the fact. See Joshua Farley & Herman Daly, "Natural Capital: The Limiting Factor, A reply to Aronson, Blignaut, Milton and Clewell" (2006) 28 *Ecological Engineering* 6-10; Hinterberger et al, "Green Growth", *supra* note 15 at 24.

²⁹² Herman E. Daly, "From Empty-world Economics to Full-world Economics: Recognizing a Historical Turning Point in Economic Development" in Robert J.A. Goodland, Herman E. Daly & Salah El Serafy, ed., *Population, Technology and Lifestyle: The Transition to Sustainability* (Washington: International Bank for Reconstruction & Development and UNESCO, 1992) at 1.

²⁹³ See Peter Mathias, *The First Industrial Nation: The Economic History of Britain, 1700-1914*, 2nd ed, (New York: Routledge, 2001) at 130 to discuss the limits of skilled labour.

²⁹⁴ Olewiler, *supra* note 237 at 117.

efficiency, as shown by rising labour productivity, is that more output can be produced by less people.²⁹⁵ In this way, labour productivity growth has been a major success of the last century.

On the other hand, after being viewed for so long as a factor of production that was in no danger of being limited, the stocks and flows of natural capital are now known to be finite –to be limited. If they continue to be used widely without consideration for how efficiency they are employed, a significant problem for intergenerational equity concerns arises. While there is certainly debate over limiting factors,²⁹⁶ natural capital is now understood to not be unlimited, and in many cases is increasingly becoming scarce,²⁹⁷ means there is a strong argument for wanting to improve the efficiency of its use. The degree to which natural capital is a complement rather than a substitute for other forms of capital is a central point.²⁹⁸ That is, if natural capital is required for many types of production, and is scarcer than other kinds of inputs, then its efficiency of use should be prioritized.²⁹⁹

Efficiency here has two meanings. First, to shift production processes along the production possibility frontier, substituting human-made capital for natural capital wherever

²⁹⁵ Hinterberger et al, “Green Growth”, *supra* note 15 at 13.

²⁹⁶ Mark Kleiman & Rebecca Young, “The Factors of Production in Retail Drug-Dealing” (1995) 30(5) Urban Affairs Review 730-748 at 732-733 provide a concise description of the limiting factor of production.

²⁹⁷ While it is true that not all natural capital and its flows of natural resources, ecosystem goods and services are becoming increasingly scarce, there is evidence that many of the aspects which are readily used in production processes – water, timber, oil and gas, for example - are in fact increasing in scarcity due to wasteful, and generally increased use. For example, United Nations, *WaterScarcity Factsheet* online: Economics of Natural Resources and the Environment which discusses water scarcity around the world; the UN REDD and REDD+ programs which were created to reduce deforestation, in large part because of the loss of carbon sinks, but it also demonstrates scarcity of forests more generally UN REDD program <http://www.un-redd.org/AboutUN-REDDProgramme/tabid/102613/Default.aspx>.

²⁹⁸ Remember this was discussed in Chapter 2’s discussion of strong versus weak sustainability.

²⁹⁹ In his departure from the World Bank, Herman Daly identified four suggestions, one of which was to “maximize the productivity of natural capital in the short run” because he believed there was sufficient common sense evidence “that natural and manmade capital are fundamentally complements and only marginally substitutable” and that “remaining natural capital appears to be both scarce and complementary, and therefore limiting”. See Herman Daly, “Fostering environmentally sustainable development: four parting suggestions for the World Bank” (1994) 10 Ecological Economics 183-187 at 185-186.

possible. Secondly, to improve the technical efficiency with which natural capital is used. This requires research and innovation, or producing improvements simply by reducing waste.³⁰⁰ In both of these cases, improvements should result in increasing NRP.

Of course, not all forms of natural capital are necessarily scarce, and there may be many degrees of scarcity. Perhaps optimally, full-cost pricing would be the best response to the scarcity of natural capital. The difficulty with full-cost pricing is that determining the marginal costs and benefits of use is difficult within one generation, and perhaps impossible when considering future ones. It is also politically very difficult to implement full-cost pricing on natural capital because the price for using the flows from natural capital as well as degrading natural capital stocks (through pollution, for example) would undeniably rise (probably significantly) because the correct marginal cost is almost certainly higher than what is currently paid. For decision making, these are fatal flaws. Therefore, it is suggested in this thesis that the current best solution to natural capital scarcity (at least from a practical perspective) is to encourage increases in its efficiency of use.

While there is not unanimous agreement that natural capital is now a much more important limiting factor of production, it seems reasonable that it is now understood to be limited in some form. So then, why the primary focus on labour productivity, especially if there are other factors of production which, given their scarcity, should also have their efficient use become a priority? One reason has to do with long term living standards and the correlation between their improvement and the growth of labour productivity.

³⁰⁰ Waste in this sense is sometimes referred to as deadweight loss. While efficient markets assume no deadweight loss, instruments may sometimes lead to better management without requiring substitution simply by increasing awareness. Of course, it is debatable the degree to which this still involves labour substitution (in terms of managerial time and attention).

This continuing policy focus on labour productivity surely has to do with the traditionally held belief that labour was the most important aspect of economic progress (many historically important economists were of this mindset, including among others Adam Smith and David Ricardo).³⁰¹ The clear association labour productivity has with long term living standards,³⁰² means it is not surprisingly that it is a key government priority.³⁰³ It is argued here that a case can also be made that NRP has an impact on future living standards. A degraded and diminished stock of natural capital from which natural resource flows used in production are drawn, has an impact on the economic potential of industries and countries reliant on natural resource inputs. Especially over the long term, this may indicate a declining productive capacity. That is, the capacity of future generations to continue to grow and produce output which they desire, uninhibited by actions of previous generations, may be negatively impacted by a degraded or diminished stock of natural capital, and this can lead to diminished opportunities, slower economic growth and reduced ability for standard of living improvement. In sum, low NRP likely indicates a current loss of economic efficiency since the maximum value is not being extracted from the natural resource inputs. In addition, this can indicate a future loss in productive capacity which may negatively impact the potential for long term standard of living growth.

Further, a degraded stock of natural capital can also negatively impact the general quality of life of citizens³⁰⁴ – in particular when aspects of natural capital such as ecosystems and renewable natural resources are considered. Here, quality of life is defined as “subjective

³⁰¹ Bleischwitz, “Rethinking Productivity”, *supra* note 282 at 26-27.

³⁰² Harris, *supra* note 249 at 1; Conference Board of Canada, *Labour Productivity: Measuring Productivity in Canada*, online: Conference Board of Canada < <http://www.conferenceboard.ca/hcp/details/economy/measuring-productivity-canada.aspx> >.

³⁰³ Apostolides, *supra* note 250.

³⁰⁴ Hinterberger et al, “Green Growth”, *supra* note 15 at 14.

wellbeing and personal growth in a healthy and prosperous environment.”³⁰⁵ Quality of life and standard of living are linked- standard of living is not just concerned with increasing wages, and consequently income, but is in essence concerned with the “material basis of everyday life.”³⁰⁶ Although standard of living can be stated in a broader way, as was just illustrated, and should include things like leisure time, environmental quality, equity, security and others³⁰⁷ (since all form the basis of life everyday), labour productivity has become engrained as the main consideration which should be measured and improved upon. It is clear, though, that a natural environment capable of providing not only inputs into production but also services such as clean air and water and aesthetic experiences seems to very easily fit within this broader definition of things needed to improve the standard of living.³⁰⁸ While higher NRP does not necessarily cause an increase in quality of life, it may do so indirectly because of probable links to less environmental degradation, and resources extraction.

One objection to focusing on NRP improvements is whether increasing NRP necessarily implies a reduction of labour productivity, and more importantly a reduction in welfare. While advocating improvements in NRP over labour productivity may not be a popular proposition, so long as the decision is welfare improving (it is an improvement in allocative efficiency) it is a logical argument. It does not, though, necessarily have to be a trade-off. In fact it in the long term, improvements in NRP could actually improve future labour productivity since the efficient

³⁰⁵ Robert E. Lane, “Quality of Life and Quality of Persons: A New Role for Government?” in Avner Offer, ed, *In Pursuit of the Quality of Life* (Oxford: Oxford University Press, 1996) at 278.

³⁰⁶ Centre for the Study of Living Standards, *Raising Canadian Living Standards: A Framework for Discussion*, Report Prepared for the TD Forum on Canada’s Living Standards, October 7-8, 2002, Ottawa, Ontario, online: <<http://www.csls.ca/reports/tdpaper.pdf>> [TD] at 4.

³⁰⁷ TD, *ibid* at 4.

³⁰⁸ In fact, in almost 94 countries around the world the right to a healthy environment is constitutionally recognized, although Canada is not one of them. See David Boyd, *The Right to a Healthy Environment: Revitalizing Canada’s Constitution* (Vancouver: UBC Press, 2012) at 74.

use now of natural resource flows means a much stronger possibility of continued productive capacity in the future. In theory, this would also lead to improvements in overall welfare. In the short term, though, the implications are less clear. It certainly could be the case that more efficient and less use of natural capital means that more labour will be used (thus causing labour productivity to decline, or at least not improve). Additionally, this decline in labour productivity is linked to higher labour inputs and not declines in output, so while wages are unlikely to rise, the number of people employed might increase. Some researchers argue that increasing employment numbers should also be considered alongside the traditional focus on labour productivity.³⁰⁹ Of course, it is also possible that instead of substituting labour for natural capital, other forms of capital (financial, manufactured) will be used and therefore impacts on labour productivity could be negligible.

4.3.2.2 Environmentally Adjusted Productivity

The second type of green productivity measure discussed is MFP adjusted to consider both desirable and undesirable outputs. The main difference between this green productivity measure – environmentally adjusted productivity (EAP) – and conventional MFP is that the numerator of the productivity equation (output), in the case of EAP, is more inclusive in that it also considers outputs of pollution, for example. For NRP the focus was on inputs, and how efficiently flows of natural resources or ecosystem goods and services were being used in production. Here, the focus is on output (traditionally measured as GDP or actual products) and how to incorporate undesirable outputs such as pollution or ecosystem damage alongside traditional ones. These additional outputs are widely acknowledged as being produced alongside traditional outputs, but

³⁰⁹ Hinterberger et al, “Green Growth”, *supra* note 15 at 13-14 and 36.

rarely are they considered in economic measures.³¹⁰ As Førsund says “multiple outputs are the rule rather than the exception” in production processes,³¹¹ yet generally productivity measures consider only positive outputs (i.e. the economic product). As a consequence, conventional productivity measures typically portray a measure of productivity which is incomplete.³¹²

4.3.2.2.1 Terminology

Similar to the research on NRP, there are a number of divergent terms used to describe the environmental adjustment of conventional MFP. In this case, however, it is less a problem of conceptual accuracy than the sheer proliferation of terms and their lack of clear definition. There are two issues –one with the overall term for productivity adjusted to include pollution and waste as outputs, and the second with what these new outputs are called.

Let us begin with the latter – terms to describe outputs (new and old). It is fairly well acknowledged by academics in this field that there is a set of outputs from economic production which are unaccounted for and which impact the natural environment.³¹³ However, difficulties arise in describing and identifying pollution/waste outputs. As *Table 4.3* illustrates, there are at

³¹⁰ Robert Ayres & Allen Kneese, “Production, Consumption and Externalities” (1969) 59:3 *The American Economic Review* 282 [Ayres & Kneese]; V. Eldon Ball et al., “Incorporating Environmental Impacts in the Measurement of Agriculture Productivity Growth” (2004) 29:3 *Journal of Agricultural and Resource Economics* 436 [Ball et al., “Incorporating Environmental Impacts”]; Rolf Färe, Shawna Grosskopf & Carl Pasurka, “Accounting for Air Pollution Emissions in Measures of State Manufacturing Productivity Growth” (2001) 41:3 *Journal of Regional Science* 381 [Färe et al., “Accounting for Air Pollution”]; Russell W. Pittman, “Multilateral Productivity Comparisons with Undesirable Outputs” (1983) 771:93 *The Economic Journal* 883 [Pittman].

³¹¹ Finn Førsund, “Good Modelling of Bad Outputs: Pollution and Multiple-Output Production” (2009) 2 *International Review of Environmental and Resource Economics* 1 [Førsund] at 2.

³¹² Färe et al, “Accounting for Air Pollution”, *supra* note 310.

³¹³ For example, Ayres & Kneese, *supra* note 310; Pittman, *supra* note 310; Robert Repetto, “Environmental Productivity and Why It Is So Important” (1990) 33:5 *Challenge* 33 [Repetto, “Environmental Productivity”]; Jon Paul Rezek & Richard Perrin “Environmentally Adjusted Agricultural Productivity in the Great Plains” (2004) 29:2 *Journal of Agricultural and Resource Economics* 346 [Rezek & Perrin].

least 13 different terms used to identify this new set of outputs. *Table 4.4* shows that inconsistencies exist as well even when choosing terms for currently measured outputs.

Table 4.3—Terms Used to Indicate Outputs Not Currently Included in Productivity Frameworks

Term Used	References
non-marketed by-products such as environmental impacts ³¹⁴	Ball et al., 2004
undesirable outputs ³¹⁵	Atkinson and Dorfman, 2005; Ball et al., 2001; Chapple and Harris, 2003; Dyckhoff and Allen, 2001; Fare et al., 1989; Fare et al., 1993; Fare et al., 2001; Fare et al., 2007; Hailu and Veeman, 2000; Hailu and Veeman, 2001; Jeon and Sickles, 2004; Kaneko and Managi, 2004; Kumar and

³¹⁴ Ball et al, “Incorporating Environmental Impacts”, *supra* note 310.

³¹⁵ A. Atkinson & J. Dorfman, “Bayesian measurement of productivity and efficiency in the presence of undesirable outputs: crediting electric utilities for reducing air pollution” (2005) 126:2 *Journal of Econometrics* 445–468 [Atkinson & Dorfman]; V.E. Ball et al, “Accounting for bads in the measurement of productivity growth: a cost indirect Malmquist productivity measure and its application to U.S. agriculture” (Paper presented at the *AAEA and CAES Meeting*, Chicago, 5–8 August 2001) [Ball et al, “Accounting for bads”]; Wendy Chapple & Richard Harris “Accounting for solid waste generation in measures of regional productivity growth” (2003) 01-2003 ICCSR Research Paper Series [Chapple & Harris]; H. Dyckhoff & K. Allen, “Measuring ecological efficiency with data envelopment analysis (DEA)” (2001) 132:2 *European Journal of Operational Research* 312–325 [Dyckhoff & Allen]; Rolf Färe et al, “Multilateral productivity comparisons when some outputs are undesirable: a nonparametric approach” (1989) 71:1 *The Review of Economics and Statistics* 90–98 [Färe et al, “Multilateral productivity”]; Rolf Färe et al, “Derivation of shadow prices for undesirable outputs: a distance function approach” (1993) 75:2 *The Review of Economics and Statistics* 374–380 [Färe et al, “Derivation of shadow prices”]; Färe et al, “Accounting for Air Pollution”, *supra* note 310; Rolf Färe, Shawna Grosskopf & Carl Pasurka, “Pollution abatement activities and traditional productivity” (2007) 62:34 *Ecological Economics* 673–682 [Färe et al, “Pollution abatement activities”]; Atakelty Hailu & Terrence Veeman, “Environmentally sensitive productivity analysis of the Canadian pulp and paper industry, 1959–1994: an input distance function approach” (2000) 40:3 *Journal of Environmental Economics and Management* 251–274 [Hailu & Veeman, “Environmentally sensitive productivity”]; Atakelty Hailu & Terrence Veeman, “Non-parametric productivity analysis with undesirable outputs: an application to the Canadian pulp and paper industry” (2001) 83:3 *American Journal of Agricultural Economics* 605–616 [Hailu & Veeman, “Non-parametric productivity”]; B. Jeon & R. Sickles, “The role of environmental factors in growth accounting” (2004) 19:5 *Journal of Applied Econometrics* 567–591 [Jeon & Sickles]; S. Kaneko & S. Managi, “Environmental productivity in China” (2004) 17:2 *Economics Bulletin* 1–10 [Kaneko & Managi]; S. Kumar & M. Khanna, “Measurement of environmental efficiency and productivity: a cross-country analysis” (2009) 14:4 *Environmental and Development Economics* 473–495 [Kumar & Khanna]; T. Kuosmanen, “Weak disposability in nonparametric production analysis with undesirable outputs” (2005) 87:4 *American Journal of Agricultural Economics* 1077–1082 [Kuosmanen]; Marthin Nanere et al, “Environmentally adjusted productivity measurement: an Australian case study” (2007) 85:2 *Journal of Environmental Management* 350–362 [Nanere et al]; Pittman, *supra* note 310; H. Scheel, “Undesirable outputs in efficiency valuations” (2001) 132:2 *European Journal of Operational Research* 400–410 [Scheel]; L. Seiford & J. Zhu, “Modeling undesirable factors in efficiency evaluation” (2002) 142:1 *European Journal of Operational Research* 16–20 [Seiford & Zhu]; Eugene Yu-Ying Lin, Ping-Yu Chen & Chi-Chung Chen, “Measuring green productivity of country: A generalized metafrontier Malmquist productivity index approach” (2013) 55 *Energy* 340-353 [Yu-Yin Lin et al]; Yu Song & Qian Li, “Environmental Productivity Growth in Chinese Construction Industry” (2013) 664 *Advanced Materials Research* 19-22 [Song & Li].

	Khanna, 2009; Kuosmanen, 2005; Nanere et al., 2007; Pittman, 1983; Scheel, 2001; Seiford and Zhu, 2002; Tao <i>et al</i> , 2012; Yu-Ying Lin, Chen & Chen, 2013; Song& Li, 2013
Externalities ³¹⁶	Hailu and Veeman, 2000
“polluting inputs” which are used in place of undesirable outputs given the difficulty in determining the latter ³¹⁷	Ferjani, 2011
pollutant outputs ³¹⁸	Hailu and Veeman, 2001
unintended outputs ³¹⁹	Førsund, 2009; Murty et al., 2011
bad or bad outputs ³²⁰	Aiken and Pasurka, 2003; Atkinson and Dorfman, 2005; Ball et al., 2001; Chapple and Harris, 2003; Chung and Fare, 1995; Fare et al, 2001; Fare et al., 2007; Fare et al., 2012; Harchaoui et al., 2002; Jeon and Sickles, 2004; Kumar, 2006; Picazo-Tado and Prior, 2009; Repetto, 2006; Rezek and Perrin, 2004; Shaik and Perrin, 1999; Song& Li, 2013
unsalable outputs ³²¹	Repetto, 2006
peculiar outputs ³²²	Tyteca, 1996
non-market outputs/goods ³²³	Gallop and Swinand 1998; Managi and Jena, 2008; Shaik and Perrin, 1999; Smith, 1998; Repetto, 1990

³¹⁶ Hailu & Veeman, “Environmentally sensitive productivity”, *supra* note 315.

³¹⁷ A. Ferjani, “Environmental regulation and productivity: a data envelopment analysis for Swiss dairy farms” (2008) 12:1 *Agricultural Economics Review* 45–55 [Ferjani].

³¹⁸ Hailu & Veeman, “Non-parametric productivity”, *supra* note 315.

³¹⁹ Førsund, *supra* note 311; S. Murty, R. Russell & S. Levkoff, “On Modeling Pollution Generating Technologies” (2012) 64:1 *Journal of Environmental Economics and Management* 117 [Murty et al].

³²⁰ D. Aiken & C. Pasurka “Adjusting the measurement of US manufacturing productivity for air pollution emissions control” (2003) 25:4 *Resource and Energy Economics* 329-351 [Aiken & Pasurka]; Atkinson & Dorfman, *supra* note 315; Ball et al, “Accounting for bads”, *supra* note 315; Chapple & Harris, *supra* note 315; Y. Chung & Rolf Färe, “Productivity and Undesirable Outputs: A Directional Distance Function Approach” (1995) Discussion Paper Series No. 95-24 [online] <http://128.118.178.162/eps/mic/papers/9511/9511002.pdf> (accessed 13 January 2014) (accessed 13 January 2014) [Chung & Färe]; Färe et al, “Accounting for Air Pollution”, *supra* note 310; Färe et al, “Pollution abatement activities”, *supra* note 315; Färe, R., Grosskopf, S., Lundgren, T., Marklund, P. and Zhou, W. (2012) “Productivity: Should We Include Bads?” (2012) CRE Working Paper, No. 13, Umea, Sweden [Färe et al, “Productivity: Should we”]; Jeon & Sickles, *supra* note 315; Kumar, *supra* note 267; A. Picazo-Tadeo & D. Prior, “Environmental externalities and efficiency measurement” (2009) 90:11 *Journal of Environmental Management* 3332–3339 [Picazo-Tadeo & Prior]; Robert Repetto, “Measuring the True Productivity Gains from Environmental Technology Improvements” in Dora Marinova, David Annandale & John Phillimore, eds, *The International Handbook on Environmental Technology Management* (Cheltenham, UK: Edward Elgar Publishing, 2006) [Repetto, “Measuring the True”]; J. Rezek & R. Perrin, “Environmentally adjusted agricultural productivity in the great plains” (2004) 29:2 *Journal of Agricultural and Resource Economics* 346–369 [Rezek & Perrin]; S. Shaik & R. Perrin, The role of non-parametric approach in adjusting productivity measures for environmental impacts” (Paper delivered at the American Agricultural Economics Association Meetings, Nashville, 8–11 August 1999) [Shaik & Perrin]; Song & Li, *supra* note 315.

³²¹ Repetto, “Measuring the True”, *supra* note 320.

³²² Tyteca, *supra* note 24.

³²³ F. Gallop & G. Swinand, “Total resource productivity – accounting for changing environmental quality” in Hulten, C., Dean, E. and Harper, J., eds, *New Developments in Productivity Analysis* (Chicago: University of Chicago Press, 2001) [Gallop & Swinand, “Total resource productivity”]; S. Managi & P. Jena, “Environmental

Environmental output ³²⁴	Kaneko and Managi, 2004
Environmental by-products ³²⁵	Jeon and Sickles, 2004
By-product residuals ³²⁶	Tran and Smith, 1983

Table 4.4—Terms Used to Indicate Outputs Currently Included in Productivity Frameworks

Term Used	References
Market/ Marketed output ³²⁷	Managi and Jena, 2008; Nanere et al., 2007; Repetto, 1990; Repetto, 2006; Smith, 1998; Ball et al., 2004; Chapple and Harris, 2003; Gallop and Swinand, 1998; Hailu and Veeman, 2001; Harchaoui, Kabrelyan and Smith, 2002; Kaneko and Managi, 2004
Good(s) Production/ Outputs ³²⁸	Murty, Russell and Levkoff, 2011; Shaik and Perrin, 1999; Tao, Li and Xia, 2012; Aiken and Pasurka Jr., 2003; Atkinson and Dorfman, 2005; Ball et al., 2001; Chapple and Harris, 2003; Chung and Fare, 1995; Fare et al., 1989; Fare, Grosskopf and Pasurka Jr., 2007; Fare et al., 2012; Fare, Grosskopf and Pasurka Jr., 2001; Rezek and Perrin, 2004; Ayres and Kneese, 1969; Fernandez, Koop and Steel, 2002.; Ferjani, 2011; Hailu and Veeman, 2001; Jeon and Sickles, 2004; Kumar and Khanna, 2009; Picazo-Tadeo & Prior, 2009

productivity and the Kuznets curve in India” (2008) 65:2 Ecological Economics 432–440 [Managi & Jena]; Shaik & Perrin, *supra* note 320; V. Smith, “Should pollution reductions count as productivity gains for agriculture?” (1998) 80:3 American Journal of Agricultural Economics 591–594 [Smith]; Repetto, “Environmental Productivity”, *supra* note 313.

³²⁴ Kaneko & Managi, *supra* note 315.

³²⁵ Jeon & Sickles, *supra* note 315.

³²⁶ N. Tran & K. Smith, “The role of air and water residuals for steam electric power generation” (1993) 10:1 Journal of Environmental Economics and Management, 35–49 [Tran & Smith].

³²⁷ Managi & Jena, *supra* note 323; Nanere et al, *supra* note 315; Repetto, “Environmental Productivity”, *supra* note 313; Repetto, “Measuring the True”, *supra* note 320; Smith, *supra* note 323; Ball et al, “Incorporating Environmental Impacts”, *supra* note 310; Chapple & Harris, *supra* note 315; Gallop & Swinand, “Total resource productivity”, *supra* note 323; Hailu & Veeman, “Non-parametric productivity”, *supra* note 315; Harchaoui *et al*, “Accounting for Greenhouse”, *supra* note 248; Kaneko & Managi, *supra* note 315.

³²⁸ Murty et al, *supra* note 319; Shaik & Perrin, *supra* note 320; F. Tao, L. Li, & X. Xia, “Industry efficiency and total factor productivity growth under resources and environmental constraint in China” (2012) 212 The Scientific World Journal, 1-10 [Tao et al]; Aiken & Pasurka, *supra* note 320; Atkinson & Dorfman, *supra* note 315; Ball et al, “Accounting for bads”, *supra* note 315; Chapple & Harris, *supra* note 315; Chung & Färe, *supra* note 320; Färe et al, “Multilateral productivity”, *supra* note 315; Färe et al, “Productivity: Should we”, *supra* note 320; Färe et al, “Accounting for Air Pollution”, *supra* note 310; Rezek & Perrin, *supra* note 320; Ayres & Kneese, *supra* note 310; Ferjani, *supra* note 317; Jeon & Sickles, *supra* note 315; Kumar & Khanna, *supra* note 315; Picazo-Tadeo & Prior, *supra* note 320.

Desirable outputs ³²⁹	Picazo -Tadeo and Prior, 2009; Pittman, 1983; Scheel, 2001; Seiford and Zhu, 2002; Chung and Fare, 1995; Fare et al., 1989; Fare, Grosskopf and Pasurka Jr., 2001; Fernandez, Koop and Steel, 2002.; Kumar and Khanna, 2009; Fare et al., 2007; Yu-Ying Lin, Chen & Chen, 2013
Salable Outputs ³³⁰	Repetto et al., 1997; Hailu and Veeman, 2000
Traditional (Economic) Outputs ³³¹	Tyteca, 1996; Aiken and Pasurka Jr., 2003; Fare, Grosskopf and Pasurka Jr., 2007
Conventional Outputs ³³²	Ali and Byerlee, 2002
Ordinary Outputs ³³³	Førsund, 2009
Intended Outputs ³³⁴	Førsund, 2009

First, consider the variety of terms used to describe the traditionally excluded outputs: “non-marketed by-products such as environmental impacts,” “undesirable outputs,” “externalities,” and “polluting inputs” are all examples of terms used to describe the pollution and waste outputs. “Pollutant outputs,” “unintended outputs,” “bads or bad outputs,” “unsalable outputs,” “peculiar outputs,” “non-market outputs” are others. What is particularly striking about the terminology in this sense, is the common practice of using several different terms in one piece of work to refer to the same thing. For example, Färe *et al.* use both ‘bad output’ as well as ‘undesirable output’ in their work.³³⁵ Nanere *et al.* consider both ‘negative externalities’ and ‘bad outputs’ in their article.³³⁶ Further, Hailu and Veeman state “both desirable

³²⁹ Picazo-Tadeo & Prior, *supra* note 320; Pittman, *supra* note 310; Scheel, *supra* note 315; Seiford & Zhu, *supra* note 315; Chung & Färe, *supra* note 320; Färe et al, “Multilateral productivity”, *supra* note 315; Färe et al, “Accounting for Air Pollution”, *supra* note 310; Kumar & Khanna, *supra* note 315; C. Fernandez, G. Koop & M.F.J. Steel, Multiple-output production with undesirable outputs: an application to nitrogen surplus in agriculture” (2002) 97 Journal of the American Statistical Association 234–242 [Fernandez et al]; Färe et al, “Pollution abatement activities”, *supra* note 315; Yu-Yin Lin et al, *supra* note 315.

³³⁰ Robert Repetto et al, “Has Environmental Protection Really Reduced Productivity Growth?” (1997) 40(1) Challenge 46 [Repetto et al, “Has Environmental Protection”]; Hailu & Veeman, “Environmentally Sensitive Productivity”, *supra* note 315.

³³¹ Tyteca, *supra* note 24; Aiken & Pasurka, *supra* note 320; Färe et al, “Pollution abatement activities”, *supra* note 315.

³³² M. Ali & D. Byerlee, “Productivity growth and resource degradation in Pakistan’s Punjab: a decomposition analysis. Economic Development and Cultural Change” (2002) 50(4) Economic and Cultural Change 839–863.

³³³ Førsund, *supra* note 308.

³³⁴ Førsund, *supra* note 308.

³³⁵ Färe et al, “Productivity: Should we”, *supra* note 320.

³³⁶ Nanere et al, *supra* note 315.

(marketable) outputs and undesirable (pollutant) outputs are incorporated into the analysis”³³⁷ and Mangai and Jena’s work similarly indicates, “...inputs, environmental output (or undesirable output) and market inputs...”³³⁸ As was noted above, it is not that the authors are incorrect in their use of terminology, but simply that inconsistency abounds. Therefore, the use of a single term throughout the research area – and at a minimum throughout an individual piece of work – is to be desired.

In addition, the terminology used to refer to the productivity measurement which uses these two sets of outputs is also inconsistent - *Table 4.5* lists seven different terms which have been employed in published research. Certainly these disparate terms are both a cause and a product of the lack of unity in the field.

Table 4.5 - Terms Used to Describe Productivity Which Considers Desirable and Undesirable Outputs

Term Used	References
Environmental Productivity ³³⁹	Ball et al., 2004; Kumar and Khanna, 2009; Managi and Jena, 2008; Song & Li, 2013
Environmentally Adjusted Productivity ³⁴⁰	Nanere et al., 2007; Rezek and Perrin, 2004; Shaik, 1998; Shaik and Perrin, 1999
Environmental Total Factor Productivity (TFP) ³⁴¹	Tao et al., 2012
Adjusted Total Factor Productivity (TFP) ³⁴²	Aiken and Pasurka Jr., 2003
Environmentally Sensitive Productivity ³⁴³	Ball et al., 2004; Hailu and Veeman, 2000; Kumar, 2006

³³⁷Hailu & Veeman, “Environmentally Sensitive Productivity”, *supra* note 315 at 252.

³³⁸ Managi & Jena, *supra* note 323 at 434.

³³⁹ Ball et al, “Incorporating Environmental Impacts”, *supra* note 310; Kumar & Khanna, *supra* note 315; Managi & Jena, *supra* note 323; Song & Li, *supra* note 315.

³⁴⁰ Nanere et al, *supra* note 315; Rezek & Perrin, *supra* note 320; S. Shaik, *Environmentally Adjusted Productivity [EAP] Measures for Nebraska Agriculture Sector* (PhD Thesis, Department of Agriculture Economics, University of Nebraska-Lincoln, 1998) [unpublished] [Shaik]; Shaik & Perrin, *supra* note 320.

³⁴¹ Tao et al, *supra* note 328.

³⁴² Aiken & Pasurka, *supra* note 320.

³⁴³ Ball et al, “Incorporating Environmental Impacts”, *supra* note 310; Hailu & Veeman, “Environmentally Sensitive Productivity”, *supra* note 315; Kumar, *supra* note 267.

Total Resource Productivity ³⁴⁴	Gallop and Swinand, 1998; Gallop and Swinand, 2001
Green (environmental) productivity ³⁴⁵	Yu-Ying Lin, Chen & Chen, 2013
Green Total Factor Productivity/Green Productivity ³⁴⁶	Cao, 2007

As Table 4.5 demonstrates, there is a lack of consistency in the terminology used for the overall measure which includes additional outputs that negatively impact the stock of natural capital. Some of the terms that have appeared include, for example, Ball *et al.*'s measurement of both “environmental productivity” and “environmentally sensitive productivity” indices,³⁴⁷ Kumar's use of the term “environmentally sensitive total factor productivity”³⁴⁸ along with Hailu & Veeman's “environmentally sensitive” studies.³⁴⁹ Ferjani's label of “productivity index with environmental indicators,”³⁵⁰ Rezek & Perrin, Shaik, Shaik & Perrin along with Nanere *et al.*'s measure of “environmentally adjusted productivity,”³⁵¹ and Fare *et al.* and Aiken & Pasurka's calculation of an “adjusted measure of productivity growth”³⁵² are others. Further, Tao *et al.* determine “environmental total factor productivity (TFP)”³⁵³ in their research although this research not only considered undesirable outputs but also focused on energy inputs as an important environmental consideration. This is similar to what Repetto refers to as

³⁴⁴ F. Gallop & G. Swinand, “From total factor to total resource productivity: an application to agriculture” (1998) 80:3 American Journal of Agricultural Economics 577–583 [Gallop & Swinand, “From total factor”]; Gallop & Swinand, “Total resource productivity”, *supra* note 323.

³⁴⁵ Yu-Yin Lin *et al*, *supra* note 315.

³⁴⁶ J. Cao, “Measuring green productivity growth for China's manufacturing sectors: 1991–2000” (2007) 21:4 Asian Economic Journal 425–451.

³⁴⁷ Ball *et al*, “Incorporating Environmental Impacts”, *supra* note 310.

³⁴⁸ Kumar, *supra* note 267.

³⁴⁹ Hailu & Veeman, “Environmentally Sensitive Productivity”, *supra* note 315; Hailu & Veeman, “Non-parametric productivity”, *supra* note 315.

³⁵⁰ Ferjani, *supra* note 317.

³⁵¹ Rezek & Perrin, *supra* note 320; Shaik, *supra* note 340; Nanere *et al*, *supra* note 315.

³⁵² Ball *et al*, “Incorporating Environmental Impacts”, *supra* note 310; Aiken & Pasurka, *supra* note 320.

³⁵³ Tao *et al*, *supra* note 328.

‘environmental productivity’³⁵⁴ – “natural resources used and residuals produced per unit of useful output”³⁵⁵– but while Repetto refers to both inputs and outputs in his definition, the case study presented only considers adjusted outputs. This is an example of inconsistency and lack of clarity, especially considering Kumar & Khanna, along with Managi & Jena and Kaneko & Managi, use the same term but appear to define it differently. Kaneko & Managi, consider ‘environmental productivity’ to be defined as the “efficient utilization of pollution abatement technologies”³⁵⁶ while Kumar and Khanna define it to be “the ratio of two estimates of TFP, one obtained under the assumption that CO₂ emissions are weakly disposable and the other obtained by ignoring the generation of these emissions.”³⁵⁷ Clearly, terminology issues exist. Given that authors publishing in the area of green productivity are often speaking a different terminological language, it is no wonder that they publish work which is similar in content but does not always integrate other findings.

There are three terminology recommendations related to productivity measures that adjust the output numerator to include outputs which negatively impact the stock of natural capital through the discharge of pollution and waste and/or habitat destruction. First, it is suggested that the general term for these measures be *environmentally adjusted productivity*. Based on the literature reviewed, this term has been used by a variety of authors, but perhaps more importantly, it accurately describes what is being measured. One good example is the definition offered by Rezek and Perrin that “an environmentally adjusted productivity index would thus be one that includes changes in the flow of environmental goods or bads.”³⁵⁸ This is

³⁵⁴ Repetto, “Environmental Productivity”, *supra* note 313

³⁵⁵ *Ibid* at 33.

³⁵⁶ Kaneko & Managi, *supra* note 315 at 2.

³⁵⁷ Kumar & Khanna, *supra* note 315 at 475.

³⁵⁸ Rezek & Perrin, *supra* note 320 at 347.

consistent with Nanere et al.'s description of “environmentally adjusted productivity estimates taking into account these negative externalities.”³⁵⁹ Both descriptions of the term clearly indicate a productivity measure which is concerned about accounting for, in their framework, a consideration of production outputs which are externalities. To clarify, terms such as “environmental total factor productivity” or “environmental productivity” seem to indicate that what is being measured is the productivity of the environment. In fact, what is being measured, as the term ‘environmentally adjusted productivity’ makes clear, is standard economic productivity adjusted to consider the impact on the environment.

The second and third recommendations propose that *undesirable* and *desirable* outputs represent the two different types of outputs used in the productivity equation. These terms are broad enough to incorporate a variety of different outputs (for example, different types of pollution, and waste) but descriptive enough to make clear which are treated as positives and which as negatives in a productivity calculation.³⁶⁰ The term ‘undesirable’ was the most commonly used in the literature reviewed, and has a history of use dating back to Pittman³⁶¹ which is one of the first articles published on this topic. This recommendation is also in line with the observations made by Picazo-Tadeo and Prior who said “it has become common practice to consider environmental externalities as undesirable outputs in production processes.”³⁶² In addition, the term undesirable avoids unnecessarily specific references to “pollution,” and is yet not overly broad in referring to “by-product residuals” or “externalities,” which might be positive as well as negative. Finally, ‘desirable’ and ‘undesirable’ are recommended in an attempt to

³⁵⁹ Nanere et al, *supra* note 315 at 351.

³⁶⁰ It should be noted that the slightly different terms undesired/desired have a quite different connotation – that these outputs are desired (or not) by individuals, or the market. Here, we are concerned about outputs that are welfare improving at the societal level, and therefore the preferred terms are undesirable/desirable

³⁶¹ Pittman, *supra* note 310.

³⁶² Picazo-Tadeo & Prior, *supra* note 320 at 3332.

maintain consistency and clarity as the terms are clearly related but also undeniably different in their emphasis.

That said, it must be acknowledged, that sometimes these outputs, while ‘undesirable’ at the level of general societal welfare, since they often contribute to the degradation of the natural environment, are actually of benefit to certain members of society. The sense in which ‘undesirable outputs’ become benefits exists in cases where new and innovative uses are discovered. Think, for example, of energy generation from methane gases given off from landfill sites – this is an example of an undesirable output becoming the opposite, becoming a ‘desirable’ input for a certain subsection of society. Further, as the world moves towards a circular economy, what is considered desirable versus undesirable or waste and not waste will likely shift – these concepts are in a way fluid as the economy begins to change. Still, at present, concern is about the overall societal welfare and therefore the recommendation for ‘undesirable output’ to be the label on outputs of pollution and waste is still strong.

4.3.2.2.2 Environmentally Adjusted Productivity Framework

EAP is a different somewhat more complex measure than NRP. NRP is focused on the use of natural resource flows as inputs in a production process, and in this way considers the depletion of the stock of natural capital. EAP focuses on the degradation of natural capital by including in its framework undesirable outputs as proxies, in a sense, for the degradation of the natural capital stocks. Therefore, EAP is essentially a productivity measure with an expanded and more comprehensive numerator (output) where the output value used includes both traditional economic output as well as some representation of the pollution/waste output which is created

alongside economic products (see *Equation 4.7*).³⁶³ This means total output also includes those which have an environment impact, instead of just outputs which have a market value.

Equation 4.7 – Environmentally Adjusted Multifactor Productivity

$$A = \frac{G(Y_D, Y_U)}{F(K, L)}$$

Where A is the residual, G is the function with combines desirable and undesirable outputs, Y_D traditionally measured desirable outputs, Y_U pollution, waste, and other undesirable outputs (which take the form of a negative value), F is the production function which combines inputs, K capital and L labour.

This more inclusive concept of total output is not new or unique to productivity measures. In fact the inclusion of additional outputs has been done by a number of academics in a variety of ways. For example, Green GDP uses a similar methodology, as does a study by Muller *et al.* (2011) which focuses on adjusting the production accounts in a national accounts framework.³⁶⁴ These studies suggest that including additional outputs is a plausible methodology. The focus of this section is specifically on their incorporation in productivity measures.

The following sections examine whether EAP is aligned with the legal commitments to sustainable economic growth and intergenerational equity and analyse research and results from past studies. Generally speaking, research on EAP has focused on MFP frameworks and has

³⁶³ Here we consider multifactor productivity, but in principle the same adjustment could be applied to partial productivity measures.

³⁶⁴ Nicholas Z. Muller, Robert Mendelsohn & William Nordhaus, “Environmental Accounting for Pollution in the United States Economy” (2011) 101 American Economic Review 1649.

found that, especially in the face of environmental regulation, conventional productivity growth rates represent underestimations.³⁶⁵ The main reason for this is that EAP estimates both include the additional inputs associated with environmental protection compliance (costs to company) as well as give credit for the associated reduction in environmental damage (benefits to environment/society). The substantive material regarding EAP's relationship with legal instruments will be dealt with in Chapter 6.

Adjusting conventional productivity frameworks to include undesirable outputs is, in many ways, an extension of 'Green GDP' work³⁶⁶ in that both measures focus on adjusted output – that is, including undesirables. While related and drawing on some of the same data, Green GDP and green productivity, provide quite different information. In both cases these measures include or account for, in some way, the (mis)use of natural capital. However, green GDP represents the total of all goods and services (desirable and undesirable) produced within the bounds of a country. Green productivity, by contrast, is the output relative to the inputs. A simple way to distinguish green GDP from green productivity measures is that the former is concerned with overall output while the latter focuses on how efficiently different inputs in the economy (alone or together) are used to produce the output. In both cases these measures include or account for, in some way, the (mis)use of natural capital.

Consider what conventional GDP and productivity measure and represent for decision makers. GDP is known as presenting the “market value of the total of all goods and services

³⁶⁵ See, for example Hailu & Veeman, “Environmentally Sensitive Productivity”, *supra* note 315 at 272.

³⁶⁶ Green GDP is a well-researched and accepted concept. A brief introduction to this field of research can be found in Chapter One and in Boyd, “Nonmarket benefits of nature”, *supra* note 16; Joel Darmstadter, “Greening the GDP. Is it Desirable? Is it Feasible?” (2002) 139 Resources 11; John Talbert & Alok K. Bohara, “Economic Openness and Green GDP” (2006) 58 Ecological economics 743

produced within the boundaries of a country”³⁶⁷ – it is an output based measure which considers the total value produced (at different levels such as a national economy, from traditional production, or by an industry).³⁶⁸ Productivity, on the other hand is a measure of efficiency, it “measures how efficiently production inputs, such as labour and capital, are being used in an economy to produce a given level of output.”³⁶⁹ While GDP provides an estimate of the output of an economy, productivity reports how inputs are being used to produce this level of output. Though there are numerous ways to calculate GDP and productivity, often GDP becomes the numerator used in a productivity calculation.

In environmentally adjusted productivity work, specifically, output is adjusted and then used in a productivity calculation instead of being the end result (the latter is what occurs with adjusted or green GDP). In both cases, the result is based on the premise that the production of goods and services gives not only positive, desirable outputs (measured in the form of GDP or individual output units), but also produces undesirable outputs (pollution, waste, etc.). In essence, EAP measurement is the next calculation in a sequence where Green GDP is a precursor. In particular, measures of EAP utilize green GDP as a numerator. NCR and NRP could also use green GDP as a base, though interesting information is still possible (as will be shown in the next few chapters) when using conventional GDP as the numerator in these calculations.

³⁶⁷ The Conference Board of Canada, *Gross Domestic Product (GDP) Forecast*, online <<http://www.conferenceboard.ca/e-data/data/gdp.aspx>>

³⁶⁸ Industry Canada, *Canada Industry Statistics: Glossary of Terms*, online: <https://www.ic.gc.ca/eic/site/cis-sic.nsf/eng/h_00005.html#gindex>

³⁶⁹ OECD, *Defining and Measuring Productivity*, online: <<http://www.oecd.org/std/productivity-stats/40526851.pdf>>

In order to measure EAP, results of the Green GDP measure are needed as an input into the productivity framework. Including an additional set of outputs within a productivity framework is not entirely unusual. Even when dealing with only desirable outputs, multiple outputs are actually the rule³⁷⁰ which means measures are already dealing with combined outputs. Generally speaking, though, except at the very micro level of analysis, the different desirable outputs have been amalgamated into a single output for ease of calculation and to reduce complexities with regards to technical issues.³⁷¹ This is done in a variety of ways – totalling GDP for a nation (the make-up of the contributions from all production processes across a country) or using a total weight measure of outputs adjusted for relative value. It is difficult, though, to continue this line of reasoning with regards to undesirable outputs since they are often under- or unvalued and have a completely different impact on society. Instead of representing economic growth, undesirable outputs represent costs – currently paid for by society through, for example, increased health costs and environmental cleanup. Under the proposed environmentally adjusted measure, these costs can be attributed to their producer. A more inclusive measure of productivity does not necessarily mean that the polluter (who produced the undesirable outputs) pays on their balance sheet but they may feel the impact and be encouraged to reduce their undesirable outputs (if results are publically available) through pressures from stakeholders, investor decisions and the like, pressures which would not have been felt otherwise. In a way, then, this type of green productivity measure can facilitate the implementation of the polluter pays principle – “the polluter should, in principle, bear the cost of pollution”³⁷² – at least in

³⁷⁰ Førsund, *supra* note 311 at 2.

³⁷¹ *Ibid.*

³⁷² Rio Declaration, *supra* note 29 at principle 16.

spirit. Further, EAP is also simply a more comprehensive measure of productivity which should align with statistical agency's continuous movement towards more accurate measurement.³⁷³

4.3.2.2.2.1 A note on how to model undesirables

While determining a value for undesirable outputs is undeniably a significant challenge for any sort of green accounting, EAP frameworks also have the problem of determining the appropriate place to put this value in the growth accounting framework. Should undesirables be identified as additional inputs (with a positive value) or as additional outputs (with a negative value)? That is, should undesirables be added to the inputs, or subtracted from the outputs? Either way, the direction of the impact on productivity growth will be the same— an increase in inputs without a change in outputs means a decline in productivity and a decrease in outputs without a decrease in inputs has the same impact. For example, Ferjani studied the productivity of Swiss dairy farms by including fertiliser use, stocking density, energy use, and use of purchased concentrate feedstuff. The results showed the geometric mean growth rate for 1993-2001 was higher (2.1%) when environmental aspects (representing undesirables) were included than when they were not (1.8%).³⁷⁴ Due to the type of pollution produced by agriculture (non-point source) and the way the Swiss legislation is set up (to limit the amount of polluting input as opposed to output), the author decided to use polluting inputs as a proxy for undesirable outputs. As you will see, his results are consistent with the trend reported below – that failure to include undesirables, generally speaking, leads to lower productivity growth rates over time.

Ferjani and others who have included undesirables on the input side of their adjusted productivity equation have considered such impacts to be a “proxy for a producer’s use of the

³⁷³ Harchaoui et al, “Appendix 1”, *supra* note 20.

³⁷⁴ Ferjani, *supra* note 317 at 50.

environment”³⁷⁵ and therefore they are considered inputs. This perspective looks at undesirables (for example emissions) as increased employment of environmental services used to absorb the pollution.³⁷⁶ In the same way, Copeland & Taylor indicate, “although emissions are an undesirable joint product of output, our treatment is equivalent if there exists an abatement technology that consumes economic resources.”³⁷⁷ Many others, though, argue that undesirables must be modeled as outputs,³⁷⁸ a position justified by the first law of thermodynamics – the principle of conservation of mass and energy.³⁷⁹ This argument proceeds by stating that treating undesirables as inputs “is inconsistent with the physical laws and the standard axioms of production theory.”³⁸⁰ The main point is that undesirables are joint outputs with desirables and in both an engineering and material balance sense, they must be considered outputs.³⁸¹ Consider the example provided by Repetto,³⁸² that in an industrial process, inputs are taken in, transformed and then must emerge in some form – desirable or undesirable. In this sense, modeling undesirables as inputs is not consistent with the physical production process. Of course,

³⁷⁵ Aiken & Pasurka, *supra* note 320 at 331; Max Keilback, “Estimation of the value of marginal product of emission in a country where emission output is regulated – and empirical study” (1995) 5 *Environmental and Resource Economics* 305.

³⁷⁶ Aiken & Pasurka, *supra* note 320 at 331.

³⁷⁷ Brian R. Copeland & M. Scott Taylor, “Free trade and global warming: a trade theory view of the Kyoto protocol” (2005) 49 *Journal of Environmental Economics and Management* 205-234 at 209.

³⁷⁸ Førsund, *supra* note 311 at 24; Rolf Färe & Shawna Grosskopf, “Nonparametric Productivity Analysis with Undesirable Outputs: Comment (2003) 85:4 *American Journal of Agricultural Economics* 1070 [Färe & Grosskopf, “Nonparametric productivity”]; Rolf Färe & Shawna Grosskopf, *New Directions: Efficiency and Productivity* (Boston: Kluwer Academic Publishers, 2004) [Färe & Grosskopf, “New directions”]; Murty et al, *supra* note 319; Pittman, *supra* note 310 at 884.

³⁷⁹ Rolf Färe et al, “Productivity: Should we”, *supra* note 320 at 4; Rezek & Perrin, *supra* note 320 at 346.

³⁸⁰ Stated by Kuosmanen, *supra* note 315 at 1077 in reference to Färe & Grosskopf, “Nonparametric productivity”, *supra* note 378 and Färe & Grosskopf, “New directions”, *supra* note 378.

³⁸¹ Førsund, *supra* note 311 at 24; Färe & Grosskopf, “Nonparametric productivity”, *supra* note 378; Färe & Grosskopf, “New directions”, *supra* note 378; Murty et al, *supra* note 319; Pittman, *supra* note 310 at 884.

³⁸² Repetto et al, “Has Environmental Protection”, *supra* note 330 at 48-49.

undesirable outputs are linked to inputs, but they are not inputs themselves, and so identifying them in such a way “goes against standard production theory.”³⁸³

While the measure presented in this thesis is based on modelling undesirables as outputs to align with operations of the physical production process, further research into whether this is practical in all circumstances should be undertaken. The Ferjani study³⁸⁴ in particular suggests that in at least some cases, modeling undesirables as inputs instead of outputs makes sense. His study of agriculture in Switzerland is a perfect example. Here those substances which produce pollution and waste (fertilizers, for example) are not regulated on the output side, but rather as polluting inputs,³⁸⁵ and therefore modelling them in the same way is consistent. This is an interesting perspective, especially when considering an industry where the pollution and waste is complex and non-point source and therefore more difficult to measure as an output. Whether this should be an exception to the general consensus of modeling undesirables as outputs remains to be seen and should continue to be studied. The correct choice may very well depend of the nature of the aspect of natural capital in question.

4.3.2.2.3 Conceptual Arguments for Improving and Measuring Environmentally Adjusted Productivity

This section has already set out the basic methodology of EAP. Before reviewing some of the existing research on EAP, it may be useful to provide an overview of some of the broader rationales for its use in relation to sustainable economic growth and intergenerational equity. Its use in policy context will be discussed in Chapter 5, and Chapter 6 will focus on EAP as a tool for instrument choice decision making, but first, a few conceptual points are made here.

³⁸³ Färe & Grosskopf, “Nonparametric productivity”, *supra* note 378; Färe & Grosskopf, “New directions”, *supra* note 378.

³⁸⁴ Ferjani, *supra* note 317 at 45-55.

³⁸⁵ Ferjani, *supra* note 317 at 46-47.

Specifically, this section argues that EAP can be considered superior to conventional measures of productivity for environmental, scientific, and economic reasons.

From an environmental perspective, EAP is an important measure of the changing environmental impact of economic processes. EAP takes into consideration the negative impacts of production processes, such as pollution or ecosystem damage. Therefore, changes in EAP measures can, in some ways, represent changes in the quality of the stock of natural capital. Undesirable outputs tend to be in the form of pollution, waste, toxins, etc. which then enter into the natural environment. This then impacts the stock of natural capital which in turn has consequences for the quantity and quality of the natural capital flows of goods and services. Without accounting for undesirable outputs, these impacts which may have serious consequences for the natural environment are going unaccounted for in the realm of economic analysis. Without recognition, these undesirable outputs and their impacts on the natural environment will be more likely to continue to occur, to the detriment of society's health and well-being.

From a scientific perspective – specifically an engineering and physics one – the exclusion of one set of outputs from a production function goes against material balance principles and standard production theory³⁸⁶ as well as the first law of thermodynamics.³⁸⁷ It is fairly well understood that whatever is used as an input into the production process must emerge as a form of output (since matter cannot be created or destroyed). And if input material does not emerge as a desirable output (something which generates GDP) it must emerge in another form, most often an undesirable one. Traditionally, the economic production function has excluded

³⁸⁶ Førsund, *supra* note 3118 at 24; Färe & Grosskopf, “Nonparametric productivity”, *supra* note 378; Färe & Grosskopf, “New directions”, *supra* note 378; Murty et al, *supra* note 319; Pittman, *supra* note 310 at 884.

³⁸⁷ Ngoc-Bich Tran & V. Kerry Smith, “The Role of Air and Water Residuals for Steam Electric Power Generation” (1983) 10 *Journal of Environmental Economics and Management* 35 at 37.

this latter type of output, but given this scientific understanding, such exclusion means an inaccurate reporting of the production process. Put simply, it is common knowledge that these undesirable outputs exist, and in very large quantities. Simply ignoring them is not an adequate response.

The economic justification for the use of EAP has to do with improving the measurement of productivity. Though improvements in the way that inputs and outputs are measured in both partial and multifactor productivity measures have occurred over time,³⁸⁸ they have not evolved to include accounting for the undesirable outputs which are undeniably produced alongside desirable ones. One response to the scientific perspective above is that although these outputs are physically substantial, they are not economically significant. That is to say that undesirable outputs have essentially zero economic value (generally), and so leaving them out of the equation does not change the result. Yet this is often not true – pollution and ecosystem damage can have very large economic impacts, especially in the long-term and at the sector and economy-wide level.

4.3.2.2.4 Past Research

There is a growing literature on the topic of including undesirable outputs in conventional productivity measures which dates back to at least the early 1980's. As has already been noted, adjusting productivity to account for undesirable outputs can be done using both traditional partial productivity (analogous to labour productivity) as well as MFP measures. More work has been done on the latter, since it is in general considered to be more comprehensive. Still, for

³⁸⁸ Chen et al, *supra* note 256 at 10; Tarek Harchaoui & F. Tarkhani, "A Comprehensive Revision of the Capital Input Methodology for Statistics Canada's Multifactor Productivity Program" in J.R. Baldwin & T.M. Harchaoui, eds, *Productivity Growth in Canada* (Ottawa: Statistics Canada, 2002). Repetto, "Measuring the True Productivity", *supra* note 262 at 293. Repetto, "Environmental Productivity", *supra* note 313.

both measures, the problem is including undesirable outputs, and therefore output can be adjusted in the same or similar way. The literature on EAP is by no means complete, nor are the authors in agreement on everything,³⁸⁹ but there are some widely accepted findings. There have been some attempts to canvas this literature,³⁹⁰ but as far as the author of this thesis is aware, this literature review is the most extensive.

To begin, it can generally be said that measuring productivity without including undesirable outputs provides incomplete results. More detailed analysis indicates that often, when undesirable outputs are not considered in the productivity framework (in particular when environmental protection measures are in place),³⁹¹ productivity growth is underestimated.³⁹² An example may help make this clear. In situation ‘A’, no environmental protection measures are in place and therefore undesirable outputs (causing environmental harm) are high. Conventional measures which do not consider undesirables show one rate of productivity growth. Environmentally adjusted measures, though, do include undesirables and therefore environmentally adjusted output will be less than output in conventional productivity measurement. This means that environmentally adjusted productivity estimates will also be lower than conventional productivity estimates. In this case, conventional productivity measures are overestimates. In situation ‘B’, environmental protection, which requires a reduction in undesirable outputs, had been implemented. Conventional measures (again, recall undesirables

³⁸⁹ See for example, the conversation between authors which has been published in the American Journal of Agricultural Economics. Atakelty Hailu, “Nonparametric Productivity Analysis with Undesirable Outputs: Reply” (2003) 85:4 American Journal of Agricultural Economics 1075; Färe & Grosskopf, “Nonparametric productivity”, *supra* note 378. The main argument here is about the assumption made in a model about the disposability of undesirable outputs. Here disposability is referred to as the ability to stockpile/discard/dispose of undesirable outputs. The former (strong) implies no private cost while the latter (weak) means some private cost will be incurred (definitions of disposability taken from Färe & Grosskopf, “New directions”, *supra* note 378 at 38).

³⁹⁰ Perhaps the most obvious is Tyteca, *supra* note 24 at 289-296.

³⁹¹ Ball et al, “Incorporating Environmental Impacts”, *supra* note 310 at 458.

³⁹² Hailu & Veeman, “Environmentally sensitive productivity”, *supra* note 315 at 272.

are not considered here) see inputs rise as compared to situation ‘A’ and as a consequence of additional requirements to meet environmental regulation. Outputs in the conventional productivity measure likely either stay the same or even possibly decline (as compared to situation ‘A’) meaning a probably decline in conventional productivity. Environmentally adjusted measures, though, while still seeing a rise in inputs, also see a rise in total outputs (as a consequence of declining undesirables) which means environmentally adjusted productivity growth should be higher than conventional productivity. Here conventional productivity estimates would be an underestimation. Note that EAP growth implies relative environmental gains – better than the year before. However, raw EAP estimates, in any given year, are probably still lower than conventional productivity for the simple reason that conventional productivity does not require undesirable outputs to be “subtracted” and therefore total output of conventional is higher. Similarly, at times, EAP growth might equal conventional productivity growth, implying no environmental improvements year over year, or be less than conventional, implying environmental damage worsened.

The majority of studies which attempt to include undesirable outputs in order to produce an EAP measure have found that the productivity growth rates they calculated were, on average, higher as compared to conventional productivity ones in the same years. When studying the inclusion of sulphur dioxide and particulate matter in a conventional productivity measure, Aiken and Pasurka Jr. found that average annual growth rates of their adjusted measure were higher than the conventional ones during both time frames measured – 1970 to 1977 and 1977 to 1996.³⁹³ Similar findings emerged in Repetto’s analysis of both the electrical and the pulp and paper sectors in the United States when emissions of nitrogen oxides, sulphur oxides,

³⁹³ Aiken & Pasurka, *supra* note 320.

particulates, volatile organic compounds, carbon monoxide and lead were included.³⁹⁴ Repetto completed calculations for conventional and revised MFP estimates in both sectors. Over the 1970 to 1991 time frame, in the electrical sector, conventional MFP average annual percentage change declined by 0.35, while revised (including undesirable outputs), over the same time period, increased by as much as 0.68.³⁹⁵ Results in the pulp and paper sector show the same trend, only with less variance.³⁹⁶

Kumar studied 41 countries (a mix of developed and developing) and considered the impact that including CO₂ emissions as undesirable outputs to conventional productivity measures would have.³⁹⁷ Results are consistent with studies already mentioned - between 1971 and 1992, annual conventional productivity declined by 0.002% while the environmentally adjusted measure showed average annual change of 0.02% growth.³⁹⁸ Färe, Grosskopf & Pasurka Jr., considered air pollutants from manufacturing industries across the United States.³⁹⁹ Their findings are also consistent - the mean average annual change in productivity (1974-1986) was higher when undesirables were included (– 1.0363) as compared to when they were not (– 1.0169).⁴⁰⁰

Studies have also been done which consider the measurement of agricultural productivity inclusive of undesirable outputs such as soil erosion and nitrogen run off. Repetto *et al.*

³⁹⁴ Repetto, “Measuring the True”, *supra* note 320 at 291-307.

³⁹⁵ Repetto, *ibid* at 303, calculated revised estimates assuming damage values remained constant over the time frame measured and here found the highest annual percentage change. He also calculated revised estimates of multifactor productivity assuming that damage values changed proportionally to GDP. Results of the latter calculations indicated less growth (0.38 over the 1970 to 1991 range) but still higher than conventional.

³⁹⁶ In Repetto, *ibid*, at 304 the pulp and paper sector results showed conventional multifactor productivity annual average percentage change between 1970 and 1990 are estimated at growth of 0.16 while revised estimates show higher growth, at 0.44.

³⁹⁷ Kumar, *supra* note 267 at 285.

³⁹⁸ *Ibid* at 289

³⁹⁹ Färe et al, “Accounting for Air Pollution”, *supra* note 310.

⁴⁰⁰ *Ibid* at 399.

undertook a study over the time frame of 1977-1992 which included agriculture in the United States. The results of this study indicated that growth rates of productivity measures which include undesirable outputs were again consistently higher than conventional productivity growth rates – conventional showed an average annual changes of 2.30% while two different estimates of environmentally adjusted showed average annual change of 2.38% and 2.41%.⁴⁰¹ Ball *et al.* studied agriculture in the United States and undesirable outputs emitted into water associated with pesticide use.⁴⁰² They found that average annual growth rates of environmentally adjusted productivity (over the entire 1960-1996 study time frame) are lower (0.98%) than conventional productivity growth rates which were found to be 1.54%.⁴⁰³ While this is not aligned with many of the other results, in principle it abides by the idea that when environmental protection measures are introduced, conventional productivity growth is in fact less than environmentally adjusted. This study shows the variance nicely since the earlier timeframe was pre-environmental protection concerns and the later timeframe was post. In the early part of the study, when pesticide use was extremely common and increasing (1960-1972), environmentally adjusted productivity growth rates were -2.56% per year and conventional were 1.68%.⁴⁰⁴ This indicates that high levels of undesirables were being emitted but not counted and therefore reported conventional productivity growth is overestimated as compared to the ‘true’ rate of productivity growth. In the latter years (1984-1996) when there was increased awareness of the dangers with pesticide use and environmental protection was on the rise, environmentally adjusted productivity growth rates were higher (4.96% year) as compared to 2.64% for

⁴⁰¹ Repetto, et al, “Has Environmental Protection”, *supra* note 330 at 52.

⁴⁰² Ball et al, “Incorporating Environmental Impacts”, *supra* note 310.

⁴⁰³ *Ibid* at 450.

⁴⁰⁴ *Ibid*.

conventional.⁴⁰⁵ Here, in the later years, the conventional results are an underestimation.⁴⁰⁶

Results from a very similar study led, again, by Ball *et al.*, confirm that in years where pesticide use was high, conventional measures outperformed environmentally adjusted (and therefore overestimated productivity growth) and as pesticide use declined and environmental protection increased environmentally adjusted measures outpaced conventional (and therefore productivity growth was underestimated).⁴⁰⁷

Gallop and Swinand studied the American agriculture industries over the period of 1972-1993 and found, on average, annual productivity growth rates over this period were slightly higher for productivity measures which included undesirables; the mean estimate (between different prices placed on undesirables) was 0.0148 for environmentally adjusted and 0.0147 for conventional.⁴⁰⁸ Further work by the same authors confirm these results in the same sectors between 1972-1993 where findings show that in all but one time frame (1972-1979) environmentally adjusted measures have higher average annual productivity growth rates.⁴⁰⁹ Nanere *et al.* in their study of Australian agriculture, included soil erosion as their undesirable output.⁴¹⁰ In this case, the author followed a similar methodology to Repetto and reported results for conventional, revised (environmentally adjusted) keeping damage values constant and revised (environmentally adjusted) making damage values proportional to GDP.⁴¹¹ In contrast to findings from Repetto where both revised estimates of average annual percentage change (regardless of whether damage values were constant or proportional to GDP) were found to be

⁴⁰⁵*Ibid* at 450, 458.

⁴⁰⁶*Ibid* at 458.

⁴⁰⁷ Ball et al, "Accounting for bads", *supra* note 315 at 16.

⁴⁰⁸ Gallop & Swinand, "From total factor", *supra* note 344 at 582.

⁴⁰⁹ Gallop & Swinand, "Total resource productivity", *supra* note 323 at 601.

⁴¹⁰ Nanere et al, *supra* note 315.

⁴¹¹ *Ibid* at 358-359

higher than conventional,⁴¹² Nanere *et al* found that in all cases (low, medium and high soil erosion), average annual percentage change of conventional productivity measures was lower than revised estimates where damage values were held constant, but higher than revised estimates where damage values were proportional to GDP.⁴¹³ Overall, this group of results indicates that the general relationship between conventional and EAP growth rates holds in both agricultural and more broadly, across industry.

In one of the only studies undertaken in Canada, Hailu & Veeman, find that the average annual growth rate of their productivity index which included undesirables was 1.00% while the index which did not include this additional set of outputs was 0.19%.⁴¹⁴ Their study was undertaken for the years 1959-1994 for the Canadian Pulp and Paper Industry. They included undesirables of water pollutants, specifically biological oxygen demand and total suspended solids.⁴¹⁵ Hailu & Veeman undertook another study of the same industry but using slightly different methodologies and again found the same results – on average, the Canadian Pulp and Paper Industry experienced productivity growth of 1.8% annually over the years 1959-1994 measured conventionally and 2.1% when measures included undesirable outputs.⁴¹⁶ These two Hailu & Veeman studies show the same general result – that average annual growth rates of productivity measures including undesirable outputs are higher than those determined from conventional measures, but the variance in actual results illustrates the variety of methods being used in similar studies.

⁴¹²Repetto, “Measuring the True”, *supra* note 320 at 303-304.

⁴¹³Nanere et al, *supra* note 315 at 358-359.

⁴¹⁴Hailu & Veeman, “Environmentally Sensitive Productivity”, *supra* note 315 at 266.

⁴¹⁵*Ibid* at 264.

⁴¹⁶Hailu & Veeman, “Non-parametric productivity”, *supra* note 315 at 611 and 616.

The reason for the common finding, that environmentally adjusted productivity measures seem to generally have growth rates that are higher than conventional productivity measures, is because the environmentally adjusted measure gives credit for improvement in environmental outcomes. That is, when calculating productivity, especially in the face of environmental regulation of some sort, conventional productivity measures consider the additional costs (of inputs) associated with compliance without considering the benefit of decreased undesirable outputs.⁴¹⁷ EAP measures, on the other hand consider both the increased input associated with these environmental measures, but also give credit for the associated reduction in undesirable outputs. This is an important point, because it illustrates how EAP incorporates not only the costs of environmental regulations, but also their benefits.

To be clear, in most cases the raw value of environmentally adjusted productivity is still lower than conventional productivity. One clear example of when it might not be is in a situation where no undesirables were produced (perhaps they were all recycled back into a production process) – this is a very rare exception, though, and certainly not the rule. Comparing conventional to environmentally adjusted productivity based on the raw values generated should (at least initially) show conventional being higher than environmentally adjusted, for the simple reason that the undesirable outputs are being considered. Nonetheless, this environmentally adjusted measure is a more accurate indicator of true productivity. Environmental regulations, however, should increase static EAP results, even if they appear to decrease conventional productivity. This is because EAP captures the benefit of environmental regulations.

⁴¹⁷ It is, of course, possible that the changes between convention and environmentally adjusted productivity could be caused by drivers other than environmental regulation – that is, there is not a clear causation in the relationship described. Still, there is a strong argument that the conventional productivity measure's failure to give credit for a reduction in undesirable outputs represents at least a portion of the difference observed.

Using growth rates, as compared to static values, means better comparisons between conventional and EAP can be done. Comparing conventional productivity in year one to conventional productivity in year two and EAP in year one to EAP in year two allows results to be reported in growth rates. This gives a better way to equate conventional versus EAP measures since the comparison is looking at “apples to apples.” Productivity growth rates are what most statistical agencies use when reporting results⁴¹⁸ and therefore it can be inferred that they are what most decision makers look at as well. Growth rate comparisons take out the inconsistency in output measurement as they measure year over year change in EAP and conventional productivity separately and then compare.

In contrast to the research presented above which indicated the generally higher growth rates of EAP, some studies have found that productivity adjusted for undesirable outputs grew at a lower rate than conventional productivity, or that findings were inconsistent. In particular, this was seen in Managi and Jena’s study of India during the 1990’s and early 2000’s.⁴¹⁹ During the first time frame studied (1991 to 1994) market productivity (conventional) declined by 0.022 and joint productivity (including both desirable and undesirable outputs) declined by less, only 0.008. Later time frames (1995 to 1998, and 1999 to 2002) saw market productivity growth rates outpace joint productivity.⁴²⁰ The overall mean change in productivity was a decline of 0.001 for market and a decline of 0.01 for joint.⁴²¹ Harchaoui, Kabrelyan & Smith found, in their study of Canadian sectors, saw that some EAP measures had growth rates higher than conventional (manufacturing, other and general business sector) while others saw the opposite effect (primary,

⁴¹⁸ Harchaoui et al, “Appendix 1”, *supra* note 20 at 143.

⁴¹⁹ Managi & Jena, *supra* note 323.

⁴²⁰ See *ibid* at 436 for overview table.

⁴²¹ *Ibid*.

transportation, and utility).⁴²² These results show conflicting findings across sectors – in some conventional productivity growth rates are higher, in others it is the environmentally adjusted results which show higher growth. Rezek & Perrin also found conflicting results in their study of agriculture productivity in the United States Great Plains States. In this study, four states were considered over the 1960 to 1996 time frame and conventional productivity was compared against environmental adjusted which included undesirable outputs represented by nitrogen and pesticide pollution. In all but one state, EAP growth rates were lower than conventional. Kansas saw conventional annual growth rates of 1.34% and environmentally adjusted of 0.83%; Nebraska 1.77% and 1.25%; and Oklahoma 0.97% and 0.84%, respectively.⁴²³ South Dakota, though, had conventional productivity growth rate of 0.93% and environmentally adjusted of 0.99%. From this set of research evidence shows that EAP growth is not necessarily higher than conventional, but that it certainly can be.

These contrasting findings suggest that something might be occurring which is causing different results than would be expected. Numerous authors have hypothesized about what may have caused contradictory findings, though a determinative answer is not easily forthcoming. Some have blamed divergent findings on variation in calculations,⁴²⁴ while others consider waning influence from environmental policies which have been in effect for some time.⁴²⁵ Still other authors have considered structural changes,⁴²⁶ geography,⁴²⁷ or macroeconomic

⁴²² Results are presented for the years 1981-1996. Harchaoui *et al*, “Accounting for Greenhouse”, *supra* note 248 at 12.

⁴²³ Rezek & Perrin, *supra* note 320 at 358.

⁴²⁴ Ball *et al*, “Accounting for bads”, *supra* note 315 at 314; Chapple & Harris, *supra* note 315. at 16; Kumar & Khanna, *supra* note 315 at 490

⁴²⁵ Nanere *et al*, *supra* note 312.

⁴²⁶ Färe *et al*., “Accounting for Air Pollution”, *supra* note 310 at 403; Ferjani, *supra* note 317 at 53.

⁴²⁷ Färe *et al*, “Accounting for Air Pollution”, *supra* note 310 at 402.

fluctuations⁴²⁸ as being responsible for contrasting findings. One study claimed that divergent results may be due to over attentive actors who change plans more frequently or substantially than conditions would warrant.⁴²⁹ An alternative explanation suggested here, is that differing results are a consequence of the design of a legal instrument targeting reductions in undesirables. That is, in a situation where EAP growth is less than conventional (a contrasting finding to the majority of the literature), if a different instrument had been implemented, it is possible that it could have achieved the same level of environmental protection – reduction in undesirable outputs – but with less impact on additional inputs or desirable outputs which could have led to a reversal in results.

The concept of “properly designed environmental standards” was given prominence by Porter & van der Linde in their hypothesis that environmental regulation is not necessarily bad for innovation, but the instruments used to gain successes must be properly designed.⁴³⁰ Extending this argument to productivity suggests that properly designed legal instruments which aim to reduce undesirable outputs can actually lead, year over year, to growth in EAP. However, sometimes instruments which are introduced and have a laudable goal – for example, to reduce carbon emissions from large polluters – might still lead to a reduction in EAP. That is, if the instrument is designed in such a way that it will cause large increases in input costs without equal or larger decreases in emissions, a decline in EAP would likely be the result since the reduction in undesirables is outweighed by the increase in input costs or reduction in desirable outputs. In that case, the instrument should not be implemented and, instead, an instrument

⁴²⁸ *Ibid* at 404.

⁴²⁹ Ferjani, *supra* note 317 at 51.

⁴³⁰ Michael E. Porter and Claas van der Linde, “Toward a New Conception of the Environment-Competitiveness Relationship” (1995) 9:4 *Journal of Economic Perspectives* at [Porter & van der Linde] 98-100, 110.

should be designed that has the same effect on emissions but with less cost to polluters. Of course some might argue that so long as pollution is reduced then the goal has been met. However, given that the concern is with regards to both environmental and economic considerations, the apparent declines in EAP may provide useful information about which instruments are more or less ideal.

The balance of the literature indicates that in the presence of environmental protection measures, conventional productivity frameworks have lower rates of growth as compared to environmentally adjusted ones. The reason for this is likely that in addition to gains in the conventional determinants of MFP (i.e. technology), the economy is also making gains in reducing environmental impacts, such as pollution or ecosystem degradation. Since EAP incorporates both of these, it often shows a higher growth rate than conventional productivity. Interestingly, in the studies with divergent findings, most often results were mixed over time frames, locations or industries with some confirming the general findings and others disproving it. Perhaps the reason for this is that there are significantly larger environmental gains at some times and places than others. This provides an opportunity for an evaluation of the different environmental protection measures which may have been implemented during these different time frames. While not within the scope of this thesis, such a research project would undeniably add to this research area.

4.3.2.3 Natural Capital & the Multifactor Productivity Residual

The previous two sections have focused on the better known measures of green productivity – the use of partial measures to consider natural capital flows as inputs in production and the adjustment of the output variable in a productivity calculation to be inclusive of both desirable

and undesirable outputs. This section addresses a more nuanced, and less prominent, way of linking natural capital and productivity - by focusing on the MFP residual. Specifically, while the residual is often described as being influenced by technology or management improvements, there is reason to think changes are also influenced by natural capital. The quality of inputs – such as timber - may decrease, or the quantity of inputs - such as rainfall - may decline. In both cases, the residual is likely to be affected. Currently, these impacts are poorly understood, and generally not considered within measurement frameworks. The following section considers the possible contributions that changes in the quality and quantity of natural capital can have on the multifactor residual.

4.3.2.3.1 Conceptual Framework

The residual, as was defined and discussed earlier in this chapter (section 4.3.1) measures “the changes in the output aggregate not explained by changes in the input aggregate.”⁴³¹ It is a measure of how efficient a production process is at converting inputs into outputs. In other words, if an industry produces 10 widgets in year one with 5 units of input and in year two increases production to 15 widgets with the same 5 units of input, the MFP residual has increased – the industry has become more productive. Traditionally, as explained by Solow (and others), this variation has been considered a measure of technological change⁴³² or advances in technology.⁴³³ But, as Rodríguez and Arias note “the use of the Solow Residual as a measure of

⁴³¹Xosé Antón Rodríguez & Carols Arias, “The Effects of Resource Depletion on Coal Mining Productivity” (2008) 30 *Energy Economics* 397 [Rodríguez & Arias] at 399.

⁴³² Solow, “A Contribution”, *supra* note 11.

⁴³³ Apostolides, *supra* note 250.

technical change relies on a number of simplifying assumptions,”⁴³⁴ which, if incorrect, means the general understanding of the residual must be adjusted.

Numerous authors have argued that these simplifying assumptions are, in fact, often inaccurate, and that there are other factors beyond technology which account for changes to the residual. For example, Hall, in two different articles, highlights other elements which can contribute to the residual, including market power, increasing returns, external technical complementarities, chronic excess capacity, unmeasured fluctuations in work effort and hours, errors in measuring capital or output, and monopoly power in the labour market.⁴³⁵

In addition, the residual may very well not capture the effects of changes in the quality of inputs.⁴³⁶ When measuring productivity, this could have two clear consequences. First, if any of the input variables (labour, capital, energy, services, timber, for example) were to experience a change in quality, the produced outputs might be less valuable. In that case, it would not be clear that the associated impact on the residual was connected to changing input quality. Secondly, a reduction in the quality of inputs could impact the residual because more inputs may be needed to produce the same amount of output. Alternatively, these lower-quality inputs might require more processing and therefore related costs could increase. In both cases, the impact is unlikely to be accurately attributed to input quality but instead considered to be as a consequence of changes in technology or management. If such is the case for conventionally measured inputs, this mis-measurement of inputs would also extend to those flowing from natural capital.

⁴³⁴Rodríguez & Arias, *supra* note 431 at 399.

⁴³⁵ Robert E. Hall, “Market Structure and macroeconomic fluctuations” (1986) 2 *Brookings Papers on Economic Activity* 265; Robert E. Hall, “Invariance properties of Solow’s productivity residual”, in Peter Diamond, ed, *Growth/Productivity/Unemployment: Essays to Celebrate Solow’s Birthday* (Cambridge: The MIT Press, 1990) 71-112.

⁴³⁶Hulten, *supra* note 255 at 27.

The impact of natural capital on the residual can manifest itself in two different ways. Perhaps most obviously, because many aspects of natural capital which are used as inputs into production are not generally measured by conventional productivity frameworks, changes in their quantity would not normally be measured. Such things could include “precipitation, temperature, short term (El-Niño-Southern Oscillation events), medium-term (decadal-scale events), and long term climate change.”⁴³⁷ These inputs and their changes are crucial to industries which rely upon them, but they are not considered in productivity studies. For example, agriculture relies heavily on rainfall as an input but it is not included in the conventional MFP framework. That means that the variability in rain patterns shows up in the residual. But because this residual is often considered to be a consequence of changes in technology, growth or decline will be attributed to associated movements in agricultural technology even if the changes are actually due to rainfall variability.⁴³⁸ This hypothesis is confirmed by the results from a study of agricultural productivity and rainfall patterns in Australia which show a strong correlation between declines in MFP and periods of drought.⁴³⁹ Measured inputs over the same period of time remained relatively constant and so the decline in output, without considering rainfall patterns, could easily be attributed to declines in technology. Of course, for changing quantities of unmeasured inputs to have a noticeable impact on the MFP residual, they must comprise a significant input for the industry.⁴⁴⁰ In this sense, changes in

⁴³⁷ Dale Squires, Christopher Reid, and Yongil Jeon, “Productivity growth in natural resource industries and the environment: an application to the Korean tuna purse-seine fleet in the Pacific Ocean” (2008) 22(1) *International Economic Journal* 81-93 [Squires et al] at 82.

⁴³⁸ Vernon Topp & Tony Kulys, *On Productivity: the influence of natural resource inputs*, Productivity Commission Staff Research Note (Canberra, Australia: Productivity Commission, 2013) [Topp & Kulys] at 1.

⁴³⁹ *Ibid* at 13.

⁴⁴⁰ *Ibid* at 1.

rainfall patterns are not an important function of industrial manufacturing production but are clearly important to agriculture.

The quantity of natural capital flows used as inputs can also be a factor when considering remaining stocks. The scarcity of the deposits of natural capital stocks and associated flows can impact the natural capital residual, but, generally speaking, is not captured in the conventional form of measurement. For example, a study of the coal mining industry in Spain showed that simply considering the residual to be a function of technological change hides the fact that the depletion of available natural resources has meant an annual increase in coal input of 1.20% is required to keep up with production, likely at least in part due to lower quality coal, or more difficult to access sources.⁴⁴¹ This may be unobserved because at the same time there have been efficiency improvements in extraction techniques as a consequence of new technologies. The author states that “decreasing reserve levels are likely to increase the cost of extraction while technical change contributes to decrease extraction costs”⁴⁴² – without considering both effects, it is hard to fully understand the impact on the multifactor residual from a declining quantity of natural capital. Similar challenges occur when productivity growth does not account for changes in fish stocks. As Squires *et al.* notes, “without accurate measures of productivity growth in fishing industries, the extent of the excess capacity plaguing global fisheries cannot be properly assessed, and appropriate conservation and management policies formulated.”⁴⁴³

The quality of natural resource inputs is an additional way that natural capital may impact the residual. As noted above, productivity calculations are generally not set up to consider the quality of any type of input regardless of whether they are conventional production inputs or

⁴⁴¹Rodríguez & Arias, *supra* note 431 at 407.

⁴⁴²*Ibid* at 398.

⁴⁴³Squires et al, *supra* note 437 at 90.

not,⁴⁴⁴ so changes to the quality of labour, capital, natural capital and others are not accounted for⁴⁴⁵ except as a part of a measure of our ignorance – as part of the residual. This causes a problem in the case of natural capital because the inputs are often not (fully) accounted for in any event. Therefore any changes that do occur as a consequence of quality improvement or decline are likely to be lumped in with others as ‘noise’.

Interestingly, declines in the quality of inputs can have the same impact as declines in quantity.⁴⁴⁶ That is, a decline in quality generally means an increase in the quantity of other types of inputs required, and therefore a decline in productivity.⁴⁴⁷ Take mineral deposits, for example, which are inputs into various types of mining production. As the quality of mineral deposits becomes less and they are located deeper or covered by more overburden, for example, the quantities of measured inputs used in the overall production process are likely to increase.⁴⁴⁸ But without considering the quality of the mineral deposits, the MFP results would simply indicate increases in overall inputs which would likely be attributed to technology change in some form or another without considering the fact that lower quality mineral deposits were the reason.

A further example may better clarify the challenge presented here. Consider water as an input into production. Many industries use large amounts of water in their production process, and some require a very high quality of water - for example, food and beverage manufacturing. If a company is used to withdrawing a certain quality of water from the natural environment, but that quality changes – it goes down for some reason – the company will need to dedicate

⁴⁴⁴ Hulten, *supra* note 255 at 27.

⁴⁴⁵ Apostolides, *supra* note 250.

⁴⁴⁶ Topp & Kulys, *supra* note 438 at 8.

⁴⁴⁷ *Ibid.*

⁴⁴⁸ *Ibid.*

additional resources (more inputs of some sort) to process the water and bring it up to the quality required for use in the production of their goods and services. But, given the way MFP is currently measured, these additional inputs which are required in order to deal with the changed water quality are likely to be associated with changes in technology (since that is generally what residual changes are considered to be a consequence of).⁴⁴⁹ Therefore the impact of the quality of the water will not be highlighted in the multifactor productivity estimates and so company decision makers may overlook its importance to the continued productivity growth. This is a classic example of what Rodríguez and Arias state, that “it is not only a matter of the use of these and other inputs in an efficient manner that produces output, but it “also depends on the characteristic of a ... natural resource.”⁴⁵⁰ In this case, the characteristic (quality) of the natural resource (water) declined.

In summary, the lack of inclusion of changes in natural capital as part of traditionally defined residual change (primarily measured as technology) may misrepresent productivity growth and probably masks declining natural capital quantity and quality. Both are concerns given the Canadian governments’ commitments to sustainable economic growth and intergenerational equity. Lack of representation in productivity measures may mean that changes in natural capital are hidden especially in industries which directly utilize natural resources thereby reducing the probability such capital will be available for future generations. Further, at times under/mis-representation of natural capital within productivity may underestimate growth (or direct policies at incorrect areas) and therefore miss opportunities to improve economic growth. Through specifically detailing how natural capital can be accounted

⁴⁴⁹ Solow, “A Contribution”, *supra* note 11.

⁴⁵⁰ Rodríguez & Arias, *supra* note 431 at 398.

for in the residual is beyond the scope of this work (indeed, researchers are still grappling with the best method to do this), the research which does exist has shown some initial ways which understanding changes in the quality and quantity of natural capital in relation to the residual can be done. Consider, for example, the case of Australian agriculture (discussed above).⁴⁵¹ This is a situation where information from those in an industry significantly impacted by changing natural capital can prompt quite different interpretations of productivity measures. Though this does not detail the way that the impacts of natural capital could be teased out from the residual in a productivity calculation, it does show the importance of working towards such a goal. Further, it illustrates that even without the calculations, considering natural capital's impact on the residual can point decision makers towards some interesting conclusions.

4.4 Chapter Summary

This chapter began by introducing the economic concept of capital and its counterpart - natural capital. A number of definitions of capital were presented and it was argued that natural capital can be considered not only a type of capital, but that it fits well with the definition of capital stocks and flows.

The second part of the chapter began by discussing the general premise and terminology for green productivity as well as its connection to broad sustainability goals. The remainder of the chapter analysed, in turn, the three green productivity measures – NRP, EAP and NCR. Discussions of these measures included recommended best practice terminology, overviews of the frameworks, connections with the goals of sustainable economic growth and intergenerational equity, and previous research. As the discussion here has shown, improvement

⁴⁵¹ Topp & Kulys, *supra* note 438.

in green productivity and its specific measures can play a useful role in moving toward sustainable economic growth and intergenerational equity. The following chapters consider, in more detail, how green productivity can be applied in public policy development and legal instrument choice.

PART TWO: APPLICATION OF GREEN PRODUCTIVITY TO LAW & POLICY

5. Green Productivity and the Policy Cycle

5.1 Introduction

This chapter explores green productivity and the policy cycle. Though the focus of much of this thesis is on ways which green productivity and its more specific measures of NRP, EAP and NCR can improve decision making, ultimately leading towards achieving commitments to intergenerational equity and sustainable economic growth, this chapter is slightly different. The following chapters (Chapters 6 and 7) detail and illustrate how green productivity measures can be used in instrument choice decision making, but here the focus is on where in the policy cycle green productivity is most likely to have influence. The chapter begins by reiterating the important role that green productivity can play in achieving the sustainability goals discussed in Chapter 2, but the bulk of chapter considers where in the policy cycle the adoption of green productivity is most likely to gain traction, and it concludes with a discussion of some factors which make this plausible. Specifically, the chapter argues that the nature of green productivity is especially well suited to the broad policy debate and cross-departmental engagement at the agenda-setting stage.

Before digging deeply into the application of green productivity in the policy cycle, this chapter first discusses how green productivity aligns with the goals of sustainable economic growth and intergenerational equity. The conclusion is that green productivity should be used as a policy priority by governments committed to such goals. Secondly, this chapter analyses green productivity and concludes that it possesses characteristics which make it especially relevant at the agenda-setting stage (Stage 1) of the policy cycle. In addition, two ways green productivity measures can improve decision making throughout the policy cycle are highlighted: that NCR can provide novel information to policy actors at a number of different policy cycle stages, and

that NRP and EAP can be used as *ex-post* evaluative tools in Stage 5 – evaluation - of the policy cycle.

5.2 Green Productivity *Should* be a Public Policy Goal

The discussion about green productivity's role in the policy cycle builds on the points made in Chapter 2 and specifically focuses on why green productivity should be a government priority.

Recall that in Chapter 2, Canada's legal commitments to sustainability are linked to increased efficiency of use of natural capital as well as considerations of intergenerational equity.

Efficiency of use of both stock and flow components of natural capital is an important way to make progress towards a maintained or restored natural environment for future generations without harming the economy. To help decision makers determine progress on improvements in efficiency of use, green productivity is an excellent tool. Its various more specific measures (in different ways) how natural capital is being used in production, whether that be the natural resource flows as inputs, or the broader stock of natural capital as a sink.

In order to achieve allocative efficiency of natural capital between generations, technical and productive efficiency within today's production processes is critically important. From the perspective of allocative efficiency (societal welfare), Kaldor-Hicks interpretations can be met through green productivity since, *ceteris paribus*, increases in green productivity indicate more or the same amount of economic output is being produced while using the same or less natural capital. That is, on a whole, society is better off because the economy is likely growing and that growth is having less of an impact on the natural environment. Therefore, economic growth is more sustainable. Of course it is possible that increases in efficient results in increasing use of natural capital (stock or flows) and therefore some type of a safety net would be an important addition to a government priority item targeting green productivity improvement.

5.3 Green Productivity and Agenda-Setting

The basic process of agenda setting was discussed in Chapter 3 as one stage in the broader policy cycle, and in this chapter it is argued that the broader concept of green productivity should be introduced at this stage of the policy cycle. The nature of green productivity, drawing on both environmental and economic factors, requires cooperation and expertise from multiple departments. This impacts both its appeal as a policy priority and the requirements for its successful implementation. Together these are relevant points strengthening the overall argument that green productivity possesses characteristics which make it most likely to succeed at becoming a policy priority if it enters the policy cycle as a central government agenda item at Stage 1.

The second part of this section addresses the actual potential for green productivity to become a government priority in the current Canadian context. The focus here is on the diffusion of political innovations based on experience and current policy priorities in other jurisdictions and by international agencies. Through an investigation of the literature and real world evidence, this chapter concludes that it is certainly plausible for green productivity to become a policy priority area in Canada.

Both of these investigations of green productivity center around the first stage in the policy cycle – agenda setting. Generally speaking “*agenda-setting* refers to the process by which problems come to the attention of governments.”⁴⁵² In Chapter 3, two parts to the agenda setting stage were identified – ‘1A’ which dealt with legitimizing an issue and is based upon external factors and actors, and ‘1B’, the definition of the problem or idea, which is more heavily

⁴⁵² Howlett et al, *supra* note 153 at 12 (italics in original).

influenced by government priorities. Stage 1A is not considered at length here – while drivers such as public opinion, the media, and significant events are important, they are beyond the scope of this research.⁴⁵³

In this chapter, the focus is on green productivity and the way which governments can define the issue as a policy priority – this occurs in Stage 1B of the policy cycle. 1B corresponds to Step I (Identify & Define Problem) in the Treasury Board’s framework⁴⁵⁴ and so this kind of problem definition is clearly part of the officially recognized policy process. Specifically, the discussion in this chapter focuses on the characteristics which green productivity possesses which lead to the conclusion that: i) it may be a concept of relevance to a diversity of government actors and therefore could improve decision making; ii) successful implementation is likely to require multiple government departments; and iii) it is reasonable to believe it is more likely to be adopted as the government response to sustainability commitments than other proposed solutions due to experience from other jurisdictions and the nature of the concept itself.

5.3.1 The Broad Appeal of Green Productivity to Policy Actors

Green productivity seems especially well suited to the agenda setting stage of the policy process because it is a concept which is likely to appeals to, as well as need, the expertise of a variety of government agencies. Green productivity’s interdisciplinary and interdepartmental nature (needing statistical and economics expertise as well as knowledge of environmental science and monitoring) makes it less likely to succeed in being adopted by a single department, such as the department of natural resources or the department of finance. Similarly, its successful

⁴⁵³ For examples of these drivers, see Stuart Soroka, *Agenda Setting Dynamics in Canada* (University of British Columbia Press: Vancouver, 2002) which discusses the media/public opinion/politics side of agenda setting.

⁴⁵⁴ Treasury Board, “Assessing, Selecting”, *supra* note 25.

implementation requires cooperation between multiple departments, which is difficult to achieve without explicit adoption at the central agenda setting level. Both of these issues indicate that green productivity is more likely to be successfully adopted at the centralized agenda-setting stage of the policy process, than by being introduced from the “ground up” in a single department.

Since green productivity incorporates environmental and economic characteristics, it is much more likely to be successful in a broad, cross-departmental and cross-discipline policy forum, rather than if developed within a single department. That is, productivity as a measure which crosses traditional bureaucratic boundaries may not find traction if presented individually to decision makers in the environment department because they might consider it to be the purview of the statistics agency, and vice versa. Instead, during the agenda-setting phase where ‘the entire policy universe’ (that is, policy actors from all sectors and departments)⁴⁵⁵ is present, the idea of green productivity can be discussed and considered by a more diverse set of decision makers (alone or in groups). As Savoie notes, in his highly influential study *Governing from the Center*, the increasing centralization of decision-making power has led to the development of forums which bring together senior officials from all departments to discuss major policy issues. For example, the Coordinating Committee of Deputy Ministers “reviews major policy issues facing the government and debates the main issues of the day.”⁴⁵⁶ This committee is evidence of the breadth of policy actors involved at the agenda-setting stage where broad issues and concerns are voiced and discussed as it is comprised of senior deputy ministers from a variety of

455 Howlett et al, supra note 153 at 12; Christopher Bosso, “The Contextual Bases of Problem Definition” in David Rochefort & Roger Cobb, eds., *The Politics of Problem Definition: Shaping the Policy Agenda* (University Press of Kansas: Lawrence, Kansas, 1994) at 195.

456 Donald Savoie, *Governing from the Centre: The Concentration of Power in Canadian Politics* (University of Toronto Press: Toronto, 1999) [Savoie] at 119.

departmental and agencies.⁴⁵⁷ Therefore, ideas such as green productivity which can appeal to diverse decision makers should be introduced at centralized forums during the agenda setting stage.

The second reason green productivity is more likely to succeed if adopted at the agenda-setting stage is that it likely requires multiple types of expertise to understand and begin to implement it as a policy priority. Implementing green productivity and turning it into a policy priority requires a number of different types of information and expertise. This means there would be a need for cooperation among multiple departments. For example, some measures of green productivity require the valuation (or costing) of different aspects of natural capital (EAP, for example). This is generally the responsibility of the environment or natural resources departments. On the other hand, the kinds of econometric calculations which measure productivity are generally the purview of statistics or finance departments. Simply put, no one department may have the employees or expertise to implement this kind of policy, along, so it is very likely to require cross departmental cooperation and/or shifts in departmental control. Yet, this kind of cooperation is notoriously difficult in practice, especially if the various decision makers and their regulatory units are not on board from the start – another reason why introducing green productivity at the agenda-setting stage (and getting broad support) is important. In fact, the massive growth in central agencies such as the Privy Council Office is precisely to manage (and enforce) this kind of cross-departmental coordination.⁴⁵⁸ The result is that without adoption by central agencies at the agenda-setting level, interdepartmental

⁴⁵⁷ *Ibid.*

⁴⁵⁸ *Ibid.*

coordination, and therefore the implementation of green productivity, is unlikely to be successful.

One interesting example of this kind of coordination and shift in regulatory control is the development and implementation of the B.C. Carbon Tax. The Department of Environment was the lead department early in the policy development cycle, and the Department of Finance was responsible for actually collecting and administering the tax. While climate change is typically the focus of environmental government agencies (or more recently agencies specific to climate change)⁴⁵⁹ British Columbia's carbon tax is administered by the Ministry of Finance.⁴⁶⁰ However, In Duff's 2008 article he notes that the 2007 *Greenhouse Gas Reduction Targets Act*⁴⁶¹ mandates the "[p]rovincial Environment Minister to establish emissions targets for 2012 and 2016 and produce bi-annual reports on provincial progress in meeting these targets."⁴⁶² The following year the carbon tax was announced, and the Department of Finance took over its implementation⁴⁶³ Given that the Department of the Environment does not have the expertise, capability, or mandate to collect and administer taxes, they were involved in the development and setting of targets, but inter-departmental coordination with the Finance Department was clearly considered essential to successfully implementing the policy. The cross-departmental coordination was considered so crucial for the issue of climate change that British Columbia actually set up a Climate Change Secretariat as a kind of central agency to coordinate climate

⁴⁵⁹ Environment Canada's Climate Change Program <http://www.ec.gc.ca/cc/Default.asp?lang=En&n=9853BFC5-1>; Ontario's Ministry of Environment and Climate Change <http://www.ontario.ca/ministry-environment-and-climate-change>.

⁴⁶⁰ British Columbia's Ministry of Finance Implements the Carbon Tax http://www.fin.gov.bc.ca/tbs/tp/climate/carbon_tax.htm.

⁴⁶¹ *Greenhouse Gas Reduction Targets Act*, SBC 2007, c 42.

⁴⁶² David G. Duff, "Carbon Taxation in British Columbia" (2008) 10 Vermont Journal of Environmental Law 87-107 at 92.

⁴⁶³ British Columbia, Ministry of Finance, *Budget and Fiscal Plan 2008/09 – 2010/11* 1 (19 February 2008) available online: <http://www.bcbudget.gov.bc.ca/2008/bfp/2008_Budget_Fiscal_Plan.pdf>.

change policy development across departments. Similar interdepartmental policy implementation is precisely what green productivity would likely need, and therefore initial adoption at the agenda-setting level where actors from the key departments would all be found is likely to be essential.

In summary, the agenda-setting stage in the policy process is where green productivity is most likely to be relevant because of the relatively large and diverse group of decision makers present (including representatives from central regulatory agencies and agencies with more defined mandates). Typically the decision makers concerned with productivity – generally in the Finance Department, Treasury Board or Statistics Canada - would unlikely be presented with the idea of green productivity because it would probably be seen as the purview of environment, natural resources, or sustainability decision makers. Similarly, those in an environment or natural resource department may well be unfamiliar with economic measures like productivity.

Introduction at the agenda setting stage mitigates this issue because the entire policy universe is made aware, including those perhaps more likely to support and understand green productivity.

In addition, the capabilities and expertise needed to implement green productivity measures are dispersed across multiple departments, and therefore require inter-departmental coordination.

This coordination is much more likely to be successful if it receives support at the central agenda-setting level, than if it is connected to a policy that is seen as being situated in a single department.

5.3.2 Determinates of the Adoption of Green Productivity.

This section shifts from discussing where green productivity should be proposed to maximize likelihood of adoption as a public policy goal, to the likelihood that green productivity could, in

practice, be adopted in Canada. It is clear that sustainability and intergenerational equity are not currently major agenda items, at least for the federal government. As noted earlier, though, this is probably in good part because of public opinion, external events, electoral commitments by parties, etc. These issues are primarily political issues, and beyond the scope of this thesis. Nonetheless, there are other considerations which are relevant here, such as how policy issues are defined in the second stage of agenda setting (1B) and the influence of diffusion on political motivations.

In the problem definition portion of the agenda setting stage (1B) the government may prefer to define and address sustainability through green productivity, rather than other approaches. As noted earlier, issues are usually legitimized and placed on the agenda in Stage 1A by public opinion, events, media coverage, etc. However, once raised, the government is typically able to define and frame the issue in a particular way, even if that is not what the external actors who were instrumental in legitimizing an issue would choose.⁴⁶⁴ In a Canadian context, green productivity is a way that governments can choose to define and achieve goals such as sustainable economic growth and intergenerational equity. The presentation of a ‘new’ productivity concept (green productivity) might have considerable support since it is clear that the lack of productivity growth has become somewhat of a focal point for Canadian decision makers⁴⁶⁵ meaning there is already a substantial level of support among decision makers and policy leaders for improving productivity.

⁴⁶⁴ Dery, *supra* note 163.

⁴⁶⁵ See, for example, Maclean’s 6-part productivity report (Macleans, *Productivity Report*, online: <http://www.macleans.ca/tag/productivity-report/> and work done by Andrew Sharpe on Canada’s productivity (Sharpe, “Three Policies”, *supra* note 5).

In addition, addressing sustainability through green productivity is likely to be much more politically palatable than other options, such as no-growth policies, or a focus on simply reducing natural capital use. Compared to these, efficiency targets may be seen as a less negative option. This is one reason, for example, why energy efficiency campaigns seem to be better received than campaigns to reduce overall energy use.⁴⁶⁶ Of course, in part this is because people are less supportive of policies which they perceive as imposing costs on them and though it is possible that policies which increase efficiency may be just as costly as those to reduce use, society does not tend to understand them in that way. Nonetheless, framing the issue as targeting efficiency or productivity increases may still increase support. From a political perspective, then, the definition of a problem and/or solution which considers broader social and public interest issues (sustainable economic growth and intergenerational equity) while potentially explaining or solving part of the ‘productivity problem’ may be more likely to become the definition chosen by decision makers.

Research on policy diffusion also suggests that green productivity is more likely to be adopted in Canada, because decision makers can rely on diffused experience from other jurisdictions. One common characteristic of political innovations is that they tend to be transferrable,⁴⁶⁷ in particular between countries with similar socio-economic and legal structures. That is, they are not simply chosen by one jurisdiction in the agenda-setting stage, rather the idea, problem or solution is transferred – or diffused from another source- and may well become part of other governments’ agendas as well. This is the idea of diffusion which, as was stated in

⁴⁶⁶ Think, for example, about how well energy guide labelling has been adopted (i.e. people seem quite happy to purchase an appliance that will save energy and money) as compared to the mixed reviews that time-of-day energy pricing have received (a situation where different prices are charged depending on when energy is used).

⁴⁶⁷ Andrew Karsh, *Democratic Laboratories: Policy Diffusion among the American States* (University of Michigan Press: Ann Arbor, 2007) at 2.

Chapter 3, is a theoretical explanation for the success of political innovations.⁴⁶⁸ Even if policy actors are unfamiliar with the concept of green productivity, this hindrance can be overcome because of the use of concepts similar to green productivity by decision makers in other jurisdictions and the promotion of such concepts by international organizations.

Diffusion is common in the area of environmental issues. In fact, the historical diffusion of environmental policy instruments across the OECD is quite striking.⁴⁶⁹ Given the focus of the European Community on resource productivity as a policy goal⁴⁷⁰ (recall this is a measure quite similar to NRP, one of the green productivity measures presented here), it seems entirely possible that the diffusion of the same or similar ideas will ‘cross the pond’, and emerge as a political innovation in the Canadian context. Since resource productivity has become an area of focus both for international institutions – the OECD, for example – and foreign jurisdictions, diffusion of these ideas and their establishment as a political innovation in Canada seems plausible. To support this point, an overview of the OECD’s work on resource productivity and other forms of environmentally adjusted productivity is considered, followed by a discussion of the European Community’s commitment to resource productivity goals. These sections are tied together with literature and in-practice evidence of the potential for a policy diffusion of green productivity to occur.

⁴⁶⁸ Berry & Berry, *supra* note 169 at 310.

⁴⁶⁹ Kerstin Tews, Per-Olof Busch & Helge Jörgens, “The diffusion of new environmental policy instruments” (2003) 42 *European Journal of Political Research* 569-600 [Tews et al] illustrates the spread of national environmental policy plans and strategies for sustainable development, eco-labels, and public access to information instruments across OECD and Central and Eastern Europe.

⁴⁷⁰ EC, “European Resource Efficiency Platform calls for a strong resource productivity target” *News* (2 April 2014) online http://ec.europa.eu/environment/resource_efficiency/news/up-to-date_news/02042014_en.htm; EC “Manifesto”, *supra* note 19.

Institutional factors and their relationship to political diffusion are considered first. The adoption and presentation of environmental issues and solutions from international organizations has been shown to increase the likelihood of political diffusion.⁴⁷¹ As such, the fact that the OECD has been active in researching and preparing guiding documents for its member states on issues related to resource productivity and efficiency means such issues are more likely to be diffused to member countries – of which Canada is one. The OECD recommends that its member countries “improve the resource efficiency and material productivity of their economies at all stages of the material life-cycle, to avoid waste of resources ...”⁴⁷² It also suggests that to do so, and to make decisions and direct actions aligned with these goals, many different policy areas (economy, trade, innovation, technology development, natural resource and environmental management, health) must be involved.⁴⁷³ Further, in 2008, along with the Kobe 3R Action plan, the OECD Council adopted the *Recommendation of the Council on Resource Productivity* which laid out a number of factors, including s. II which states that the OECD Council

[r]ecommends, with regard to the policies concerning the improvement of resource productivity, that Member countries: Take appropriate actions to *improve resource productivity* and reduce negative environmental impacts of materials and product use, by *encouraging environmentally effective and economically efficient uses of natural resources* and materials at the macro, sectoral and micro levels and by involving all relevant ministries and departments of government as well as research and other non-governmental organisations.⁴⁷⁴[*emphasis added*]

⁴⁷¹ In reference to the UN spreading environmental discourse, see John Meyer et al., “The structuring of a world environmental regime, 1870-1990” (1997) 51(4) *International Organization* 623-651; with regards to environmental non-governmental organizations disseminating ideas, approaches and practices, see K. Kern, H. Jörgens & M. Jänicke, *The diffusion of environmental policy innovations: A contribution to the globalisation of environmental policy* (Discussion Paper FS II 01-302) (Berlin: Wissenschaftszentrum Berlin für Sozialforschung, 2001) at 9; and for a general discussion of international systems and transfer of policies see Tews et al, *supra* note 469 at 572-575.

⁴⁷² OECD, *Material Resources, Productivity and the Environment: Key Findings* (Paris: OECD) at 11

⁴⁷³ *Ibid.*

⁴⁷⁴ Recommendation of the Council, *supra* note 19 at II.

Further, the OECD has begun to undertake work looking at natural capital and productivity measurement, with a specific focus on including natural capital inputs in multifactor productivity measurement.⁴⁷⁵

These recommendations and research programs indicate that the OECD recognizes the importance of both measuring and improving resource productivity and other environmentally adjusted measures of productivity. It is clear that within the OECD there is a belief that improvements in resource productivity will have a positive impact on the environment as well as the economy.⁴⁷⁶ As an OECD member, this belief should help guide Canada towards the same conclusions. Therefore, since the OECD has an agenda focus directed at resource productivity and other measures of ‘greened’ productivity, this should make green productivity more likely to emerge as a policy priority in Canada.⁴⁷⁷

In addition to the OECD’s promotion of greened productivity, the European Union has been aggressively targeting improvements in resource productivity which they define as “gross domestic product (GDP) divided by domestic material consumption (DMC).”⁴⁷⁸ As was noted in Chapter 4, this is a broader measure than what this thesis terms “natural resource productivity” because DMC includes all materials used directly by an economy. More specifically, it is “the

475 Nicola Brandt, *Productivity Measurement with Natural Capital* (Paris: OECD, 2013).

476 Resource Productivity in the G8 and the OECD: A Report in the Framework of the Kobe 3R Action Plan at 5.

477 In explanation of why decision-makers adopt new environmental policy instruments, Tews et al argues “that the motivation...to an important extent, [is] influenced by the increasing vertical integration of the international system and intensification of the efforts of international organizations” Tews et al, supra note 469 at 579. In Fabrizio De Francesco, “Diffusion of Regulatory Impact Analysis Among OECD and EU Member States” (2012) *Comparative Political Studies* 45(10)1277-1305 at 1278, the author indicates that “the most rapid increases in the frequency of adoption [of regulatory impact analysis] occurred in two time intervals, that is, 1995–1999 and 2003–2006, in concomitance with the 1995 OECD recommendations on regulatory reform signed by ministers responsible for public administration (OECD, 1995) and the 2002 European Commission’s launch of the Integrated Impact Assessment system (European Commission, 2002)”.

478 Eurostat, “Resource Productivity” European Union Open Data Portal, online: <<http://open-data.europa.eu/en/data/dataset/tW7OPOopKoIg8iKH5sCrYw>>.

annual quantity of raw materials extracted from the domestic territory of the focal economy, plus all physical imports minus all physical exports.”⁴⁷⁹ NRP is only concerned with one subsection of resource productivity – raw material extraction and use, but there is still a substantial amount of similarity between the two measures.

Over the past ten years or so, the EU has set ambitious targets for improving resource productivity based on a belief that an increase in resource productivity will result in boosts to competitiveness and to overall quality of life of its citizens.⁴⁸⁰ The European Commission (EC) has established the European Resource Efficiency Platform which, in 2014, “called upon the EU to set a target to double – at least – resource productivity by 2030 ...such a target would be equivalent to an increase of resource productivity of well over 30% by 2030.”⁴⁸¹ This same Platform produced, in 2012, *Manifesto & Policy Recommendations* which laid out the arguments for aiming to become increasingly more resource efficient (to see a growing improvement in resource productivity).⁴⁸²

The promotion of green productivity by the OECD, and the focus on increasing resource productivity by the EU, demonstrate a potential for policy diffusion, which makes the adoption of green productivity in Canada more likely. That other jurisdictions think such concepts deserve to be policy priorities is important, since it means implementation is plausible. Further, it provides experiences which Canadian decision makers can draw on. This is particularly important because the relative lack of time that policy actors have during the agenda setting

⁴⁷⁹ *Ibid.*

⁴⁸⁰ EC, “European Resource Efficiency Platform calls for a strong resource productivity target” *News* (2 April 2014) online http://ec.europa.eu/environment/resource_efficiency/news/up-to-date_news/02042014_en.htm.

⁴⁸¹ *Ibid.*

⁴⁸² EC, “Manifesto”, *supra* note 19 at 4.

stage of the policy process⁴⁸³ (due, in part, to the abundance of information which they are presented with) means they are more likely to consider ideas which come from other jurisdictions. In addition, diffusion from the EU to Canada is perhaps especially likely at present after the recent completion of an EU-Canada free-trade agreement.⁴⁸⁴ All of these factors encourage policy diffusion, and make the adoption of green productivity more likely in Canada.

5.4 The Influence of Natural Capital and the Residual (NCR) on the Policy Cycle

The analysis of natural capital and the residual (NCR) can play a distinct role in the policy cycle, different from the other two measures of green productivity. NCR is not proposed here as a standard measure to be regularly calculated, because it might be quite difficult to actually compute as a precise quantitative indicator. Rather, the recommendation here is that NCR can be used as a critique of current productivity measures which can raise questions and issues. Further, NCR has the potential to aid decision makers desiring to undertake policy priorities and implement legal tools which might typically be faced with industry opposition.

Recall that, as discussed in Chapter 2, NCR analyses would take into account changes in the quality or quantity of inputs currently not measured, and thus which are incorporated in to the residual. For example, this might include rainfall's impact on the agriculture industry, or changes in the quality of timber. The precise valuation and quantitative measurement of these effects is likely to be very difficult. However, although industry decision makers are unlikely to consistently measure changes in their own multifactor residual, those who rely on natural capital as an input (i.e. agriculture or timber operations) will certainly be familiar with any changes in

⁴⁸³ Karsh, *supra* note 170 at 4.

⁴⁸⁴ D.W Drezner, "Globalization and policy convergence" (2001) 3 International Studies Review 53-78 [Drezner] at 57; Tews et al, *supra* note 469 at 573-575.

these inputs. That is, farmers are very likely to be aware of the impact of lower than average rainfall on yields, in a general sense, even if precisely measuring the effect is difficult.

NCR is less likely to be useful in selecting or evaluating specific instruments in the decision making and evaluation stages of the policy cycle, in part, because there has been very little research which has dealt with producing precise quantitative estimates of the impact of natural capital on the multifactor residual. This is because there has not – yet – been developed a consistent method to separate the effect of the quality or quantity of natural capital from other kinds of multifactor residual change, such as technology. Therefore separating the effect of improvements from environmental regulation and improving technology would be very difficult. While this thesis supports the use of NCR and advocates for its improved measurement, the actual mechanics of how this could be done are beyond the scope of this work.

Nonetheless, because changes in the quality and quantity of natural capital are often unmeasured or under-measured, decision makers may be unfamiliar with the significant impact they can have on the productivity of certain sectors of the economy. Certainly relying on conventional productivity would give an incomplete picture of those sectors. The key insight of NCR is not that rainfall affects agriculture, but is in recognizing the effects that these environmental factors have on the productivity growth of important industries. Thus, NCR might function as a sort of caveat, or an alternative scenario indicating that productivity is likely to be over or under estimated in certain areas or at certain times.

Given the fact that the agenda setting phase is where the policy universe converges,⁴⁸⁵ those impacted by changing natural capital characteristics are most likely to be able to voice

⁴⁸⁵ Howlett et al, *supra* note 153 at 13.

concern here and inform various decision makers who are capable of changing and improving measurement and putting new practices into place. Further, despite the current lack of a specific NCR measurement which likely reduces its practical use in evaluating specific instruments, it may well be that the stakeholders whose industries are significantly impacted by changing qualities and quantities of natural capital can still have an impact at these Stages (2 and 3) of the policy cycle. In particular, these stakeholders may be proponents of instruments which are information providing or which create data collection burdens focused on the use of natural capital because they desire to see better measurement and more government understanding of the situations within which they operate (of course with the hopes that this is followed by further government support). Therefore, industry stakeholders may give decision makers encouragement to create and implement such instruments (in Stages 3 and 4) – encouragement they might not typically count on given that environmental instruments are often seen negatively by industry.

At the same time, stakeholders from natural capital reliant economic sectors can influence other stages of the policy cycle as well. For example, the perspectives that these stakeholders have on how natural capital influences the productivity of their industries (agriculture, forestry, fisheries are three good examples) may also be useful in Stage 5 (evaluation). Further, this overall exchange of information (throughout the policy cycle) between decision makers and stakeholders is essentially consultation, which is an important piece of the Treasury Board's analytical framework.⁴⁸⁶

5.5 Measures of Green Productivity and Evaluation

⁴⁸⁶ Treasury Board, "Assessing, Selecting", *supra* note 25 at 10.

Finally, the role of green productivity in last stage of the policy cycle is considered. As will be discussed at length in Chapter 6, measures of green productivity can be useful in *ex-ante* evaluation within the instrument choice stages of the policy cycle. Similar functions, though, can also occur in the evaluation stage (Stage 5). Recall that Stage 5 of the policy cycle occurs *ex-post*, after implementation, of the instrument(s) which were chosen through instrument choice decision making processes. Though a detailed discussion about the ways which the various green productivity measures can be employed in evaluating legal instruments is presented in Chapter 6, similar pieces of information are useful for the evaluation stage of the policy cycle.

For example, green productivity measures can be used to measure the success of legal instruments utilizing prices or which impose information requirements. One analysis might be to compare the relevant NRP measure before and after the introduction of the instrument or as prices change. After the introduction of the legal instrument (or a change in the price of the natural resource), does NRP go up? If so, this suggests that the instrument can lead to using natural capital more efficiently. If not, it may have simply had no effect, or simply reduced use by reducing production and economic activity. Chapter 7 is a good example of how this can be done. It presents a case study of water productivity in comparison to water prices and considers whether changes in water prices (which are a proxy for a water pricing instrument) impact water productivity.

Notably – though perhaps unfortunately - sometimes the use of green productivity measures to evaluate instruments may be easier at the evaluation stage (Stage 5 of the policy cycle) than in instrument choice because evidence of what has actually occurred is available, whereas in the instrument choice framework, proxies and other estimates are used to indicate what *should* or *could* happen. That is, *ex-post* evaluation has the advantage of real world

evidence of the implications of a given instrument, and this allows decision makers to choose whether they should continue on the same path, alter the instrument in use, or repeal the instrument and go in a different direction. Other than the availability of real data, in comparison to estimates and proxies, these and other techniques in the *ex-post* stage are essentially the same as *ex-ante* evaluation, which are discussed in detail in Chapter 6, and illustrated in the case study in Chapter 7.

In summary, green productivity measures can play an important role in the evaluation stage of the policy cycle. Similar to using green productivity measures as tools to help choose the best legal instrument(s), once those instruments have actually been implemented, periodic evaluation of whether they are in fact successful can also be aided by green productivity measures. Because the various measures of green productivity are a good indicator of whether economic production is continuing in a sustainable manner, considering their growth or decline alongside the implementation of different instruments can help guide decision makers towards decisions to terminate, alter, or extend the use of the instrument.

5.6 Chapter Summary

This chapter discussed where and how green productivity as a general concept, as well as the various more specialized measures, can be relevant and influential within the broader policy cycle. The main focus of the chapter was on the potential for green productivity to become itself a government priority at the agenda-setting stage (Stage 1) of the policy cycle. It was argued that because of the nature of green productivity (incorporating both economic and environmental factors) there is good reason to believe that this stage is where green productivity should be introduced and where it could most plausibly be adopted in the current Canadian context. It is at the agenda-setting stage where decision makers from many areas and departments are included

in a wide-ranging policy debate – which suggests that cross-discipline and cross-departmental concepts like green productivity are more likely to be adopted here. Further, implementation of green productivity likely requires expertise and cooperation from multiple departments. Adoption at the agenda-setting stage makes this kind of cooperation much more likely than if the policy is driven by a single department.

A distinct point, but one related to the likelihood of green productivity being adopted at the agenda-setting stage, is the possibility of policy diffusion and the introduction of green productivity as a political innovation on Canada's list of government priorities. The current focus on resource productivity (a related measure of how the economy uses natural resources) by the European Union and international organizations such as the OECD suggests that there is some potential for green productivity to diffuse into the Canadian context.

The chapter also highlighted ways which information provided through analyses of NCR could be influential at various stages of the policy cycle, including agenda-setting, policy formulation, and decision making. Finally, a brief mention of green productivity measures as evaluation tools in Stage 5 (evaluation) of the policy cycle was made. Certainly this is a place where green productivity can have influence, but as the implementation is similar to the ex-ante evaluation in the instrument choice framework, the details will be discussed in the following chapter.

6. Green productivity as a new tool for legal instrument choice

6.1 Introduction

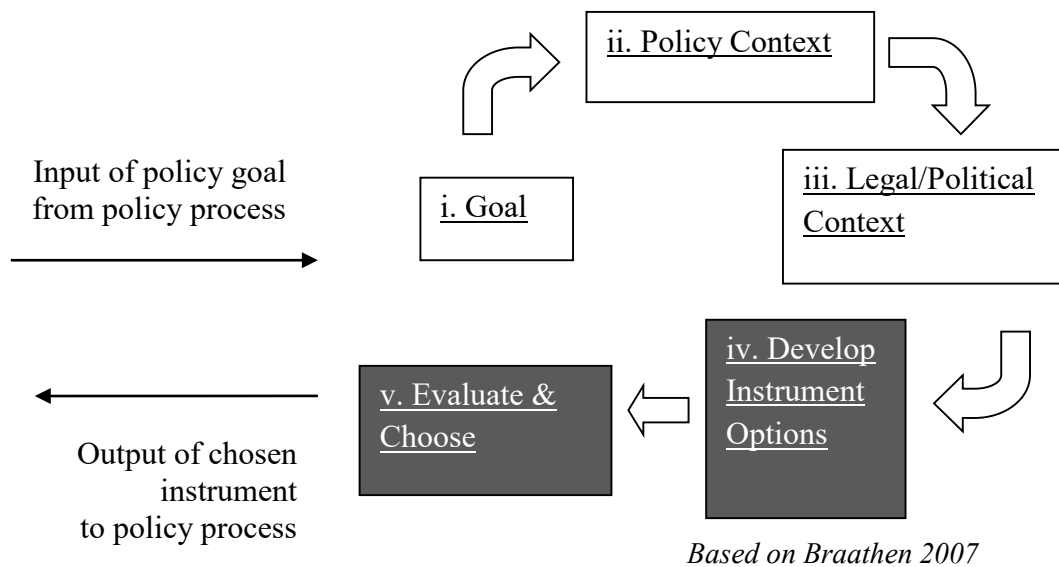
This chapter sets out how the different measures which make up green productivity can be used within an instrument choice framework. It will primarily focus on two such measures – natural resource productivity (NRP) and environmentally adjusted productivity (EAP) – and their use as tools for legal instrument goal setting, design and evaluation.⁴⁸⁷ Specifically this chapter will present how i) NRP can be used to set detailed goals for instruments by pinpointing leaders and laggards in the efficiency of use of natural resources; ii) NRP can identify standards or ideas to use in instrument design; and iii) both NRP and EAP can be evaluative tools useful in informing decision makers about whether the outcome of an implemented instrument is likely to align with legal commitments to sustainable economic growth and intergenerational equity.

The instrument choice framework within which NRP and EAP are applied is shown in Figure 6.1. It was initially presented in Chapter 3 as part of the broader policy cycle-legal instrument framework diagram (Figure 3.1), but here the focus is solely on the instrument choice framework (which falls within the policy formulation – Stage 2 - and decision making – Stage 3 - stages of the broader policy cycle). This framework is used to discuss where and how measures of green productivity can be introduced and how they can improve overall decision making. The instrument choice cycle discussed here is generalized for broader application, but recall (from Chapter 3) that the Canadian federal government’s current process – the Treasury Board

⁴⁸⁷ Recall that in the previous chapter (Chapter 5) *ex-post* evaluation (after implementation) was briefly discussed. Here, the focus is on *ex-ante* evaluation (that which occurs during the instrument choice process). The use of green productivity indicators in both cases, though, is very similar.

Secretariat’s ‘Analytical Framework for Selecting Instruments’⁴⁸⁸ aligns quite well and so reference to it will also be made throughout.

Figure 6.1 – Instrument Choice Framework



This chapter argues that the different measures of green productivity can provide important information in choosing and designing instruments that align with moving towards the goals of sustainable economic growth and intergenerational equity which were discussed in Chapter 2. Green productivity measures will be most useful in Steps i, iv, and v of the instrument choice cycle (shaded dark grey in Figure 6.1). The chapter proceeds by examining, in detail, the ways that NRP and EAP can be used to improve the goal setting, design, and evaluation of legal instrument options.

⁴⁸⁸ Treasury Board, “Assessing, Selecting”, *supra* note 25 at 10.

As an aside, it is certainly true that context is an important piece of the instrument choice process (it represents stages ‘ii’ and ‘iii’ in *Figure 6.1* and is also a component of Steps III and IV in the Treasury Board’s framework), though it is not the focus of this chapter. If and when measures of green productivity are implemented as tools in the instrument choice framework, the policy, political, and legal context within which they are operating would need to be considered. The one point that deserves some attention here is about legal context, especially given that the focus of this dissertation is on improving compliance with environmental law and policy commitments in Canada which, as has often been highlighted, is typically hindered by the lack of clarity over jurisdiction to regulate the environment. That is, since the environment is not specifically mentioned in the constitutional division of powers⁴⁸⁹ it is unclear whether the federal or provincial government has the authority to legislate various related matters (including setting up programs or implementing instruments to improve the efficiency of use of natural capital). The clear connection to the research undertaken in this thesis is that the focus has been (for the most part) on commitments and recommendations at the federal level, though it is the provinces that have primary jurisdiction over natural resources⁴⁹⁰ (the use of which is also a focus of this research). Still, recommendations provided in both this chapter and Chapter 5 are certainly relevant to both federal and provincial governments in Canada and, of course, could only be implemented where jurisdiction exists. As with all environmental issues and legal instruments targeting the environment in Canada, strong consideration of the constitution and

⁴⁸⁹ *Constitution Act, 1867* (U.K.), 30 & 31 Vict., c.3 s.91, 92, reprinted in R.S.C. 1985, App. II, No. [*Constitution Act, 1867*].

⁴⁹⁰ Section 92A (1) of the *Constitution Act, 1982*, Schedule B to the Canada Act 1982 (UK), 1982, c 11 [Constitution Act 1982] states that “In each province, the legislature may exclusively make laws in relation to (a) exploration for non-renewable natural resources in the province; (b) development, conservation and management of non-renewable natural resources and forestry resources in the province, including laws in relation to the rate of primary production therefrom; and (c) development, conservation and management of sites and facilities in the province for the generation and production of electrical energy.”

provincial/federal jurisdiction is essential to successful implementation of an instrument that ultimately targets or uses green productivity measures.

6.2 Green Productivity Can Help Target Goals for Instrument Choice

Step ‘i’ of the instrument choice framework is the goal selection stage, the result of which is what the instrument chosen at the end of the process is directed at achieving. While sometimes this goal is identical to the agenda item identified in Stage 1 of the policy cycle (agenda-setting), other times a number of legal instruments may be needed in order to achieve the ultimate goal of a particular government agenda item. Therefore, the goal of an instrument might only be to partially address the agenda item, or to tackle a subset of issues. Recalling the example in Chapter 5 of the MDGs and Canada’s focus on maternal, newborn, and child health as a government agenda item, it is clear that there may well be a number of instruments and tools needed to successfully address this broad priority. Each instrument, while aligned with the ultimate objective of improving maternal, newborn, and child health, would need its own more specific goal such as improving immunization for children or reducing mortality during labour.⁴⁹¹

Consider a situation more focused on this research, where the broader government priority is sustainability, sustainable development, or even more specifically green productivity, it is easy to imagine how NRP, in particular, could provide decision-makers with information to set more specific goals. NRP can do so by identifying areas of particular (in)efficiency, with regards to the use of natural resources. This information could be used to set goals and targets (Step ‘i’ in the instrument choice framework). Further, the results of NRP studies can help ensure

⁴⁹¹ References to these specific issues are taken from: Unicef Canada, *Canada’s G8 Summit Legacy*, online: <<http://www.unicef.ca/en/advocating-for-children-globally/canada%E2%80%99s-g8-summit-legacy-paving-the-way-for-women-and-children-wit>.

that the standards the goal sets are not too low or too high leading to something which is too easily achieved or, alternatively, unachievable. Either would likely stunt innovation. As mentioned in Chapter 3, this same idea (goal setting) is encapsulated in the Treasury Board's Step II 'set objective' and therefore these same conclusions can be made more specific to the federal government's instrument choice process.

NRP measures can provide information on particularly efficient or inefficient industries or jurisdictions with regards to their use of natural resources. Here efficiency means how much output is being produced per unit of natural resource input. An analysis of NRP (or any individual natural capital flow measure – water or timber productivity, for example) can highlight whether there is relatively consistency in the efficiency of use of natural resources or if there are marked differences. If decision makers see that their jurisdiction (or industry) has considerably lower NRP than others, especially those they consider to be particularly important to them for trade, diplomatic, or other reasons, they may be more likely to introduce changes in their policies or to implement new instruments.⁴⁹² For example, determining NRP estimates could allow for global comparison and ranking in a similar way to labour productivity. It is possible that if Canada is ranked as having comparatively worse NRP as compared to some of its key allies or trading partners, that those results would be politically motivating and could provide incentives to target improvements in the nation's efficiency of use of natural resources. NRP reporting could also be used to evaluate changes over time in a given jurisdiction. So long as it is publically available, this information may also be of interest to investors as well as the firms

⁴⁹² Drezner, *supra* note 484 at 57 notes that “states alter institutions and regulations because a set of belief has developed sufficient normative power that leaders fear looking like laggards if they do not adopt similar policies’.

themselves. Of course, there are many possible NRP measures that could be used to do such comparisons, notably water or energy.

Ensuring standards are not too lax or rigorous is crucial for the effectiveness of an instrument and is something that the results of NRP can help decision makers understand through the identification of leaders and laggards. If the requirements of a legal instrument are too great, in comparison to the NRP of, for example, different industries, it is entirely possible to see the closing down of operations. While this might be desirable to some extent, too great a negative impact is likely to result in politicians vetoing the use of the instrument because the cessation of an industry can be extremely unpopular. An analysis of NRP can provide decision makers with information about the industry so they are not setting goals or targeting areas where implementation is likely to fail, either because the targets are too rigorous, or too lax.

In some cases, the information provided from NRP studies may help set initial targets for specific regions or subsectors which are actually a pre-cursor to the main target. To clarify, additional legal instruments may sometimes be needed to target specific subsectors, for example, which are performing substantially worse than the norm. The objective of setting a specific target and implementing a legal instrument to achieve it would be to create a somewhat level playing field so that the overall target and the legal instrument(s) used to achieve it are able to be more effective. Results of NRP analyses can point out these laggards at the level of analysis desired (international, provincial, sectoral, etc.) and then identify those areas where productivity is distinctly higher or lower. Here the key is identifying subsectors, either geographically, by industry type, company size, etc., which are performing substantially worse. This can help set appropriate goals to determine whether a particular industry in Canada, for example, needs a targeted instrument to bring it up to a level of NRP more aligned with others. Analysis done for

Chapter 7 (see Appendix I) found that some subsectors in the Canadian manufacturing industry – paper manufacturing, for example – have significantly lower water productivity than other subsectors. Therefore these ‘laggards’ may be the ideal target for a first wave of individual instruments if, for example, a sector wide (i.e. all manufacturing sectors) instrument was to be the ultimately implemented.

As noted earlier, if differences in impact are too great, the instrument is unlikely to succeed. Here, a trading system is a good example. It is well known that this type of instrument is more cost effective, relative to command and control regulation, when there are differences in the cost between firms to achieve the requirement.⁴⁹³ If, on the other hand, the differences are too great, the laggards (likely those with relatively lower NRP) may in fact simply cease to operate. But, if the first step is to increase the NRP of the laggards (those with much lower levels of NRP) to a level considered ‘reasonable’, the implementation of a trading system may, in fact, operate well. In this case, the information gained from NRP studies is important because otherwise it is entirely plausible that neither the environmental component (reduced use of natural resources) nor the economic one (sustainable growth) could be realised due to political opposition or the loss of some industry operations.

Finally, if regulation is costly or difficult to implement – as it very often is - it may well be better to focus on particularly problematic subsectors, rather than the entire industry or country. In this case, the information about differences in NRP between different sectors or regions could be used to determine the scope of the instrument. That is, rather than helping to determine what kind of instrument should be used, NRP can be useful in determining where and

⁴⁹³ Robert N. Stavins, “Experience with Market-Based Environmental Policy Instruments” in Karl-Göran Mäler & Jeffrey Vincent, eds., *The Handbook of Environmental Economics*, Volume II (Amsterdam: Elsevier B.V., 2005).

at whom the instrument should be targeted. Of course, this may not be the best solution from the perspective of economic efficiency as having different requirements or prices in different sectors or regions will certainly result in market distortions. Nonetheless, the cost of regulations, or the lack of political will for universal implementation means that these kind of partial coverage instruments are common, and therefore information to improve them is important.

For example, an analysis of NRP for timber might find that the pulp and paper industry has far lower NRP than the agriculture sector. Therefore, regulations might be focused on one industry, rather than economy wide. Alternatively, manufacturing in a certain geographic area might use water far less efficiently than in other areas, and therefore have lower water productivity. Since physically installing and monitoring water meters is very expensive (compared to the current permit system used in many areas), targeted programs may be more likely to be implemented. Note that here NRP gives different information than water use data because rather than simply showing the volume of water used, it provides information on how much water is being used relative to the economic activity it is associated with. In both of these examples, if instruments with partial coverage are to be implemented, NRP can help target them.

Given the discussion above, it is clear that NRP, in particular, is well suited to help identify appropriate goals and targets for Step ‘i’ in the instrument choice framework. This is done, largely, through the calculation and comparison of various NRP measures (total or individual to natural capital flows such as timber or water) which can show particularly (in)efficient areas. This information can be useful for decision makers in a number of ways, including helping to set appropriate goals, suggesting when there are certain regions or sectors which need additional time or need assistance in “catching up”, or determining where or whom should be the focus of a more narrowly targeted instrument.

6.3 Green Productivity Measures Can Improve the Design of Legal Instrument Options

In *Figure 6.1*, Step iv of the instrument choice framework is the point where a suite of legal instruments is developed each (or a combination) of which could be implemented to achieve the goal previously set (in Step ‘i’) or more broadly in the agenda-setting stage of the policy cycle. In the Treasury Board framework, this process occurs in the first part of Step V. This section explores how NRP can contribute to improving the design of legal instruments intended to stimulate sustainable economic growth and intergenerational equity. The focus here is similar to that in the previous section - on identifying leaders and laggards - but in this case the emphasis is on what occurs in these specific situations that can be incorporated into new instrument design.

Using the same information that can assist decision makers in determining what the goal of a given instrument should be focused on (as discussed above, with regards to targeting areas of particular inefficiency), the identification of leaders and laggards can help decision makers when *designing* legal instruments options. In the context of choosing legal instruments appropriate for moving towards sustainable economic growth and intergenerational equity, this information can aid decision makers by identifying actions that have been successful in other jurisdictions and which could be used within new legal instrument design. That is, decision makers may use leaders as case studies to look for what kinds of policies, strategies, technologies, management practices, etc. are successful.

While results of NRP studies cannot, themselves, determine exactly why a ‘leading’ industry or jurisdiction is more efficient with their natural resources, they can certainly point out anomalies as places to dig deeper. If the reason for the higher NRP in some area is found to be reproducible by other industries or in other areas, decision makers may want to develop an instrument – a technology standard or subsidy program, for instance – to encourage the adoption

of the same mechanism. In a Canadian context, this is something that the federal government could do more broadly to encourage provinces to raise their levels of NRP (it would likely, in this case, need to be an incentive or informational instrument given that natural resources are constitutionally a provincial matter).⁴⁹⁴ Alternatively, provinces could look to each other to determine whether there are practices that could be implemented in their own jurisdiction in order to improve NRP. For example, British Columbia might find that Ontario has a higher NRP and they could investigate to see whether they could implement a legal instrument requiring the use of a new piece of technology currently employed by industry in Ontario. Alternatively, provincial governments might decide that instead of trying to transfer technology or management practices they should instead implement legal instruments which encourage innovation in natural resource use.

This sort of process is, in many ways, a replication of comparisons between labour productivity in different jurisdictions. If one jurisdiction has significantly higher labour productivity than another, often the laggard looks to what is happening in the leaders' jurisdiction to see whether there is something which clearly improves labour productivity that they might also implement. In the same way as labour productivity comparisons are made and therefore labour productivity has become a well-known indicator, so too can NRP. As discussed in the following chapter, the case study on water productivity suggests that Alberta has a higher manufacturing water productivity than some other provinces. Decision makers might examine the policy environment in Alberta – such as the water transfer (trading) system⁴⁹⁵ – in order to help

⁴⁹⁴ Constitution Act, 1982, *supra* note 490 at s. 92A

⁴⁹⁵ This is facilitated by provisions in the *Water Act*, RSA 2000, c W-3. More information about the program, see Alberta Water Portal, *Water Licenses, Transfers and Allocation* Online: <http://albertawater.com/how-is-water-governed/water-licences-transfers-and-allocation>.

design instruments for other jurisdictions. The identification of leaders and laggards in this sense can help decision makers to know where to start looking for ideas about what type of instrument, and more specifically, what design features, could stimulate improvements. The key role here of green productivity (and more specifically NRP) is in showing decision makers where to look for best practices.

At the international level, examining the instrument choice decisions of jurisdictions with high (or low) NRP might provide important information for instrument choice decisions in Canada. Understanding where Canada ranks as compared to other nations with regards to NRP could help decision makers in determining which other countries might provide useful policy frameworks and/or legal instruments that could be transferred to Canada. Recall that in Chapter 5, there was a discussion about the emphasis that the European Union is placing on resource productivity and how that might impact decision making in Canada. Of course instruments or policies are not always easily transferrable for a number of reasons, including political and legal considerations.⁴⁹⁶

6.4 Ex-Ante Evaluation of Legal Instruments Using Measures of Green Productivity

As was discussed in Chapter 3, the evaluation of legal instrument options is an important component of both the policy cycle and instrument choice decision making framework and should occur both *ex-ante* and *ex-post*. *Ex-post* evaluation was discussed briefly in Chapter 5, but given its similarity to *ex-ante* evaluation (with regards to how green productivity measures can be used) the detailed discussion is presented here. To clarify, *ex-ante* evaluation occurs during the

⁴⁹⁶Legal transplants can be difficult because of differences in legal systems and legal culture, among other things (Annelise Riles, “Comparative Law and Socio-Legal Studies” in Matthais Reimann & Reinhard Zimmerman, *The Oxford Handbook of Comparative Law* (Oxford: Clarendon Press, 2006) at 796-9; See David Nelken, “Defining and Using the Concept of Legal Culture” in Esin Örüci & David Nelken, eds., *Comparative Law: A Handbook* (Portland: Hart Publishing, 2007).

decision making Stage (3) of the policy cycle and therefore is part of the instrument choice decision making framework. This is in contrast to *ex-post* evaluation which occurs as Stage (5) of the policy cycle after implementation of the instrument(s) that have been ultimately chosen. The focus of *ex-post* is on evaluating real world responses to the instrument(s) while *ex-ante* evaluation is undertaken based on the normative criteria to determine which instrument(s) should be implemented. Interesting, though *ex-ante* evaluation is certainly part of Step V in the Treasury Board framework, *ex-post* evaluation is not explicitly mentioned. Instead, Step VI in the Treasury Board framework refers to setting performance indicators⁴⁹⁷ which are clearly used for evaluation⁴⁹⁸ so, likely related to the general policy cycle Stage 5. In many ways, the proposal that EAP and NRP be used as performance indicators is what Step VI of the Treasury Board framework intends and therefore shows that their focus is on *ex-post* evaluation.⁴⁹⁹

NRP can provide novel insights for evaluating instruments in order to help make decisions that can assist in directing society towards sustainable economic growth and intergenerational equity. EAP, on the other hand, presents essentially the same information as cost-benefit analysis, though in a different format which may also be useful to decision makers. In this way it is not necessarily novel insights that are provided by EAP, but it is the way that the information is presented that is unique. In a sense it shifts the lens through which this information is presented and perhaps, given it is a measure of productivity, could gain more traction with certain groups of decision makers. In addition, what EAP measures present are important because they are a more inclusive version of the currently used measures of MFP. That

⁴⁹⁷ Treasury Board, “Assessing, Selecting”, *supra* note 25 at 10.

⁴⁹⁸ The document indicates that “performance indicators are essential for determining whether the instrument or mix of instruments is performing as intended” – this is clearly a form of *ex-poste* evaluation. Treasury Board, “Assessing, Selecting”, *supra* note 25 at 22.

⁴⁹⁹ Treasury Board, “Assessing, Selecting”, *supra* note 25 at 22.

is, though decision makers already use both cost-benefit and productivity measures, the productivity measures they currently use are biased because of their exclusion of undesirable outputs and their lack of focus on natural capital.

The evaluation of instruments (*ex-ante* or *ex-post*) typically requires the calculation of the measures of NRP, EAP, and NCR. Though the data used in calculating these measures is not necessarily new – the same component data should be available through a well implemented environmental accounting framework (Chapter 1 discusses this type of adjusted system of national accounts) - the meaning and presentation of the data would be different because of its focus on efficiency of use by presenting a ratio of output to input(s).

6.4.1 Natural Resource Productivity and Legal Instrument Options

NRP, essentially a measure of efficiency, can provide important and novel information for decision makers faced with choosing between a suite of instrument options in order to make progress towards the goals of sustainable economic growth and achieving intergenerational equity. Recall that it has already been argued, in previous chapters, that to make progress towards these goals, a more efficient use of natural capital is necessary. If so, to be effective, an instrument should both maintain or grow production (output) while using less or the same amount of natural resource input. If done successfully, these outcomes may also satisfy the criteria of intergenerational equity. That is, sustainable economic growth which, over time, reduces the relative impact on the natural environment hopefully also means that the environment is left in a better state for future generations. Of course, there are possible situations where this might not be the case. For example, it is possible that economic activity could decline, but natural capital use would decline much faster, and similarly, if economic

growth grew very fast, it could outweigh the increasing use of natural resource inputs.

Nonetheless, NRP (and the other measures of green productivity) are a good way of taking into account concerns about economic growth and the environment - they tell us what the relative change of one is to the other. Certainly they are much better than conventional measures of productivity, especially when being used to evaluate legal instruments targeting environmental improvements.⁵⁰⁰

When considering different options for legal instruments, NRP can provide useful information about expected effectiveness. For example, the effect of each instrument on NRP could be estimated and then the estimates could be compared to help determine whether a given legal instrument is likely to have the desired impact – that is, whether it would be effective at improving efficiency of use of natural resources. In this way, an increase in NRP may signal a shift towards more sustainable economic growth (the same or more output produced using less or the same natural resource input) and intergenerational equity (the same or less use of natural resources should mean the likelihood of more left for future generations than in a business –as-usual situation). The case study – Chapter 7 – provides an excellent example of how this type of information can be gathered from an analysis of water productivity and water acquisition costs.

As was mentioned above, not being able to compare the real-world evidence of what happens upon implementation of an instrument means the analysis must be done another way. Using a proxy is one option. For example, comparing the differences in cost – over time, or in different areas - of a given natural resource input against its NRP can help determine whether a relationship exists between price and productivity (that is, whether NRP changes with price).

⁵⁰⁰ Chapple & Harris, *supra* note 315 at 18 note that traditional productivity measures ignore bad outputs and therefore have limited use with regards to environmental policy evaluation. The same could be set for conventional productivity measures of other sorts and their usefulness to evaluating environmental instruments.

This would help establish if the implementation of a pricing instrument is likely to improve the efficiency with which the resource is used. For example, in the forestry industry stumpage fees are common but they are rarely associated with trying to improve the efficiency of use of timber. The Ontario Ministry of Natural Resources which, in reference to s. 31(1) of the *CFSA* which discusses how prices for harvest are set, says “the minimum price component ensures a secure level of revenue to the provincial treasury regardless of market conditions.”⁵⁰¹ This statement indicates that the stumpage fees are not designed to improve the efficiency of use of timber, but rather to secure revenue for the Government of Ontario. Should the government increase stumpage fees to increase the efficient use of timber? The success of such an instrument is not guaranteed – its implementation might simply lead to higher prices for consumers purchasing timber, or reduce overall use of timber, but not result in any improvements in how efficiently timber is used. A comparison of stumpage fees against the forestry industry’s timber productivity (output per unit of timber input) could indicate whether the industry would likely be responsive to a pricing instrument – that is, would they respond to increases in price by increasing their efficiency of use of timber inputs or by simply reducing production? Alongside a similar study comparing the changing stumpage fee prices with overall use a fairly good picture emerges of whether a pricing instrument could be successful at moving Canada towards sustainable economic growth and intergenerational equity in the forestry context.

Though showing the relationship between price and NRP may be one of the simpler analyses to perform, similar examinations could be done for other types of instruments. For example, considering the impact of already implemented instruments in other, similar, areas

⁵⁰¹ Ontario Ministry of Natural Resource, “Crown Timber Charges” online: MNR <http://www.mnr.gov.on.ca/en/Business/Forests/2ColumnSubPage/STDPROD_091543.html>.

would be a first step. Energy efficiency is essentially a partial measure of productivity, and therefore closely related to NRP. Notably, energy efficiency has been the focus of many legal instruments and policy agenda items over the past number of years. Therefore, studying the instruments which have had success in the energy area should be able to provide insights into the relationships which may exist between similar instruments and results of NRP studies.

One example of this might be to look at eco-labels focused on energy efficiency. Many studies show both energy savings⁵⁰² as well as carbon dioxide savings⁵⁰³ associated with the implementation of eco-labels, which indicates its overall success at improving energy efficiency. Transferring this experience to the NRP context, it seems reasonable to believe that an information standard could have similar impacts on improving efficiency of use and thereby reducing or using the same amount of natural resources while still producing the same amount or more output. In particular, relationships may be more similar if instruments – eco-labels - are used on similar items – heavy water using appliances (washers, dryers, dishwashers) or paper products which rely heavily on wood products to be created. The success of these instruments could be evaluated in terms of NRP.

This kind of analysis can also be applied to other kinds of non-pricing instruments, such as legally binding regulatory targets (command and control). Importantly, because command and control instruments are coercive, they are generally very successful if their effectiveness is evaluated on a use basis. That is, if governments legally require less use of a resource, it is quite

⁵⁰² H Geller, *National appliance efficiency standards: cost-effective federal regulations*, ACEE Rep. A951, AM. (Washington, D.C: Counc. Energy-Effic. Econ., 1995); H. Geller, T. Kubo & S. Nadel, *Overall Savings from Federal Appliance and Equipment Efficiency Standards* (Washington, DC: Am. Counc. Energy-Effic. Econ, 2001).

⁵⁰³ McMahon, JE., Chan, P., Chaitkin, S. “Impacts of U.S. appliance standards to date” (Paper delivered at the International Conference on Energy Efficiency in Household Appliances and Lighting, Naples, Italy, 27-29 September 2000).

likely that less will indeed be used. However, that tells us nothing about how efficiently the resource is employed. Perhaps command and control regulations simply result in a decline in the relevant economic activity, rather than investment in more efficient equipment (though this certainly depends on the type of command and control instrument implemented). Information relevant to what NRP's relationship might be to these types of instruments can be gathered by considering what has already occurred regarding instruments targeted at other, similar, improvements.

NRP measures should be considered in contrast to indicators focused on total use in that they measure total use in relation to economic outputs and not as the end result. Of course, as noted in Chapter 2, there are times when minimum levels of natural capital many need to be maintained and therefore simple measures of use may be more important. Nonetheless, NRP provides an important way to evaluate instruments through their impact of the efficiency of use of natural resources.

Further, it is important to highlight that NRP is different from cost-benefit analysis (a commonly used tool in instrument choice evaluation) because of its focus on efficiency, and in this case on the ratio of total output to one type of input. Cost benefit analysis compares, as its name suggests, total costs (analogous to inputs) against total benefits (analogous to outputs) and in many senses is similar to EAP (as is discussed below). However, cost benefit analysis is quite different than NRP in both presentation – an efficiency ratio – and focus. Perhaps the best way to think of cost benefit analysis as compared to NRP, and in fact, EAP, is to compare them to well-known and commonly used accounting ratios such as return on investment and price earnings ratio. It is well known and accepted that accountants use a number of key ratios when presenting the welfare of a business even though the data necessary for the ratios comes from the same

source (the business balance sheet) and the same values may be used (at least in part) to produce different ratios. In the same way, the measures of green productivity in comparison to cost benefit analysis and even green GDP may use the same data (from an environmentally adjusted system of national accounts) to compute results. The difference is what the indicators present and, sometimes, what format would be most accepted and understood by decision makers.

This section of Chapter 6 has provided a discussion about ways which NRP measures can be used to evaluate whether instruments have the potential to improve efficiency of use of natural resources while (ideally) avoiding economic decline and thereby moving Canada towards sustainable economic growth and intergenerational equity. As this is *ex-ante* evaluation (prior to implementation) it is rare to have information on how, in reality, the instruments would perform, so two methods have been proposed as alternatives. The first is to use proxies closely related to that which the instrument would impose. The example used in this chapter is timber stumpage fees as a proxy for a timber pricing instrument. Evaluating the relationship between changes in stumpage fees and timber productivity should tell decision makers whether a pricing instrument is likely to succeed at improving the efficiency of use of timber. This evaluation technique is further explored in Chapter 7 which provides an empirical analysis of the relationship between water productivity and water acquisition costs.

The second method by which measures of NRP can be used to improve the evaluation of instrument choices is through the transfer of information from situations where similar instruments and measures can provide real world examples. When evaluating instruments which have less obvious proxies (information instruments, for example), looking to previous implementation in similar areas can also be useful. The consideration of the success or failure of instruments directed at improving energy productivity/efficiency should be useful to decision

makers concerned about how similar proposed instruments might impact NRP and natural resource efficiency. Together, these uses of NRP measures should allow decision makers to better consider and ultimately choose legal instruments to move Canada toward intergenerational equity and sustainable economic growth.

6.4.2 Environmentally Adjusted Productivity and Legal Instrument Options

Environmentally adjusted productivity can also provide important information to decision makers when evaluating potential instruments and can be a compliment to the previously discussed analysis. While the measure of NRP is useful with a single goal – increasing the efficiency of use of a resource - EAP compares total inputs against desirable and undesirable outputs. This can help decision makers understand how different instruments impact the undesirables (output of pollution, waste etc.) while also considering the impact on the composition of inputs as well as desirable outputs.

This section considers EAP as a tool to indicate the likely success or failure of the choice of instrument upon implementation. That is, models (*ex-ante* evaluation) and real world application (*ex-post* evaluation) of legal instruments can be judged based on their impact on EAP growth. EAP measures are intended to be inclusive measures of efficient economic production – they consider total inputs and total outputs (including both desirable, conventionally measured, and undesirable, those which impact natural capital). With the justifications presented earlier in Chapter 4 for why EAP is aligned with Canada’s legal commitments to sustainability – economic, environmental and scientific – it can be argued that improving this type of productivity growth on its face, both reduces the impact on the stock of natural capital and

allows for a more productive economy as a whole. Given this, the evaluation of instruments should aim to see (amongst other things) improvements in year over year growth in EAP.

Though in some ways it is similar to green GDP, EAP still provides additional useful information. For example, the introduction of a legal instrument which required the conservation of boreal forests would show up in a green GDP framework as an improvement because the level of biodiversity and the stock of natural capital would be improved (from reduced use of forests). What would not be considered, though, is whether this instrument is efficient as well – whether it is designed and implemented in a way that the environmental improvement outpaces the economic cost to comply. The relationship of these costs to the benefits is not considered in green GDP but is in the environmentally adjusted measure of productivity.

EAP is essentially a different way to present the results of a cost-benefit analysis; it presents the data through a new lens which could potentially gain more traction with decision makers. Cost-benefit analysis estimates the difference in costs (with and without the implementation of an instrument) and compares them to changes in the benefits. If the costs are less than the benefits, then (all else being equal) the instrument should be implemented. In addition, cost-benefit analysis can also facilitate the ranking of different instruments. EAP is presented (as Chapter 4 highlighted) as a residual – the changes in the outputs not accounted for by the changes in the inputs. This residual typically demonstrates technological change, management operation shifts etc. – more generally, innovation. These are highly complex factors, which are difficult to identify and quantify, and therefore may not be properly accounted for in a cost-benefit analysis. The ranking of instruments in the case of EAP would be presented as percentage changes in the residual. While EAP does not identify where, exactly, gains (or

losses) might come from, these complex factors are nonetheless captured in the residual. If interest is in understanding the impact of different instruments on innovation and technical improvements, perhaps EAP is a better measure since it focuses in on this point. These same changes are, at least theoretically, implicit in changing costs and benefits, but are not the focus of a cost benefit analysis.

Overall, the design of studies to evaluate the impact of instruments on EAP would be more difficult than NRP, both because valuing negative outputs can be difficult, and because the effect of the instrument might be relatively small compared to the many other causes. Nonetheless, some kinds of instruments might be more likely to produce innovation and technological change, and some legal instruments could contain explicit targets to that end (e.g. technology funds). EAP, therefore, might be especially useful in evaluating these kinds of instruments.

6.5 Chapter Summary

This chapter identified the green productivity measures of NRP and EAP as additional tools for instrument choice decision making. It did so by presenting where and when in the instrument choice framework these measures could be used to improve goal setting, instrument design, and instrument evaluation. NRP was shown to be able to identify leaders and laggards in the efficiency of natural resource use. This information can be used to set goals and specific targets, to locate cases to study for best practices, and to discover what policies lead to high (or low) NRP. The ranking of regions or sectors might also motivate decision makers, leading them to take action to improve their ranking. NRP could also be used to evaluate general effects that different kinds of instruments, such as pricing and command and control, are likely to have on the efficiency of use of natural resources. Finally, EAP was suggested as being an alternative to

cost-benefit analysis within the evaluation stage of the framework, specifically if there is interest in whether an instrument stimulates innovation and technology improvement. Further, depending on the decision maker and their priorities or interests, the presentation of results in a productivity framework may draw more attention than similar results presented in cost-benefit form.

Given that both measures of green productivity (NRP and EAP) provide information about efficiency, equity and effectiveness in the case of natural capital, their use in the instrument choice framework is well aligned with making choices which should move towards sustainable economic growth and intergenerational equity. Having proposed a number of ways to use green productivity measures in legal instrument choice, the following chapter tests some of these insights by examining the relationship between water price and water productivity (a NRP measure) to evaluate the possible effectiveness of a pricing instrument.

7. Application of Natural Resource Productivity: A Water Productivity Case Study of the Canadian Manufacturing Sector

7.1 Introduction

This chapter will first demonstrate how a measure of NRP – water productivity (WP) - can be calculated. Then, a series of analyses are performed, to show some of the insights this kind of measure can offer decision makers. The analysis here is limited, due to data restrictions,⁵⁰⁴ but it still illustrates how one type of green productivity measure can be used to improve instrument choice decision making. The first analysis performed examines WP in the manufacturing sector by province, and finds large differences between provinces. The second analysis examines the relationship between the price of water and WP, and finds an initially strong relationship.

Undertaking a more detailed analysis, this relationship is only found for those in the manufacturing industry who receive water from municipal sources, and not for those who self-supply water. This information can prove useful when decision makers are faced with choosing between different instruments – specifically, it can help evaluate pre- and post-implementation (*ex-ante* and *ex-post*)⁵⁰⁵ of a price based instrument. Further, this research points to ways that analyses of NRP can help identify areas in need of more research in order to determine the appropriateness of certain legal instruments such as pricing, information, or technology standards.

7.2 Past Research & Context

7.2.1 Importance of Water Productivity as an Indicator

⁵⁰⁴ Discussed in more detail later in this chapter.

⁵⁰⁵ See section 5.5 and 6.4 for a discussion on these types of evaluation.

Water productivity is a form of NRP specific to the natural capital flow of water.⁵⁰⁶ That is, it uses the framework of partial productivity presented in Chapter 4, but instead of measuring all natural capital inputs, it focuses on one – water. The measure of WP can provide important information that water use data alone cannot. Comparing water use and water price to determine whether increases in the latter stimulate decreases in the former is useful, but this analysis does not tell us what happens to output - to economic production. Understanding comparisons between WP and water price is important, because increases in water price might simply lead to declining production and less overall economic activity. While this might be the optimal outcome in some senses, it also is likely to lead to the instrument being weakened or vetoed entirely. Therefore, the impact of price changes on WP is an important piece of information in the decision making process. If companies are forced to pass along the increase in the price of water to their customers in the form of increased product prices (and if demand is elastic) the likely result is that customers will purchase less of these products, leading to decreased production. Thus, the decrease in natural resource use would result in a decrease in production, and therefore a possible decline in employment and standard of living. Indeed, this is exactly what industry often claims when faced with environmental regulation.⁵⁰⁷ On the other hand, higher water prices may not decrease production. Through innovation, substitution or technology change, the same or more output might be produced using less or the same quantity of water input.

WP, in contrast to metrics of water use, considers water use relative to economic output in order to determine how much output (in GDP) is produced per unit of water used. This may help

⁵⁰⁶ In this case study, water refers to fresh water and not to total water (fresh and saline)

⁵⁰⁷ The Economist, “Industry and Carbon Limits: Claws in the Dirt” in About Democracy Blog, online: The Economist < <http://www.economist.com/blogs/democracyinamerica/2014/06/industry-and-carbon-limits> > discusses these concerns over time in the context of American industry and different environmental regulation proposals.

decision makers to determine if water pricing caused reductions in water use because of declining production, or because of improved efficiency.⁵⁰⁸ It is this metric – the relationship between output per unit of water input and water prices that will allow decision makers to determine if a pricing instrument could allow sustained or improved economic growth, while at the same time using less or the same amount of water (the latter is important to ensure a continued stock for the future). Recall that improving the efficiency of resource use is one of the aims of sustainable economic growth so that both the goals of environmental preservation and economic production can be met.

7.2.2 Past Research on Water Productivity

The study of WP is becoming more important, and there is wide recognition that water scarcity is increasingly a reality. Many authors⁵⁰⁹ state that the scarcity of water is a motivation for their research and a reason that WP improvement is critical. In many cases, the goal of improving WP is based on the fact that there is a finite supply of water and a growing demand for its use. There is also increasing recognition of the water needs of ecosystems, rather than only considering needs for human use. In the past, water management has focused mostly on ways which technology and infrastructure could move increasingly larger amounts of freshwater to individuals, industry and municipalities.⁵¹⁰ Very little attention has historically been given to considering how much water ecosystems and the natural environment need to continue to

⁵⁰⁸Of course, there are many possibilities here. Most obviously, some mix of these outcomes is possible. Alternatively, there might be a shift in the goods produced, rather than the method of production. Nonetheless, these are the two possibilities most generally discussed, especially in public debate, and so the dichotomy is useful.

⁵⁰⁹ R. J. Cabangon, T.P. Tuong & N.B Abdullah, “Comparing Water Input and Water Productivity of Transplanted and Direct-Seeded Rice Production Systems” (2002) 57:1 *Agricultural Water Management* 11 [Cabangon et al] at 11; B.A.M. Bouman and T.P. Tuong, “Field Water Management to Save Water and Increase its Productivity in Irrigated Lowland Rice” (2001) 49:1 *Agricultural Water Management* 11 at 11; David Molden, Hammong Murray-Rust, R. Sakthivadivel & Ian Malkin, “A Water Productivity Framework for Understanding and Action” In J.W. Kijne, Randolph Barker & David Molden, eds, *Water Productivity in Agriculture: Limits and Opportunities for Improvement* (Cambridge, M.A.: CABI Publishing, 2003) at 1.

⁵¹⁰ Peter. H. Gleick, “A Look at Twenty-First Century Water Resources Development” (2009) 25:1 *Water International* 127 [Gleick] at 128.

operate.⁵¹¹ With increased recognition of the importance that water plays not only as an economic resource, but also as a prerequisite for life,⁵¹² a new paradigm for water management has been proposed by a variety of authors and WP is a central piece of the puzzle. Postel, for example, argues that to meet future water challenges ensuring ecosystems are given adequate water for their functions is essential, and that, ultimately, WP must double.⁵¹³ Given the current state of water use in many places, in order to succeed at the first (adequate water supply for ecosystems), the second must be accomplished. Gleick's solution is similar – he believes it is essential to work towards “(1) increasing the efficiency with which current needs are met; and (2) increasing the efficiency with which water is allocated among different uses.”⁵¹⁴ The key recommendation from these authors is that future water management paths turn on improved efficiency – that is focusing on ways to increase WP.

Much of the research which has been undertaken with regards to improving WP has focused on the agriculture industry. Given that irrigation from agriculture is responsible for about 72% of global water withdrawals (closer to 90% if one looks just at developing countries),⁵¹⁵ improvements in agricultural WP are critical.⁵¹⁶ For example, studies have been undertaken that identify what rice production systems need less water to produce the same amount of crop,⁵¹⁷ which consider livestock water demand per unit of livestock product,⁵¹⁸ and which analyse the

⁵¹¹ *Ibid.*

⁵¹² Sandra Postel, “Entering an Era of Water Scarcity: The Challenges Ahead” (2000) 10 *Ecological Applications* 941 [Postel] at 941.

⁵¹³ *Ibid* at 945

⁵¹⁴ Gleick, *supra* note 510 at 131.

⁵¹⁵ Ximing Cai & Mark W. Rosegrant, “World Water Productivity: Current Situation and Future Options” in J.W. Kijne, Randolph Barker & David Molden, eds, *Water Productivity in Agriculture: Limits and Opportunities for Improvement* (Cambridge, M.A.: CABI Publishing, 2003) [Cai & Rosegrant] at 163.

⁵¹⁶ Postel, *supra* note 512 at 945.

⁵¹⁷ Cabangon et al, *supra* note 509.

⁵¹⁸ Amare Hailelassie et al., “Adapting livestock water productivity to climate change” (2011) 3:2 *International Journal of Climate Change Strategies and Management* 156.

differences in global WP of cereal crops.⁵¹⁹ Results from such studies often inform law and policy makers which crop, livestock or water management practices should be encouraged, or to create financial incentives for research and development in areas which are, for example, more prone to water scarcity and therefore need innovative ways to improve water productivity. As discussed in Chapter 2, while transmitting the real price of water to users might also improve efficiency with less market distortion, other factors (equity for example) may be important alternative considerations. Further, policies such as full-cost pricing are often simply not politically acceptable.

WP in other sectors is also important, especially since in countries like Canada, agriculture is not the largest user of water.⁵²⁰ WP improvements should also be studied for water management by municipalities and industry. Industrial WP has increased since its peak water use period – the 1970’s⁵²¹ – but there are still improvements to be made. The efficiency of municipal water use can also be improved greatly, for example, through relatively simple actions such as dealing with water leakage from transportation pipe systems.⁵²² More research must be done to integrate WP study results which consider different water users because the water system is interconnected and therefore what is done in managing water for one user type has an impact on other water users as well. It is because of this, that integrated planning and a detailed

⁵¹⁹ Cai & Rosegrant, *supra* note 515 at 168.

⁵²⁰ In Canada thermal electric hydro power, followed by municipalities and manufacturing top the list of those making water withdrawals (Environment Canada (2004, 2006, 2009) Municipal Water and Wastewater Survey. Statistics Canada (2005, 2007, 2009) online: <https://www.ec.gc.ca/indicateurs-indicators/default.asp?lang=en&n=5736C951-1>.

⁵²¹ Gleick, *supra* note 510 at 131.

⁵²² Richard Dobbs et al., *Resource Revolution: Meeting the world’s energy, materials, food, and water needs* (Washington D.C.: McKinsey Global Institute, 2011) at 94-95.

understanding of WP by all user types is important, especially so law and policy decisions can be made with a full understanding of the impact of water use decisions.⁵²³

Perhaps the leading expert in Canada on water use in the manufacturing sector is Dr. Steven Renzetti who has published numerous pieces which deal with efficient water use,⁵²⁴ water use in the manufacturing sector,⁵²⁵ and economic instruments and water use,⁵²⁶ among others. The results of many of Renzetti's studies have helped inform and formulate the motivation and hypotheses for this research. Specifically, one of the insights reported in a study considering the role of water use in manufacturing, is that "industrial water use is inefficient" and "that manufacturing water use is sensitive to its economic environment."⁵²⁷ However, the data from this study is now some 20 years old and – unfortunately – the data series used was terminated. The case study here instead uses new data and also compares WP across provinces and includes different types of water intake, something previous research has not emphasized. More generally, the point of this case study is not to establish the economic facts on the ground, but rather it is to demonstrate that a measure of WP is usable and easily interpretable for decision makers.

Existing research argues for increasing WP for a number of reasons, perhaps most prominently increasing water scarcity. The past research in this specific area – the

⁵²³ Rivers and Groves present an analysis of integrated water pricing and suggest that volumetric charges on abstraction/consumption of water could, among other things, more efficiently allocate rights to water between users in Canada. (Nicholas Rivers & Steven Groves, "The Welfare Impact of Self-supplied Water Pricing in Canada: A Computable General Equilibrium Assessment" (2013) 55 *Environ Resource Econ* 419-445 [Rivers & Groves].

⁵²⁴ Joel Bruneau, Diane Dupont & Steven Renzetti, "Economic Instruments, Innovation, and Efficient Water Use" (2013) 39 *Canadian Public Policy* S11-S22 [Bruneau et al].

⁵²⁵ Diane P. Dupont & Steven Renzetti, "The Role of Water in Manufacturing" (2001) 18 *Environment and Resource Economics* 411-432 [Dupont & Renzetti]; Steven Renzetti, "An Econometric Study of Industrial Water Demands in British Columbia, Canada" (1988) 24(10) *Water Resources Research*, 1569-1573 [Renzetti].

⁵²⁶ Bruneau et al, *supra* note 524.

⁵²⁷ Dupont & Renzetti, *supra* note 525 at 425-426.

manufacturing industrial sector – has used older data and a different method for calculation, but the findings that manufacturing water use is inefficient, and that water is substitutable⁵²⁸ underpin the hypotheses in this case study. This case study provides a measure of water use efficiency – WP for provincial manufacturing sectors – and examines its relationship to water prices. WP is also calculated for national manufacturing subsectors, results of which provide important insights into what a more detailed subsector level analysis could show. Most importantly for the goal of the dissertation, the policy and instrument choice implications of the findings are drawn out.

7.3 Hypothesis & Data

The case study in this chapter presents two hypotheses that are tested against data on water productivity.

H₁: There will be differences in the water productivity of the manufacturing sector in different provinces.

H₂: Increases in water price will cause increases in water productivity

7.3.1 Implications of Hypotheses

Results that confirm *H₁* are important because they could point decision makers towards potential areas for intervention and further examination. As discussed in Chapter 6, identifying leaders in WP is useful as a first step in locating successful policies and practices which could be transferred. This kind of analysis might be the first step in an in-depth case study, for example. Similarly, identifying provinces with lower WP could suggest room for improvement, and therefore might highlight good locations for pilot programs or targeted legal instruments. Of

⁵²⁸ *Ibid.*

course it is possible that differences between provincial WP's are a consequence of the composition of the manufacturing sector and so the subsector composition of various provinces will be discussed, in order to reduce the possibility of such confounding factors.

H_2 is an important hypothesis because, if confirmed, it suggests that the manufacturing industry should respond to a pricing instrument which increases water prices by using water more efficiently. Alternatively, little connection between changes in water price and changes in WP might be found. This is an especially useful piece of information for legal instrument choice because it can indicate whether a pricing instrument is likely to be successful or not at moving towards sustainable economic growth and intergenerational equity in the context of water.

7.3.2 Data

In order to carry out the analyses to test H_1 and H_2 , three types of data are needed –water price, water use, and economic output. This analysis primarily draws on data from Statistics Canada's current Industrial Water Survey (IWS),⁵²⁹ as well as from various other Statistics Canada sources of data. For the IWS, data for 2005, 2007, 2009 and 2011 is used (2013 data, has been collected, but not yet been released). This data is available for the manufacturing sector at the provincial level, although some data for smaller jurisdictions (especially Prince Edward Island and the Territories) has been censored. While considering industry subsectors by province would provide the best comparison, this data is simply not available. In fact, in general, detailed data on water use is difficult to obtain. Although Statistics Canada reports the IWS, this data is bi-annual

⁵²⁹ Statistics Canada collected IWS data previously (from 1972-1996) but the data was collected for various industries (not always the same) (Statistics Canada, "Environment Surveys of Establishments: The Canadian Experience" (November 2007) online: <http://www.statcan.gc.ca/pub/16-001-m/2007004/4129632-eng.htm#h2_4>.) and is unfortunately not comparable to current IWS collection which began in 2005 (personal communication, Dr. Steven Renzetti, December 4, 2014). Many of Dr. Renzetti's studies (for example, Dupont & Renzetti, *supra* note 525) use the earlier data, but we have chosen to use the most recently available numbers.

and higher levels of detail are censored to preserve confidentiality. Thus, the following analysis calculates the WP of the manufacturing sector by provinces and to help interpret that analysis, uses manufacturing subsectoral WP's at the national level. That said, well respected authors and organizations⁵³⁰ report results of WP at an even less detailed level – nationally – and therefore the measure used in this thesis is at a finer detail than those previous analyses.

The IWS provides various types of data on water price, but for the purpose of this analysis, water acquisition cost is the most appropriate.⁵³¹ Total water acquisition cost is “defined [by Statistics Canada] to include amounts paid to public utilities for water, amounts paid to provincial or territorial ministries for a licence to take water and for operation and maintenance costs incurred in the upkeep of self-supplied water acquisition facilities.”⁵³² This data was collected from CANSIM table 153-0077, which gives total water acquisition cost, as compared to other water cost components such as discharge treatment, and 153-0075 which shows only costs for total water acquisition and breaks them down by public and self-supplied costs.⁵³³

To determine WP, data on both water use and GDP output is required. GDP output for manufacturing by province and territory was acquired through CANSIM table 379-0025 which reports GDP at basic prices, chained to 2002 dollars. Water use data was collected from the IWS

⁵³⁰ Canada's Ecofiscal Commission, “Canada Can Do Better” (2015) Options Politiques Jan-Feb 2015 at 44.

⁵³¹ Other costs include the cost of treatment of water upon intake, cost of wastewater treatment, and costs related to the recirculation of water.

⁵³² Statistics Canada, *Industrial Water Survey* (Ottawa: Statistics Canada, 2012) online: <http://www.statcan.gc.ca/pub/16-401-x/16-401-x2012001-eng.pdf> at 12

⁵³³ Data in these two tables is current for the year collected. To normalize comparison to the year that the GDP data (used in the water productivity calculation) is constant to, the water acquisition costs were adjusted for inflation to be in 2002 Canadian dollars. This was done using the Bank of Canada's Consumer Price Index. Results with the current year dollars were also calculated and show slightly more conservative estimates.

and is presented in CANSIM table 153-0048 which provides total water intake⁵³⁴ numbers for the manufacturing sector, by province/territory in cubic meters. In addition, it is interesting to examine whether WP in the manufacturing sector had a different relationship to price based on its source (municipal or self-supplied). CANSIM table 153-0051 provides the breakdown of water intake from municipal sources versus water intake that is self-supplied. Together, this data allows the calculation of WP using total water intake (which is compared to total water acquisition costs), WP using municipal water intake (compared to water acquisition costs paid to public utilities), and WP using self-supplied water intake (compared to license fees and maintenance costs for self-supplied water facilities).

In order to strengthen the analysis, several control variables are used. Given that evidence for H_2 would suggest substitution of some other input for water or the presence of innovative operations, it is important to include capital costs and labour compensation. A higher price of capital, for example, could reduce substitution of financial capital for water, because it makes investment in new, more efficient equipment more difficult. Data on capital costs and labour compensation is taken from Statistics Canada's multifactor productivity data set. CANSIM table 383-0026 reports these factors.⁵³⁵ Due to the nature of Statistics Canada's release of data, labour compensation costs for 2011 were not available, so 2010 values were used instead. Capital costs are not available for 2009, 2010 or 2011, so 2008 values were used in 2009 and 2011. This is unfortunate, but is preferable to not including the control variables. Moreover, the key is to

⁵³⁴ Water intake is slightly different than total water use because it excludes re-circulated water. For our purposes, this is acceptable because we are really concerned with the extraction of virgin water resources (those taken directly from the stock of water).

⁵³⁵ It is not indicated in this data to which year the prices are chained. It is, though, reasonable to assume that 2002 is the year (making it comparable to the GDP data and the inflation adjusted water acquisition data) since in the same data series, there are indices which use 2002 as their '0' value.

include the differences in capital and labour costs between provinces, since these dwarf the change in capital and labour costs over the time period (see Appendix I).

Another important factor is the subsector composition of the manufacturing sector in the different provinces. Because data that breaks down water intake/acquisition costs by both province and subsector is not available, as was indicated above, this analysis is for the entire manufacturing sector broken down by province. It is possible, though, that some of the effects that are found are actually a consequence of which manufacturing subsectors are prominent in different provinces. For an inter-temporal comparison in the same geographical location (i.e. in the same province over time), this would be less important, but this static comparison across provinces could be much more impacted. One possible solution is to control for the percentage of the various subsectors that exist in the different provinces. This allows us to better estimate the effect of water price on WP independent of subsector composition. Based on available Statistics Canada data for the time period covered by this analysis, the subsector composition of provinces was based on the percentage contribution of sales to the provincial total using data found in CANSIM table 304-0015. This data is provided monthly, and the results are summed for each year of analysis. Unfortunately, there are 17 subsectors, and only 36 data points, and thus it is not possible to control for all of the subsectors in the regression analysis. Therefore, finding whether there are subsectors with distinctly higher/lower WP and controlling for them seems logical. To do this, the WP of each subsector is calculated at a national level (see Appendix I). By far the machinery manufacturing subsector has the highest WP, while the lowest WP is found in the paper manufacturing subsector. By controlling for the percentage of the manufacturing sector in each province that is machinery and paper, the biases produced by the differences in these particular subsector compositions across provinces can at least be reduced.

Importantly, if including subsectors as control variables substantially reduces the effect of price on WP, then concern is warranted. If not, then this will at least increase the confidence that the effects on WP are indeed due to the price of water.

Finally, provincial fixed effects are included. Controlling for fixed effects can reduce the likelihood of spurious correlation due to an unobserved variable. In this case, the data is at the provincial level but there are many differences between provinces other than their water prices, such as size, urbanization, industry, and as already noted, subsector make up. By including fixed effects, the estimates of the effect of price will reflect intra-province differences, rather than inter-province differences.

7.4 Method

A partial productivity measure of manufacturing WP was produced across eight years (four IWS surveys) and for ten provinces and one amalgamated category ‘territories’. The results indicate how much GDP is produced per cubic meter of water intake. The formula for this calculation is:

$$WP = \frac{Y}{X}$$

Where WP is water productivity of the manufacturing sector, Y represents output, in this case represented by GDP, and X is input, in this model, cubic meters of water intake.

While partial measures of productivity alone are regularly used by decision makers to set priorities or compare against other jurisdictions (e.g. labour productivity and its prominent place in the policy arena), understanding their value in comparison to other factors is also useful. For this case study, changes in the manufacturing sector WP over time are considered as compared to changes in water acquisition costs, in the manufacturing sector, over time. The analysis section of this chapter presents the results of the 2-factor, bivariate, regression as well as regression

results controlled for other, potentially significant, contributors. These include the cost of capital and labour (important given the probability of substitution of one of these forms of capital for water if the cost of water was to rise drastically) and the percentage of each provincial sales total associated with the subsectors of machinery manufacturing (which has the highest national WP) and paper manufacturing (which has the lowest national manufacturing subsector WP). Additionally, provincial fixed effects are included.

7.5 Analysis

The analysis is presented here in two stages – the first considers H_1 and the second H_2 . To test H_1 , WP is presented across geographical areas (provinces). These results are considered alongside the manufacturing subsector breakdown for each province. This allows some specific WP comparison between provinces with similar manufacturing sector compositions. Stage two of the analysis considers the relationship between WP and water price to evaluate H_2 . Two sets of regression models are presented, with and without control variables.

7.5.1 Testing H_1

To test H_1 , manufacturing WP across time (2005, 2007, 2009, and 2011) and geography (Canadian provinces and territories) is first presented (see *Figure 7.1*). Only Total WP is displayed here as it is the focus of this analysis. Appendix I provides the tables of data used to create this figure as well as the results of the Municipal Supply and Self-Supply WP analyses.

In *Figure 7.1*, and in the data charts in the Appendix, there are some missing data-points. This is as a consequence of a lack of data available from Statistics Canada, either because it has been suppressed due to confidentiality concerns, because the data was not reported at all, or because it was considered too unreliable to publish. It should also be noted that throughout this

analysis four data points have been removed; total and self-supply water intake in Saskatchewan in 2007 and 2009. For all other provinces, self-supply water intake is much larger than municipal water intake, but for Saskatchewan in those years the self-supply data points are smaller. This results in self-supply WP being an order of magnitude higher than any other province or year (\$670 of GDP per cubic meter in 2007, compared to the next highest, Ontario, which produced \$52 of GDP per cubic meter in the same year). Although this data is reported by Statistics Canada, it seems most likely to be an error in reporting. Therefore, the self-supply and total (since total water use is self-supply plus municipal use) data for Saskatchewan is not included in the analysis.

Figure 7.1 - Total Manufacturing Sector Water Productivity, by Province (2005-2011)

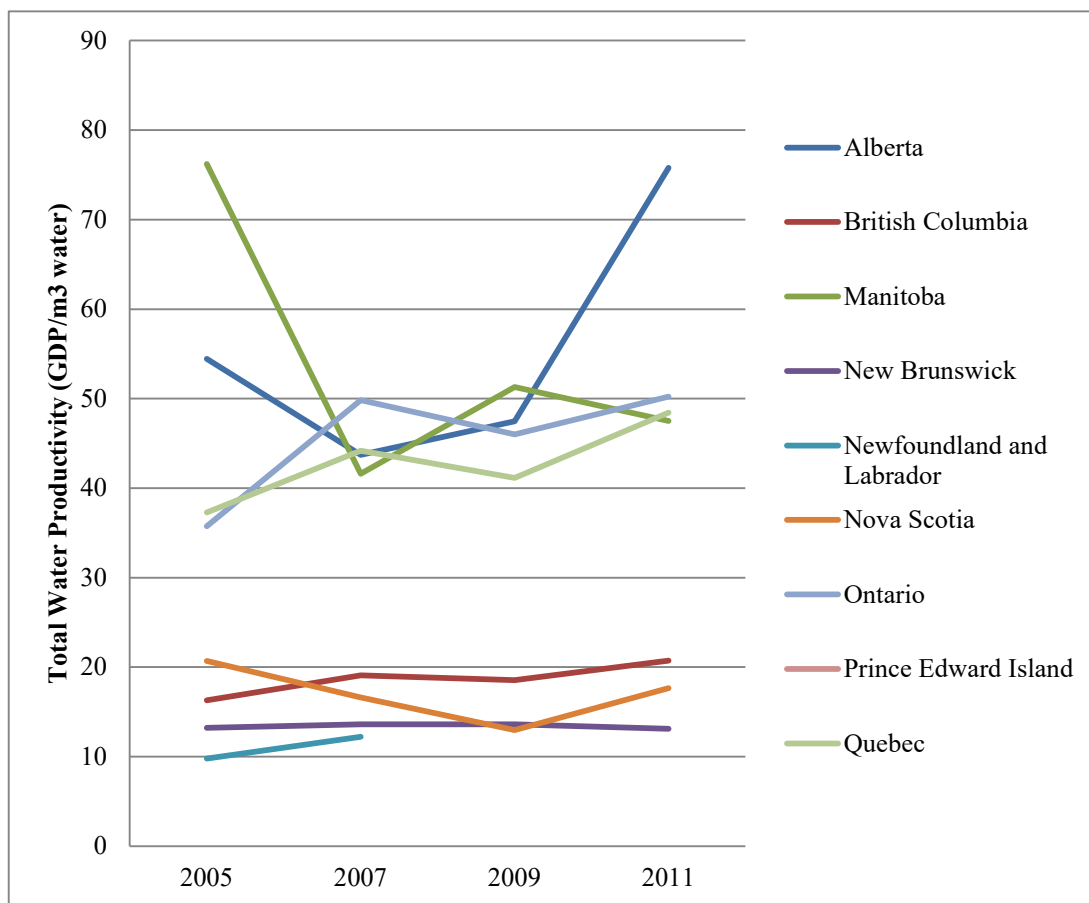
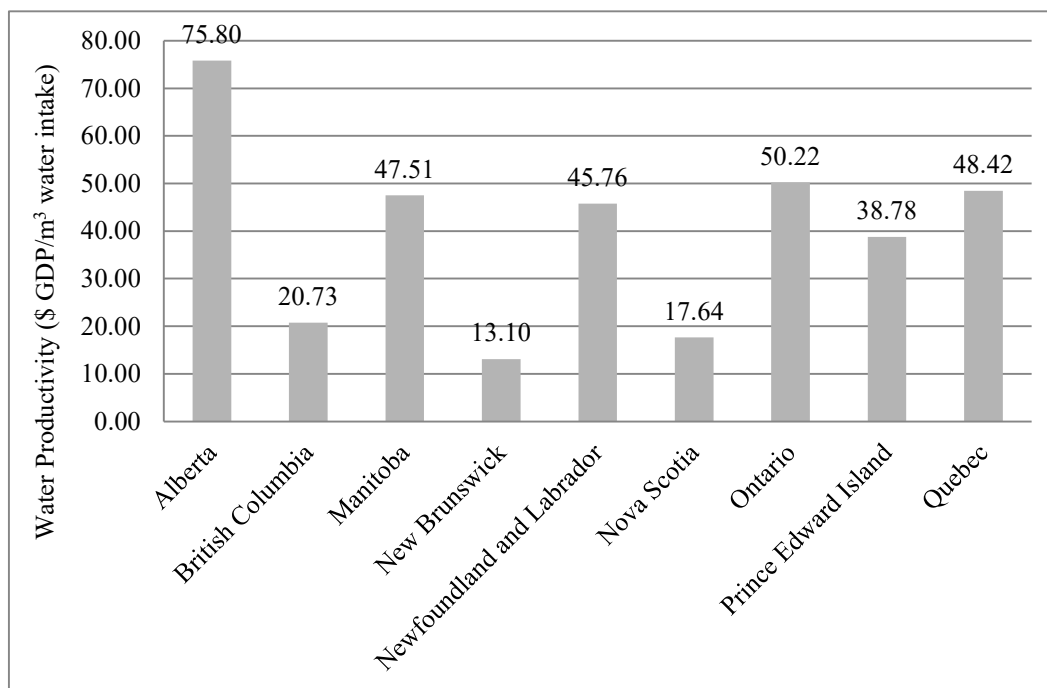


Figure 7.1 indicates that some provinces have substantially higher WP than others.

Figure 7.2 illustrates the 2011 WP's for provinces (provinces with missing data omitted) as an example of these variances.⁵³⁶ The key conclusion is that there are considerable differences in the WP of the manufacturing sector in different provinces. For example, the manufacturing sector in New Brunswick and British Columbia has quite low WP, while Ontario and Alberta's manufacturing sector has much higher WP.

Figure 7.2- Total Water Productivity - 2011



It is important to next consider the composition of the manufacturing sector across the provinces to help clarify whether higher (or lower) WP is because the manufacturing sector is more efficient with its water or whether it is because the manufacturing industry is composed of particularly water-intensive subsectors. If the former, this is an excellent place for decision

⁵³⁶ This is the same data as is presented in Figure 7.2 but for ease of comparison, the most recent year's data has been transformed into a bar chart.

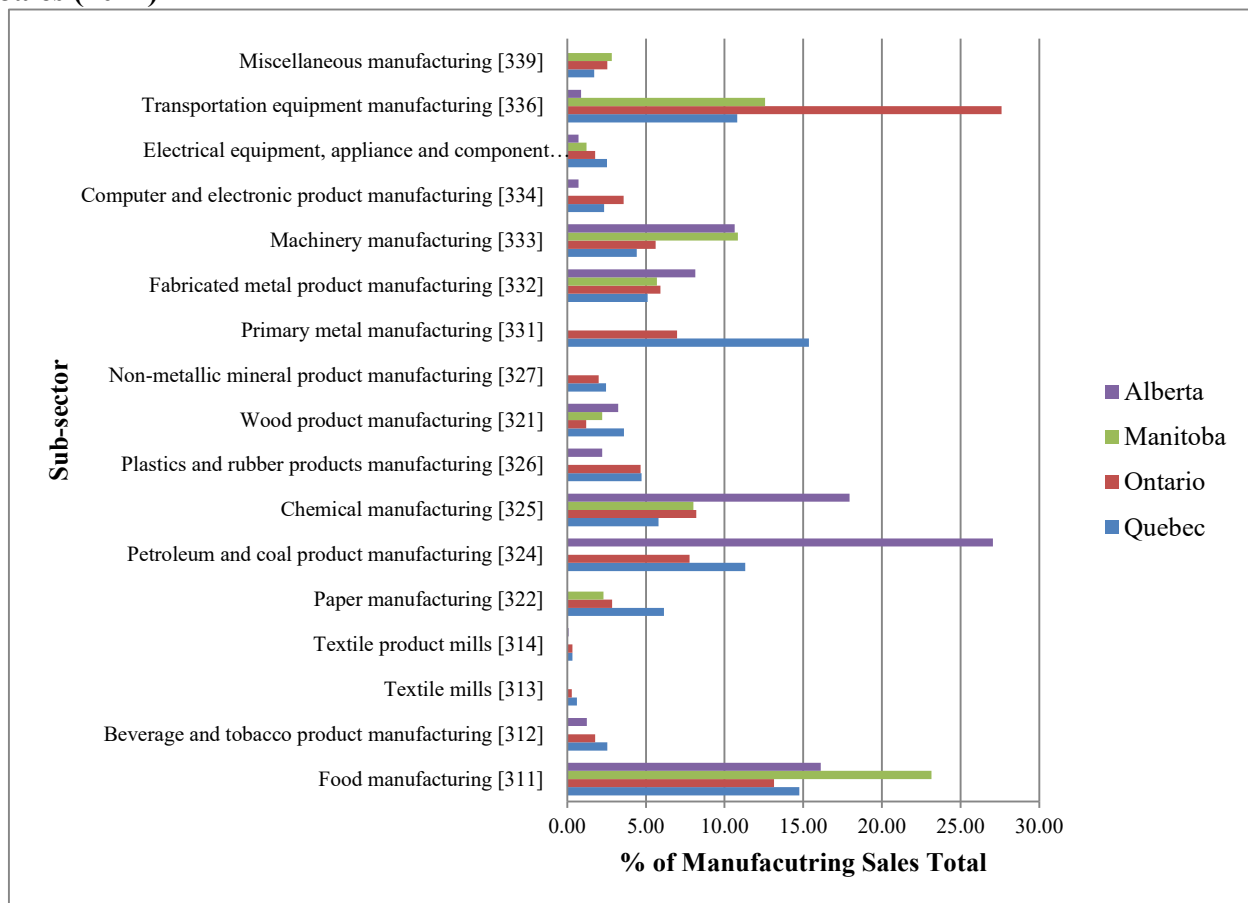
makers to begin looking if they are considering establishing benchmarks or technological standards as part of a set of legal instruments and policy goals to improve overall WP in Canada.

Figure 7.3 presents the manufacturing sector composition (in percentage of sales for 2011 associated with various subsectors) for Ontario, Quebec and Manitoba – which all have similar 2011 WP's – and Alberta, which has a substantially higher 2011 WP. The subsectors which appear to dominate Ontario, Quebec and Manitoba have similar overall WP's at the national level. In Quebec, food manufacturing represents 14% of sales and has a WP of \$672/m³, while primary metal manufacturing is 15% of sales and has a WP of \$114/m³, and transportation equipment manufacturing is 11% of sales and has a WP of \$13,770/m³. Ontario's largest subsector, by percentage of manufacturing sales, is transportation equipment manufacturing (28%) with food manufacturing coming in at 13%. Manitoba's food manufacturing subsector represents 23% of sales and transportation equipment manufacturing 12%. The fact that provinces with similar subsector make-ups have similar WP suggests a link between the two. It would not be surprising if at least some of the variation in WP between provinces was due to differences in the subsector make-up of the province's manufacturing sectors.

Alberta, on the other hand, has a different make-up than the other three which would suggest (based on the subsectoral WP's) that the provincial WP would be lower. Yet Figure 7.3 shows exactly the opposite – Alberta has a very high WP. Even though petroleum and coal product manufacturing account for 27% of manufacturing sales and has a WP of \$126/m³, chemical manufacturing makes up 17.9% of sales (with a WP of \$341/m³) and food manufacturing a further 16.1%, Alberta's overall WP is much higher than the other provinces which all have significant percentages of their manufacturing sector composed of subsectors with higher WP's (perhaps most obviously transportation equipment manufacturing). Even

considering that Alberta's 2009 WP was slightly ($\sim \$3/\text{m}^3$) lower than Manitoba's and historically has been similar to Ontario, Manitoba and Quebec, given the subsectoral composition, this still presents an anomaly. Given Alberta's subsector make-up, the overall manufacturing sector WP could be expected to be substantially lower than these other three provinces, but this is not the case. The obvious answer for this has to do with geographical and meteorological concerns such as water drought and, perhaps, the policies that have been developed in response.

Figure 7.3 - Manufacturing Sub-sectors by Percentage of Total Provincial Manufacturing Sales (2011)



An alternative way to investigate the impact of subsector composition would be to take national subsector WP in proportion to the provinces subsector makeup, and compare this to the

actual provincial WP. Essentially, this would compare the actual provincial subsector WP to what it would be if all provinces had the same subsector WP. This could provide further insight into the impact of composition. Unfortunately, in order to do this for the case study presented here, the data available were again incomplete and required a number of aggregations up and down in levels of analysis. That is, some subsectors were broken down into “sub-sub” sectors, while others were presented only at higher levels of analysis (a combination of two subsectors). Since data is censored depending on the number of companies in the unit of analysis, the sub-sub sectors cannot simply be combined to add up to the same units. The result is that it would be impossible to determine whether the results were indicative of differences in subsector composition, or simply aggregation and data censorship issues. That said, future research should attempt to undertake such an analysis as, if done using reliable data, it could enable better comparisons of WP between provinces.

In summary, then, this analysis shows that there are considerable differences in WP between provinces. Unfortunately, Statistics Canada does not release data for specific subsectors at the provincial level, and therefore the calculation of those WP measures cannot be completed. Still, a comparison of the provincial subsector composition and the 2011 WP of the four comparator provinces proved useful.⁵³⁷ Combining this with the national manufacturing subsector WP’s, it seems plausible to conclude that the differences in manufacturing subsector composition contribute to the differences in provincial WP, but that there are also other important factors at play. This means that there is room for decision makers to implement policies or instruments

⁵³⁷ It is certainly also true that even if subsectors are the same, there may still be differences in composition – for example, some pulp and paper firms produce primarily pulp and other produce primarily paper. These considerations should also be further studied.

without necessarily requiring a change in subsectoral make up (which is likely an unrealistic prospect).

7.5.2 Testing H_2

Recall that H_2 stated that WP would results in increases in water price. In order to test this hypothesis, OLS regression is used to evaluate the relationship between water price and WP. In total seven models are estimated, for Total Water Productivity, Municipal Water Productivity, and Self-Supplied Water Productivity, each with and without controls, as well as a municipal WP model with natural log variables.

7.5.2.1 Bivariate Regression Analysis

To test H_2 , first simple bivariate OLS regression models are estimated. In each, the dependent variable is WP (total, municipal and self-supplied) and the independent variable is water price (total water acquisition costs, municipal costs and self-supplied water costs [licenses and maintenance]). To determine price per unit (\$/m³ of water) total acquisition costs (in dollars) were divided by total water intake (in m³ of water). This gave per unit (m³) water cost which could be used in the regression analysis. The municipal per unit water costs are significantly higher (ranging from ~ \$0.18 - \$1.00 per cubic meter of water) than self-supplied water costs (~\$0.01 - \$0.05). Self-supplied water costs are predominantly related to the industry's own cost of acquiring the water as, generally speaking, license fees are relatively low. To take into account the effect of differences between provinces, the water price and water productivity variables are "demeaned", as is common in econometric analysis. That is, the values used in the model are the difference from the provincial average. For example, the value used is the difference between the 2011 WP in Alberta and the mean of the WP's in Alberta across all years where data is available.

This is useful because it avoids the problem of unobserved variables between provinces - similar to the use of fixed effects in the multivariate models below. Equation 7.1 shows the bivariate regression equation.

Equation 7.1: Bivariate Regression Model

$$Y = \alpha + \beta_1 X_1 + \varepsilon$$

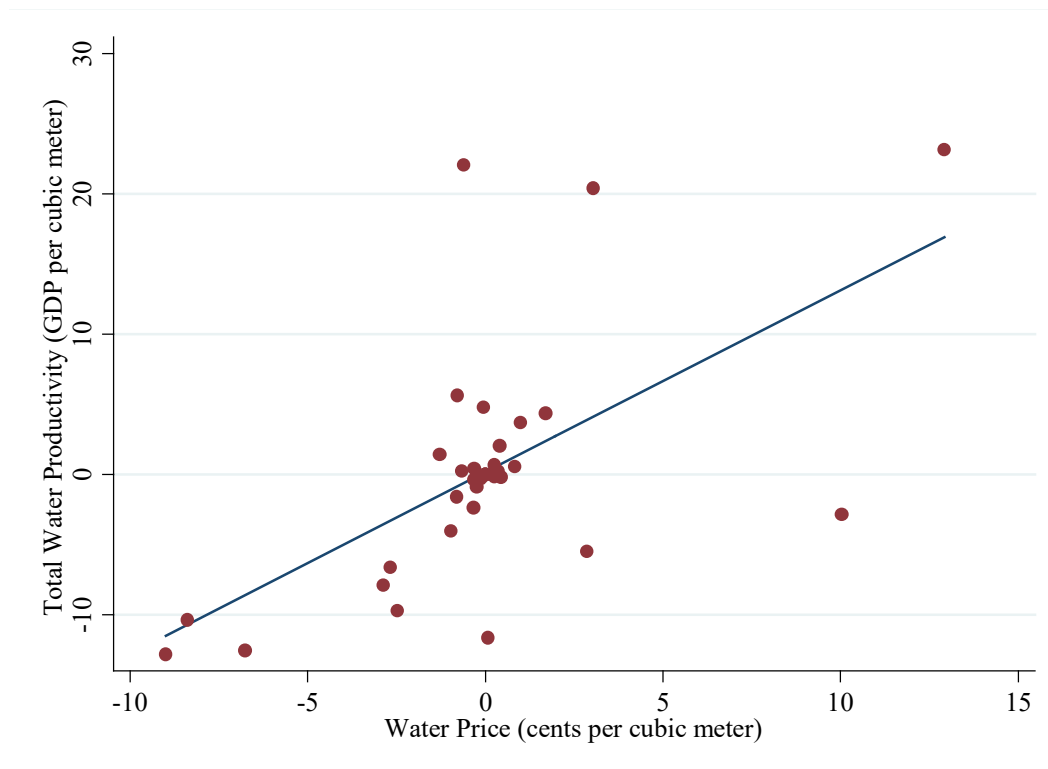
Where Y is water productivity (total, municipal, or self-supply), α is the intercept, X_1 the water price (total, municipal, or self-supply water acquisition cost), and ε the error term.

The results of the bivariate regression models are presented in Table 7.1, and a scatterplot of the relationship between total WP and total acquisition cost is presented in Figure 7.4, between municipal WP and municipal water acquisition cost in Figure 7.5, and between self-supply WP and self-supply water acquisition cost in Figure 7.6.

Table 7.1 - Results of Bivariate Analysis of Water Productivity and Water Price

Dependent Variable	Independent Variables	Coefficient	Standard Error	p-value
Total Water Productivity n=34 adj. r ² = 0.346	Total Water Price (in cents)	1.298	0.302	<0.001
	Intercept	0.171	1.175	0.885
Municipal Water Productivity n=24 adj. r ² = 0.495	Public Water Price (in cents)	4.047	0.798	<0.001
	Intercept	-1.602	7.913	0.841
Water Acquisition Cost (Self Supplied) n=21 adj. r ² = -0.0511	Self-supplied Water Price (in cents)	2.901	0.952	0.871
	Intercept	0.690	1.771	0.701

**Figure 7.4 - Total Water Productivity and
Total Water Acquisition Costs (Variables Demeaned)**



**Figure 7.5 - Municipal Water Productivity and
Municipal Water Acquisition Costs (Variables Demeaned)**

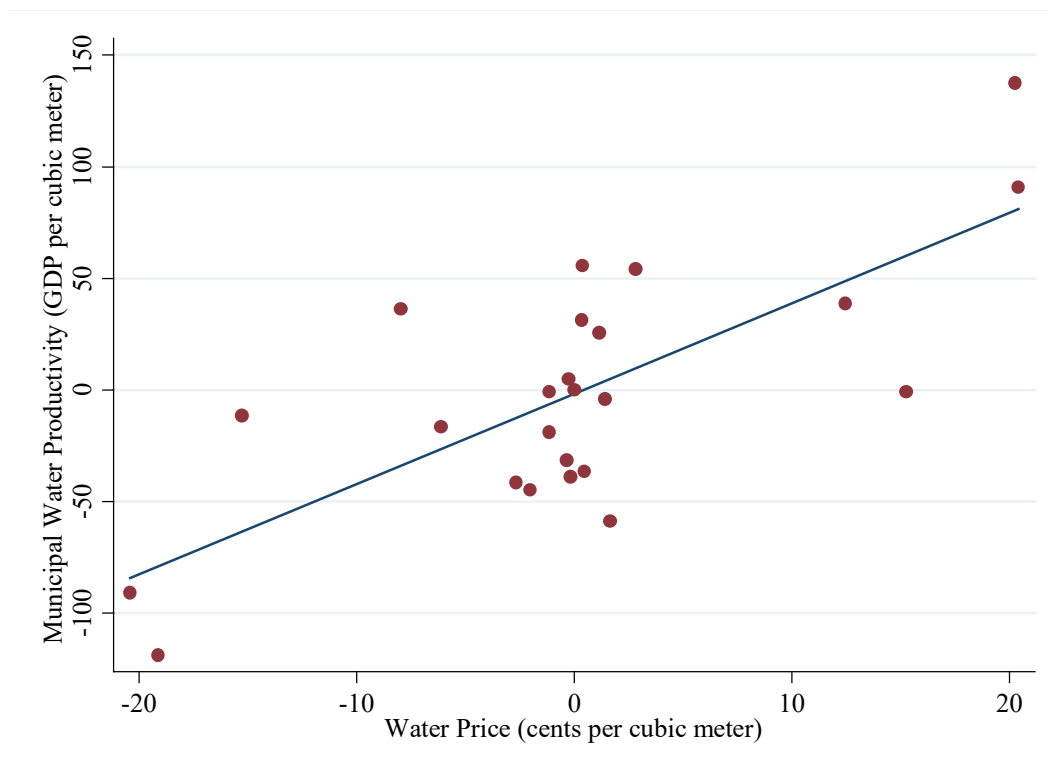
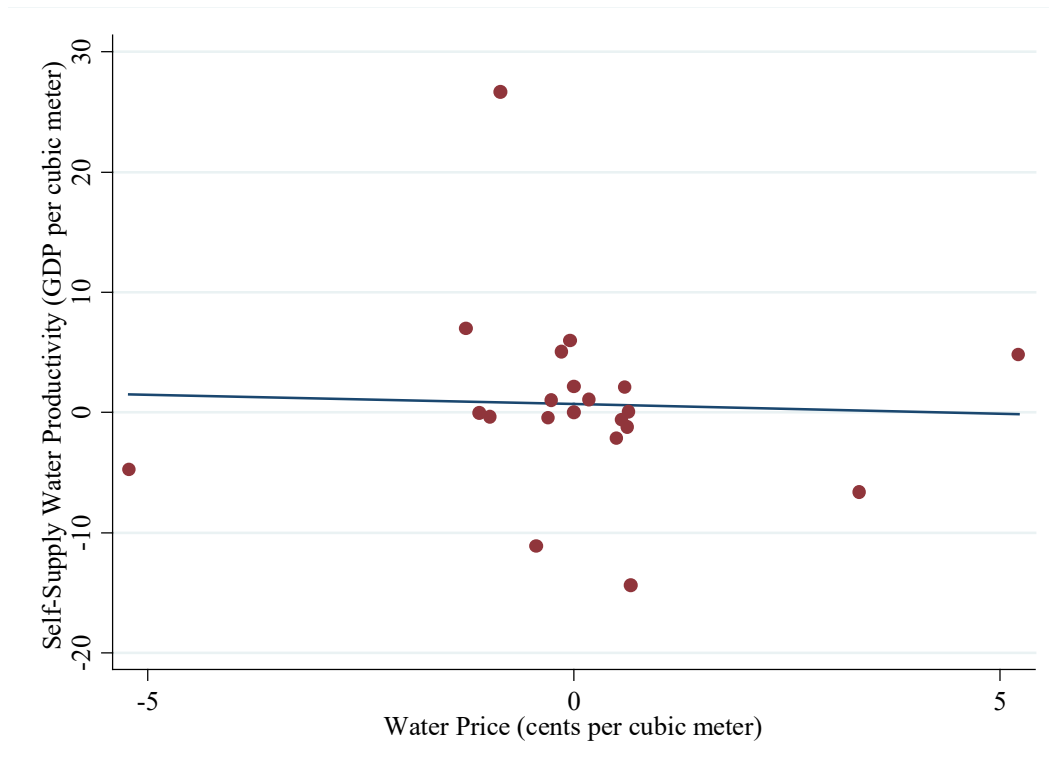


Figure 7.6 – Self-Supply Water Productivity and Self Supply Water Acquisition Costs (Variables Demeaned)



The relationship between water price and WP is obvious in Figures 7.4 and 7.5 which show, as a scatter plot, total water acquisition costs and total WP, and municipal water acquisition costs and municipal WP (respectively) by province, in the manufacturing sector. These two bivariate regression analyses confirm H_2 . The coefficient of total water intake is 1.298, which is highly statistically significant ($p < 0.001$). In other words, \$0.01 increase in the acquisition cost of water is on average correlated with \$1.3 more GDP generated per cubic meter of water intake. With regards to the municipal water relationship, the coefficient is 4.047 and is again highly statistically significant ($p < 0.001$). However, the relationship found between self-supply water acquisition costs and self-supply WP is not statistically significant ($p = .871$).

Overall, this analysis provides clear evidence in favour of H_2 , though not for self-supply water. The implication is that increases in water price do, in fact, lead to increases in WP.

7.5.2.2 Multivariate Regression Analysis

A more rigorous test of H_2 requires controlling for various other factors. As before, the dependent variable is WP (total, municipal and self-supplied) and the independent variable is price (total acquisition cost, municipal cost and self-supply cost). The control variables are provincial fixed effects, labour compensation, capital cost, percentage of the province's manufacturing sector that is machinery manufacturing, and percentage of the manufacturing sector that is paper manufacturing. The provincial fixed effects results are in comparison to Ontario (the reference category).

Recall that labour compensation and capital costs are necessary control variables, because they are (like water) inputs into a production process which have a price. In places where labour compensation or capital costs are high companies might be less likely to invest, for example, in equipment to use water more efficiently (improve WP) even though water prices have increased. This is because the price of water plus the cost of improving its efficient use may still be less than the cost of new equipment. As noted before, the subsector make-up of the province might contribute to differences in WP. Unfortunately, controlling for all subsectors at the same time is not possible - because of missing data, each additional variable reduces the number of data points available. Therefore, those subsectors with the highest (machinery manufacturing) and lowest (paper manufacturing) WP (nationally) are controlled for. More generally, including the provincial fixed effects should control time-invariant differences between provinces. Since data is missing for some of these control variables, the sample size (reported in Table 7.2) is

smaller than for the bivariate models. The control variables are reported by province and therefore are the same for all three regression analyses. *Equation 7.2* is the multivariate regression model.

Equation 7.2: Multivariate Regression Model

$$Y = \alpha + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \beta_5 X_5 + \beta_5 X_5 + (V_1 + \dots V_{12}) + \varepsilon$$

Where Y is water productivity (total, municipal, or self-supply), α is the intercept, X_1 the water price (total, municipal, or self supply water acquisition cost), X_2 machinery manufacturing, X_3 paper manufacturing, X_4 capital costs, X_5 labour compensation, $(V_1 + \dots V_{12})$ the provincial fixed effects, and ε the error term.

Table 7.2 - Results of Multivariate Analysis of Water Productivity and Water Price

Dependent Variable	Independent Variables	Coefficient	Standard Error	p-value
Total Water Productivity n=20 adj. r2 = 0.644	Total Water Price (Cents per unit)	0.786	0.737	0.314
	Labour Composition	0.000	0.003	0.969
	Capital Costs	-0.001	0.003	0.695
	Machinery Manufacturing	-3.730	3.475	0.311
	Paper Manufacturing	0.729	6.985	0.919
	Quebec	-16.178	53.151	0.768
	Manitoba	-14.056	66.714	0.838
	Saskatchewan	-21.380	77.911	0.790
	Alberta	-7.148	60.377	0.908
	British Columbia	-56.803	101.704	0.590
	Intercept	86.361	68.565	0.240
Municipal Water Productivity n=17 adj. r2=0.7533	Public Water Price (Cents per unit)	4.954	1.483	0.016
	Labour Composition	-0.004	0.023	0.878
	Capital Costs	-0.002	0.027	0.938
	Machinery Manufacturing	16.714	28.220	0.575

	Paper Manufacturing	-26.424	52.420	0.632
	Quebec	192.739	422.607	0.664
	Manitoba	-570.193	443.339	0.246
	Saskatchewan	-436.564	482.303	0.400
	Alberta	-89.789	419.383	0.838
	British Columbia	180.614	714.572	0.809
	Intercept	205.665	541.222	0.717
Self-supply Water Productivity n=15 adj. r2 = 0.9525	Self-Supply Water Price (Cents per unit)	0.744	0.498	0.195
	Labour Composition	-0.001	0.001	0.394
	Capital Costs	0.001	0.002	0.538
	Machinery Manufacturing	-5.714	4.061	0.218
	Paper Manufacturing	-13.540	3.797	0.016
	Quebec	25.682	24.088	0.335
	Manitoba	-9.725	33.269	0.782
	Alberta	-9.278	26.835	0.744
	British Columbia	77.285	47.199	0.162
	Intercept	154.513	37.560	0.009

The municipal analysis (based on municipal WP and municipal water acquisition cost) appears to show a relationship. The results show that, even controlling for machinery and paper manufacturing composition, capital and labour costs, and provincial fixed effects, on average, a \$0.01 increase in the acquisition cost of municipally supplied water means an increase in WP of ~ \$5.00 of GDP/cubic meters of water ($p = .02$). Importantly, this relationship holds even after controlling for subsectors with the highest and lowest WP, and the size of the effect is not much different. On the other hand, neither the total water analysis (based on total WP and total water acquisition cost) nor the self-supply analysis (based on self-supply WP and self-supply water acquisition costs) show evidence of a relationship (neither result is statistically significant).

While clearly an imperfect test, this suggests that the results are not determined only by the subsector make-up of the province's manufacturing sector. While adding more subsector controls is difficult because missing data quickly reduces the number of data points, the

municipal analysis results are robust to using alternative sectors. For example, substituting other subsectors that are especially high or low in WP such as Petroleum and Coal Product Manufacturing, Wood Product Manufacturing, Food and Beverage Manufacturing, or Transportation Equipment Manufacturing as controls produces essentially the same results. Therefore, it does not appear that these results are driven by any particular subsector.

To aid in interpretation and comparison of the results, the municipal water analysis is repeated,⁵³⁸ with municipal water productivity and municipal water price transformed as natural logs. The model is otherwise identical to the multivariate analyses. Taking the natural log of variables allows interpretation of the results as percentage changes. Doing so here allows comparison with the substantial amount of conventional productivity research which reports results in percentage change in productivity, rather than increase/decrease in dollars of GDP (as in the initial analyses).⁵³⁹ Note that using logged variables does not change the statistical significance or direction of results for the other analyses (not shown), and so the focus here is on an alternative way to interpret and use significant findings.

As Table 7.3 shows, the coefficient of the logged municipal water price is 1.043. This means that a 1 percent increase in water price is correlated with a 1.04 percent increase in water productivity. In addition, it is possible that water prices would increase by far more than one percent over a short period of time. A 10% increase in the price of water, which is certainly plausible, would imply an increase of 10.4% in water productivity.

⁵³⁸ The other two analyses (total and self-supply) did not result in statistically significant findings and therefore were not repeated.

⁵³⁹ For example, productivity trends reported by the Bank of Canada are in percent changes. See Allan Crawford, “Trends in Productivity Growth in Canada” (2002) Bank of Canada Review 19-32, online: <<http://www.bankofcanada.ca/wp-content/uploads/2010/06/crawfe.pdf>>

Table 7.3 - Results of Multivariate Analysis of Municipal Water Productivity and Municipal Water Price with Logged Variables

n=17 adj. r2 = 0.7833	Dependent Variables	Coefficient	Standard Error	p-value
	Municipal Price (Cents per unit) logged	1.043	0.348	0.024
	Machinery Manufacturing	0.114	0.082	0.215
	Paper Manufacturing	-0.134	0.154	0.416
	Labour Composition	0.000	0.000	0.735
	Capital Costs	0.000	0.000	0.622
	Quebec	1.871	1.379	0.224
	Manitoba	-1.129	1.305	0.420
	Saskatchewan	-1.160	1.415	0.444
	Alberta	0.157	1.240	0.904
	British Columbia	1.664	2.106	0.460
	Intercept	1.140	2.322	0.641

7.6 Discussion

The analyses performed confirmed, at least broadly, both H_1 and H_2 , showing that manufacturing WP varies based on geographical location, and that water price has a positive relationship with WP. The clear difference in the WP of the manufacturing sector across different provinces suggests that there is room for improvement. For decision makers, this analysis might indicate areas for concern and opportunities to discover best practices both in terms of industry techniques and instrument implementation. In addition, the analysis of subsector composition suggests that there appear to be other important factors besides subsectoral differences that contribute to the variation in WP.

The outlier with substantially higher provincial manufacturing WP in 2011 is Alberta. Despite having a subsectoral composition of moderately weak performers (in terms of the national subsectoral WP analysis), Alberta has a total manufacturing sector WP of \$75.80 in 2011 which is ~ \$25/cubic meter of water higher than the next closest province (Ontario's WP in 2011 is \$50.22). It seems likely that there is another factor at play - perhaps most obviously water stress⁵⁴⁰ - which presumably has meant public policy interventions to reduce water use. In other words, the water shortages have likely caused Albertan manufacturing firms to be more efficient in their use of water. Unfortunately, a more detailed analysis requires data that is not released to the public by Statistics Canada – but if this is indeed the case, then the technologies and procedures used in Alberta may be transferrable across the country through the introduction of new legal instruments such as information instruments, subsidies, or technology standards. The key finding here with regards to instrument choice is that WP analysis can highlight areas and sectors with exceptional performance in terms of WP. Decision makers may then be able to encourage the proliferation of successful techniques elsewhere, or target poor performing areas for intervention, and thus improve the WP of other areas and sectors.

The second part of the chapter examined the relationship between water price and WP. The regression analysis partially confirmed H_2 , showing, that for part of the manufacturing sector, water price does indeed have a positive relationship with WP – that is, higher water prices are correlated with higher WP. The implication is that these companies are responding to higher

⁵⁴⁰ It might also be assumed that another reason for Alberta's high WP is that Alberta's GDP surged when the price of oil increased around 2011. In the case of this research, though, that spike in oil prices (and its consequent impact on GDP and WP) can be ruled out for two reasons: 1) the GDP used in the equation is only from manufacturing industries and is not the overall provincial GDP. Oil and gas extraction (where the majority of the increases in oil price would show up) is not a manufacturing industry and therefore is not included in this study. 2) Petroleum and Coal Product Manufacturing (refining, for example) is considered manufacturing and is included in this study, but the WP for this sub-sector at the national level is actually quite low. Therefore, it is unlikely that it would be responsible for the high WP of Alberta manufacturing sector.

water prices by increasing their efficiency of use of water, perhaps by substituting human-made capital for natural capital, rather than simply decreasing production. This is a very important piece of information for decision makers. The municipally supplied section of the manufacturing sector shows a correlation between water price and WP, while there is no such correlation for the part of the sector that self-supplies water. Importantly, that the relationship was still significant, even controlling for subsector make-up and provincial fixed effects, is another piece of evidence that the results are not determined by differences in subsectors between provinces.

This analysis was meant as a proof-of-concept piece and it should be noted that there are significant data limitations. Specifically, the small number of data points might reduce the statistical significance of these results, and did prevent the use of all subsector controls simultaneously. A larger dataset would clearly enable a more robust analysis. Nonetheless, this study shows how decision makers could analyze the potential effect of a legal instrument (i.e. a pricing instrument) on the behavior of industry using a green productivity measure. The analysis here suggests that at least parts of the manufacturing industry would respond to increases in water prices by improving WP (likely through substitution or innovation),⁵⁴¹ rather than with reduced production. More generally, this analysis shows that the use of WP (and other associated forms of NRP) does in fact offer useful insights to decision makers.

In terms of establishing causality, two points are worth noting. The first is endogeneity, or the problem of the direction of causation. That is, do changes in water price cause changes in water productivity, or could it be the other way around? In general, it seems most likely that water prices cause changes in water productivity, if only because this fits with standard

⁵⁴¹ This aligns nicely with conclusions made by Dupont & Renzetti in their article considering water in the Canadian manufacturing sector, where they found that water intake is a substitute for other inputs – notably, labour, capital and energy – Dupont & Renzetti, *supra* note 525 at 425.

economic theory (if prices rise, generally, people will purchase/use less of the good or service). One alternate possibility is that GDP causes changes in prices via a use mechanism. That is, increases in manufacturing GDP are associated with more factories, higher production, etc., which probably increases water use. If increasing water use leads to increases in water price, then there might be a problem of reverse causation. However, in many cases, developers pay the initial cost for expanded water use (to set up new pipes, facilities etc.)⁵⁴² and once the infrastructure wears out decision makers often have to raise water prices to pay for repairs and replacement.⁵⁴³ Since water infrastructure often lasts for many years, price increases do not occur for decades after the initial expansion. For example, many cities are now facing water price increases to replace infrastructure built in the post WWII period. As a result, it seems unlikely that water prices are primarily driven by water use linked to rising GDP and expansion, and therefore this type of endogeneity is not too serious a threat for this analysis.⁵⁴⁴

The provincial fixed effects (in the multivariate model) and the demeaning of the variables (in the bivariate model) help rule out spurious correlation due to other unobserved differences between provinces. For example, one might assume that there are differences

⁵⁴² In Ontario, for example, the *Development Charges Act, 1997*, SO 1997, c 27 allows municipalities to charge developers for cost related to growth (such as water services).

⁵⁴³ For example, the City of Guelph explains water rate increases as a consequence of future water and wastewater infrastructure renewal, amongst others. Notably, there is no explicit mention of rate increases because of rising use of water. See, City of Guelph, *Water Rates*, online: <http://guelph.ca/living/environment/water/water-rates/>.

⁵⁴⁴ Because of the way that water price was calculated in this study (total water acquisition costs by the manufacturing sector in a given province for a given year divided by total water intake by the same part of the Canadian manufacturing sector), there is a risk of endogeneity caused by the methodology. That is, because some of these costs are fixed, changes in water use might produce apparent (but incorrect) changes in water price. Since water use is also included in the water productivity calculation, the estimates of a relationship between the two might be biased by endogeneity. Unfortunately, data on actual fee schedules is very difficult to obtain because these are set by each municipality or are specific to each individual manufacturing company. However, this potential issue is unlikely to be too serious, since only a small amount of total acquisition costs are fixed – those which relate to permits paid for self-supply water withdrawal (0.7% of the total water acquisition costs for the entire manufacturing sector in Canada according to the 2009 Industrial Water Survey) - while the rest is, in most cases, volume-based (depending on amount of water used).

between provinces which are not included in the model such as urban/rural concentrations or different ways of pricing water – including provincial fixed effects and using demeaned variables should eliminate the impact of these differences. Further, adding additional control variables in the multivariate analysis helps show that the bivariate model results are not a result of differences in, for example, capital costs or labour compensation.

The analyses presented here show clear differences in results for total, municipal, and self-supply WP. Although the bivariate analysis showed a relationship between total price and total WP, once controls are added, this relationship does not appear to hold. Digging deeper, there is no evidence of a relationship between self-supply WP and self-supply water acquisition cost (both in the bivariate and multivariate model), but there does appear to be relationship for municipal WP and municipal water acquisition costs. These differences might be a result of how water is currently priced.

Companies in the manufacturing sector who get their water from municipal sources are likely to be charged per unit of water used which may encourage knowledge of water use and stimulate efficiency actions. This may be why the WP for the manufacturing sector which gets its water from municipal sources shows a relationship to water price. On the other hand, the WP of those who self-supply their water does not seem to be price responsive. Self-supply water users are typically awarded a license for a given amount of water for a given length of time (usually annually). In contrast to municipal water supply which is metered and paid per unit used, self-supply water users pay a lump sum for a license and for further operational/maintenance issues that emerge. This mechanism does not seem to encourage efficient use because operators are no better off if they use less water than they have been allocated (they gain nothing economically from using less water than they are licensed for).

While self-supply users might pay less if they request permits for less water, these permits are renewed much less often than municipal billing, and so adjustments are therefore more difficult. Moreover, there is often no direct monitoring of water use for self-supply – that is, there is no actual “meter”.

Another possible explanation for the relationship that was found between self-supply water users’ WP and water prices is that the lack of price responsiveness is a result of the low prices they pay for water. This could be instead of, or in combination with, the pricing structure challenge. While licence fees are charged,⁵⁴⁵ these are described in some studies as “free or nearly free,”⁵⁴⁶ and certainly are much less than municipal water costs. In fact, if water costs are negligible, management may not think it is worth their time and energy track and monitor water use. Therefore, to produce changes in behavior, it may be that price increases may need to be quite large. This could occur in conjunction with, or independent of, recommendations made above dealing with pricing structure. All of these issues make self-supply water users less likely to respond to price signals by increasing the efficiency with which they use water.

This finding, that the WP of self-supply water users in the manufacturing sector are not price sensitive whereas the WP of those in the same sector that get their water from municipal sources are, has significant implications for instrument choice. The manufacturing sector drawing on municipal water supply is likely to respond to increased water prices by increasing their WP. Therefore, pricing instruments such as taxes are likely to be effective. However, it is well documented that many, if not most, industrial water users in Canada self-supply water.⁵⁴⁷

⁵⁴⁵ Canada West Foundation, “Water Pricing Policy in Canada” (2011) Canadian Water Policy Backgrounder at 2, online: < http://cwf.ca/pdf-docs/publications/Water_Backgrounder_7_Sept_2011.pdf>.

⁵⁴⁶ Rivers & Groves, *supra* note 523 at 421-422.

⁵⁴⁷ Dupont & Renzetti, *supra* note 525 at 412.

Yet these water users do not seem to respond to price signals. Increasing license fees may seem the easiest solution, but given the current relationship with water acquisition costs (license fees and operational costs) this may be ineffective. This is a serious issue for decision makers, since a common policy instrument to increase efficiency of use – pricing instruments – may have little effect on the largest group of manufacturing water users.

In order to encourage improvements in WP amongst self-supply water users, one option would be to alter the way which they are charged for water so they are charged per unit of water used thereby encouraging efficiency. While perhaps an ideal long-term strategy, such a process would undoubtedly be costly both from a financial and temporal perspective, because it would have to involve installing and monitoring meters.

Since an overall shift in pricing structure seems likely to be challenging and expensive, alternative instruments might be deployed (at least in the interim). Two potential, separate but related, instruments are here suggested. The first is a pure information instrument which seeks to educate about the importance of water use efficiency and provide recommendations for how to improve it. This aligns well with what some scholars have noted- that often times one of the reasons natural capital is not used efficiently is because corporate decision makers are not even aware of their use of it⁵⁴⁸ and therefore do not focus on using it efficiently. For self-supply water users, corporate decision makers may in fact be unaware of how much water they use because they have no incentive to monitor use given the way they pay for it. Given the appearance of

⁵⁴⁸ This is alluded to by Porter & van der Linde when they discuss that the act of having to collect and report data may mean companies will find improvement all on their own (in other words, they were not aware of their usage/efficiency because they were not collecting/reporting the data and the act of doing so, or being made aware of the issue, might on its own improve actions) Porter & van der Linde, *supra* note 430 at 100.

unresponsiveness to price changes, perhaps beginning by simply informing corporate actors of why they should care about their use of water is an important – and effective – first step.

A second option is a right-to-know instrument. Similar to an information instrument, public reporting through right-to-know regulation may prove effective at both increasing awareness of water use and ultimately increasing how efficiently self-supply water users employ water. Though data reporting by these same actors is legally required under the *Statistics Act*,⁵⁴⁹ reporting levels are below 75%,⁵⁵⁰ and, of course, data is only released in anonymous form. Public reporting is quite different. Required reporting and publication of water use data, as is done with the National Pollutant Release Inventory,⁵⁵¹ would require accurate accounting for water use and would allow the public to understand how different corporate actors are using water. Both could lead to improved WP. This type of reporting could also easily be linked to corporate social responsibility in that companies concerned about their reputation of water use or productivity might even voluntarily choose to report their progress in company documents such as annual or sustainability reports.⁵⁵²

This case study also provides broader insights for decision makers. At its most basic, this analysis shows that the measures of NRP (and more natural capital flow specific measures, such

⁵⁴⁹*Statistics Act*, RSC, 1985, c S-19 [SA].

⁵⁵⁰ For the 2011 reference year, the response rate for the manufacturing component of the Industrial Water Survey was 62%, for the mining component, 65% and 90% for the thermal-electric component in the 2011 reference year (see: Statistics Canada, *Industrial Water Survey (IWS)* (2 July 2014), online: <<http://www23.statcan.gc.ca/imdb/p2SV.pl?Function=getSurvey&SDDS=5120>>.)

⁵⁵¹ See website here: <https://www.ec.gc.ca/inrp-npri/default.asp?lang=En&n=4A577BB9-1>

⁵⁵² The idea of companies voluntarily reporting on environmental data is not a new idea. A study of environmental reporting in the UK and Spain found that, though Spain had a legal requirement and the UK did not, it was UK businesses which had a higher rate of environmental reporting. Clearly there was a belief by UK companies that reporting on environmental data was important (due to pressure from NGOs and plausibly also concern about reputation) despite a lack of legally binding requirement. See Jan Bebbington Elizabeth A. Kirk & Carlos Larrinaga, “The production of normativity: A comparison of reporting regimes in Spain and the UK” (2012) 37 *Accounting, Organizations and Society* 78-94. A similar belief is possible with reporting on water data.

as WP which was used in this analysis) can be calculated, analysed and useful. Given the commitments made by many governments (Canada included) to achieve both sustainable economic growth as well as use natural resources efficiently so natural capital can be preserved for future generations, measures of NRP are excellent measures of progress as well information sources for whether different legal instruments are in fact (able to) achiev(ing) these goals. While there have been comparisons between legal instruments (pricing, for example) and water use,⁵⁵³ these results are only able to show if a given instrument will promote the maintenance of the stock of natural capital (through reductions in use) - they are not able to say much about the relationship between natural capital use and economic growth. While these analyses are still important, they are not sufficient to allow decision makers to be fully informed on the impact of their instrument choices. In order to consider both water use (to meet requirements of long-term natural capital stock maintenance) and sustainable economic growth, a measure such as NRP is needed which can tell how efficiently natural resource(s) are being used. That is, a measure is needed which considers both economic output (in this analysis, output is represented by GDP) and inputs of a form of natural capital flow, something this case study shows can be done using measures of NRP.

This case study also simply shows that while the calculation of measures of NRP is possible, in order to provide more robust results, that better data is required. This analysis is based on the manufacturing sector, in part because it has some of the best reporting of data. Despite requirements by the *Statistics Act*,⁵⁵⁴ though, the reporting rate from those in both the

⁵⁵³For example, Greg Barrett, “Water Conservation: The Role of Price and Regulation in Residential Water Consumption” (2004) 23(3) *Economic Papers* 271-285; Sheila M. Olmstead and Robert N. Stavins, “Comparing price and nonprice approaches to urban water conservation” (2009) 45 *Water Resources Research* W04301; Steven Renzetti, “Economic Instruments and Canadian Industrial Water Use” (2005) *Canadian Water Resources Journal* 30(1) 21-30.

⁵⁵⁴ *SA, supra* note at 549.

manufacturing and mineral extraction sectors is below 75%, though the thermo-electric power generation sector has a much higher response rate to the IWS.⁵⁵⁵ Further, Statistics Canada censors a great deal of data due to confidentiality which also impedes analysis. This latter challenge, though, might be not so large for those within government who may have access to the full set of reported data. The results of this case study are provisional given these data issues, but they do show how NRP studies can provide decision makers with information to better ensure instrument and instrument mixes are effective, efficient and equitable.

7.7 A Note on Modelling Other Green Productivity Measures

This chapter has presented evidence that a measure of NRP – water productivity – can provide novel and useful information for decision makers. Recall, though, that there are two other measures of green productivity that have been analysed and discussed throughout the rest of this thesis. Modelling WP instead of another measure was chosen in large part because of its relative ease of calculation as well as data availability (though, as was just mentioned, even in this case, data is a significant hindrance). Although data is not available to calculate the other two types of green productivity measures, it is useful to consider what a case study using them might show.

Modelling EAP with a focus on water would provide information that is different than what the WP case study presented above and would require additional data as well. Because EAP is measured as a residual, the result would represent the change in outputs not accounted for by a change in combined inputs and could present information about technology, operational or innovation advances within a given province in the manufacturing sector. In order to calculate

⁵⁵⁵ For the 2011 reference year, the response rate for the manufacturing component of the Industrial Water Survey was 62%, for the mining component, 65% and 90% for the thermal-electric component in the 2011 reference year (see: Statistics Canada, *Industrial Water Survey (IWS)* (2 July 2014), online: <<http://www23.statcan.gc.ca/imdb/p2SV.pl?Function=getSurvey&SDDS=5120>>.)

EAP, data on water use (which was used in the water productivity case study above) and on pollution discharged to the water and/or degradation of the water sources (some of which is provided by the IWS) would be needed. As explained in Chapter 4, the indicator is calculated by dividing total outputs by inputs. Total output is desirable outputs (i.e. GDP) minus undesirable outputs. Undesirable outputs are determined by the cost of pollution/degradation of the water source. . Total input is sometimes only capital and labour, but can also include inputs such as energy, services, and materials. (*Equation 7.1*)

Equation 7.3: Water Focused EAP

$$\text{Water Focused EAP} = \frac{\text{GDP} - \text{Value of undesirable outputs on water}}{F(K, L, E, M, S)}$$

Where F is the production function, K is capital, L is labour, E is energy, M is materials, S is services.

Instead of indicating which province's manufacturing sector is most efficient with its use of water and/or how different legal instruments could impact WP, a water focused EAP could present results on which provinces appear to have better technology, operational or innovation techniques while taking into account their production of undesirables which impact water sources. That is, improvements in technology or management might reduce water pollution which would not be reflected in standard productivity estimates – but would be reflected in this EAP measure. This can be useful if interest is focused on the effects legal instruments could have on generating innovation and technology, or capturing their improvements in environmental outcomes. Moreover, this information is useful in refuting common claims that environmental regulation decreases productivity.

Calculating an indicator of the impact of the quality/quantity of natural capital on the multifactor residual is slightly more abstract. Again, in the case of water, the focus would be on how much of the residual is attributed to changes in the quality or quantity of water (used or remaining in the stock) instead of to innovations in technology, operations management, etc. This is especially useful in situations where there has been a clear change in the quality or quantity of water which is not incorporated into standard productivity measures. That is, the effects of this change is visible in the change in the residual, but the cause – changes in water inputs – is not apparent and is lumped into the residual along with other unknown factors. These kinds of calculations are obviously difficult to do on a systematic basis. Nonetheless, recognition that low rainfall, for example, might be responsible for declines in output, could aid in the interpretation of productivity measures.

7.8 Chapter Summary

This chapter has provided evidence that studies of NRP (a measure of green productivity) can provide decision makers with valuable information to improve decision making, in particular, with regards to legal instrument design and evaluation. Chapter 6 argued that NRP measures could provide evidence of leaders, laggards and highlight potential benchmarks as well as provide information about legal instrument choices and their effectiveness, efficiency and equity. This chapter provided concrete examples of how this can be done, based on the comparison of provincial manufacturing sector WP's and the analysis of the relationship between WP and water acquisition costs.

There are four main findings presented in this chapter:

1. that comparisons between provincial manufacturing WP can highlight leader and laggard provinces as well as identify sources of potential information for developing technology standards or other benchmarks to use within different instrument design;
2. that comparing WP to water acquisition costs results in a statistically significant positive relationship, in some cases;
3. that more detailed analysis may show varied responses to water costs amongst different parts of the manufacturing sector; and
4. that improved data collection is essential in order to provide robust results that are truly usable by decision makers.

The identification of leaders, laggards and benchmarks is useful information for designing instruments. The results of this case study indicate that Alberta's higher than expected WP may be a place for decision makers to dig deeper in case policies, technologies, management processes or other factors are making for higher WP and can be transferred to other jurisdictions. Similarly, other provinces such as British Columbia have lower than average WP and so are good cases for pilot programs or targeted instruments. Finding a statistically significant relationship between WP and water acquisition costs (both with and without controls) indicates that parts of the manufacturing sector in Canada are responsive to price signals and therefore a pricing instrument aimed at increasing the efficiency of use of water should be successful. When evaluating instrument options, such information is helpful to decision makers.

Further analysis seemed to indicate that those in the manufacturing sector who self-supply their water are not price responsive – that is, higher prices are not correlated with higher WP. Given the current pricing structure for self-supply users, price changes do not provide incentives to improve efficiency, nor do they encourage an understanding of why water should not be wasted. It seems, then, that decision makers should either reform the structure of the self-supply pricing regime, or consider different legal instruments. Combining information or educational

instruments with pricing ones may, in fact, be a better solution to improving WP in the overall manufacturing sector (at least in the short term) and therefore important in moving Canada towards having more sustainable economic growth and at the same time improved consideration for intergenerational equity.

8. Conclusion

8.1 Introduction

The world today is stretching natural capital to its limits, and concern is intensifying over how the economy uses natural capital, in its various forms, for production and consumption.

International agencies, regional governance structures, and even the prominent Rio+20

Conference of the Parties, have indicated a concern for natural capital use, and specifically, the need to use it more efficiently. Further, Canada has made numerous legal commitments to sustainability – at the provincial, national, and international level – which result in responsibilities to move towards sustainable economic growth and intergenerational equity.

Given the commitments to sustainable economic growth and intergenerational equity, the federal and provincial governments in Canada need to develop policies that encourage the efficient use of natural capital as well as moving towards incorporating both the value and damage that economic processes have on natural capital, into decision making. This dissertation discussed the concept of green productivity and argued that it is useful for decision makers charged with such goals. Specifically, the research question asked was “*in what way(s) can green productivity measures be used in the policy cycle and to improve instrument choice decision making?*”

In order to answer this question, the dissertation progressed through four key sections:

- First, the legal and methodological foundations were set out, and an argument was made that Canada has legal commitments to sustainable economic growth and intergenerational equity. The key implication derived from this was that natural capital needs to be used, overall, less and, in general, more efficiently, and that law and policy decisions should encourage such outcomes. Law and economics methodology is best suited to this kind of analysis;

- Second, the dissertation explored the different types of green productivity measures, and developed of a set of consistent concepts and terminology;
- Third, the thesis analysed how and where in the policy cycle and legal instrument choice decision making frameworks green productivity measures could be influential; and
- Finally, a case study using WP (one type of green productivity measure) was undertaken in order to demonstrate how instrument choice decision making could benefit from such analyses.

8.2 Contributions

This dissertation makes four key contributions to academic knowledge. These are: the presentation of a coherent and consistent set of concepts and terminology for three types of green productivity, the place of green productivity in the policy cycle, how green productivity can be used in instrument choice decision making, and a demonstration of some of these uses in a case study. A number of other notable points are highlighted, including interdisciplinary contributions, linking of different EAP research programs, and recommendations for data collection,

Contribution 1 – Presentation of a cohesive and coherent suite of green productivity measures with consistent terminology

This dissertation provides recommendations for a consistent and conceptually coherent set of terminology in the area of green productivity. Research on different measures of green productivity is inconsistent and the terms used are sometimes misleading. In particular, terminology emerged as a significant concern throughout this dissertation because, if measures of green productivity are to be used by decision makers, and in interdisciplinary research, how they are defined and what they measure must be clear.

Chapter 4 of the dissertation presented a discussion and analysis of the various terms used in green productivity studies and proposed numerous recommendations for consistent

terminology for use in future research. Using consistency, conceptual accuracy, and broad acceptance as criteria, recommendations were made for green productivity as an umbrella term, natural resource productivity and environmentally adjusted productivity as more specialized measures of green productivity and desirable/undesirable outputs to represent conventional and traditionally excluded outputs. Ideally these will become standard so that researchers who study these types of productivity, as well as those who use the measures in other research (particular law and policy) and in practice, will have a clear understanding of comparable studies as well as how green productivity measures can be used.

Contribution 2 – Analysis of how green productivity can be influential in the agenda setting stage of the policy cycle

The second contribution of this dissertation is the discussion of green productivity with references to different parts of the policy cycle. Specifically, this thesis argues that the nature of green productivity gives it more appeal at the central agenda setting stage than to single departments, and that adoption at the agenda-setting stage is necessary for its successful implementation. Both arguments turn on the fact that the agenda setting stage is where the largest and most diverse group of decision makers congregate to discuss broad issues of public policy. Because of its appeals to diverse decision makers and its requirement for cross-departmental expertise, green productivity should be introduced at the agenda setting stage of the policy cycle. In addition, two reasons exploring the plausibility of adopting green productivity in the Canadian context were discussed – that green productivity is a preferable way for the government to frame sustainability and that the potential for policy diffusion of this idea is high.

The nature of green productivity as integrating environmental factors into an economic measure makes it particularly well suited to the agenda setting stage of the policy cycle. As

Howlett *et al* put it, the entire policy universe participates at this stage in the policy cycle,⁵⁵⁶ and green productivity is more appealing to this kind of a broad policy debate than it is to a single department. This is particularly important for green productivity, because of the importance that many in the policy arena put on productivity, but these are not the same actors who generally deal with environment or sustainability proposals. Further, much of the agenda-setting occurs in central agencies. Since implementing green productivity is likely to require cross-departmental coordination, involvement of these actors at the agenda-setting stage is essential to its success.

There are two main characteristics which increase the likelihood of green productivity being adopted in Canada. It is well known that one of the ways political innovations emerge is through policy diffusion.⁵⁵⁷ At present the European Union has policy goals focused on similar measures of resource efficiency/productivity. Importantly, they justify becoming more resource efficient as necessary condition for achieving and securing sustainable growth⁵⁵⁸ - is something which should also resonate with Canadian decision makers who have legal commitments to similar goals. Further, the fact that as a policy goal resource productivity appears to be successful and perhaps even popular (prominent international organizations – the OECD, for example - have also become interested in this idea) coupled with Canada's recent free trade agreement with the EU should mean that the diffusion of this idea from the EU to Canada is certainly plausible.

Finally, Chapter 3 discussed how governments frame and define the issues as part of the agenda-setting process. Green productivity is one way to define issues of sustainability and intergenerational equity and may be preferable to other options, such as no-growth or overall

⁵⁵⁶ Howlett et al, *supra* note 153 at 12.

⁵⁵⁷ Berry & Berry, *supra* note 169 at 310.

⁵⁵⁸ EC, *A resource-efficient Europe – Flagship initiative of the Europe 2020 Strategy* online: <http://ec.europa.eu/resource-efficient-europe/>.

reductions in resource usage. Of course, nothing guarantees that sustainability and intergenerational equity will make it onto the public agenda, but if they do, then governments may prefer to define them and set goals in terms of green productivity.

Contribution 3 – Analysis of how environmentally adjusted productivity and natural resource productivity can improve goal setting, design and evaluation within instrument choice decision making frameworks

The dissertation presents EAP and NRP as tools to improve decision making in instrument choice frameworks. While much previous research has focused on which type of instrument is best and what evaluation criteria should be used, this dissertation instead focuses on analysing the value of a new tool (green productivity measures) in instrument choice decision making. These measures of green productivity can be used to improve goal setting as well as the design and evaluation of legal instruments.

The setting of goals, design, and evaluation of legal instruments, it is argued in this thesis, can be improved through the use of information from NRP measures. The discussion in this dissertation as well as the analysis of the case study results shows that NRP studies can point out leaders and laggards. This information points decision makers towards where to look to a) determine whether there are leaders who have technologies, policies, activities which are causing significant improvements in NRP and therefore should be encouraged to be transferred elsewhere and b) determine which are the laggards in need of targeted instruments to bring up performance on how efficiently natural resources are being used.

NRP studies can also be used for the *ex-ante* or *ex-post* evaluation of different types of instruments using either proxies (i.e. differences in water acquisition costs as a proxy for a water pricing instrument) or real-world data after the implementation of an instrument to determine the

relationship between improvements in efficiency of use and the instrument of choice. In addition to common analysis which examines the relationship between given instruments and overall use, NRP gives a picture of whether output is likely to be maintained or decline with reductions in use of natural resources. Such a consideration is essential in order for decision makers to choose instruments best able to encourage sustainable economic growth mindful of intergenerational equity.

EAP can aid in the evaluation of instruments through its alternative perspective on cost benefit analysis. In addition, because EAP growth is presented as changes in the residual (that is the changes in outputs not accounted for by changes in the inputs) and the residual is typically considered to be a consequence of changes in technology, ranking instrument options based upon EAP change might provide information about how instruments could impact innovation.

Further, measures of EAP can provide evidence that environmental regulation does not necessarily reduce productivity growth. This is because EAP gives credit for improvements in environmental protection through reductions in undesirable outputs and therefore better represents the actual impact of environmental regulation on productivity growth.

Contribution 4 – A demonstration of how measures of natural resource productivity can be used by decision makers in instrument choice decision making frameworks

The case study of WP in the Canadian manufacturing sector was developed as a ‘proof-of-concept’ piece to illustrate how measures of NRP can provide new and useful information to decision makers. Results indicate that simple comparisons between the WP of provincial manufacturing sectors can be a starting point for decision makers interested in finding new and innovative ideas to integrate into the decision of legal instruments. Further, as was described above, this case study demonstrates how relationships between NRP and acquisition costs can be

determined, which is useful in predicting what could happen given the introduction of a pricing instrument.

Interestingly, a more detailed analysis of WP and water acquisition costs (this time considering municipal and self-supply water users separately) shows that not all actors in the manufacturing sector are equally responsive to price signals. This information suggests intervention in the form of different legal instruments is needed to improve the efficiency of water use. Recommendations are that this could be accomplished, perhaps, through either reforming the licensing system for self-supply users, or by introducing alternative instruments (perhaps designed to inform and create behavioural norms) targeted at self-supply water users.

8.3 Other Notable Points

In addition to the key contributions listed above, there are a number of other notable points worth emphasizing. Specifically, the dissertation introduces green productivity into policy and legal instrument choice decision making frameworks – a novel application and an important interdisciplinary fusion. It also synthesises a series of disconnected research programs on environmentally adjusted productivity. Finally, the thesis points out the inadequacies in data available on natural capital use, and makes recommendations for improvements.

Introducing Green Economic Concepts into the Policy Cycle and Legal Instrument Choice Frameworks

Much interdisciplinary research is focused on filling the gaps between disciplines,⁵⁵⁹ and especially considers research focused on broader social and environmental problems. In the case of this dissertation, the focus was on sustainable economic growth and intergenerational equity

⁵⁵⁹ Bruer, *supra* note 143 at 223.

within the context of Canada's legal commitments. The research aimed to provide new tools which would allow better decision making leading to the successful achievement of these goals (or at least movement towards success). These legal issues are addressed using an economic measure – green productivity – which is not new in economics, but its use as a tool for decision makers in order to try and fulfill legal commitments is certainly novel.

One author has indicated that IDR research is the understanding of different disciplines and the use of concepts from one to help solve difficult issues in another.⁵⁶⁰ Clearly, the research presented in this dissertation does just that by taking a relatively well known concept in environmental and ecological economics – green productivity – and applying it as a tool to help move decisions made about policy and legal instruments towards choices more able to achieve legal commitments related to sustainability.

Synthesis of Environmentally Adjusted Productivity Research

While research on green productivity is poorly integrated in general, as Chapter 4 details, this is especially so for EAP. This concept is certainly not new - in fact, work done in a similar vein can be traced back at least to the early 1980's.⁵⁶¹ Yet the field, if it can be called that, has been highly fragmented and similar research has been conducted by various academics in quite divergent areas, looking at agriculture, industry operations, and national studies. Not only are the different research programs sometimes unconnected, they often use different concepts, and different methods – not necessarily a problem if there is an internal debate, but in this case parts of the research seem unaware of other options. Therefore, the 'state of literature' presented surrounding this measure is, in itself, a contribution of knowledge as the author was unable to

⁵⁶⁰ *Ibid.*

⁵⁶¹ Pittman, *supra* note 310.

find any recent similar synthesis.⁵⁶² This synthesis presented here, it is hoped, might contribute to developing a more coherent approach to EAP.

Data Recommendations

While the results of this case study are very interesting and succeed in showing that NRP studies can provide useful information to decision makers, it also revealed substantial shortcomings in the data. While there are a number of data sources relevant to natural capital, including natural resource stock accounts, material and energy flow accounts (including greenhouse gases and energy), and the waste management industry survey, on closer inspection many of these data sources are deeply inadequate.

For example, the Industrial Water Survey used in this dissertation is better than many other surveys, yet still there is a substantial amount of missing data. This is sometimes because companies simply ignore reporting requirements, sometimes because the reported data is clearly incorrect, and sometimes because it is censored by Statistics Canada. As discussed in Chapter 7, the analysis of subsectors at the provincial level, for example, is not practically possible. Despite this data supposedly being collected, it is not publically reported. Therefore, a recommendation of this dissertation is that in order to produce many of the green productivity measures proposed here, there needs to be significant improvement in the collection of natural capital data across the country at a variety of levels. Consistent reporting from all companies and industries is necessary to ensure the most accurate and robust measurement and consequently that the best legal instrument and policy recommendations are produced. Most obviously, the requirements

⁵⁶² The work done in 1996 by Tyteca is the closest that was found. See Tyteca, *supra* note 24 at 289-296.

under the *Statistics Act* need to be better implemented, monitored and enforced, but a wide array of other improvements is also possible.

8.4 Limitations

This dissertation makes a number of significant contributions to academic knowledge but it has a number of limitations as well. Among others, it does not attempt to develop a new economic measure, nor to establish that green productivity will necessarily be adopted. It makes several pragmatic assumptions, including that assessing real prices may be impossible, and that whole-sale transformation of the economy is unlikely. Instead, the dissertation tries to suggest how decision making can be improved within these constraints.

First, this thesis does not endeavor to create a new method of economic modelling, nor to make an empirical contribution to economics – all three green productivity measures used in this thesis are already established in economics. It is their combination as a suite of green productivity measures *and* their application to law and policy frameworks which is the novel piece of work. Clearly there is a need to develop these tools from an economic perspective – the many different approaches to EAP and the lack of precise ways to measure the impact of natural capital on the residual both represent potentially rich research programs. However, this is not the focus on the dissertation.

The legal foundations laid out in Chapter 2 argues that Canada has a legal obligation to sustainable economic growth and intergenerational equity, but this is not an empirical claim stating that the government will meet this commitment. Unfortunately, governments commonly violate their legal obligations and commitments, as has been seen over the years with different

international agreements. Nonetheless, the analysis of legal commitments provides an important normative foundation which motivates the need for tools to improve decision making.

The dissertation also makes a number of concessions to the reality of today, including that environmental concerns will not likely lead to a dramatic reshaping of the economy, such as near-complete divestment from fossil fuels, or a no-growth stance. This informs the focus on efficiency, rather than strict limits on natural capital use. Similarly, this dissertation recognizes that decision makers are often constrained by many factors, including political will, available information, etc. As a result, they may not be able to adopt the most theoretically optimal instrument. In principle, these might be preferable, and might generate quite different conclusions. However this dissertation instead chooses to focus on generating plausible tools and recommendations for decision makers.

8.5 Directions for Future Research

This research is a starting point for a number of potential future research directions. The case study shows that it is possible to calculate NRP measures in Canada and so future research could expand on the WP measure and calculate other single resource productivity measures or a total NRP measure. To do this, however, better data needs to be collected. Once calculated, future research could take these results and apply them against any number of legal instrument options to determine their impact or consider where particularly (in)efficient practices are located. Similar research could be undertaken by calculating EAP in Canada.

The natural capital and residual measure is a future research direction for environmental economists, one which it appears has received relatively little attention. Understanding the contribution of the quality of natural capital to the residual might help give context to the

interpretation of the multifactor residual. Clearly, some consistent method of evaluating its importance needs to be developed. The results from future research on such a topic could both inform economics by advancing research on the multifactor residual, and inform law and policy research, by highlighting new areas for intervention.

Development of natural capital data that is internationally comparable could also offer important insights. The use of resources productivity by the EU, for example, offers a wide range of policy environments in comparable developed economies. By creating data that is compatible, decision makers could easily compare productivity measures, and better evaluate the effects of different instruments and policies across multiple countries.

Finally, further work linking green productivity measures to research on valuation is necessary. Many of these measures require the use of non-market valuation. This is a large field in its own right, and this thesis does not explore the implications of the different kinds of valuation and pricing.

8.6 Moving Toward a Green, Sustainable Economy

In conclusion, this dissertation makes three key points. First, that Canada and Canadian governments have legal commitments to making decisions that move the country towards sustainable economic growth and actions securing intergenerational equity. Second, decision makers need to better manage natural capital, which includes incorporating natural capital contributions to economic activity, be more aware of the damage and degradation of natural capital, and improve natural capital's efficiency of use. Third, that green productivity and its individual measures can and should be used to improve decision making at the agenda-setting phase in the policy cycle and as providers of information in legal instrument choice decision

making frameworks. It is very important to highlight that the recommendations for using green productivity are not recommendations to abandon the other tools currently used by decision makers. Instead, green productivity, as is shown throughout the dissertation, can provide new and useful information *in addition to* what is already used and therefore should be considered another tool in the instrument choice and policy toolbox. This is especially important because, though shown to be helpful in moving towards achieving goals of sustainable economic growth and intergenerational equity, improvements in green productivity are not enough on their own. Specifically, improvements in green productivity could be outpaced by economic growth leading to overall increases in natural capital use which would undermine the sustainability targets. To mitigate the potential of such a situation, the use of alternative tools – perhaps caps to limit the maximum use of natural capital, should also be promoted. Therefore, this dissertation argues that green productivity measures are part of the solution, but cannot, alone, successfully achieve goals related to an issue as complex as sustainability.

In summary, this research should encourage decision makers to use green productivity as a tool to help align policy goals and instrument choice decisions with overarching sustainability commitments to sustainable economic growth and intergenerational equity. Though not sufficient alone to solve these problems, the adoption of these measures as part of the policy maker's toolbox is a step in the right direction. Canada has significant commitments towards sustainability and if serious is extended towards achieving them, the introduction of green productivity into the policy cycle and legal instrument choice frameworks can play an important role.

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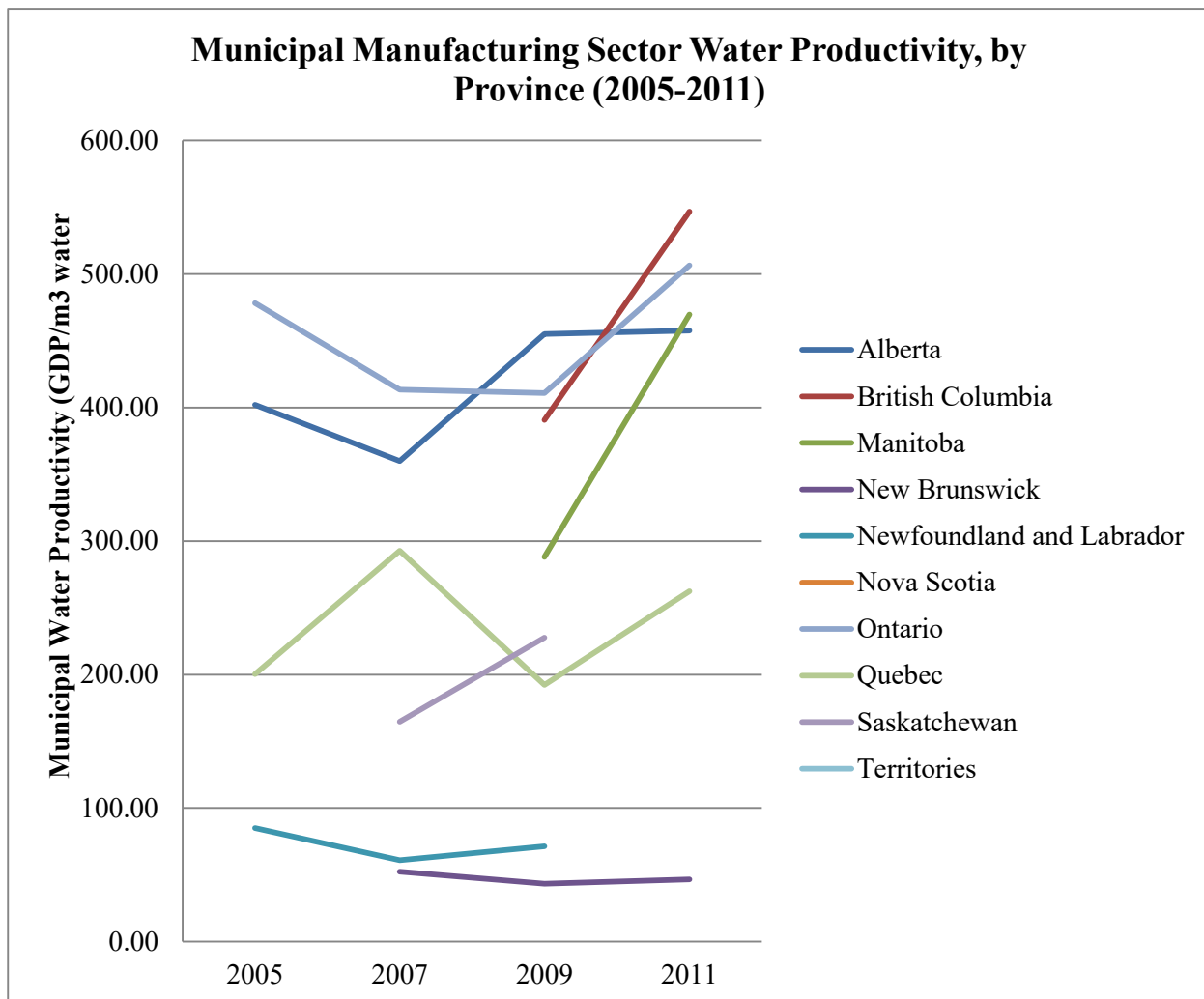
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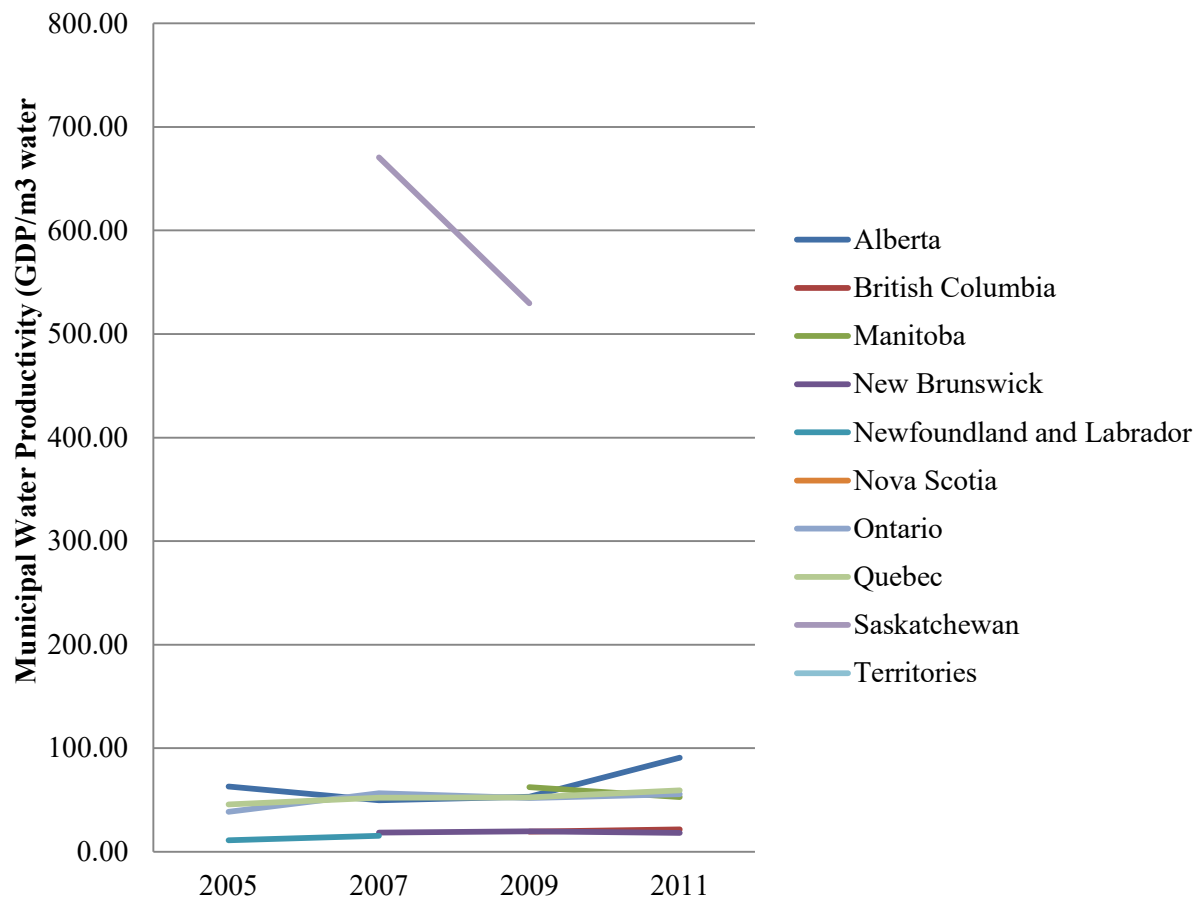
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APPENDIX A: CASE STUDY DETAILS

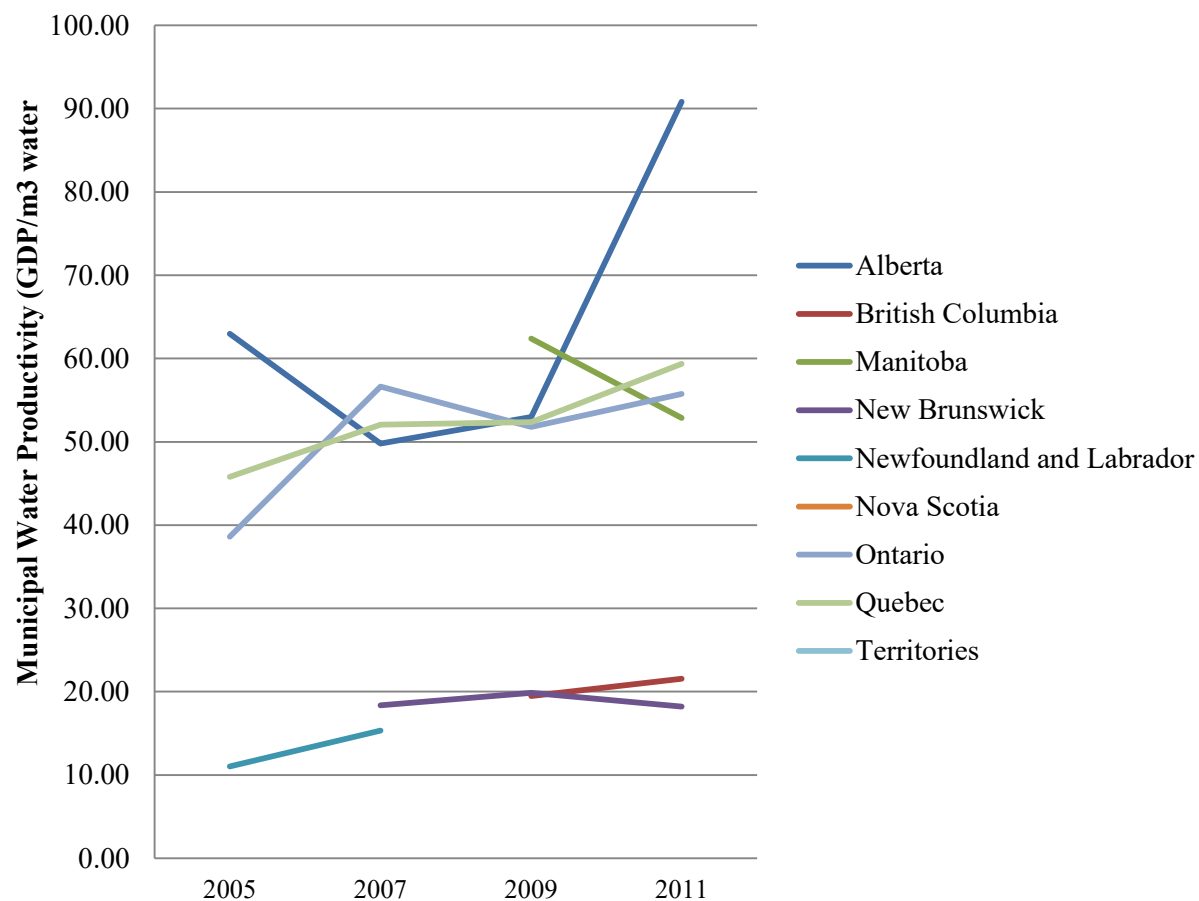
Municipal and Self-Supply Bivariate Results



Self Supply Manufacturing Sector Water Productivity, by Province (2005-2011) with Saskatchewan



Self Supply Manufacturing Sector Water Productivity, by Province (2005-2011) Saskatchewan Removed



National Sub-sector Water Productivities

Manufacturing Sub sector WP (2005-2011) - National Level				
<i>Sub-sector</i>	<i>WP 2005</i>	<i>WP 2007</i>	<i>WP 2009</i>	<i>WP 2011</i>
Food manufacturing [311]	720.81	757.67	694.97	672.99
Beverage and tobacco product manufacturing [312]	812.96	910.79	1157.21	1129.89
Textile mills [313]	1261.05	1924.15	9927.50	5188.24
Textile product mills [314]	2383.85	3363.55	1957.58	4828.57
Wood product manufacturing [321]	1329.51	1555.03	4553.13	4352.24
Paper manufacturing [322]	56.68	66.65	63.43	79.58
Petroleum and coal products manufacturing [324]	112.13	106.13	117.74	126.10
Chemical manufacturing [325]	363.67	387.17	431.94	341.40
Plastics and rubber products manufacturing [326]	3500.45	5135.02	3042.83	3593.18

Non-metallic mineral product manufacturing [327]	1098.11	1659.63	1399.23	1378.71
Primary metal manufacturing [331]	91.70	119.22	100.54	114.70
Fabricated metal product manufacturing [332]	4295.63	6445.23	9337.70	24476.83
Machinery manufacturing [333]	27254.74	34442.39	48550.00	46748.89
Computer and electronic product manufacturing [334]	-	11996.42	-	-
Electrical equipment, appliance and component manufacturing [335]	-	8819.77	-	35591.82
Transportation equipment manufacturing [336]	13756.47	17088.00	13925.37	13770.66
Miscellaneous manufacturing [339]	16452.86	7876.38	14363.21	29525.71

Labour Compensation and Capital Costs

<i>Geography</i>	<i>Year</i>	<i>Labour Composition (\$)</i>	<i>Capital Costs (\$)</i>
Alberta	2005	8650.2	6931.6
British Columbia	2005	10174.2	4959.4
Manitoba	2005	2879.8	2206.9
New Brunswick	2005	1692.8	1381.7
Newfoundland and Labrador	2005	670.1	250
Nova Scotia	2005	1822.7	1166.9
Ontario	2005	54634.5	36233.2
Prince Edward Island	2005	244.4	117.6
Quebec	2005	27761.8	20404
Saskatchewan	2005	1494.1	1311
Territories	2005		
Alberta	2007	10270	7845.1
British Columbia	2007	10501	5440.6
Manitoba	2007	3191.3	3030.2
New Brunswick	2007	1585.7	1587.7
Newfoundland and Labrador	2007	695	375.5
Nova Scotia	2007	1674.4	934.5
Ontario	2007	53164	33446
Prince Edward Island	2007	250.3	164.4
Quebec	2007	28131.4	19437.6
Saskatchewan	2007	1487.7	1533.5
Yukon	2007		
Alberta	2009	8954.3	7301.4
British Columbia	2009	8917.8	5156.9
Manitoba	2009	3125.9	3249.8
New Brunswick	2009	1534.3	1202.1
Newfoundland and Labrador	2009	665.6	281.7
Nova Scotia	2009	1731.1	893.4
Ontario	2009	45404.8	25806.2
Prince Edward Island	2009	249.8	183.7
Quebec	2009	25186.3	18913.3
Saskatchewan	2009	1584.4	2470.5
Yukon	2009		

Alberta	2011	9369.7	7301.4
British Columbia	2011	8694.6	5156.9
Manitoba	2011	3110.4	3249.8
New Brunswick	2011	1607	1202.1
Newfoundland and Labrador	2011	598	281.7
Nova Scotia	2011	1779.3	893.4
Ontario	2011	44525.4	25806.2
Prince Edward Island	2011	246.5	183.7
Quebec	2011	24884.4	18913.3
Saskatchewan	2011	1572.4	2470.5
Yukon	2011		

Table of Data for Case Study – Water Intake

<i>Geography</i>	<i>Year</i>	<i>GDP</i>	<i>Water Intake</i>		
			<i>Total</i>	<i>Municipal/Public</i>	<i>Self-Supply</i>
Alberta	2005	15442.8	283.7	38.4	245.3
Alberta	2007	15943.8	364.6	44.3	320.3
Alberta	2009	13014.8	274.2	28.6	245.6
Alberta	2011	15742.7	207.7	34.4	173.3
British Columbia	2005	15434.7	946.6	53.1	893.5
British Columbia	2007	15885	832	x	x
British Columbia	2009	12656.6	682.2	32.4	649.8
British Columbia	2011	13562	654.3	24.8	629.5
Manitoba	2005	4589.1	60.2	x	x
Manitoba	2007	4938.1	118.7	F	x
Manitoba	2009	4524.7	88.2	15.7	72.5
Manitoba	2011	4556.5	95.9	9.7	86.2
New Brunswick	2005	2710.7	205.2	x	x
New Brunswick	2007	2533.5	186.3	48.3	138
New Brunswick	2009	2305	169.2	53.1	116.1
New Brunswick	2011	2502.7	191.1	53.6	137.5
Newfoundland and Labrador	2005	832.6	85.2	9.8	75.4
Newfoundland and Labrador	2007	779.4	63.7	12.8	50.9
Newfoundland and Labrador	2009	693.5	F	9.7	x
Newfoundland and Labrador	2011	736.8	16.1	x	x
Nova Scotia	2005	2820.5	136.4	x	x
Nova Scotia	2007	2549.2	153.3	x	x

Nova Scotia	2009	2322.7	179.3	9.4	169.9
Nova Scotia	2011	2467.9	139.9	x	x
Ontario	2005	95638.6	2676.5	200	2476.5
Ontario	2007	89667.8	1799.9	216.9	1583
Ontario	2009	68916.1	1498.2	167.7	1330.5
Ontario	2011	75160.3	1496.7	148.4	1348.3
Prince Edward Island	2005	372.6	F	F	x
Prince Edward Island	2007	400.2	x	x	x
Prince Edward Island	2009	394.9	F	F	x
Prince Edward Island	2011	356.8	9.2	x	x
Quebec	2005	47083.7	1263.2	234.9	1028.3
Quebec	2007	45390.6	1027.3	155.1	872.2
Quebec	2009	40482.9	983.7	210.6	773.1
Quebec	2011	41158.8	850	156.8	693.2
Saskatchewan	2005	2845.2	60.1	F	x
Saskatchewan	2007	2884.1	21.8	17.5	4.3
Saskatchewan	2009	2754.5	17.3	12.1	5.2
Saskatchewan	2011	2785.5	x	x	x
Territories	2005	27.1	2.2	1.8	0.4
Yukon	2007	24.9	x	x	x
Yukon	2009	22	x	x	x
Yukon	2011	21.9	x	x	x

Table of Data for Case Study – Water Acquisition Costs & Sub-Sector Percentage of Provincial Manufacturing Sales

<i>Geography</i>	<i>Year</i>	<i>Water Acquisition Costs</i>			<i>Percentage of Provincial Manufacturing Sales</i>					
		<i>Inflation Adjusted Total in cents (per unit)</i>	<i>Inflation Adjusted Municipal/Public Utilities in cents (per unit)</i>	<i>Inflation Adjusted License, Operation and Management in cents (per unit)</i>	<i>Machine ry</i>	<i>Paper</i>	<i>Food Product</i>	<i>Petroleum and Coal Product</i>	<i>Transportation Equipment</i>	<i>Wood Product</i>
Alberta	2005	11.23029961	52.47109375	4.774341623	8.44910476	2.77406	14.77	21.47	1.42	5.8
Alberta	2007	11.54744926	60.23295711	4.813862004	9.22359301	2.96357	15.17	22.89		4.55
Alberta	2009	8.595565281	50.62461538	3.701302932	8.75606922	2.91368	19.75	22.65		3.42
Alberta	2011	14.51012037	71.05813953	3.285354876	10.6443674	x	16.1	27.06	0.88	3.23
British Columbia	2005	4.229602789	48.41088512	1.60394404	5.14680809	13.0752	12.22			27.33
British Columbia	2007	4.249362981	x	x	5.25235363	13.742	12.89		3.95	19.14
British Columbia	2009	4.814588097	66.37753086	1.744967682	4.54986317	13.2855	18.29		3.14	14.71
British Columbia	2011	4.962714351	87.79354839	1.699482129	5.27329356	13.2648	17.03		3.82	15.96
Manitoba	2005	20.11006645	x	x	7.11126846	3.7904	24.59	0.2	12.84	5.45
Manitoba	2007	13.93976411	x	x	7.29953883	2.75562	22.45	0.24	13.6	3.83

Manitoba	2009	30.751111 11	110.5380892	13.473103 45	10.30078 33	2.480 51	25.55		12.44	2.42
Manitoba	2011	18.044671 53	151.3558763	3.0432946 64	10.85020 53	2.302 9	23.14		12.57	2.22
New Brunswick	2005	5.2629922 03	x	x	1.220471 84	x	11.78			9.63
New Brunswick	2007	4.1608695 65	10.47391304	1.9513043 48	x	x	11.31		0.44	6.43
New Brunswick	2009	5.1739007 09	12.1493032	1.9836003 45	x	x	12.88			5.42
New Brunswick	2011	4.7076923 08	9.583208955	2.8071272 73	x	x	10.6		0.45	4.37
Newfoundland and Labrador	2005	4.9692018 78	x	x	0.275155 55	x	33.72		1.55	2.69
Newfoundland and Labrador	2007	5.5794348 51	21.6	1.5506876 23	0.405881 93	x	21.75		1.55	1.23
Newfoundland and Labrador	2009	#VALUE!	52.13773196	x	x	x	25.78		1.5	1.15
Newfoundland and Labrador	2011	31.361739 13	x	x	x	x	29.09		1.2	1
Nova Scotia	2005	5.9749266 86	x	x	1.645934 65	x	22.29		8.65	6.3
Nova Scotia	2007	4.6661448 14	x	x	1.578363 25	x	20.93		7.3	5.57
Nova Scotia	2009	4.0181595 09	48.35319149	1.5652501 47	x	x	21.9		7.75	5.06
Nova Scotia	2011	5.2393423 87	x	x	x	x	19.93		7.23	4.23

Ontario	2005	8.9161449 65	x	x	5.068883 32	3.405 89	8.95	5.28	33.98	2.17
Ontario	2007	13.086827 05	93.85435685	2.0201958 31	5.317901 28	2.802 58	9.71	6.37	32.86	1.54
Ontario	2009	12.225374 45	91.3746452	2.2491754 98	5.426328 4	3.233 39	14.69	6.9	25.35	1.39
Ontario	2011	11.339410 7	96.86603774	1.9259630 65	5.616181 74	2.859 84	13.14	7.78	27.61	1.2
Prince Edward Island	2005	x	x	x	1.838503 86	x	61.13		14.87	4.14
Prince Edward Island	2007	x	x	x	x	x	61.22		16.47	2.36
Prince Edward Island	2009	x	x	x	x	x	53.78			1.28
Prince Edward Island	2011	7.4869565 22	x	x	1.166045 61	x	58.01		17.32	1.43
Quebec	2005	8.4120028 5	19.08612175	5.9736574 93	3.744988	7.549 72	10.6	9.62	11.63	6.13
Quebec	2007	4.2615302 25	18.97253385	1.6455285 48	4.186929 71	6.849 86	11.46	10.18	11.24	4.68
Quebec	2009	4.7456663 62	16.59422602	1.5180028 46	4.356440 54	6.944 65	15.38	10.94	11.31	3.95
Quebec	2011	4.7533129 41	19.74375	1.3625158 68	4.426975 55	6.156 14	14.75	11.32	10.8	3.6
Saskatchew an	2005	12.177770 38	x	x	8.066987 29	5.966 44	20.76		3.29	8.22
Saskatchew an	2007	46.956880 73	54.73542857	15.3	9.571701 4	0.418 66	23.32			2.73

Saskatchewan	2009	62.937803 47	55.43272727	80.401538 46	12.22436 28	0.926 74	21.23			1.68
Saskatchewan	2011	x	x	x	9.998491 39	x	20.8		1.72	1.64
Territories	2005	9.4854545 45	x	x						
Yukon	2007	x	x	x						
Yukon	2009	x	x	x						
Yukon	2011	x	x	x						