Three Essays on
Demographic Changes and International Trade

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Abstract

Chapter 1: A Population Aging Analysis for Canada Using the National Transfer Accounts Approach: This analysis develops a new data set for Canada using an accounting methodology called National Transfer Accounts (NTA). NTA permits building an accounting system that introduces age into national accounts. NTA is consistent with the conventional national accounts and allows the estimation of lifecycle patterns for labour income and consumption from private and public sources. It also allows the calculation of per capita and aggregate lifecycle deficits (LCD) or surpluses (LCS) in an economy. In this chapter we calculate Canada's per capita and aggregate LCD for 2006. Using demographic projections for the next five decades, we present the aggregate LCD in Canada for the period 2006 to 2056 assuming a constant per capital LCD during this time horizon. The projection results show that labour income needs to increase rapidly or consumption needs to be cut significantly to compensate for the pressure on the aggregate lifecycle deficit as a result of population aging.

Chapter 2: An Overlapping Generations Computable General Equilibrium (OLG-CGE) Model with Age-dependent Rates of Time Preference: This analysis develops a methodology to introduce an age-dependent rate of time preference to calibrate an OLG-CGE model with per capita age profile consumption path derived from the NTA framework of Chapter 1. The results show that the economic impact from an aging population will be significant. The living standard will decline by 15% from the present to 2050 and decline by 20% by the year 2105. To reduce such a decline, the Canadian government may introduce policies that could encourage labour force participation. We analyze the impact of: a) an increase in the general labour force participation rate for age 20 to 64; b) an increase in the labour force participation rate for workers aged 50 to 64; c) late retirement. Our results suggest that maintaining the current

standard of living will be extremely difficult after 2026. Nevertheless, this would help reduce the economic pressure from population aging.

Chapter 3: 9/11 Security Measures and North American Security Perimeter: A Computable General Equilibrium Analysis: The objective of this analysis is to assess the impact of the North American Security Perimeter (NASP) on both the Canadian and the U.S. economies. The NASP is a change in Canada-U.S. security paradigm that would allow the liberalization of the post 9/11 security measures at the Canada-U.S. border. This study applies a multi-sector and multi-region general equilibrium model together with econometric analysis. After simulating the NASP, Canada's capital market was found to become more attractive. Under the NASP, the welfare of Canada is estimated to increase by $19 billion or 1.8% of GDP, and that of the U.S. is estimated to increase by $32 billion or 0.3% of GDP.

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General Introduction

This doctoral dissertation includes three analyses that study the economic impact related to demographic changes and international trade within the computable general equilibrium (CGE) methodology. The first chapter, entitled “A Population Aging Analysis for Canada Using the National Transfer Accounts Approach”, develops a database to introduce age into the conventional national accounts for Canada; the second chapter, entitled “An Overlapping Generations Computable General Equilibrium (OLG-CGE) Model with Age-dependent Rates of Time Preference”, calibrates an OLG-CGE model on some data from the NTA project in Chapter 1; the third chapter, entitled “9/11 Security Measures and North American Security Perimeter: A Computable General Equilibrium Analysis” explores the economic impact of building North American Security Perimeter (NASP) for North America.

Population aging is a slow but irreversible process that has been examined by many studies using macro variables of the System of National Accounts (SNA) to evaluate its economic and fiscal impacts; however, the conventional national accounts database lacks the information of the age factor. The NTA database provides a new way to measure flows and stocks in an economy that takes age into account while being consistent with the SNA data. The objective of the first chapter is to build a NTA database for Canada so as to provide a tool to improve the quality of the research on the economic impact of population aging in Canada.

The first chapter focuses on the foundation of the NTA principles to build lifecycle deficit (LCD) and lifecycle surplus (LCS). This chapter first builds the per capita LCD or LCS from labour income and consumption spending profiles household surveys data source. The second step ensures that these profiles at the aggregate level are consistent with the SNA database by using a macro-control procedure. The third step estimates the evolution of the aggregate LCD between 2006 and 2056 based on demographic projections and a constant 2006 per capita LCD.

This paper finds that the aggregate LCD of Canada in 2006 equals 9% of total labour income, and is projected to increase from $100 billion to $300 billion in half a century. Two thirds of this increase is due to the change of age composition of the population, and one third is from the increase in the total population. To keep the aggregate LCD constant at its 2006 level, the average annual growth rate of aggregate labour income would need to be about three times larger than in the “business as usual” scenario. Alternatively, the average annual growth rate of aggregate public consumption would need to decline to about one third of the rate projected in the benchmark scenario.

The second chapter uses the NTA age profiles of consumption, labour income, and public expenditure on health care and education in an OLG-CGE model to study the economic and fiscal impacts of population aging in Canada. This chapter introduces an age-dependent rate of time preference to calibrate the OLG-CGE model on the per capita age profile consumption path derived in Chapter 1. Chapter 2 also briefly surveys the theoretical and empirical on age-dependent time preference. The OLG-CGE model includes demographic changes, production, household consumption, pension system, investment, government and market clearing conditions. The simulation results show that output increases mainly because of the increase in the capital stock as an older population accumulates more assets than a younger population. Government age-sensitive expenditures and “pay-as-you-go” pension benefits increase significantly due to population aging. The living standard for Canada goes down even after removing the impact from total population growth.

In Chapter 2, we find that the Canadian government may try to increase the labour force participation to offset the negative impact due to population aging. However, the results show that the policy on labour force market would just slightly mitigate the decline in Canada's living standard. The Canadian government may also try to enhance living standards by deepening the North American economic integration in particular, by reducing the current obstacles at the Canada-U.S. frontier. This is discussed in Chapter 3 with the help of a CGE model.

Since the terrorist attack in New York and Washington on September 11th, 2001, the U.S. and Canadian governments tightened security measures at the Canada-U.S. border. These enhanced security measures have imposed longer waiting times which increase the cross-border costs and may adversely affect Canadian exports. For certain industries with "*just-in-time*" inventory strategy and high valued goods or services, the producers may choose to reallocate their factories in the U.S. to avoid these border costs. In this case, post-9/11 security measures may also divert foreign direct investment (FDI) in Canada to U.S. or the rest of the world (ROW). Besides the existing programs of FAST and NEXUS that tend to alleviate the burden at the frontier, the Canadian and U.S. governments have studied the possibility to establish a NASP.

Chapter 3 uses a CGE model to examine the economic impact of liberalizing the post-9/11 security measures at the Canada-U.S. border while introducing a NASP at the external border with the ROW.

Chapter 3 first describes how the sectoral exports of the three regions (Canada, U.S. and the ROW) have changed since 9/11. Even though the U.S. is still Canada's main export partner, the results show that 9/11 has lead to significant negative trade impacts between Canada and the United States. Chapter 3 also develops a CGE model to analyze the economic impact of removing post-9/11 security measures. This model is a multi-region and multi-sector CGE model which includes production and consumption activities, and investment allocation among regions by distinguishing domestic ownership and foreign ownership firms. This chapter models a NASP that permits to reduce the security barriers at the Canada-U.S. border conditional on the fact that Canada harmonizes its security measures with respect to the ROW at the levels imposed by the United States.

Chapter 1

A Population Aging Analysis for Canada Using the National Transfer Accounts Approach

1. Introduction

Canada's population is currently aging at an accelerated rate. The median age in Canada has changed from 26.2 years in 1971 to 39.5 years in 2009.[1] The number of elderly (i.e. population 65 years or older) has increased at the fastest rate among all the age groups. Factors behind this change are: low fertility rates (i.e. average number of children per woman of child-bearing age), increased life expectancy (i.e. the expected number of years remaining at a given age), and the aging baby boomers (i.e. persons who were born between 1946 and 1964 during the baby boom period). A possible reason for the low fertility rate was the increased number of women who chose to enter the labour force rather than stay at home. Life expectancy at birth has increased from 59 years for males and 61 years for females in the 1920s to 79 years for males and 83 years for females in 2009.[2]

The demographic projections suggest that the number of elderly in Canada will approximate 10 million in 2036, more than twice the number in 2011.[3] As shown in Figure 1.1, the proportion of elderly with respect to the total population will increase from 13.2% in 2011 to 24.5% in 2036. From 2036 to 2056, that proportion will slowly continue to rise to 27.2%. The support ratio (i.e. the number in working age over the number of seniors) will drop from approximately 4 to 1 in 2013 to about 2 to 1 in 2061.[4]

This rapid change in the age composition of the population has led researchers to investigate the potential impact of this demographic change on the economy. While most studies have used macro variables observed in the System of National Accounts (SNA) to evaluate this impact, a major issue is that the SNA includes limited information on age. A series of studies by Lee and Mason (e.g. Lee, 1980, 1994a, 1994b; Mason, 1977, 1987,

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[1] Data source is from Statistics Canada, estimates of population, by age.
[2] Data source is from Statistics Canada, CANSIM, Table 102-0512.
[3] The number of population projection is from United Nations Commission for Social Development for the 5th Anniversary of the 2002 United Nations Second World Assembly on Aging.
[4] The working age is from 20 to 64 years old.

1988; Lee and Mason, 2011, 2013), which will be reviewed in Section 2, has introduced a new way of measuring flow and stocks in an economy that takes age into consideration, while still consistent with the SNA data. This method is called National Transfer Accounts (NTA). The main objective of this paper is to build a NTA database for Canada in order to improve the quality of the research related to the impact of population aging in Canada.

The fundamental interest of NTA is the shape of economic lifecycles. Studies suggest that young and old persons have lifecycle deficits (LCD) because they consume more than they produce; however, working age individuals produce more than they consume to generate a lifecycle surplus (LCS). Economic and social factors drive the shape of economic lifecycles, for example wages, historical work experience, culture, and politics affect labour income. Consumers' preferences, market prices, interest rates, and political systems affect consumption. Following the NTA methodology, we first need to build the per capita LCD or LCS from labour income and consumption spending profiles using diverse household surveys. The second step is to ensure, using a macro-control procedure, that these profiles at the aggregate are consistent with the SNA. A final step of the NTA methodology is the financing of the aggregate LCD, which is basically done through transfers and asset-based reallocation. This financing step is discussed in Appendix 1 (Section A 1.1) but is not the principle objective of this paper.

The specific objectives of this paper are, therefore: first, to develop a data set for Canada that permits an evaluation of the lifecycle patterns for labour income and consumption for each age group; second, to measure the aggregate economic lifecycle for the Canadian economy for the year 2006; third, to estimate the evolution of the aggregate LCD between 2006 and 2056 on the basis of demographic projections.

This paper shows that the aggregate LCD of Canada in 2006 equals 9% of total labour income. The aggregate LCD is projected to increase from $100 billion to $300 billion between 2006 and 2056. Two thirds of the increase in the aggregate LCD comes from changes in the age composition of the population, and one third is from the increase in the total population. To maintain the aggregate LCD to its 2006 level, the average growth rate of aggregate labour income would need to increase annually from 0.23% in the benchmark projection to 0.65%. It means that the average growth rate of labour income needs to be about three times larger than in the "business as usual" or benchmark scenario. Alternatively, the average annual growth rate of aggregate public consumption would need to decline from 0.59% in the benchmark projection to 0.21%. Reducing public consumption means that the government needs to cut spending on public programs or other government expenditures. A 0.38% percentage point (from 0.59% to 0.21%) reduction in the growth rate of public consumption on average for the next five decades would be a real challenge, especially because there will be larger spending on public health care and pension programs due to an aging population. As these two components will represent a higher proportion of total public consumption, this will require an even further reduction on other components of government spending.

The rest of paper is constructed as follows. Section 2 gives a review of selected papers that provide the foundation of NTA. In Section 3, we build a Canadian database that will allow a study of the lifecycle patterns of consumption and labour income (and their components) for individuals of all ages for the year 2006. Section 4 provides the results for Canada and compares these with the results obtained from other countries. Section 5 projects the aggregate LCD based on demographic projections from 2006 to 2056. Section 6 states the conclusions of this study.

2. Review of Selected Literature on NTA

The idea that an older population in Canada would affect the economy is straightforward. Individuals' economic behaviour, such as schooling, childbearing, working, retiring, saving and consuming, varies through life. With the age structure changing, the proportions of those individuals who are in school, in the labour market, or in retirement are also changing. One of the effects of population aging is a heavier burden on the working-age generations. The government also is facing additional budgetary pressure, mainly from health care and public pension programs. However, an older population also brings some positive effects. For example, an aging population carries more wealth into the economy because middle age people save. This increases the productivity of labour, thanks to a higher capital per worker (Lee and Mason, 2013).

The expected change in the population structure is a general problem for most OECD countries and their governments are searching for accurate solutions such as pushing back the age of retirement, encouraging couples to have more children, attracting more immigrants, and investing in human capital to eventually increase the productivity of labour (Lee and Mason, 2013).

Although some of these policies may favour certain generations at the expense of others, it remains a difficult task for economic models to assess these effects properly because these models are calibrated to data from the SNA for which the age dimension is absent. Hence, heroic assumptions have to be made to generate income and consumption age profiles. Of course, these assumptions affect the simulation results which limit their validity. To mitigate these problems, NTA has been designed so as to build a database consistent with the SNA, but including age.

Historically, NTA has developed from a large range of studies on the lifecycle of the individual. Samuelson (1958) introduced the lifecycle concept into an overlapping generation model so as to be able to emphasize transfers among generations. Studies by Arthur and McNicoll (1978) and Lee (1980) combined more precise demographic data into the overlapping generations model, and more precise age profiles of labour income and consumption. Mason (1987, 1988) applied Lee's approach (1980) to study aggregate savings, while Willis (1988) studied public and private transfers and wealth. Willis (1988) derived the identities of the age accounting system, hence providing the foundation of NTA, while Lee (1994a, 1994b) extended Willis' research.[5]

Auerbach et al. (1991) investigated intergenerational income reallocation in the public sector through generational accounts, which are used to assess the fiscal issues (relevant with government policies) for current and future generations. Therefore, generational accounts only capture the intergenerational reallocation in the public sector. It does not capture private (i.e. familial) transfer. Thereafter, several researchers made efforts to develop a generational accounting system from theoretical to empirical studies, and from the public sector to the private sector, such as Lee (1994a, 1994b), Lee and Tuljapukar (1998), and Mason and Miller (1998). For example, Lee and Tuljapurkar (1998) applied taxes and benefit age profiles on the U.S. social security system. Mason and Miller (1998) expanded the generational accounting system on the savings and capital accumulation with demographic projections, while addressing the significance of familial and public transfer for young and old generations. Lee (1980) and Mason (1977) provide useful empirical results on the impact of the population aging on the pattern of consumption and labour income. A guide to NTA (Lee and Mason, 2013) which emphasizes the practical steps required to build the NTA has recently been published.

These theoretical and empirical studies are the foundation of the NTA framework for the United States. In 2002, NTA turned into an international project, including, in addition to the U.S., Taiwan, Japan, Indonesia, Brazil, Chile and France. At the time of

[5] Other researchers (Kotlikoff and Summers, 1988) have also contributed to the modeling of the age related social and economic issues.

writing, there are 41 countries included in the NTA network.[6] Lee and Mason (2011) present an NTA state-of-art methodology through contributions emphasizing different aspects such as fundamental principles and concepts, and including several county studies. Canada was not included in this text as it was written before the entrance of Canada into the NTA project.

3. Building an NTA for Canada

This section describes the procedure to construct per capita age profiles for consumption and labour income, and their components. To ensure international comparability, the NTA guide (Lee and Mason, 2013) proposes specific procedures and alternatives when data problems are present. Here, we adapted the methodologies to fit Canada's data availability.

The main NTA identity is given by an equation where "inflow" or "resources" equals "outflow" or "uses" for an individual of age a, as follows:

$$\underbrace{Y_L(a) + Y_A(a) + Tr_I(a)}_{\text{Inflow}} = \underbrace{C(a) + S(a) + Tr_O(a)}_{\text{Outflow}},^{7} \tag{1}$$

in which the inflow includes labour income, $Y_L(a)$; asset income, $Y_A(a)$ (i.e. returns to capital, land and credit); and transfer inflow, $Tr_I(a)$.[8] The outflow includes consumption, $C(a)$; saving, $S(a)$ which is equal to investment in capital, land and credit; and transfer outflow, $Tr_O(a)$. Note that this identity is assumed to hold at the individual level, not at the household level. The transfer inflow and outflow exist in both private and public sectors so that Eq. (1) can be rearranged as follows:

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[6] These 41 countries are Australia, Cambodia, China, India, Indonesia, Japan, Philippines, Republic of Korea, Taiwan, Thailand, Vietnam in Asia-Pacific; Argentina, Brazil, Canada, Chile, Colombia, Costa Rica, El Salvador, Jamaica, Mexico, Peru, United States, Uruguay in the Americas; Austria, Finland, France, Germany, Hungary, Italy, Poland, Slovenia, Spain, Sweden, Turkey, United Kingdom in Europe; Benin, Kenya, Mozambique, Nigeria, Senegal, South Africa in Africa.

[7] The Eq. (1) holds at any time t.

[8] The asset income in the private sector includes imputed rent, operating surplus, capital share of mixed income, and property income. In the public sector it includes capital, other non-financial assets (e.g. land and minerals), and credit (e.g. public debt and student loans) (Lee and Mason, 2013).

$$\underbrace{C(a) - Y_L(a)}_{\substack{\text{Lifecycle} \\ \text{Deficit}}} = \underbrace{\underbrace{Y_A(a) - S(a)}_{\substack{\text{Asset-based} \\ \text{Reallocation}}} + \underbrace{\underbrace{[Tr_I(a) - Tr_O(a)]_{\text{pri}}}_{\text{Net Private Transfer}} + \underbrace{[Tr_I(a) - Tr_O(a)]_{\text{pub}}}_{\text{Net Public Transfer}}}_{\text{Net Transfer}}}_{\text{Age Reallocation}}, \tag{2}$$

which holds at the individual level. The left-hand side of Eq. (2) is defined as the per capita LCD. The right-hand side terms represent ways to finance the LCD by asset-based reallocation (first term), or by private and public transfers (second and third terms). In the public sector, the age reallocation is driven by local, regional, and central governments through public programs, such as education, social security, pensions, health care, and national defence, and taxes. In the private sector, the age reallocation is mediated by markets, households, families, voluntary agreements, social traditions, and other behaviour patterns, such as savings, borrowing, or dissaving.

This identity also holds if we multiply each component with the number of population in each age group, as in the following equations:

$$Y_L(a)^{Agg} + Y_A(a)^{Agg} + Tr_I(a)^{Agg} = C(a)^{Agg} + S(a)^{Agg} + Tr_O(a)^{Agg}, \tag{3}$$

where $Y_L(a)^{Agg} = Y_L(a).Pop(a)$; $\quad Y_A(a)^{Agg} = Y_A(a).Pop(a)$;
$C(a)^{Agg} = C(a).Pop(a)$; $\quad S(a)^{Agg} = S(a).Pop(a)$;
$Tr_I(a)^{Agg} = Tr_I(a).Pop(a)$; $\quad Tr_O(a)^{Agg} = Tr_O(a).Pop(a)$.

By summing each component in Eq. (3) across all age groups, this identity holds at the aggregate level:

$$\begin{aligned} &\textstyle\sum_a Y_L(a).Pop(a) + \sum_a Y_A(a).Pop(a) + \sum_a Tr_I(a).Pop(a) \\ &= \textstyle\sum_a C(a).Pop(a) + \sum_a S(a).Pop(a) + \sum_a Tr_O(a).Pop(a). \end{aligned} \tag{4}$$

In short, it is written as:

$$Y_L + Y_A + Tr_I = C + S + Tr_O, \tag{5}$$

where C is aggregate consumption, S is national saving, Y_L is aggregate labour income, Y_A is aggregate asset income, Tr_I is aggregate transfer inflow, and Tr_O is aggregate transfer outflow. Aggregate national saving S is equal to, I_K, the investment in capita, land, and credit. The objective of Section 3 is to build the per capita consumption age profile, $C(a)$, and the per capita labour income age profile, $Y_L(a)$.

3.1. Data and Methodologies of Constructing Consumption per Capita Age Profiles

According to NTA categorisation, consumption includes private and public consumption with three components: education, health care, and other consumption. NTA age profiles of consumption and production must refer to individuals, not to households, but most expenditure surveys are conducted under household categories. This section shows how to allocate consumption expenditures from households to individuals.

3.1.1. Private Consumption Profile

The data used to construct private consumption is extracted from the Survey of Household Spending (SHS) for 2006 which includes household and personal files. The household files include information at the household level, such as household spending on education and health care. The personal files include information at the personal level (i.e. members composing the household), such as the household members' age and employment status. From these two resources, information on an individual's age (single year) and household consumption on goods and services has to be combined so as to allocate expenditures to each family member within the household.

3.1.1. A. Private Education Consumption

From the household files in SHS, "total expenditure on education" measures private consumption on education. To allocate the private expenditure from households to family members, school attendance rate by age must be estimated using the information on enrolment rates (i.e. full/part time student for the reference year) which is available in the Survey of Labour Income Dynamics (SLID).[9] To estimate enrolment rates as a percentage or a probability (%), a dummy variable is defined. This variable is equal to

[9] In SLID, if the individual is a full-time student, this variable is equal to one; if the individual is a part-time student, the variable in SLID is equal to two; if the individual has a mixed status of full-time and part-time student, the variable is equal to three.

one if the individual is full-time student, part-time student, or a mixture of both, and is equal to zero otherwise. In SLID, the respondents for school status are individuals aged from 16 to 69. We assume that individuals between age 0 and 5 are not attending school, and the individuals between age 6 and 16 have enrolment rates of 99%.[10,11]

In the next step we apply estimated enrolment rates on household education consumption to family members. There are many ways to estimate the individual profile of private education expenditure by a single year of age. Appendix 2 describes alternative methods that have been proposed depending on the types of data available. The main challenge is to combine SLID and SHS information. In household j, for example, there are different members $i \in [1, n]$. Let us denote total education expenditure for household j as CFE_j. We need to allocate this amount across members i within household j. From SLID as shown above, we calculate the enrolment rate for each age, $ENR(a)$, where $a \in [0,90]$ represents age groups. For household j, the education expenditure for a member i of household j is a share of CFE_j where the share is given as the ratio of i's ENR over the sum of all i included in j, as follows:

$$CFE_{ij}(a) = \frac{ENR_i(a)}{(\sum_i ENR_i(a))_j} . CFE_j. \tag{6}$$

For example, assume that the education expenditure is $4,000 in household j, which is made up of four members with ages 10, 20, 45, and 50. Given Figure 1.2, the ENR for those ages are 0.99, 0.6, 0.1, and 0.05, respectively, so that the summation is 1.74. The first individual's education expenditure then is simply given as $CFE_j(10) = \frac{0.99}{1.74} . \$4{,}000.$

The results obtained when all households j of the survey are taken into account are shown in Figure 1.3. Note that the path derived in Section 3 can be viewed as a "per capita" path (and not the aggregate level of spending for each age group) because

[10] The reference for this assumption is borrowed from a Statistic Canada study by Hicks (1997).
[11] The enrolment rates for individuals older than 69 are assumed to be zero. Estimated enrolment rates are given in Figure 1.2. The school enrolment rates drop dramatically around age 24, and are below 20% after age 30.

equations such as Eq. (6) capture the share of spending per family member in the household.

Section 4 will illustrate how to construct aggregate age profiles that show the level of spending per age group given the population size of each age group from per capita age profiles. In 2006, per capita private education expenditure increases largely around age 18, and reaches a maximum at age 21. Private education consumption drops dramatically around age 23. After age 28, per capita private education consumption falls below $500 in 2006.

3.1.1. B. Private Health Care Consumption

Three elements finance the Canadian health care system: private out-of-pocket expense (15% of total health care expenditure), private insurance and other programs in the private sector (15.2% of total health care expenditure), and public programs (69.1% of total health care expenditure) (see Figure 1.4).

The variable selected in the household survey to estimate the age profile of private consumption on health care is “total expenditure on health care” from SHS. To allocate private health care expenditure of a household to individual members, we need to estimate the health care utilization rates. The data used is from the Canadian Community Health Survey (CCHS, 2005). The first variable needed is the number of consultations with medical doctors;[12] the second variable is the number of nights spent as patients in hospitals, nursing homes or convalescent homes. Then the sum of the number of consultations with medical doctors and the number of nights spent as a hospitalized patient in the past 12 months gives the measure of health care utilization per age group, $HUR(a)$.

The estimated results of health care utilization rates are reported in Figure 1.5. The

[12] Medical doctors include family doctors or general practitioners, and other medical doctors but not eye specialists.

rates increase from youth (i.e. age 10) to elderly. The slope of the health care utilization curve is slightly flatter for those aged between 27 and 60. The utilisation rate doubles from 6 to 12 units of health care usage after age 60, reflecting a higher demand for health care services in the elderly.[13] The health care utilisation shows a downward slope from age 0 to 11. This is because new born babies in Canada are required to visit doctors on a more frequent regular basis for vaccines or other medical checks. This frequency is reduced gradually as children grow older.

There are multiple ways to estimate the age profile of private health care consumption as reviewed in Appendix 2. Here we use a simple regression method with a linear equation.[14] Household health care expenditure, CFH_j, is regressed on the number of household members in each year of age, $P_j(a)$, multiplied by their corresponding health care utilisation rates, $HUR(a)$:

$$CFH_j = \sum_a \beta(a).HUR(a).P_j(a) + \varepsilon_j, \tag{7}$$

where $\beta(a)$ is the share parameter per age group to be estimated, and ε_j is the error term. The result of per capita private health care consumption per age is shown in Figure 1.6. The main trend of the profile shows an increase with age. It increases from \$274 at age 0 to \$939 at age 12, and rises again to \$1,436 at age 86. Private health care consumption for younger children is low in Canada because most of the cost is covered by public plans (as will be seen in Section 3.1.2).

3.1.1. C. Other Private Consumption

There are three main categories under "other consumption": alcohol, tobacco, and others. Alcohol and tobacco are consumed mainly by young and middle-age males, so that the tobacco and alcohol tax, which is part of indirect taxation, is allocated

[13] The unit of health care utilization is the number of visits to doctors, or the number of nights spent at health care institutions.
[14] The other simple regression method on non-linear equation is described in Appendix 2 (Section A 2.2).

accordingly. A simple regression method is used to allocate alcohol and tobacco consumption:

$$CFALC_j = \sum_a \beta_{alc}(a).P_j(a) + \varepsilon_j\,; \tag{8}$$

$$CFTOB_j = \sum_a \beta_{tob}(a).P_j(a) + \varepsilon_j, \tag{9}$$

where, $CFALC_j$ represents private alcohol consumption, and $CFTOB_j$ represents private tobacco consumption of household j, and, as before, $P_j(a)$ is the number of household members in each age year. The share parameters per age group, β_{alc} and $\beta_{tob}(a)$, must be estimated.

The equivalence scale method is used to allocate the rest of other private consumption.[15] Other private consumption of household member i is assumed proportional to an equivalence scale that is equal to 1 for adults aged between 20 and above. It declines linearly from age 20 to 0.4 for age 4, and is constant at 0.4 for those aged 4 and younger. The formula for this method is thus:

$$\begin{cases} 1 & if\ a \geq 20\,; \\ \alpha(a) = 1 - 0.6 * \frac{20-a}{20-4} & if\ 4 \leq\ a \leq 20; \\ 0.4 & if\ a \leq 4. \end{cases} \tag{10}$$

The path of the equivalence scale $\alpha(a)$ is shown in Figure 1.7. This scale is then used to allocate private health care consumption to member i in household j as follows:

$$CFX_{ij} = CFX_j.\frac{\alpha(a)}{\sum_a \alpha(a).P_j(a)}. \tag{11}$$

Figure 1.8 illustrates the level of other private consumption by age group for 2006. The age profile is higher for middle age groups.

3.1.1 D. Total Private Consumption

Total per capita private consumption per age group is defined as the sum of private education consumption, private health care consumption, and other private consumption:

[15] See NTA manual book (Lee and Mason, 2013).

$$TCFC(a) = CFEC(a) + CFHC(a) + CFXC(a), \quad (12)$$

where $TCFC(a)$ is the private consumptions of $C(a)$ in Eq. (1).

3.1.2. Public Consumption Profile

As in private consumption, public consumption also consists of three parts: education, health care, and other consumption. Public consumption allocation is based on administration data. In Canada, there is no administration data about public health care and education consumption by single year of age. Thus, we need to allocate an aggregate level of public consumption using other techniques.

3.1.2. A. Public Education Consumption

Public education consumption refers to the government spending on primary, secondary and post-secondary education levels. Note that formal education is measured on a per student basis.

Public formal education consumption by age, $CGEC^f(a)$, is estimated by summing the unit cost per student per level, c_l (where l is the education level: primary (age 6-11), secondary (age 12-16), post-secondary (age 17 and older)) to the number of students by age in each level, $cgec^f(a)$:

$$CGEC^f(a) = \sum_l cgec^f(a).c_l. \quad (13)$$

The unit cost per level, c_l, is estimated by dividing public education consumption at level l by the estimated number of students at that level.[16] The estimated number of students by age, $cgec^f(a)$, is given by:

$$cgec^f(a) = ENR\ (a) * pop(a), \quad (14)$$

where $pop(a)$ is the size of population by age. The results for public education consumption per age group are shown in Figure 1.9 for year 2006.

[16] We use public education consumption from OECD source (dataset: Expenditure by Funding Source and Transaction Type, 2006) so that the unit cost of education with each level is constant by age.

3.1.2. B. Public Health Care Consumption

Public health care consumption includes health care cost paid by individuals and reimbursed through public programs, direct spending on health care personal services offered by government health care institutions and hospitals, and collective services (e.g. health care, education and prevention programs) provided to the public (Lee and Mason, 2013).

Public health care consumption by age, $CGHC(a)$, is estimated by summing over h (i.e. provincial and local governments) of the unit cost per patient, $c_h(a)$, multiplied by the number of patients by age, $cghc(a)$:

$$CGHC(a) = \sum_h cghc(a).c_h\,(a), \tag{15}$$

where h is the levels of governments (e.g. provincial and local governments) where the administrative data of health care expenditure is collected.

Since the data on public health care consumption are available only by large age groups, public health care spending needs to be reallocated per single year of age. One way to solve this problem is to apply the individual age profile of health care utilisation rates from household survey. The estimated age profile of health care utilisation rate has been illustrated in private health care expenditure section (Figure 1.5). Given the health care utilisation rate, and the government health care expenditure by age group, the per capita public health care spending can be estimated. For example, public health care consumption for the age group 20 to 24 is $3,312 million. We apply health care utilisation rate by age as given in Figure 1.5, which are 3.44, 3.31, 3.49, 4.31 and 3.74, respectively. Thus, the aggregate amount of public health care consumption to be allocated to age 20 is $623 million (i.e. $\$3{,}312 * \left[\frac{3.44}{3.44+3.31+3.49+4.31+3.74}\right] = \$623$). Then, the per capita public health care consumption for age 20 ($1,399) can be computed as dividing $623 million with the population for age 20 (i.e. 445,200). The per capita public health care consumption for other ages can be done by the similar steps.

Per capita profiles of public health care consumption are shown in Figure 1.10. Observe that the public consumption on health care is larger for babies than for older children, which was not seen in private consumption. This suggests that the cost of health care for babies is mostly covered by government plans.

3.1.2. C. Other Public Consumption

Other public consumption includes national defence, justice and police. It is equally allocated to all members of the population:

$$CGXC(a) = \sum_a pop(a).c, \tag{16}$$

where c is the average of "other public consumption" per capita, and $pop(a)$ is the population in age a. Public expenditure is computed as the residual of public education and health care expenditure from total provincial and territorial government expenditure. The value of c is then captured as this residual divided by the total Canadian population. The value of c is given in Figure 1.11, at $3,893.

3.1.2. D. Total Public Consumption

Total public consumption per age group is defined as the sum of public education consumption, public health care consumption, and other public consumption:

$$TCGC(a) = CGEC(a) + CGHC(a) + CGXC(a), \tag{17}$$

where $TCGC(a)$ is the public consumption of $C(a)$ in Eq. (1). Thus, $C(a) = TCFC(a) + TCGC(a)$, where $TCFC(a)$ was given in Eq. (12).

3.1.3. Per Capita Profiles Smoothing

The per capita age profiles are noisy partly because the number of observations for some age groups in the household survey is small. The noise is from sampling variation, random variation, and other sources of errors. To solve this issue, the components of per capita profiles must be smoothed so as to reduce the sample variance without weakening the real data, such as larger health care spending for individuals over 65 and for newborns (Lee and Mason, 2013).[17] In order to preserve the age pattern discontinuities in private and public education with individuals entering and leaving school at specific ages, the age profiles for education spending are not smoothed. Smoothing is done at the disaggregate levels. For instance, private and public health care expenditure should be smoothed separately, while the sum of private and public health care expenditure should not be smoothed. Similarly, the elements in consumption or labour income should be smoothed, but the lifecycle deficit should not be smoothed. Figure 1.12 provides an example of a smoothed age profile for per capita private and public health care consumption.[18]

3.1.4 Labour Income per Capita Age Profile

The second component underlying the LCD concept of the NTA is labour income per age group, that is, $Y_L(a)$ in Eq. (1). Labour income in the NTA refers to workers' compensation as a return for working. Labour income also includes the labour share of self-employed income. Two-thirds of the operating surplus of entrepreneurial income is assumed to be labour income, and the remaining part, capital income.

The data used to compute per capita labour income is directly taken from SLID (2006). In SLID, wages and salaries are defined as "employment income before tax deductions".[19] Self-employment income is defined as "self-employment net income, including both farm and non-farm net income". Worker's compensation (fringe) benefits are defined as such in SLID. SLID covers individuals of age 16 or older. The results of per capita profiles of labour income and its components (wages, self-employment, and

[17] NTA user guide recommends not to smooth per capita education consumption.
[18] Friedman's SuperSmoother method is applied to smooth the sample-weighted per capita profile, incorporating the number of observations as weights.
[19] Here "before deduction" means before direct labour income tax deduction. Thus, we will need to have indirect tax adjustment, which is discussed in Appendix 3.

fridge benefits) are shown in Figure 1.13. As explained, individuals between age 23 and 56 are the high labour income earners with an income above $30,000.

3.2. Macro Control Procedure

The purpose of the macro control procedure is to ensure that the areas under the per capita age profile paths derived above, once properly weighted by the population size for each age group, are equal to their corresponding values given in the SNA (i.e. the "macro controls"). The area under the per capita age profile multiplied by the population size at each age is given by:

$$\sum_a AP_{unadj}(a).Pop(a), \tag{18}$$

where $AP_{unadj}(a)$ are the per capita age profile paths previously derived. If this area is not equal to its equivalent value in the SNA (its macro control level), then $AP_{unadj}(a)$ must be adjusted according to a scale parameter, θ:

$$\theta = \sum_a AP_{unadj}(a).Pop(a) / Macro\ Level. \tag{19}$$

Using this scale parameter, the adjusted per capita and aggregate profiles are eventually given by:

$$AP_{adj}(a) = AP_{unadj}(a)/\theta, \tag{20}$$

with guarantees, using Eq. (19), that:

$$MacroLevel = \sum_a AP_{adj}(a)Pop(a). \tag{21}$$

Therefore, this procedure ensures that the area under the population-weighted adjusted age profiles is equal to its corresponding levels observed in the SNA. The values of these variables are given in Table 1.1. The rest of the section gives the data source for these variables. These levels will be named macro control levels or simply, macro controls.

Table 1.1: Macro Control Levels, Million CAD, Canada, 2006

Definition	Abbreviations	Macro Control Levels
Private Consumption, Education	CFE	9,179
Private Consumption, Health Care	CFH	29,706
Private Consumption, Other	CFX	668,266
Private Consumption, Total	CF	707,151
Public Consumption, Education	CGE	67,632
Public Consumption, Health Care	CGH	83,271
Public Consumption, Other	CGX	126,705
Public Consumption, Total	CG	277,608
Labor Earnings	YLE	664,208
Fringe Benefits	YLF	93,880
Self-Employment	YLS	52,791
Labor Income	YL	810,879

Source: OECD website

3.2.1. Consumption Macro Control

The macro control values for consumption spending are based on "final uses in GDP" in the SNA. After adjustment under the NTA, the total NTA consumption refers to the national account concepts of "final consumption expenditure", "general government final consumption expenditure", "household final consumption expenditure" and "NPISHs' final consumption expenditure."[20] The macro controls for private consumption of health care and education are obtained from the classification of private consumption by categories. The residual part of private consumption goes as macro control for the NTA variable "other". Likewise, the macro control for public consumption of health care, education and other public consumption is matched to the classification of public consumption by categories.

The values of consumption taken from the SNA include indirect taxes on consumption (e.g. taxes on retail sales). In the NTA, consumption must represent the amount before consumption taxes. Thus, the estimation of taxes on products should be deducted from the amount reported in household surveys. The details of allocation of taxes, including the tax reallocation on labour income, are listed in Appendix 3.

[20] NPISH represents non-profit institutions serving households.

3.2.2. Labour Income Macro Control

Macro control for labour income is estimated from the SNA and includes compensation of employees, labour's share of mixed income (i.e. self-employment income, including capital and labour shares), and labour's share of taxes on net production and on imports less business subsidies. Labour's share of mixed income is estimated to be equal to two-thirds of the household mixed income (the remaining part is capital income).

Taxes on production include taxes on products payable on producing, delivering, selling or transferring good and services, and taxes on owning or using land, buildings or other assets used in production and labour. In the SLID, wages and salaries, labour share of self-employment income, and workers' compensation benefits are given before deduction of direct tax. Thus, we do not need to adjust direct labour income tax. To obtain the final (adjusted) labour income per capita profile in the NTA, we add the part of indirect taxes that belongs to labour income. Again, the details of tax adjustment on labour income are listed in Table 1.8 in Appendix 3.

4. Per Capita and Aggregate LCD and Countries Comparison

Section 4 constructs the population weighted per capita age profile for the LCD (or LCS) based on the per capita age profiles for consumption and labour income in Section 3. Then we construct the aggregate LCD. This section also compares Canada's results with those of some selected countries.

4.1. Per Capita and Aggregate LCD for 2006

Smoothed consumption, labour income, and the LCD per capita age profiles are shown in Figures 1.14 and 1.15 for year 2006. Figure 1.14 shows that young age groups from age 0 to 25 and the older age groups with age 60 and older consume more than they produce, while the middle age groups (ages 26 to 59) produce more than they consume.

Figure 1.15 reports the per capita LCD, which is defined as the difference between consumption and labour income at each age group. We can also compute an aggregate LCD by multiplying the per capita LCD by the population size per age group, that is:

$$LCD^{Agg}(a) = LCD^{per\ capita}(a).Pop(a). \qquad (22)$$

Figure 1.16 illustrates the aggregate LCD for Canada and reveals that the turning points are at age 26, when the productive period starts (i.e. when labour income exceeds consumption), and at age 59, when labour income falls below consumption. Thus, the Canadian lifecycle has a period of surplus of 35 years. Such a short productive period may be attributed to long periods spent in education, early retirement provision, and high unemployment for age 50 and older (Lee and Mason, 2011, Chapter 16). Studies by Mason et al. (2006) and Lee (1994b) show that if an economy were in golden rule steady state, the overall aggregate LCD would be zero, that is:

$$\sum_a LCD^{Agg}(a) = 0. \qquad (23)$$

The proof of this statement is provided in Appendix 1 (Section A 1.2). From Figure 1.16, the aggregate LCD for age $a \in [0,25]$ is equal to 23% of total labour income (of $810 billion), and the aggregate LCD for $a \in [60,90]$ equals 16% of total labour income in 2006. Summing both young and old LCD covers 39% of total labour income. However, the aggregate LCS for age 26 and 59 is just 30% of total labour income. The net aggregate LCD for Canada is therefore 9% of total labour income (i.e., about $72.9 billion) which suggests that Canada's economy was not at its "golden rule" steady state in 2006.

4.2. Comparison with Other Countries

This section compares Canada's per capita results with those of some other countries, such as Japan, Taiwan, France, Sweden and United States. To facilitate comparison, all profiles given in Figure 1.17 are normalised (i.e., level values have been divided by the average of per capita labour income for ages 39 to 49). Figure 1.17 illustrates that per capita labour income profiles are relatively similar across the countries till age 40, after which some disparities become apparent.[21] Labour income per capita is higher in Japan than in other countries for age 40 to 57 while it is lower in Taiwan for age 47 to 60. Per capita labour income in Canada starts to decline earlier than in the U.S., Sweden, and Japan, but later than in Taiwan and France.

Table 1.2 reports the peak age for per capita labour income, and the share of labour income for those under 25 and those above 65 across countries. The peak age in Canada (52 years old) is similar to most other selected countries with the exception of Taiwan. The share of labour income per capita for those under age 25 over the labour income per capita for all the age groups is 7.8%, a slightly higher share in Canada than in the other countries. The share of labour income per capita for those above age 65 is lower in Canada (2.9%) than in other selected countries except France (1.2%).

Table 1.2: A Summary of per Capita Labour Income of Selected Countries

	U.S. (2003)	**Canada (2006)**	**Sweden (2003)**	**France (2001)**	**Japan (2004)**	**Taiwan (2003)**
Peak Age	47	52	49	49	48	41
Share under age 25 (%)	6.0	7.8	7.1	7.0	5.7	6.9
Share above age 65 (%)	7.8	2.9	9.6	1.2	5.7	4.2

The shape of per capita total (private and public) consumption age profiles for the selected countries is relatively similar but there still exist important differences (Figure 1.18). To facilitate comparison of profiles, we again normalize with respect to the average per capita labour income for ages 30 to 49. Compared to the U.S., the consumption path in Canada is lower for most ages except for ages 21 to 36. The growth rate in the U.S. is higher than in Canada after age 40, and increases dramatically for age 80 and older. In France and Japan, the shapes of consumption are flatter than in other countries, and there

[21] Note that Canada's results are based on year 2006. Figure 1.16 indicates the corresponding years for other countries.

is no large increase at older ages. In Sweden, per capita consumption increases rapidly for the older ages.

In all countries, the children and elderly consume more than they produce, and hence generate a per capita LCD for these age ranges (see Figure 1.19). The younger population starts to produce more than they consume at age 23 in Taiwan, at age 26 in the U.S., at age 25 in Canada, and at age 23 in Japan, France and Sweden. Adults stop producing more than they consume at age 59 in the U.S. and France, at age 60 in Canada, at age 65 in Sweden, at age 62 in Japan, and at age 56 in Taiwan. Among these countries, the span of years with a LCS is 33 years in Taiwan and the U.S., 35 years in Canada, 36 years in France, 38 years in Japan, and 42 years in Sweden. Table 1.3 presents some of these statistics.

Table 1.3: Comparison of Economic Lifecycle of Selected Countries

	U.S. (2003)	Canada (2006)	Sweden (2003)	France (2001)	Japan (2004)	Taiwan (2003)
Cross age (LCD to LCS)	26	25	23	23	23	23
Cross age (LCS to LCD)	59	60	65	59	62	56
Span (years) of LCS	33	35	42	36	38	33

4.3. Comparison of Consumption Age Profile of Canada and the U.S.

Figures 1.20 and 1.21 report per capita private and public consumption levels (and their components) for Canada (2006) and the United States (2003). Private education consumption for Canada is flatter but with a longer span than in the United States. Canada’s private health care consumption slightly increases from young to old. In the U.S., it shows a greater magnitude with a peak around age 60, and another increase around age 75.

For both countries, other private consumption takes a larger share than private education and health care consumption. Public education in Canada is proportionally larger than in the United States. Public health care expenditure in Canada increases dramatically around age 80 but less so in the United States. Other public consumption is flat everywhere in both countries.

The ratios comparing Canadian and U.S. results are given in Tables 1.4 and 1.5. Table 1.4 indicates that total private consumption is 67.4% in Canada and 73% in the United States. The 6 percentage points difference is mostly due to private health care consumption. On the other hand, the total public consumption in Canada and the U.S. is 32.6% and 27%, respectively. Public education consumption in Canada is about 1 percentage point higher than in the U.S., while public health care consumption in Canada is about 4 percentage points higher. The share of other public consumption is essentially the same in both countries.

Table 1.4: A Summary of per Capita Consumption Profiles for Canada (2006) and the U.S. (2003)[22]

	Canada (2006) % of Total	U.S. (2003) % of Total
Consumption	100%	100%
Private Consumption	67.4	73.0
Education	0.7	1.2
Health Care	3.2	9.7
Others	63.4	62.1
Public Consumption	32.6	27.0
Education	5.7	4.3
Health Care	14.7	10.2
Others	12.3	12.6

Table 1.5 compares shares of private versus public health care and education spending for Canada and the United States. The share of private education consumption for the age group younger than 25 over the total (i.e. private and public) education consumption for all age groups is 15.5% in the U.S. and only 8.5% in Canada. The same ratio for public education consumption reaches 78.2% in Canada and 73.5% in the United

[22] U.S. results are available at NTA website: www.ntaccounts.org.

States.[23] The allocation of public education consumption in Canada is more concentrated towards the younger ages (i.e. those younger than 25) relative to the U.S., while it is the opposite for private education. The share of private health care consumption for the age group older than 65 years over the total (i.e. private and public) health care spending is 22.7% in the U.S. and 8.1% in Canada. Conversely, the proportion of public health care consumption for the elderly in Canada is 18 percentage points higher than in the U.S. with ratios equal to 57.2% for Canada and 39.4% for the United States. This reflects the fact that the Canadian health care system for the elderly is funded more proportionally by the public sector, while U.S. health care system for seniors is proportionally more financed by the private sector.

Table 1.5: Comparison of Private versus Public Shares of Health Care and Education Consumption for Canada (2006) and the U.S. (2003), by Percentage (%)

	Canada	**U.S.**
Private Education / Total Education for whole ages	8.5	15.5
Public Education/ Total Education for whole ages	78.2	73.5
Private Health Care/ Total Health Care for whole ages	8.1	22.7
Public Health Care/ Total Health Care for whole ages	57.2	39.4

5. Projection

Given the results obtained in Section 4, we are able to project the aggregate level of LCD using demographic projection and assuming no change in the individual's behaviour and economic status. Alternatively, we can study to what extent the public consumption and each of its components should be adjusted in order to avoid an increase in the aggregate LCD due to population aging Section 5.1 projects the aggregate LCD for the next five decades assuming a constant per capita LCD. Section 5.2 then discusses the economic adjustments needed to maintain the aggregate LCD at its level in 2006. Both sections are useful in investigating the economic pressure of a changing age structure in

[23] Note that the summation of private and public shares is not equal to one because we excluded the consumption of those older than 25 for education and those younger than 65 for health.

the long-term.

5.1. Projecting the Aggregate LCD: Keeping the per Capita LCD Constant

It might be useful to project the aggregate LCD into the future assuming a constant per capita LCD. Thus, in this section, we assume per capita age consumption (i.e. private and public consumption) and per capita age labour income profiles to remain at the 2006 level, that is, we assume no change in agents' behaviours and government policies. Recall that the difference between per capita and aggregate LCD is due to the population size per age group. Thus, when we impose per capita population projections for years 2007 to 2056 on the 2006 per capita LCD, we can project the evolution of the aggregate LCD over this period of time.

As shown in Section 4.1, the net aggregate LCD in Canada in 2006 was around $72.9 billion. Figure 1.22 shows that the aggregate LCD will continue growing from 2006 to 2056 due to the population projections. Of course, as the per capita LCD is assumed to remain constant at its 2006 level, no behavioural changes can push back the aggregate LCD to its 2006 level.

Figure 1.23 reports the annual growth rates of the aggregate LCD. Two factors drive these rates. The first comes from the increase in total population. As the aggregate LCD is positive in 2006, with constant per capita LCD patterns, the aggregate LCD increases naturally with the population. The second factor is aging, or more generally, the change in the age structure of the population. Once we control for the growth rate of the total population, we can compute the age structure impact on the annual growth rates of the aggregate LCD. It is simply the difference between the growth rate of the aggregate LCD and the growth rate of the population. Figure 1.23 shows that the pressure on the aggregate LCD growth occurs mostly between 2006 and 2026 and the principal factor behind the rapid rise of the aggregate LCD is the age factor, not the growth rate of the population. This is due to the fact that the working age population declines up to 2026, thus imposing downward pressure on aggregate labour income. In addition, as the number of the elderly increases in the total population, aggregate private and public spending on health care will increase also. We observe that the aggregate LCD increases rapidly from 2006 to reach a maximum annual (year-on-year) growth rate of 3.5% in 2026. From 2006 to 2026, the average annual (year-on-year) growth rate of aggregate LCD is 2.6%. Although the annual growth rates are lower after 2026, the level of the aggregate LCD will continue to increase. Such a profile over the next 50 years suggests that the aging of the population will constitute a real challenge for the Canadian economy.

The contribution of the overall growth rate of the population to the aggregate LCD is about 19% to 31% (i.e. the annual growth rate of population, 0.5% to 0.8% divided by the average annual growth rate of aggregate LCD, 2.6%). After 2026, the contribution of the population growth rate to the LCD converges to 0.5%. The impact of the age structure of the population is much more significant than the population growth itself, except for a short period of time between 2006 and 2008. The age structure factor reaches its maximum growth rate at 2.8% in 2026. The average contribution of the age factor on the annual growth rate of the aggregate LCD is 1.9% between 2006 and 2026. The age factor captures 73% of the overall growth impact of the aggregate LCD (2.6%).

From this analysis, we conclude that population projections bring a significant economic challenge for Canada, mainly because of the age structure factor, that is the aging population. The most challenging period will be between 2018 and 2038 when the aggregate LCD will increase at an average rate of 3% or more per annum, and population aging will account for roughly two-thirds of this increase.

5.2. Keeping the Aggregate LCD Constant: Needed Economic Adjustments

Several studies have tried to estimate the economic adjustment needed to address the aging issue. For example, Robson (2009) demonstrates that population aging will bring a huge pressure on Canada's current age-sensitive government programs such as health care, education, elderly and familial transfers. He considers that the Canadian government is poorly prepared for the challenge. His quantitative assessment suggests that the decreasing number of young people will reduce the cost on education and family programs far less than the expected increase in the cost of health care services. Pressures from aging will increase health care spending by $1.9 trillion while reduction on education will be only $67.6 billion between 2007 and 2057. Denton and Spencer (2006), using a simple approach, conclude that output per capita will decline by almost 10% between 2006 and 2036 under a constant labour productivity scenario.[24] Alternatively, to keep output per capita constant, the annual increase of labour productivity will have to be 0.41% higher for the period 2011 to 2016, 0.63% higher for the period 2016 to 2021, and 0.61% higher for years 2021 to 2026. In the spirit of Denton and Spencer, this section also tries to discover the needed economic adjustments.

To recap, Section 5.1 illustrates the growth in the aggregate LCD when we apply demographic projections up to 2056 to a per capita LCD, which is assumed to remain constant throughout. In Section 5.2, we try to determine how consumption and labour income would need to adjust so that the aggregate LCD would remain constant at its 2006 level.[25]

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[24] The simple approach in Denton and Spencer (2009) applied output per worker as the measure of productivity while assuming the average labour productivity being constant.

[25] It implies that the per capita LCD would decrease in this case.

Table 1.6: Average Growth Rate of Labour Income, Total Consumption, Public Consumption, and Its Components at the Aggregate Level from 2006 to 2056, by Percentage[26,27]

	YL	CON	CONG	CONGE	CONGH
Benchmark Average Growth Rate	0.23%	0.59%	0.75%	-0.01%	1.37%
Average Growth Rate (Adjusted)	0.65%	0.21%	-0.64%	2022 zero	2043 zero

Here, we examine by how much labour income needs to rise to keep the aggregate LCD constant at the 2006 level (scenario 1) and then we repeat the exercise for aggregate consumption (scenario 2). The results are reported in Table 1.6. The first row is the growth rate for each variable in the benchmark projection (i.e. when we keep the per capita LCD constant and apply the population projections as in Section 5.1). These rates are those underlying the paths in Figure 1.22. The second row is the necessary growth rate to keep the aggregate LCD constant ceteris paribus. For example, if the aggregate LCD must remain constant at its 2006 level, then the aggregate labour income needs to increase by an average annual growth rate (from 2006 to 2056) of 0.65% as compared to 0.23% in the benchmark.[28] Similarly, all else constant, the growth rate of the total aggregate consumption would need to be 0.21%, instead of 0.59% in the benchmark. The aggregate labour income needs to increase faster than consumption needs to decline because of the change in the age composition of the population. Indeed, the size of the elderly population increases, while the relative size of the working-age population declines. Consequently, the relative size of the labour force is declining and hence aggregate labour income must change by a larger percentage.

Finally if the aggregate LCD is assumed to remain constant as its 2006 level while the aggregate labour income and private consumption evolve according to their benchmark projections, then the adjustment must be borne by the aggregate public

[26] YL refers to the aggregate labour income; CON refers to the aggregate total consumption; CONG refers to the aggregate public consumption; CONGH refers to the aggregate public health care consumption; CONGE refers to the aggregate public education consumption.
[27] The average growth rate of the aggregate labour income is calculated as $(YL_{2056}/YL_{2006})^{1/50} = 1 +$average growth rate of $YL_{2006-2056}$.
[28] This result has the same magnitude as the paper by Denton and Spencer (2009).

consumption at a growth rate of -0.64% (instead of +0.75% as in the benchmark). If only the public health care consumption adjusts while education and other government consumption evolve accordingly to the benchmark projections, then the aggregate public expenditure on health care will reach zero by 2043. If only the public education adjusts, the public expenditure on education will reach zero by 2022.

Figures 1.24 and 1.25 report the evolution over time of the growth rate of the aggregate labour income and consumption necessary to keep the aggregate LCD at its 2006 level. To construct Figure 1.24, we keep the aggregate LCD at its 2006 level and apply the projected aggregate consumption from 2006 to 2056 from Section 5.1 (Figure 1.22). The aggregate labour income is thus estimated residually as the difference between the aggregate LCD and the aggregate consumption for each year. The growth rate of the estimated aggregate labour income is then calculated for each year and is represented in Figure 1.24, as well as its benchmark rate (computed from the profile in the level given in Figure 1.22.) The difference is also plotted in Figure 1.24. The growth rate of labour income in the benchmark projection is 0.89% in 2007 and reaches 0.09% in 2024. This ongoing decline suggests that the Canadian economy is already under pressure due to population aging, and that this pressure will intensify in the next 15 years. To keep the aggregate LCD constant as the 2006 level, the labour income growth rate would need to start at a much higher rate in 2007 and slowly decline up to 2056. The difference between counterfactual and benchmark growth rates shows an increasing gap that reaches a maximum in 2023. This illustrates again that the population aging pressure will be high for the next two decades. After 2024, the pressure of population aging slightly declines.

To keep the aggregate LCD constant, we could also maintain labour income at its benchmark level but adjust the consumption. Figure 1.25 shows that in the benchmark projection, the growth rate of consumption declines. However, to maintain the aggregate

LCD constant, the growth rate of total consumption must decline much faster in the counterfactual experiment. The growth rate between counterfactual and benchmark consumption becomes negative during the 2007-2029 period.

6. Conclusion

This paper builds a NTA database for Canada, in particular the per capita and aggregate LCD for year 2006. In the first step, our estimates are based on national representative household surveys, such as SHS, SLID, and CCHS. Household surveys allow us to derive age-specific consumption and labour income profiles. Then, in a second step, we reconcile these age specific profiles with the SNA through a macro-control procedure.

The per capita age profiles for Canada have key characteristics that are worth reemphasizing. The average private consumption of a youth (i.e. those aged 25 and younger) is $15,672, which tends to be lower than the consumption of a working-age adult ($25,579), or a senior ($20,570). The public sector usually spends more on children (i.e. education and health care) and seniors (i.e. health care) than on working-age persons. The average public consumptions for youth, working-age group, and seniors are $10,810, $6,500, and $13,182, respectively. The age profile of public consumption exhibits a hump shape for the young cohorts, and a rising profile for the old cohorts (i.e. those at age 65 and older), which reflects the large health care spending by seniors through public programs. Labour income exhibits a hump shape profile, rising from age 20, peaking at age 52, and then decreasing from age 53 to age 70 (indicating a gradual retirement process).

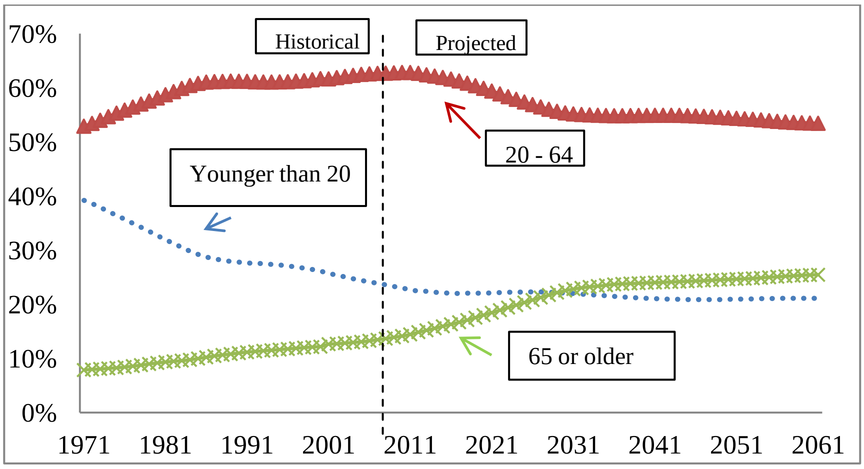
Per capita consumption and labour income profiles provided the basis for constructing the economic lifecycle for Canada in 2006. Compared with some selected countries, these per capita age profiles are broadly similar, but some key differences are notable. For instance, in Canada the labour income per capita reaches to 1% of its average labour income for ages 30-49 at age 70, but in the U.S. it reaches to 1% of its average labour income of the same age groups at age 77. This indicates that on average U.S. workers leave the job market later than the Canadian workers. Meanwhile, the consumption per capita profile in Canada, although rising for seniors, is flatter than the consumption profiles for United States.

By applying Canadian demographic data to a constant per capita LCD, we project an aggregate LCD of about $100 billion in 2006 but rising to $300 billion in 2056. Both population growth and population aging have an impact on these results, but most of it is due to population aging. With no adjustment in fertility rates, immigration policies, or other channels, the government budget would face serious challenges for health care, pension and other public programs. Finding ways to reduce the expected pressure on the aggregate LCD during the next five decades should be a priority for policy makers. By keeping constant the aggregate LCD at the 2006 level, we underline the needed economic adjustments. For example, the average growth rate of labour income needs to increase from 0.23% in the benchmark to 0.65%, and the average growth rate of aggregate consumption needs to decline from 0.59% in the benchmark to 0.21%. Ceteris paribus, the average growth rate of public consumption needs to decrease by 1.39% each year from 2006 to 2056. Other solutions (not studied here) could target increasing labour productivity; late retirement policy could also effectively extend the per capita LCS period, although it remains an open issue whether this would more than offset the loss of job opportunities for young workers. Immigration policy could be another channel that would extend the LCS period if Canada attracts more immigrants to the labour market.

Appendix for Chapter 1

Figures

Figure 1.1: Historical and Projected Percentage of Youth, Working Age Population and Seniors, Canada, 1971-2061



Source: Statistics Canada, Table 510001 - Estimates of population, by age group, and Table 520005 - Projected population by age group.

Figure 1.2: Enrolment Rates by Age Estimated from SLID, 2006

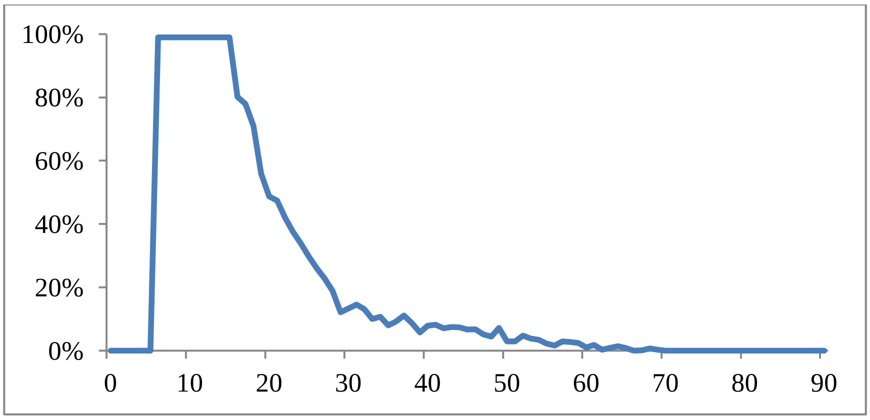


Figure 1.3: Private Education Consumption per Capita Age Profile, CAD $, SHS, 2006

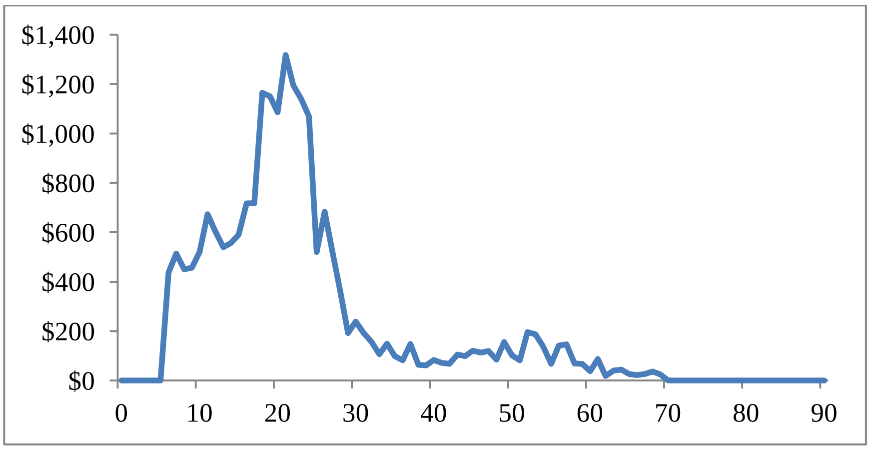
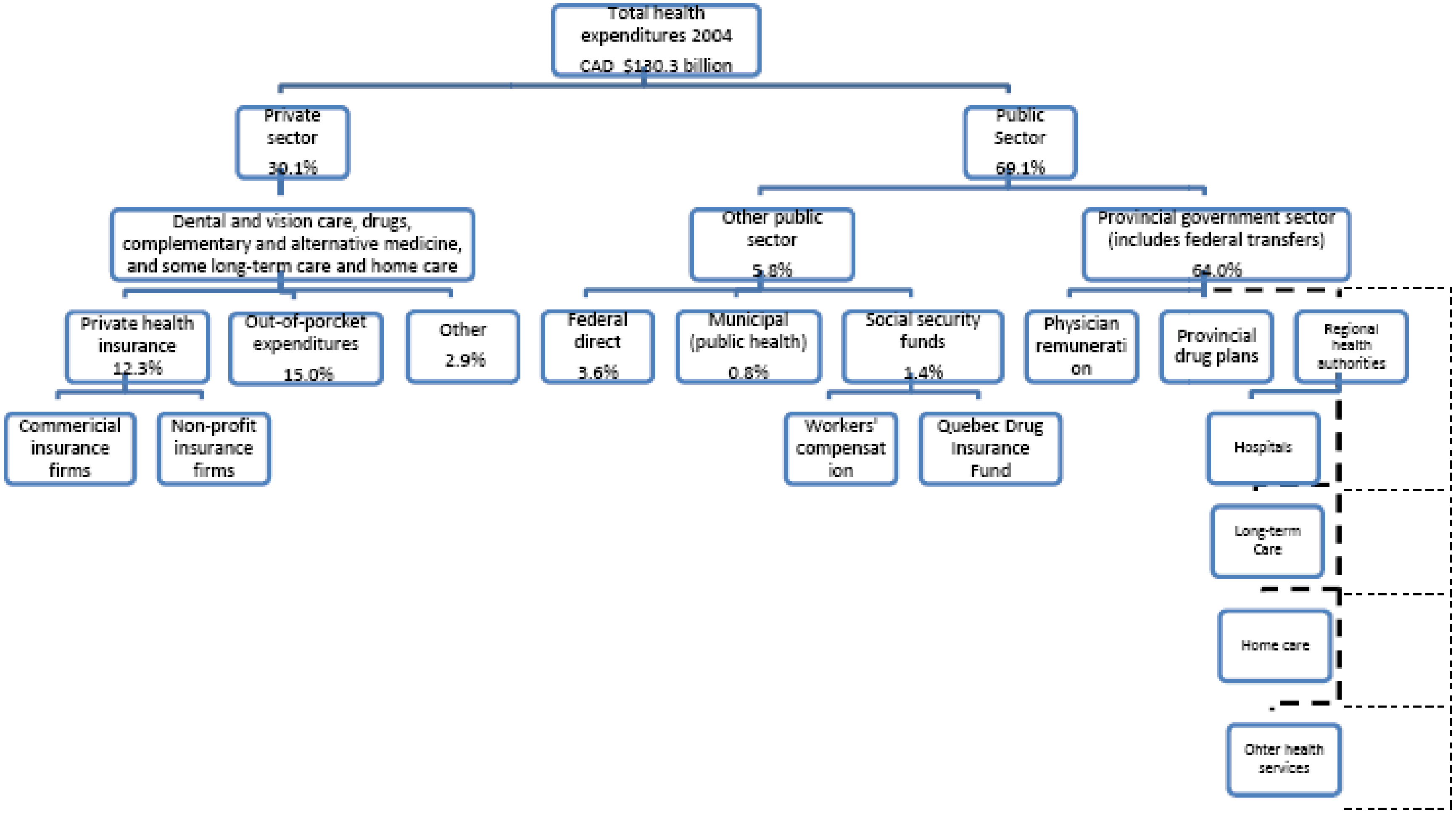


Figure 1.4: Framework of Financing of Health Care, 2004



Data source: http://www.ecosante.org/ocde.htm.

Figure 1.5: Health Care Utilization Rates by Age Estimated from CCHS, 2005, Unit: Number of Visits to Doctors, or Number of Nights Spent at Health Care Institutions[29]

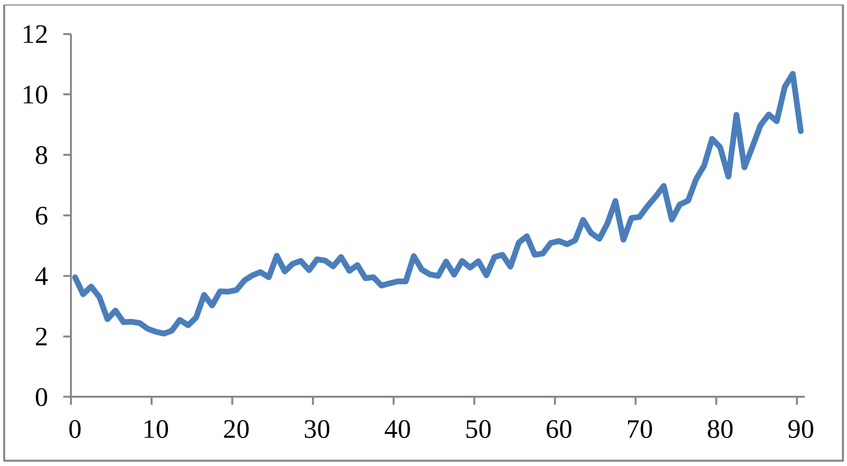


Figure 1.6: Private Health Care Consumption per Capita Age Profile under Simple Regression Method with Linear Equation, CAD $, SHS 2006[30]

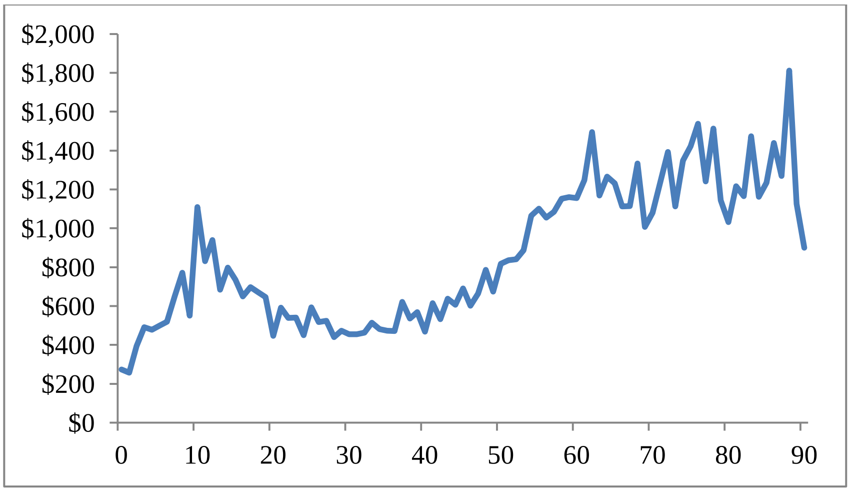
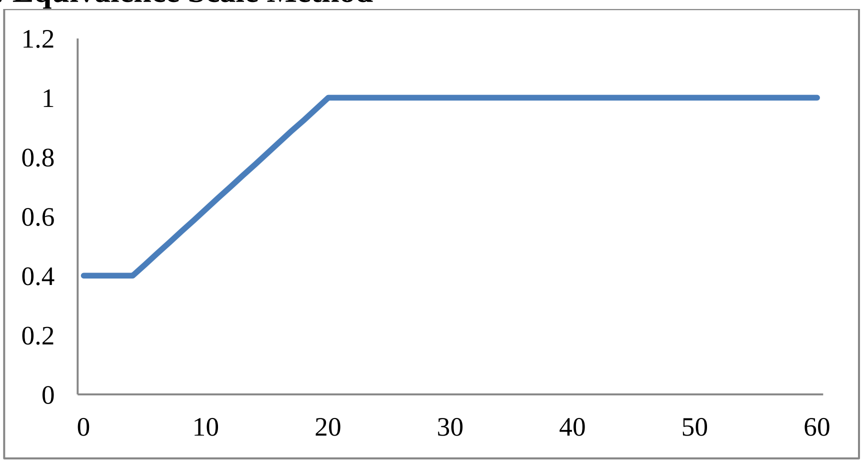


Figure 1.7: Equivalence Scale Method



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[29] We assume that the growth rates for age 12 to 24 are the same for age 0 to 11. As CCHS is not conducted for the year 2006, we apply health care utilisation rates in 2005 for the estimates in 2006.

[30] The drop of private health care consumption per capita for this age group of 90 years and older in Figure 1.6 is due to the small size of observations in this age group.

Figure 1.8: Private Other Consumption per Capita Age Profile, CAD $, SHS, 2006

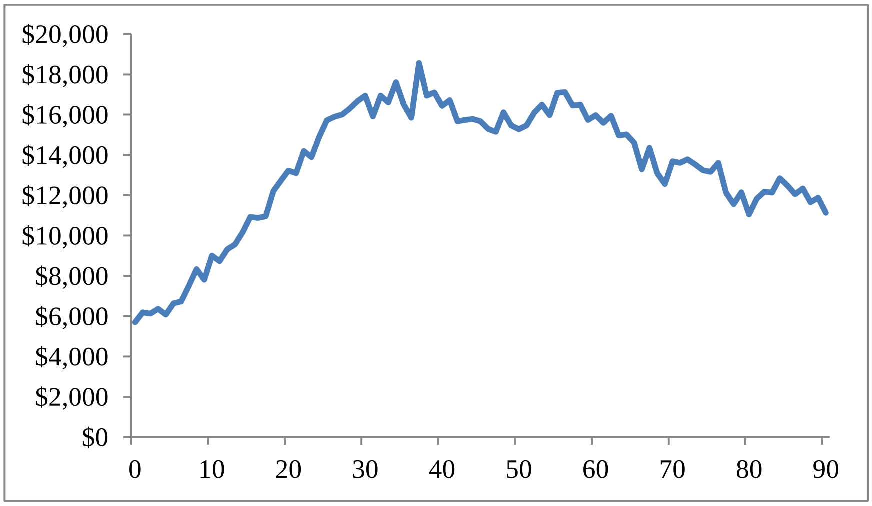


Figure 1.9: Public Education Consumption per Capita Age Profile, CAD $, 2006

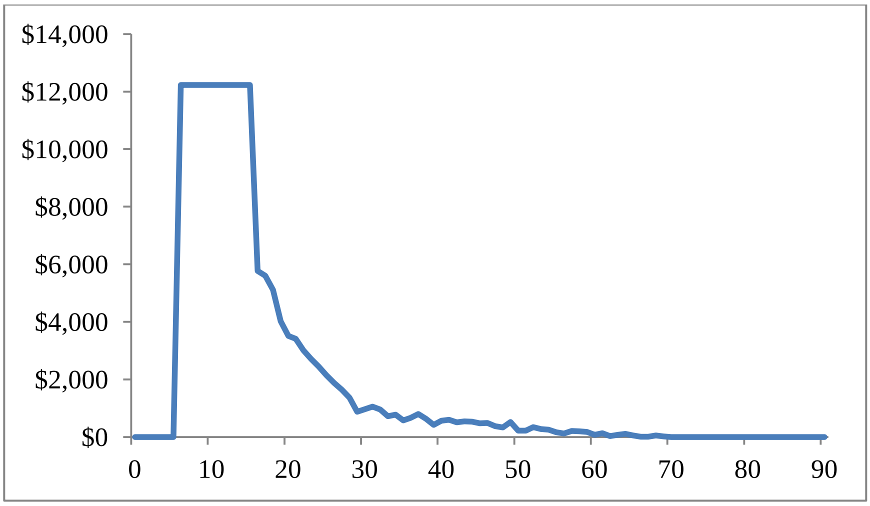


Figure 1.10: Public Health Care Consumption per Capita Age Profile, CAD $, 2006

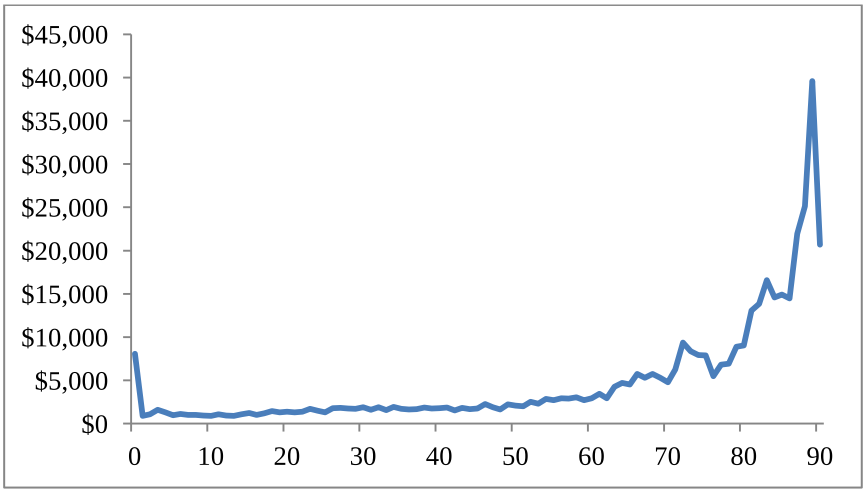


Figure 1.11: Provincial and Territorial Government Other Expenditure (Excluding Education and Health Care Expenditure), per Capita, CAD $, 2006

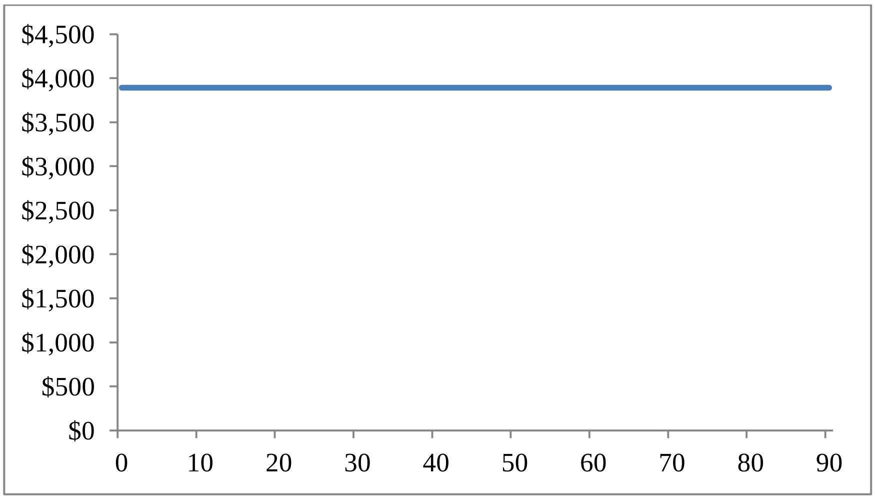


Figure 1.12: Smoothed per Capita Age Profiles of Private and Public Health Care Consumption

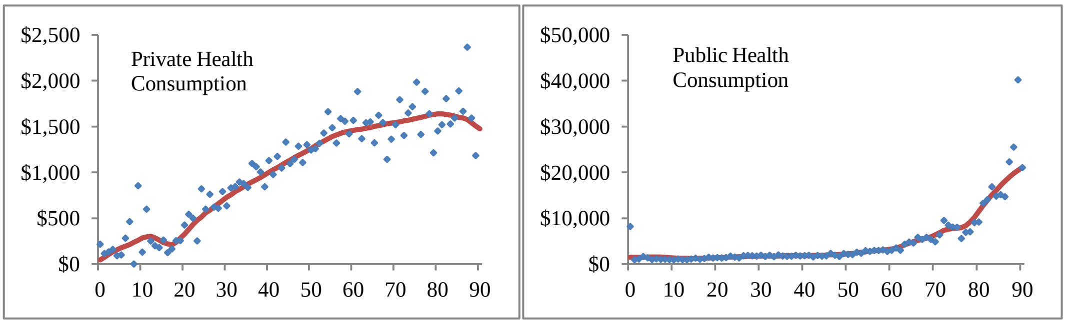


Figure 1.13: Labour Income and Its Components per Capita Age Profile from SLID, CAD $, 2006

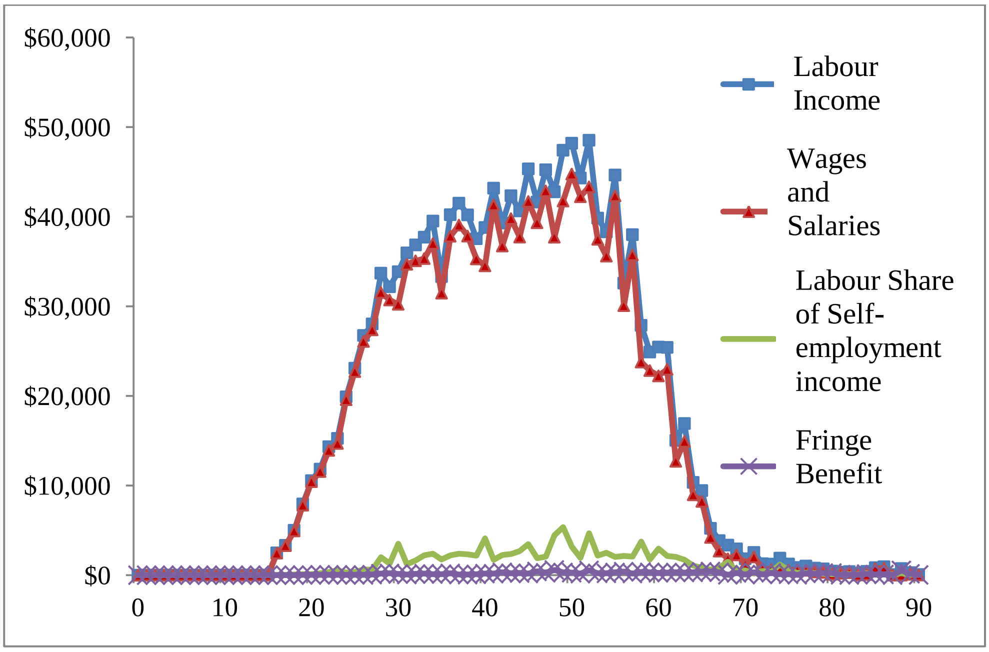


Figure 1.14: Per Capita Age Profiles of Labour Income and Consumption, Canada, 2006

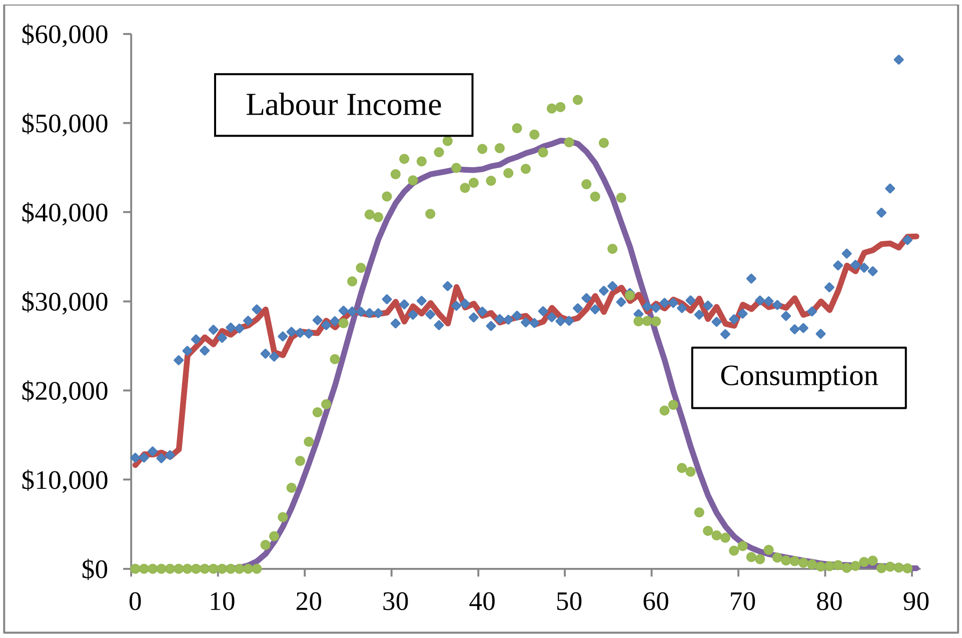


Figure 1.15: Per Capita Age Profile of LCD, Canada, CAD $, 2006

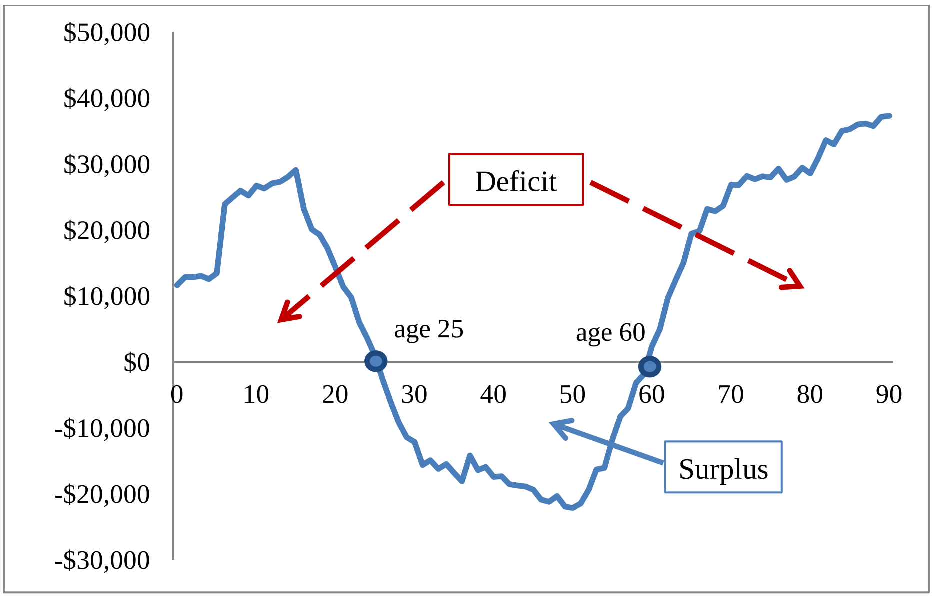


Figure 1.16: Aggregate Age Profile of LCD, Canada, CAD $ Billion, 2006

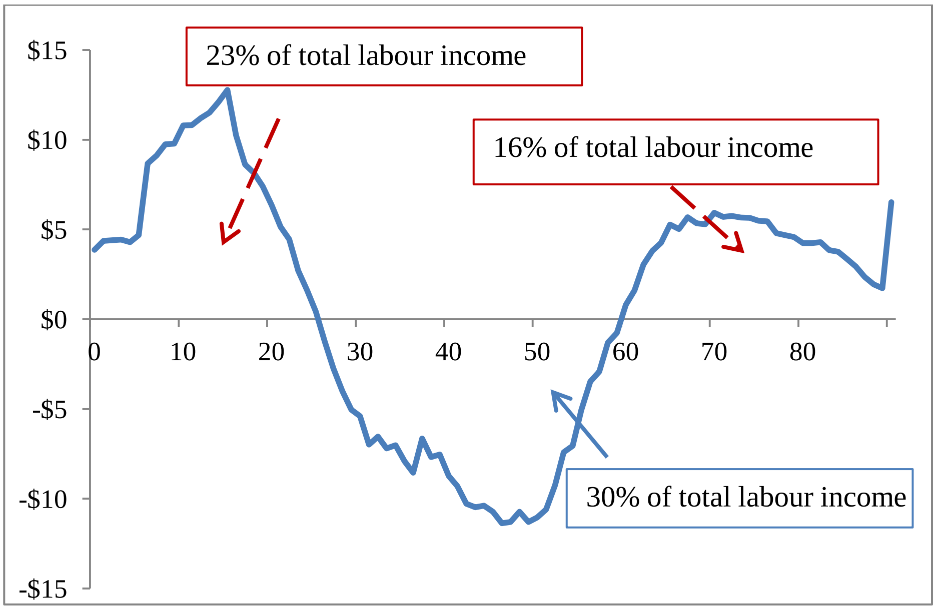
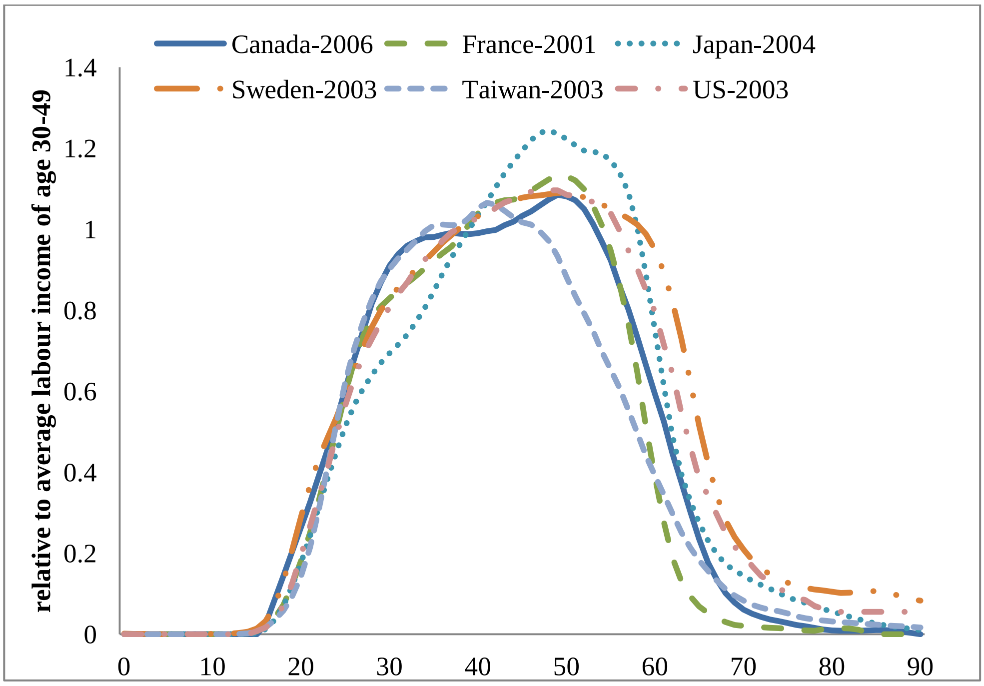
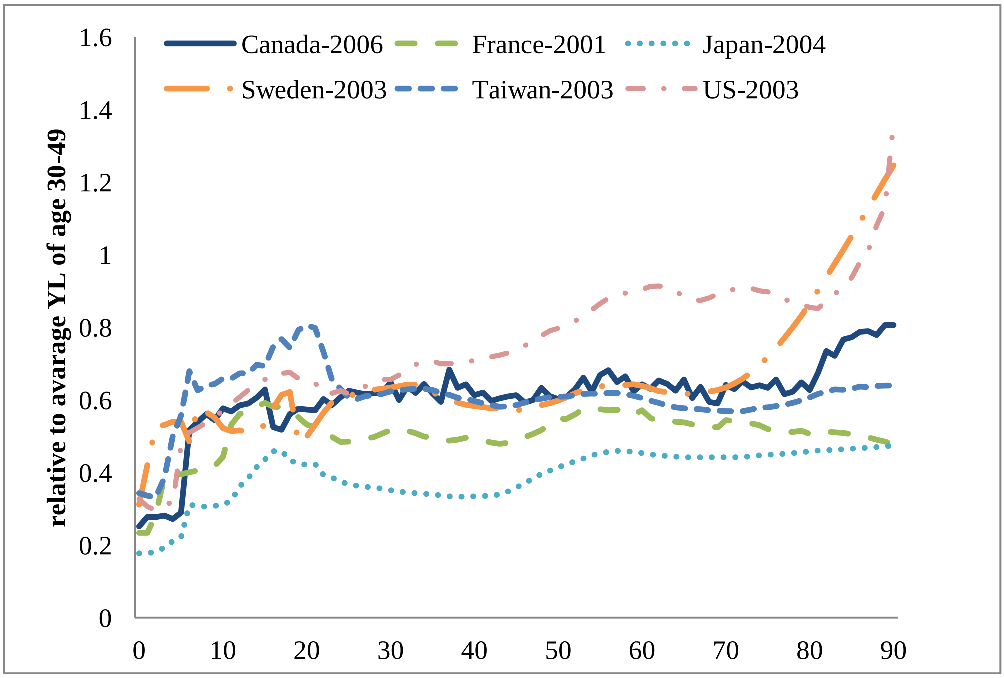


Figure 1.17: Comparison of Normalized Labour Income per Capita Age Profiles for Selected Countries



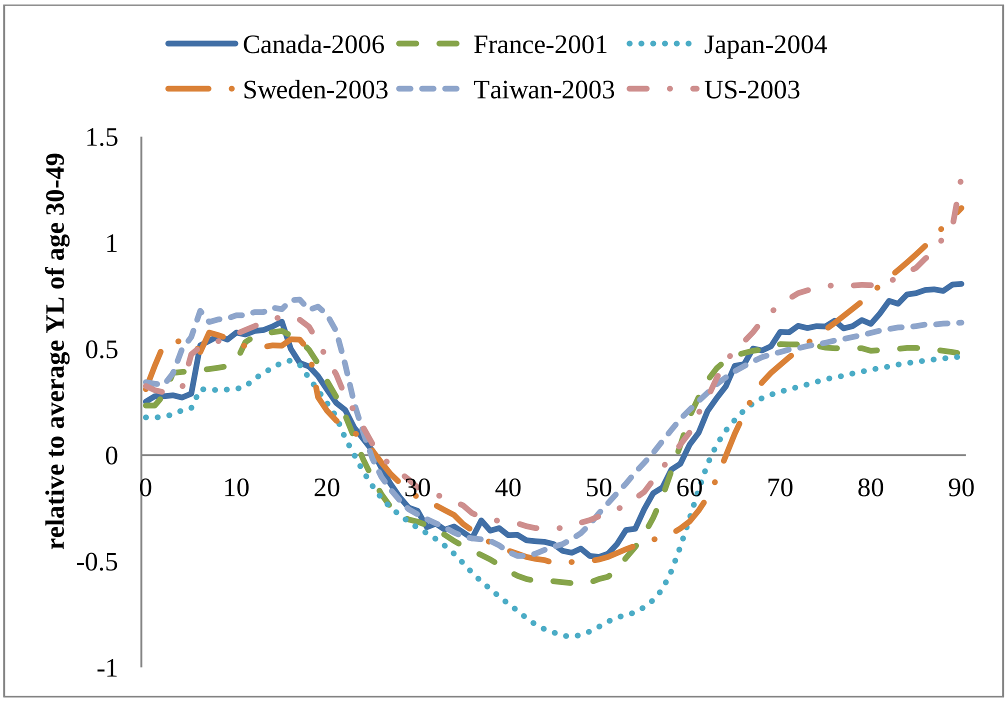
Data source: NTA website for countries other than Canada. Selected countries are France, Japan, Taiwan, Sweden, and U.S.

Figure 1.18: Comparison of Normalized Consumption per Capita Profile for Selected Countries



Data source: NTA website for countries other than Canada. Selected countries are France, Japan, Taiwan, Sweden, and U.S.

Figure 1.19: Comparison of Normalized LCD per Capita Profile for Selected Countries



Data source: NTA website for countries other than Canada. Selected countries are France, Japan, Taiwan, Sweden, and U.S.

Figure 1.20: Per Capita Consumption, Private and Public by Sector, Canada, CAD $, 2006

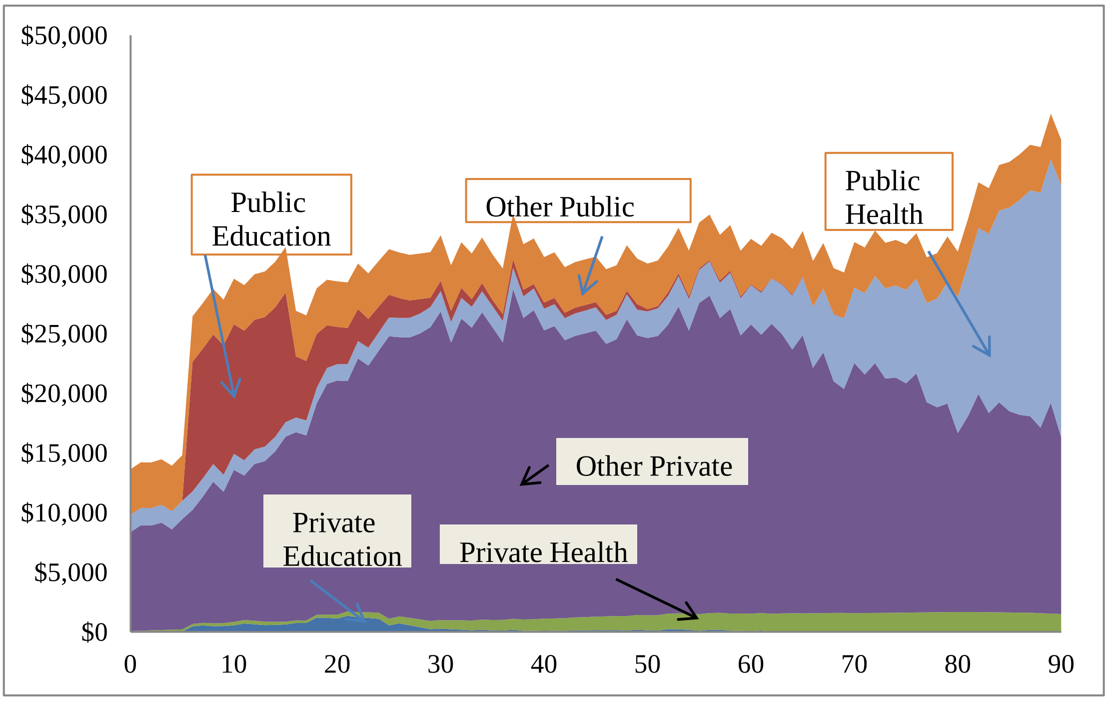
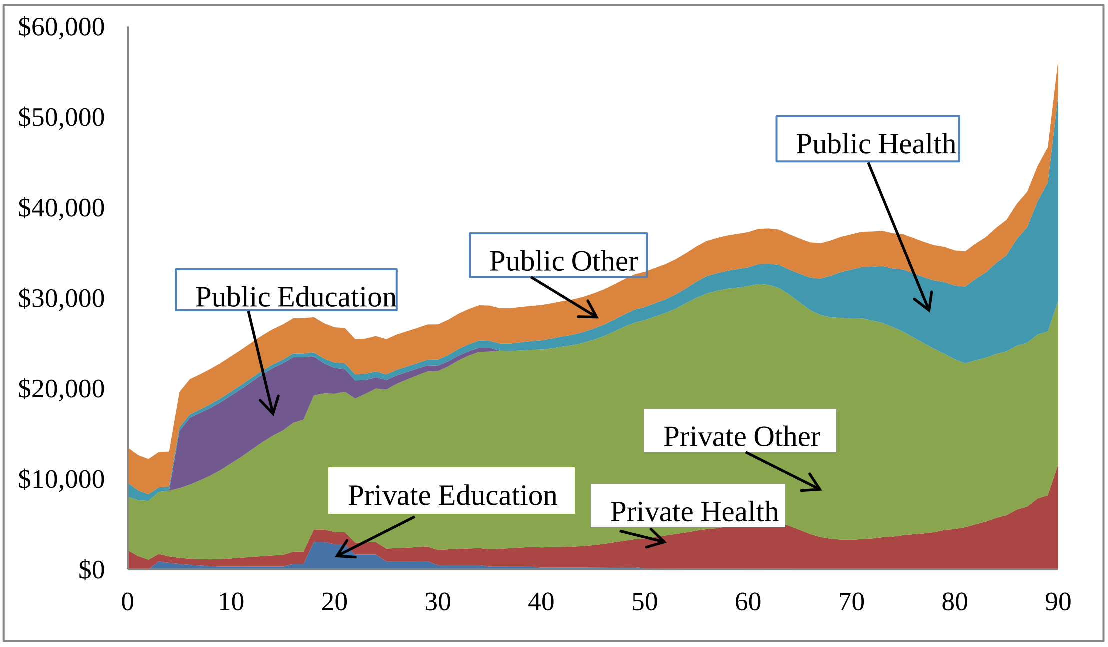


Figure 1.21: Per Capita Consumption, Private and Public by Sector, the U.S., 2003



Data source: NTA website: www.ntaccounts.org.

Figure 1.22: Projection of LCD, Labour Income, Consumption, Public Consumption and its Components from 2006 to 2056, CAD $ Billion

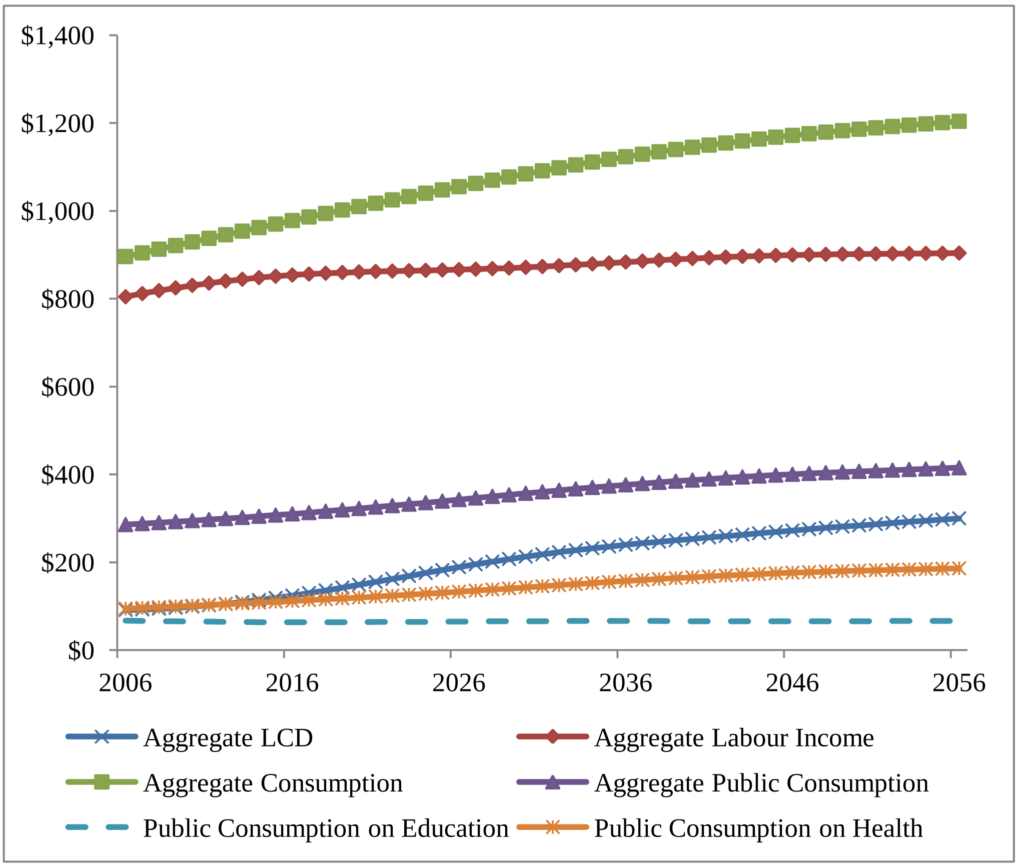
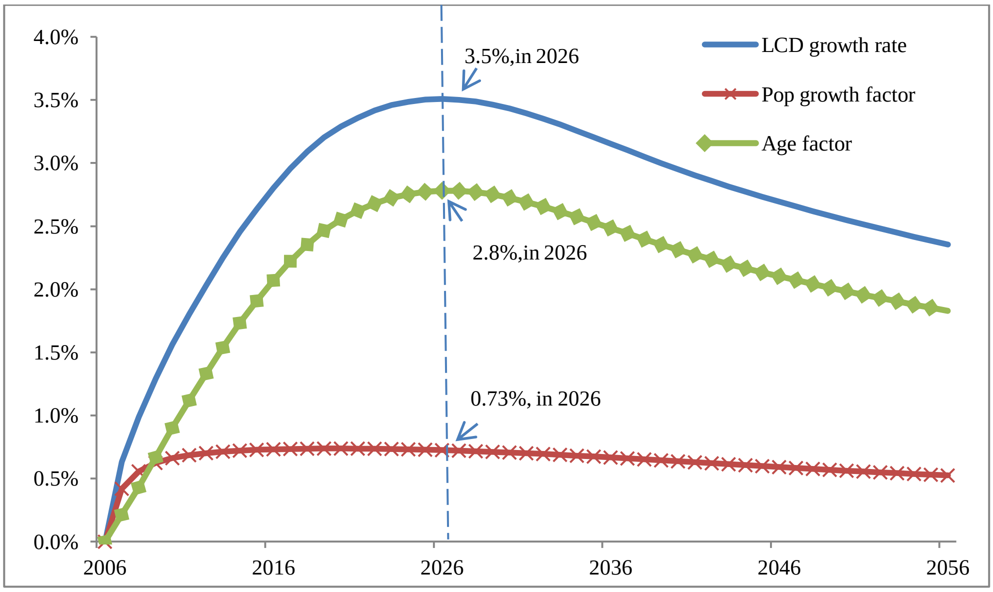


Figure 1.23: Projection of Annual Growth Rate of Aggregate Level of LCD, Population, and Age Factor



Data source: Data for population projections are from Statistics Canada (catalogue no. 91-520-XIE) under assumptions of medium-growth and medium migration trends scenario.

Figure 1.24: Projected Growth Rate of Aggregate Labour Income to Maintain Aggregate LCD at Its 2006 Level

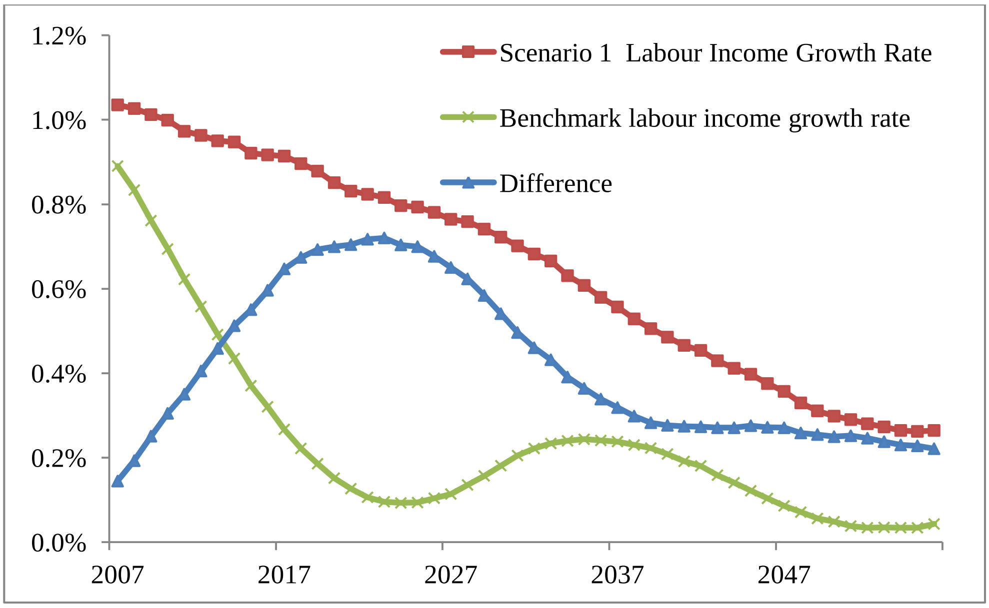
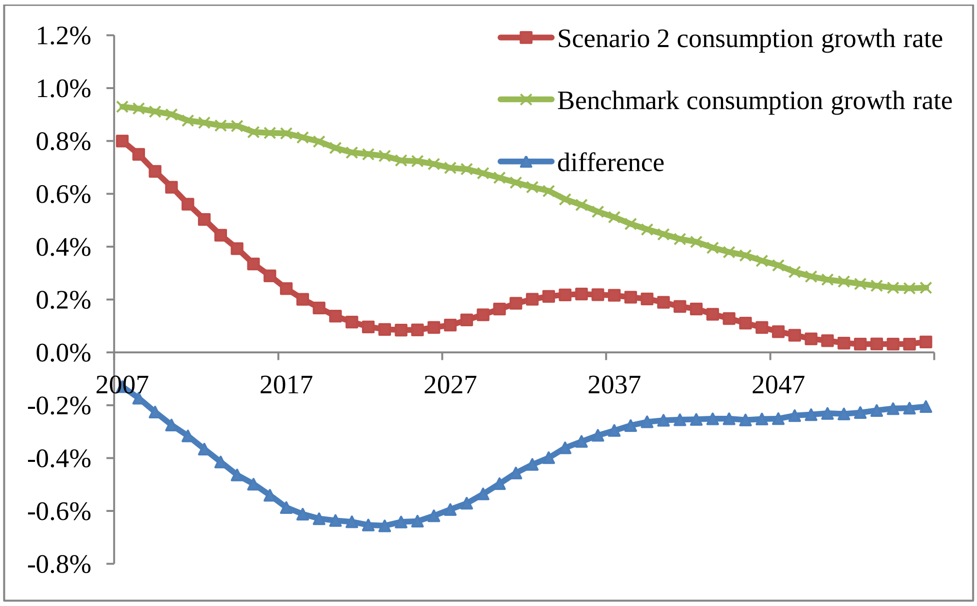


Figure 1.25: Projected Growth Rate of Aggregate Consumption to Maintain Aggregate LCD at Its 2006 Level



Appendix 1 Other Concepts in the NTA

A 1.1. Financing the LCD

The NTA identity (Eq. 2) shows that the age reallocation equals to the LCD for each age group, which indicates that the age reallocation is the resource for financing LCD. It includes two components: transfers and asset-reallocation. Transfers include public and private transfers (i.e. the second term of the right-hand side in Eq. 2). Public transfer should be equal to the amount of public consumption, which is discussed in Section 3.1.2. Private transfer includes interhousehold transfers (i.e. transfers between households) and intrahousehold transfers (i.e. transfers among family members within each household), which can be conducted under certain methodologies from the household survey. Generally, there are net positive public and private transfers for children (i.e. from public education transfers, and from parents paying expenses for their children) and net positive public transfer for seniors (i.e. from pension and health care transfers).[31] Working age generations generally have negative net transfers, which are

[31] In most Asian countries (e.g. Japan, China, and South Korea), there are positive net private transfers because adult

due to the burden of funding transfers to other generations (i.e. through the tax system for public transfer, and through paying family expenses for private transfer).

The second component of financing the aggregate LCD is asset-based reallocation, which also exists in private and public sectors (i.e., the first term in the right-hand side in Eq. 2). Public asset-based reallocation means the asset income from natural resources or financial assets which are accumulated from previous years. With a positive public asset reallocation, a country can use it to fund the LCD or to save. A negative public asset reallocation indicates that the taxpayers are paying interest on public debt (Lee and Mason, 2013). Private asset-based reallocation is composed of private asset income, and this amount is substantial for working age groups. It can be used to fund consumption, and net public and private transfers. The residual will be saved if a positive amount remains; otherwise, dissaved. Private asset-based reallocation for seniors is significant because they generate resources by dissaving.

A 1.2. LCD or LCS in Golden Rule Steady State

In a closed economy, the net private and public aggregate transfer (across all age groups) must be equal to zero, meaning that total inflow of transfer equals total outflow of transfer. This must be true because in a closed economy, a transfer from a resident must go to another resident (as a receiver) in the country. Therefore, we have:

$$\sum_a \underbrace{[Tr_I(a) - Tr_O(a)]_{\text{pri}}}_{\text{Net Private Transfers}} + \underbrace{[Tr_I(a) - Tr_O(a)]_{\text{pub}}}_{\text{Net Public Transfers}} = 0, \tag{A.1}$$

so that Eq. (2) can be rewritten as:

$$C - Y_L = Y_A - S. \tag{A.2}$$

Lee (1994a) demonstrates that the aggregate LCD is equal to zero at the golden rule

children are financially supporting their parents (seniors). More regional studies of NTA can be found in NTA website: www.ntaccounts.org.

steady state, i.e., $C - Y_L = 0$. Thus, $Y_A - S = 0$, or $Y_A = S$.

A possible way to prove this is by starting from the Solow Growth Model (Solow, 1956) assuming a constant return to scale (CRTS) production function: $Y = f(K, L)$. CRTS implies that if each input is multiplied by a factor z, output changes by the same scale, so that: $zY = f(zK, zL)$. In this case, let $z = 1/L$, which implies that: $Y/L = f(\frac{K}{L}, 1)$. Define $y = Y/L$, and $k = K/L$, where y is the output per worker, and k is capital per worker. The production function can thus be written as $y = f(k)$.

The per capita demand of goods, in this simple model, consists of consumption plus investment: $y = c + i$, where $y = Y/L$, $c = C/L$, and $i = I/L$. The consumption function is assumed to be a linear function of output, i.e. $C = (1 - s) * Y$, or $c = (1 - s) * y$, where $0 < s < 1$ is the marginal propensity to save. Given this, at the equilibrium where production equals demand, we have that: $y = (1 - s) * y + i$, which means that $s * y = i$: savings equals investment, or:

$$i = s * y = s * f(k). \tag{A.3}$$

We can assume also that a certain amount of capital is consumed each period through depreciation. Let δ be the depreciation rate, which means that the depreciation of capital stock is $\delta * k$. The change of capital stock is thus: $\Delta k = i - \delta * k$. Given Eq. (A.3), this can be written as $\Delta k = s * f(k) - \delta * k$. At a steady state, $\Delta k = 0$ so that $s * f(k) = \delta * k$. The following figure shows that the steady state level of capital per labour is determined when saving is just equal to the depreciation of capital stock per labour.

From all possible steady states, the golden rule level of capital accumulation is the steady state with the highest level of consumption. The idea is that if a government can move the economy to a new steady state, an optimal choice would be to maximize consumption per capita. In order to change the steady state, the government must alter the saving rate. Recall that $y = c + i$ so that $c = y - i = f(k) - s * f(k)$. Thus, in a steady state, it means that $c = f(k) - \delta * k$. To maximize c, we must take the total differentiation of c and set it equal to zero: $dc = \frac{\partial f(k)}{\partial k} dk - \delta * dk = 0$ so that $\frac{\partial f(k)}{\partial k} = \delta$. That is, the marginal production of capita (i.e., rate of return of capital in a competitive economy) equals the depreciation rate. Therefore, we have that $s * f(k) = \delta * k$ and $\frac{\partial f(k)}{\partial k} = \delta$. Thus, $s * f(k) = \frac{\partial f(k)}{\partial k} * k$ so that $s * y = r * k$, which means that saving per capita ($\frac{S}{L} = s * y$) equals asset income per capita ($\frac{Y_A}{L} = r * k$). Thus, $\frac{S}{L} = \frac{Y_A}{L}$, or $S = Y_A$. Substituting in Eq. (A.2) we get that $C - Y_L = 0$, which indicates that the aggregate LCD equals zero at a golden rule steady state. Additional details can be found in Lee's study (1994a).[32]

Appendix 2 Alternative Methods

A 2.1. Alternative Method for Allocating Private Education Consumption

The NTA proposes the use of the following regression equation:

$$CFE_j = \sum_a \alpha(a) E_j(a) + \sum_a \beta(a) NE_j(a); \tag{A.4}$$

$$CFE_{ij}(a) = CFE_j \frac{\alpha(a)}{\sum_a \alpha(a) E_j(a)}, \tag{A.5}$$

where CFE_j is the private consumption spending on education in household j, $E_j(a)$ is the number of members of age a in household j enrolled in an education program, $NE_j(a)$ is the number of members not enrolled. The coefficients $\alpha(a)$ and $\beta(a)$ are the corresponding parameters to be estimated, and $CFE_{ij}(a)$ is the private consumption on education of member i of specific age a in household j as given by Eq. (A.5). This method cannot be used for Canada because there is no information about student

[32] NTA identities also holds for an open economy, in which case total transfer does not sum to zero for the total economy (residents of all ages) because of inflow and outflow from the rest of world. However, transfer inflow to the residents and the rest of world must equal transfer outflow to the resident and the rest of world.

indicators, $E_j(a)$ and $NE_j(a)$, in SHS.

A 2.2. Alternative Methods for Allocating Private Health Care Consumption

In the main text, we applied a simple regression method to allocate private health care consumption spending with a linear equation. There are also other methods which are available.

Method 1: Based on Health Care Utilisation Rate

Private health care consumption spending can be reallocated to each family member through the following equation:

$$CFH_{ij}(a) = \frac{HUR_i(a)}{(\sum_i HUR_i(a))_j} . CFH_j, \tag{A.6}$$

where $HUR_i(a)$ is the health care utilisation rate for age a for individual i in household j; CFH_j is the total private health care spending in household j. The denominator, $(\sum_i HUR_i(a))_j$, is the summation of health care utilisation rate over all the family members i in household j and $\frac{HUR_i(a)}{(\sum_i HUR_i(a))_j}$ is the proportion of household health care spending allocated to family member i.

Method 2: Regression Method Based on Inpatient and Outpatient

According to this method, the relevant regression equation is:

$$CFH_j = \sum_a \alpha(a). IN_j(a) + \sum_a \beta(a). OUT_j(a), \tag{A.7}$$

where $IN_j(a)$ represents the amount of inpatient services (e.g. the number of nights spent in hospital or other health care institutions such as clinics) used by the members with age a in household j, $OUT_j(a)$ represents the number of outpatients services (e.g. the number of medical doctor visits) used by the members with age a in household j, $\alpha(a)$ and $\beta(a)$ are the corresponding coefficients to be estimated, and CFH_j is private consumption on health care in household j.

Method 3: Regression Method Based on the Number of Members/Individuals in a Household[33]

According to this method, private health care consumption can also be regressed with the number of members $P_j(a)$ in household j, and health care utilisation rate by age a, $HUR(a)$, by a non-linear equation:

$$CFH_j = \sum_a \beta_0(a).HUR(a)P_j(a) + \sum_a \beta_1.a.(a).HUR(a)P_j(a) + \sum_a \beta_2.a^2.(a).HUR(a)P_j(a). \quad \text{(A.8)}$$

Method 4: Non-parametric Iterative Method

In this approach health care expenditure initially assigns equal shares to each household member and an initial per capita profile is generated. The per capita profile is then used as weights to allocate health care consumption to household members. This generates a new per capita profile. An example of this alternative method is illustrated in Table 1.7.

First, health care consumption in household number 1 is 70 (column 4, rows 4, 5, and 6) so that the equal share to each of the assumed three members is $70/3 = 23.33$ (column 5, rows 4, 5 and 6). The health care consumption in household number 2 is 80 (column 4, rows 7, 8, and 9). The equal share to each of the assumed three members is $80/3 = 26.67$ (column 5, rows 7, 8 and 9). The health care consumption in household number 3 is 40 (column 4, rows 10 and 11). The equal share to each member is $40/2 = 20$ (column 5, rows 10 and 11). The health care consumption in household number 4 is 20 (column 4, rows 12 and 13). The equal share to each member is $20/2 = 10$ (column 5, rows 12 and 13).

[33] The simple regression method with linear equation is applied to allocate private health care spending in the main text (see Eq. 7).

Table 1.7: Non-parametric Iteration Method: An Illustration

Col.	1	2	3	4	5	6	7	8	9	10
Row	**Iterative Method**				**Estimated C after Iteration**					
	Age	**True C**			**Iteration1**	**Iteration2**	**Iteration3**	**Iteration4**	**Iteration5**	**Iteration6**
1	5	10			14.44444	11.89655	10.82563	10.36457	10.16299	10.07359
2	35	30			25	27.42374	28.7414	29.40266	29.72062	29.87027
3	65	20			22.22222	21.53846	20.8525	20.43188	20.20952	20.09938
	HH No	**Id No**	**Age**	**HH C**						
4	1	1	5	70	23.33333	15.68966	12.4769	11.09372	10.48896	10.22077
5	1	2	35	70	23.33333	27.15517	28.76155	29.45314	29.75552	29.88961
6	1	3	35	70	23.33333	27.15517	28.76155	29.45314	29.75552	29.88961
7	2	1	35	80	26.66667	27.69231	28.72124	29.35218	29.68571	29.85093
8	2	2	35	80	26.66667	27.69231	28.72124	29.35218	29.68571	29.85093
9	2	3	65	80	26.66667	24.61538	22.55751	21.29564	20.62857	20.29814
10	3	1	65	40	20	20	20	20	20	20
11	3	2	65	40	20	20	20	20	20	20
12	4	1	5	20	10	10	10	10	10	10
13	4	2	5	20	10	10	10	10	10	10

Second, after obtaining the equal share of household health care spending for each member, we calculate the average health care consumption for each age group (given in column 3). For example, the average health care consumption for age 5 in iteration 1 is $(23.33 + 10 + 10)/3 = 14.44$ where 23.33 is from column 5, row 4; 10 is from column 5, rows 12 and 13; 14.44 is the average health care consumption for age 5 in iteration 1 (column 5, row1). Similarly, the average health care consumption for age 35 in iteration 1 is $(23.33 + 23.33 + 26.67 + 26.67)/4 = 25$ (column 5, row 2); for age group 65, it is $(26.67 + 20 + 20)/3 = 22.22$ (column 5, row 3). These figures will now be used as weights in the second iteration. For example, health care consumption of individual 1 in household number 1 (age 5) is $70 * [14.44/(14.44 + 25 + 25)] = 15.69$ (column 6, row 4); for individual 2 in household number 1 (age 35), it is now $70 * [25/(14.44 + 25 + 25)] = 27.16$ (column 6, row 5); for individual 3 in household number 1 (age 35), it is $70 * [25/(14.44 + 25 + 25)] = 27.16$ (column 6, row 6). The same iteration procedure is done for individuals in other households. In the second step of the second iteration, we again calculate per capita health care consumption as $(15.69 + 10 + 10)/3 = 11.90$ (column 6, row 1) for age 5; $(27.16 + 27.16 + 27.69 + 27.69)/4 = 27.42$ (column 6, row 2) for age 35; and $(24.62 + 20 + 20)/3 = 21.54$ (column 6, row 3) for age 65. The procedure is repeated up to iteration 6 in Table 1.7. The main objective of the method is that the eventual estimated health care consumption per capita profile approaches the real one (compare column 10, rows 1, 2, 3 with column 10, rows 4, 5, 9).

Appendix 3 Reallocation of Taxes on Products and Production

Table 1.8: Reallocation of Taxes on Products and Production to Labour Income, Asset Income and Consumption, Million CAD $, Canada, 2006

	Total	**Allocations**			**Allocated Amount**		
	Amount	YA	YL	C	YA	YL	C
Taxes on products	**111,117**	0	0	1	0	0	111,117
Federal	48,024						
Provincial	62,689						
Local	404						
Taxes on factors of production	**65,586**						
Federal	273	0.28	0.72	0	76.44	196.56	0
Provincial	22,926						
Corporation tax (not on profits)	3,249	0.28	0.72	0	909.72	2339.28	0
Motor vehicle licences and permits	1,178	0.28	0.72	0	329.84	848.16	0
Other licences, fees and permits	594	0.28	0.72	0	166.32	427.68	0
Miscellaneous taxes on natural resources	1,088	0.28	0.72	0	304.64	783.36	0
Real property tax	3,579	1	0	0	3579	0	0
Payroll taxes	9,561	0.28	0.72	0	2677.08	6883.92	0
Miscellaneous	3,677	0.28	0.72	0	1029.56	2647.44	0
Local	42387						
Licences, fees and permits	723	0.28	0.72	0	202.44	520.56	0
Real and personal property tax	39,132	1	0	0	39132	0	0
Business tax	544	0.28	0.72	0	152.32	391.68	0
Developer's fees	1,938	0.28	0.72	0	542.64	1395.36	0
Miscellaneous	50	0.28	0.72	0	14	36	0
Allocated shares of taxes	**176,703**				**49116**	**16470**	**111,117**
Subsidies on products	14,857	0	0	1	0	0	14857
Subsidies on factors of production	1,006	0.28	0.72	0	281.68	724.32	0
Allocated shares of subsidies					**281.68**	**724.32**	**14857**
Allocated shares of taxes less subsidies	**160,840**				**48834.32**	**15745.68**	**96,260**

Source: NIPA, Canada, OECD database, 2006.

As mentioned in the main text, taxes on products and productions are reallocated as listed in Table 1.9. In the NTA, we need to reallocate indirect taxes to asset income, labour income, and consumption by appropriate rules. The amount of “taxes on products” goes fully to consumption. In the category of “taxes on factors of production”, for example, corporation tax reallocates 28% to capital income, and 72% to labour income;

real property tax reallocates 100% to asset income, and nothing to labour income. Note that 28% and 72% are the asset and labour income shares in production calculated in the NTA framework. The labour income is calculated from employees' compensation, and one-third of mixed income taken from the SNA; the asset income is calculated from net property income, and two-thirds of mixed income taken from the SNA, as well. At the end, the specific shares of asset and labour for Canadian income are 28% and 72%. This ratio is calculated through the value of labour income over capita income as listed in Table 1.9.

Table 1.9: Labour and Capital Share Allocation, Million CAD $, Canada, 2006

Labour Income Allocation		**Asset Income Allocation**	
Compensation of Employees:	743,392	**Net Property Income:**	(2,226)
Labor Share of GMI:	51,767	**NOS + Capital Share of GMI:**	309,952
YL share:	795,159	**YA share:**	307,726
Ratio:	0.72	**Ratio:**	0.28

Source: NIPA, Canada, OECD database, 2006. GMI: gross mixed income; NOS: net operating surplus, which is gross amount less consumption of fixed capital.

Chapter 2

An Overlapping Generations Computable General Equilibrium (OLG-CGE) Model with Age-dependent Rates of Time Preference

1. Introduction

Population aging is a significant socioeconomic trend in Canada that is expected to cause considerable economic and fiscal impacts on the Canadian economy including a declining living standard. The higher proportion of seniors in the Canadian population will lead to a heavier pressure on public spending on age-sensitive programs, such as health care and pension benefits.

This paper examines the impact of population aging on the Canadian economic performance using an overlapping generations computable equilibrium (OLG-CGE) model. The OLG framework has been used in a series of papers using CGE modelling, the first being the seminal contribution of Auerbach and Kotlikoff (1987). The OLG-CGE model has been typically applied to studies related to demographic changes, pension reform, social security system, and other public policies (Börsch-Supan et al., 2005).

Calibrating an OLG-CGE model is more challenging than calibrating a typical CGE model. The calibration itself requires simulations because age-profile data is typically not available. For example, although aggregate consumption can easily be obtained from the System of National Accounts (SNA), researchers typically have no data on consumption by age group. Consequently, such data needs to be generated endogenously to provide the model with plausible initial paths. The traditional way to proceed is to assume a steady state with a stable population and to use theory based on the Euler equation for the evolution of consumption over the lifecycle of an individual as a function of a) the inter-temporal elasticity of substitution, b) the market interest rate, and c) the rate of time preference. A typical assumption is to impose a constant rate of time preference, which implies an upward sloping profile for consumption per age group. The alternative methodology that we propose in this paper is to impose directly the bell-shaped consumption age profile of National Transfer Accounts (NTA) (see Chapter 1). In order to do this, we need to introduce an age-dependent rate of time preference. Theoretically, there are several studies which have discussed the possibility that the rate of time preference should vary with age (Ramsey, 1928; Bishai, 2004; Chao et al., 2009; Rogers, 1994; Posner, 1995). The rest of the paper is as follows. Section 2 presents a survey of the literature with respect to age-dependent rate of time preference. Section 3 describes the OLG-CGE model including the demographic shock, the producer and household problems, the pension system, the investment, and market clearing conditions. Section 4 presents the calibration of the model. Section 5 discusses the simulation results of the economic impact of population aging and the policy interventions to mitigate this impact. Section 6 concludes.

2. Age-dependent Rate of Time Preference

Instead of the traditional assumption of a constant rate of time preference in past models, the calibration method used in this chapter will apply an age-specific rate of time preference. This is a significant change in the role of time preference. This section discusses the theoretical and empirical evidence from several studies regarding the age-dependent time preference. In this section, we first explain why a constant time preference is normally applied in the usual case for an individual's lifetime utility, and then discuss at which point we can apply the age-specific time preference at the generational level.

In economics, the objective of a time preference is to evaluate the (relative) value of a good at an earlier time compared to the same good in the future (Fetter, 1927). The time preference of an individual is determined by his personal preference. For instance, if one prefers to save money rather than to spend it at the present, he is considered as a low-time preference person. Rate of time preference is also called discount rate. The subject of "discount" was initiated in the theory of capital by various researchers, such as

Rae (1905), Marshall (1920), Ramsey (1928), Fisher (1930), Pigou (1932), Harrod (1948), and Böhm-Bawerk (1959).

Ramsey (1928) raises the issue of dynamic inconsistency, which states that without a constant discount rate, an individual will change his decision if he is at a different time period. The decision which he makes today may not be the same tomorrow. Therefore, to avoid this inconsistency, he states that a single person has to apply a constant discount rate for both the present utility and the future utility. This is also coherent with Koopmans' stationary axiom (1964), which claims that preferences between two time periods remain the same even if we move these periods forward. For example, if we have a consumption benchmark path $(c_t, c_{t+1}, \dots, c_{t+n})$, and one of the two following adjustments can happen: a) either we add a units to consumption in time period t, or b) we add b units to consumption to time $t + m$.[34] The adjustment of consumption, a and b, are chosen so as to let this individual be indifferent between the two alternative consumption paths. In other words, the individual has the same utility level between the consumption path of $((c + a)_t, c_{t+1}, \dots, c_{t+n})$, and the alternative consumption path of $(c_t, \dots, c_{t+m-1}, (c + b)_{t+m}, \dots, c_{t+n})$. Assuming a constant discount factor, β, we must therefore have:

$$\beta^t U(c + a) + \beta^{t+m} U(c) = \beta^t U(c) + \beta^{t+m} U(c + b). \quad (1)$$

Dividing both sides of this equation by β^t, Eq. (1) can then be simplified to:

$$U(c + a) + \beta^m U(c) = U(c) + \beta^m U(c + b). \quad (2)$$

Then the time dimension t will not affect the individual's decision anymore, but only the absolute time difference remains. This simply tells us that the two adjustments on the consumption paths return an indifferent utility level as long as we keep the same gap m between two time periods. It does not matter whether a happens in time period 2 and b in time period $2 + m$, or whether b happens in time period 50 and b in time period

[34] m represents the gap of the starting time period between two consumption adjustments options, a) and b).

b +m. If a person prefers one apple today to two apples tomorrow, then this person prefers one apple in 30 days to two apples in 31 days.

However, now suppose that we introduce two discount factors, β^t for period t and $\emptyset^{t+m}$ for period $t+m$ where $\beta \neq \emptyset$. We again choose a and b so that the agent is indifferent:

$$\beta^t U(c+a) + \emptyset^{t+m} U(c) = \beta^t U(c) + \emptyset^{t+m} U(c+b). \tag{3}$$

Compared to the previous experiment, we cannot eliminate β^t throughout so that the time dimension t remains in the Eq. (3). Thus our preference over the adjustments are dependent not only on the time difference, m, but also on the actual time t when the first adjustment happened. Koopmans' stationary axiom is not fulfilled. The absence of stationarity means that we can have dynamic inconsistency with variable discount factors, i.e., plans that are made at one point of time are contradicted by later behaviour. Intuitively, a person could prefer one apple today to two apples tomorrow, but at the same time prefer two apples in 31 days to one apple in 30 days. As time passes this person may change his mind and choose to get the apple one day later.

Accepting the possibility of time inconsistency, we apply the concept of varying time preference into a generational framework. Intuitively, adding the age dimension to time preference means that the generation g of time t has rate of time preference β, but the generation $g+1$ of time $t+1$ has rate of time preference $\emptyset$ where $\beta \neq \emptyset$. It suggests that individuals of generation g maximizes their inter-temporal utility by choosing the optimal consumption choices for themselves, and similarly for future generation $g+1$. When the new time, $t+1$ arrives, the individuals of generation $g+1$ will make the same choice so that they maximizes their inter-temporal utility with the consumption choices, under the discount factor $\emptyset$. This consumption plan will not be the same as the one which is chosen by the individuals of generation g. In other words, generation $g + 1$ will plan for themselves (based on their own discount rate $\emptyset$) instead of following the plans from the previous generation g. This suggests again time inconsistency, but now operating at the generational level.

From the above analysis, although a variant time preference does not satisfy the Koopmans' stationary axiom, several empirical studies prove that varying discounting can be applied at the individual level. Based on empirical data, individuals tend to make decisions that are inconsistent over time. Age-specific discounting at the individual level is empirically tested by Bishai (2004). Bishai mentions that if discounting is changing with ages, then aging will change the individual's rate of time preference. Therefore, given that social time preference is a complex aggregation of all individuals' time preference, aging will affect the social rate of time preference. Bishai conducts an empirical model with endogenous rate of time preference, and concludes that the rate of time preference estimated by using the National Labour Survey of Youth declines from 27 to 30 years old, but starts to increase quickly and consistently as individuals grow older.[35] Therefore, Bishai confirms that aging is one of the major predictors of the endogenous time preference. His findings also suggest that schooling is another factor that causes the possibility of dynamic inconsistency in the inter-temporal consumption paths. Intuitively, dynamic inconsistency is a reflection that a person is changing his decision while facing the same object when young compared to when old. Bashi explains that youth may not foresee fully their future so that when they mature and learn from personal experiences, they value objects differently.

In contrast, the study by Chao et al. (2009) has a different finding as they conclude that age is not related to the subjective discount rate, but health status and survival probability are. They provided empirical evidence that the subjective discount rate is

[35] The targeted population of the National Labour Survey of Youth is the U.S. youth.

large when the individual's health status is very poor or very good while others (who have normal health status) have relatively smaller subjective discount rates. Moreover, individuals with either very low or very high survival expectation also have large subjective discount rates. One disadvantage of this empirical work is that age and health status are possibly correlated, so that it affects the accuracy of their results. The other problem, as admitted by the authors, is that their results may be biased because the sample size is not large enough to reflect the age effect as the proportion of individuals aged 55 and over is only one quarter of the whole sample.[36]

There are several researchers who try to explain why people change their discount rate over their lifetime. Rogers (1994) explains that the marginal rate of time preference should vary with age, with young adults discounting the future at a higher rate than seniors. Posner (1995) believes that there are several different selves in an individual's life. The present and the future selves are different and they make separate decisions. People weigh their present consumption more heavily than their future consumption.

Trostel and Taylor (2001) assume that consumers do not need to have an intrinsic preference on consumption in order to have the instantaneous utility function varying with age. In fact, the ability of enjoying consumption is worsened as consumers get older, just as mental and physical abilities also deteriorate over time. To prove this point, they construct a utility function varying with age, and estimate the Euler equation with independent variables, such as interest rate, age, survival probability, permanent income, and education.[37] The key finding is that the impact of age is negative and is statistically significant. A "surprising" result is that the estimated coefficient on survival probability is

[36] The whole sample size is N=175 in the study by Chao et al. (2009).

[37] Trostel and Taylor (2001) first conduct their own format of utility function, then derive the Euler equation, and set an OLS equation with discount factor as the dependent variable, and age, interest rate, permanent income, education as independent variables. Secondly, they substitute the discount factor with age, interest rate, permanent income, and education and error terms into the Euler equation. Lastly, they take the logarithm of both size of the Euler equation. The estimated equation is logarithm of change of consumption path as the left-hand side, and the rest of terms in the Euler equation as the right-hand side.

not statistically significant. The explanation is that the planned bequests and annuities can eliminate the impact from survival probability. The same conclusion was arrived at by Yaari (1965), whose study demonstrates that the impact of survival uncertainty can be eliminated by annuities and planned bequests. Other researchers, such as Kotlikoff et al. (1982), conclude that private pensions, social security, and familial transfers can also act as imperfect annuities. Trostel and Taylor (2001) propose that it is the age factor that causes the discount rate to increase with age, not mortality uncertainty. In other words, it is aging that causes the discounting, not the probability of dying. The empirical finding in their study is that the rate of time preference is estimated to rise by a range of 1.1 to 2.8 percentage points per decade of an adult's age. Our calibration strategy also shows that the rate of time preference increases with age (see Section 4).

3. Model Description

The OLG-CGE model that we have built is based on the studies by Wright et al. (2012), Mérette and Georges (2010), and Börsch-Supan et al. (2006). The model includes aspects of the demographic changes, the production and consumption sectors, the government budget constraint, and the pension system.

3.1 Demographic Changes

The whole population is divided into 19 generations according to age groups.[38] The demographic projection, as an exogenous shock, is introduced in this model with demographic factors of fertility and survival rates which are calibrated from the United Nations (UN) population data.[39] The size of the population of generation $g1$ at time t is the size of population $g1$ at time $t-1$, $Pop_{j,t-1}$, times the birth rate, $birrate$, in that time period. The size of population for the other generations g $(g2, \dots, g19)$ is the

[38] The age groups are $g1$: $0-4$ years old; $g2$: $5-9$ years old; …; $g18$: $85-89$ years old; $g19$: 90 and older.
[39] The UN population projection data can be found at http://www.un.org/en/development/desa/population.

size of population of generation g at time $t-1$, $Pop_{j,t-1,g+\gamma-1}$, times the survival rate, $surrate$, of that generation in that time period. This population structure is expressed by the following two equations:

$$Pop_{j,t,g+\gamma} = Pop_{j,t-1,g+\gamma} * birrate_{j,t-1} \qquad \text{for } \gamma=0; \tag{4}$$

$$Pop_{j,t,g+\gamma} = Pop_{j,t-1,g+\gamma-1} * surrate_{j,t-1,g+\gamma-1} \qquad \text{for } \gamma=1,\ldots,18. \tag{5}$$

The expression in Eq. (4) simply means that the number of newly born is equal to the number of their preceding generation times the birth rate in the preceding period. Note that a time period in our model represents five years. The expression in Eq. (5) shows that the population, besides the first generation, depends on the population in the previous time period and the corresponding survival rate for that age group. We use UN population projection data to capture the birth rates and survival rate across time and ages. Hence, the model is capable of reproducing UN population projections.[40]

3.2 Producer

We assume an economy which produces one good only and which represents the GDP of this economy. One representative firm produces this good. The firm uses at time t, labour input L, and rents physical capital K, to produce output Y, with a Cobb-Douglas technology. The total factor productivity is TFP, and the share of physical capital is α. Thus, the production function is expressed as:

$$Y_{j,t} = TFP_j * K_{j,t}^{\alpha} * L_{j,t}^{1-\alpha}. \tag{6}$$ [41]

The firm maximizes its profit by selecting the optimal level of input of labour and capital by satisfying the first-order conditions:

$$\frac{wage_{j,t}}{P_{j,t}} = \left(1-\alpha_j\right) * TFP_j \left(\frac{K_{j,t}}{L_{j,t}}\right)^{\alpha_j}; \tag{7}$$

[40] The survival rate is defined as: $Survial\ rate = \frac{the\ population\ of\ G+1\ at\ time\ t+1}{the\ population\ of\ G\ at\ time\ t}$. The birth rate is defined as: $Birth\ rate = \frac{the\ population\ of\ g1at\ time\ t+1}{the\ population\ of\ g1\ at\ time\ t}$.

[41] The total factor productivity TFP is assumed to be constant over time. Therefore, there is no time dimension for this variable

$$\frac{rent_{j,t}}{P_{j,t}} = \alpha_j * TFP_j(\frac{K_{j,t}}{L_{j,t}})^{\alpha_j - 1}, \tag{8}$$

where $wage$ is the wage rate paid to the workers, $rent$ is the rental price for physical capital, and P is the output price. As this is a single good model, the price of the good will be assumed equal to 1 (i.e. the numeria).

3.3 Household

There is one representative household for each generation so that there are 19 representative households in this model. The young generations include $g1$ to $g4$ (age 0 to 19 years old), the working generations include $g5$ to $g13$ (age 20 to 64), and the retired generations include $g14$ to $g19$ (age 66 and over). Individuals start to work at age 20, and retire at age 65. In this model, utility maximization is done over the lifecycle, when the representative individual reaches 20 years of age. Young children depend on their parents' financial supports and public programs of health and education, and are implicitly included in their parents' optimization problem.

A representative household of age 20 at time t maximizes the inter-temporal utility by choosing the consumption bundles during its life-time. The inter-temporal utility function is expressed as follows:

$$U = \frac{1}{(1-\vartheta)} \sum_{\gamma=0}^{14} [\frac{(\prod_0^{\gamma} surrate_{t+\gamma,g+\gamma})(Con_{j,t+\gamma,g+\gamma})^{1-\vartheta}}{\prod_0^{\gamma}(1+\tau_{j,g+\gamma})}]. \tag{9}$$ [42,43]

$Con_{t,g}$ denotes the consumption by the household of generation g at time t, $\tau_{j,g}$ represents the rate of age-specific time preference, and ϑ (where $0 < \vartheta < 1$) is the inverse of the constant inter-temporal elasticity of substitution. The utility function captures the discounting of values of the future consumption through an age-dependent discount factor, $\frac{1}{1+\tau_{j,g}}$, and also captures the probability to consume through the survival

[42] The derivation of household utility function is given in Appendix A.2. There is only one region in the model, so j represents Canada.

[43] $\prod_{\gamma=0}^{14} surrate_{t+\gamma,g+\gamma} = surrate_{t,g} * \ldots * surrate_{t+14,g+14}$.

rate. In other words, we separately model the age-specific time preference and the survival rate. The advantage is that the survival rate does not affect the choice of consumption across time (as the survival rate is cancelled out when deriving the Euler equation), but the age-specific discount rate does.

The income of a representative household includes the labour income net of contribution on pension and net of labour income tax, plus the interest income net of tax, as well as the pension benefit (if this household is a retiree). The household consumes, pays the consumption tax, and accumulates the household assets. The household budget constraint of the representative household of generation $g+\gamma$ (where $\gamma = 0, \ldots 14$) is given by:

$$\begin{gathered} Hasset_{j,t+\gamma+1,g+\gamma+1} = \left(\frac{1}{surrate_{t+\gamma+1,g+\gamma+1}}\right) \\ \left\{\left(1 - LTax_{j,t+\gamma,g+\gamma} - Contr_{j,t+\gamma}\right) IncL_{j,t+\gamma,g+\gamma} \right. \\ + \left[1 + (1 - KTax_{j,t+\gamma}) R_{j,t+\gamma}\right] Hasset_{j,t+\gamma,g+\gamma} \\ \left. - \left(1 + CTax_{j,t+\gamma}\right) Con_{j,t+\gamma,g+\gamma} + Pens_{j,t+\gamma,g+\gamma}\right\} \end{gathered} \tag{10}$$

where $IncL$ is the labour income, R is the rate of return on household assets, $Hasset$. $Ktax$ and $Ltax$ are capital and labour income taxes, $Contr$ is the contribution rate of labour income to the pension plan, and $Pens$ is the pension benefit received by the household during retirement.[44] If the person is still working, then this individual does not receive pension benefit (i.e. $Pens = 0$). The inter-temporal budget constraint of the representative household can be obtained from Eq. (10), which is written as follows:

$$\sum_{\gamma=0}^{14} \frac{\prod_{\gamma} surrate_{t+\gamma,g+\gamma} 1+CTax_{t,g+\gamma}) P^{c}{}_{j,t+\gamma,g+\gamma} Con_{j,t+\gamma,g+\gamma}}{\prod_{\tau=t}^{t+\gamma} [1+(1-Ktax_{j,\tau}) R_{j,\tau}]} =$$

$$\sum_{\gamma=0}^{14} \left\{ \frac{\prod_{\gamma} surrate_{t+\gamma,g+\gamma}}{\prod_{\tau=t}^{t+\gamma} [1+(1-Ktax_{j,\tau}) R_{j,\tau}]} \left[IncL_{j,t+\gamma,g+\gamma} * (1 - Ltax_{j,t+\gamma} - \right.\right.$$

[44] The derivation of the representative household's budget constraint is given in Appendix A.2.

$$Contr_{j,t+\gamma}) + Pens_{j,t+\gamma,g+\gamma}]\Big\}.^{45} \tag{11}$$

The labour income earned by the household of generation g at each period is referred to as:

$$IncL_{j,t,g} = wage_{j,t} * EL_{j,g} * Lsup_{j,g} * Lpar_{j,gw} \tag{12}$$

where $Lsup$ is the non-effective units of labour supply of a representative household at generation g. EL is an earning profile, which is estimated from the Survey of Labour Income Dynamics (SLID), a longitudinal household survey conducted by Statistics Canada. $Lpar$ is the labour force participation rates.[46]

The household maximizes the inter-temporal utility (Eq. 9) with respect to the inter-temporal household budget constraint (Eq. 11). The first-order condition from the household's utility maximization is:

$$\frac{Con_{j,t+\gamma+1,g+\gamma+1}}{Con_{j,t+\gamma,g+\gamma}} = \{\frac{(1+CTax_{j,t+\gamma})}{(1+CTax_{j,t+\gamma+1})}\frac{[1+(1-Ktax_{j,t+\gamma+1})R_{j,t+\gamma+1}]}{(1+\tau_{j,g+\gamma+1})}\}^{1/\vartheta} \tag{13}$$

where $Ctax$ is the tax rate on household consumption.[47] As mentioned earlier, in our model the Euler equation (Eq. 13) is different from a more conventional OLG-CGE model. Given a traditionally imposed constant rate of time preference, the slope of consumption path should be constant across time. Older generations always consume more than their young counterparts as long as $\tau < R$. However, the age-specific rate of time preference, $\tau_{j,g}$, in our model, allows the slope of consumption path to vary across time and generations so as to be able to replicate a consumption age profile which reflects the observed profiles from the household survey and the NTA methodology.[48] This procedure overcomes the inaccuracy of the assumption of a constantly increasing consumption pattern over generations in more conventional OLG-CGE models.

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[45] $P^c{}_{j,t+\gamma,g+\gamma}$ is set to be one.

[46] The details of the estimation of per capita labour income age profile are in the study by Zhang et al. (2013).

[47] The derivation of the Euler equation is given in Appendix A.2.

[48] The age profile of consumption is estimated through the Survey of Household Spending, and the Canadian Community Health Survey. The details of the estimation are in the study by Zhang et al. (2013).

3.4 Pension System

The public pension plan is modeled as a "pay-as-you-go" system, where the pensions of the elderly are funded by contributions from current workers. Given that the pension benefits received by the retired generations are an exogenous replacement proportion, $PenR$, of the average labour income of their lifetime labour income, the pension benefit is defined as:

$$Pens_{t,gr} = PenR * \frac{1}{9}\sum_{gw}(wage_{j,t-9-ord(gr)+ord(gw)} * EL_{j,gw} * Lsup_{j,gw} * Lpar_{j,gw}), \tag{14}$$

where gr is the retired generations ($g14, \ldots, g19$), and gw is the working generations ($g5, \ldots, g13$); $ord(gr)$ is the ordinal number of set gr, and $ord(gw)$ is the ordinal number of set gw.[49,50] Pension benefits defined in Eq. (14) are financed by the labour income of the workers as suggested by Eq. (15) where the contribution $Contr$, is determined endogenously in the model to ensure that the total pensions benefits equal total contribution collected:

$$\sum_{gr} Pop_{j,t,gr} * Pens_{j,t,gr} = Contr_{j,t} * (\textstyle\sum_{gw} Pop_{j,t,gw}\, wage_{j,t} * EL_{j,gw} * Lsup_{j,gw}\, Lpar_{j,gw}). \tag{15}$$

3.5 Investment

Capital stock, Ks, depreciates at a constant rate, $depr$, so that the change of capital stock across time is given by:

$$Ks_{j,t+1} = Inv_{j,t} + \left(1 - depr_j\right) * Ks_{j,t}, \tag{16}$$

Where gross investment, Inv, is equal to the change in the capital stock plus the capital depreciation. The net rate of return on the capital stock is defined as the rental price deducted by the depreciation rate:

$$R_{j,t} = rent_{j,t} - depr_j. \tag{17}$$

[49] The further explanation of Eq. (14) is provided in the Appendix A.3.
[50] The ordinal number returns the position of gw or gr in their respective sets, starting from the first value.

3.6 Government

The government is assumed to have age-specific public programs for health care and education, and other age-neutral programs, such as national defence. Government revenue includes tax revenue on labour income, interest income, and consumption spending by the household. The government budget constraint is expressed as follows:

$$(Bond_{j,t+1} - Bond_{j,t}) + \sum_g Pop_{j,t,g} * (Ltax_{j,t} * IncL_{j,t,g} + Ctax_{j,t} * Con_{j,t,g} + Ktax_{j,t} * R_{j,t} * Hasset_{j,t,g} = {Gov_{j,t}}^O + {Gov_{j,t}}^E + {Gov_{j,t}}^H + R_{j,t} * Bond_{j,t}, \quad (18)$$

where $Bond$ is government public debt, and $Hasset$ is household assets. Gov^E and Gov^H are government spending on education and health care programs, and Gov^O is the spending on other sectors. The right-hand side of this equation (Eq. 18) represents all the government expenditures, including interest payment on the public debt. The second term in the left-hand side of equation (Eq. 18) refers to the government revenues. Eq. (18) can hold either because the government issue debt when government expenditures exceed revenues, or because tax rates are adjusted. In our model, we assume that the public debt remains constant per capita. Any further adjustment is borne by the labour income tax rate which is determined endogenously to ensure that the government fulfills its budget constraint. The tax revenues from consumption, labour income and interest income depend of course on the cohort sizes ($Pop_{j,t,g}$). Because public expenditure on health care and education are age-dependent, we construct the parameters of public expenditure by age group.[51] Per capita public expenditure on health care by age group is represented by $hecps$, while per capita public expenditure on education by age group is represented by $edups$. The total public health care expenditure is thus expressed as:

$${Gov_{j,t}}^H = \sum_g Pop_{j,t,g} * hecps_g, \quad (19)$$

[51] The public spending on health care and education will be discussed in the calibration section. A more detailed description of the estimation of age profiles of per capita public expenditure is in Chapter 1.

and the total public education expenditure is expressed as:

$$Gov_{j,t}{}^{E} = \sum_g Pop_{j,t,g} * edups_g. \tag{20}$$

The public expenditure on other sectors is age-independent and given by:

$$Gov_{j,t}{}^{O} = Tpop_{j,t} * othps_j \tag{21}$$

where $Tpop$ is the size of total population, and $othps$ is a constant amount of other government spending allocated per capita. Gov^H and Gov^E are affected by the age structure of the population while Gov^O is not and depends only on the total size of the population.

3.7 Market Clearing Conditions

The market clearing conditions include the goods, labour, capital, and asset markets. The goods market is cleared when the supply of output equals the demand of goods on household consumption, investment, and government consumption:

$$Y_{j,t} = \sum_g Pop_{j,t,g} * Con_{j,t,g} + Inv_{j,t} + Gov_{j,t}{}^{O} + Gov_{j,t}{}^{E} + Gov_{j,t}{}^{H}. \tag{22}$$

In the labour market, labour supply equals labour demand:

$$\sum_{gw} Pop_{j,t,gw} * Lsup_{j,gw} * EL_{j,gw}\, Lpar_{j,gw} = L_{j,t}, \tag{23}$$

and in the capital market, capital supply equals capital demand:

$$Ks_{j,t} = K_{j,t}. \tag{24}$$

Finally, as an aggregation condition, we must satisfy the equation:

$$\sum_g Pop_{j,t+1,g+1} * Hasset_{j,t+1,g+1} = Bond_{j,t+1} + Ks_{j,t+1}, \tag{25}$$

where the left-hand side of this equation is the asset accumulated by the household due to private savings. We assume that $Bond$ and Ks are perfectly substitutable so that net returns on financial asset and physical capital are equalised (R).

4. Calibration

The model is calibrated on the basis of the SNA data for Canada. The tax rates of consumption, labour income, and interest income are calibrated through the tax revenues for the corresponding categories. The age-specific government spending on education and health care is from the NTA database for Canada (Zhang et al., 2013). Government spending on education is mostly focused on the young generations, while health care spending is geared towards the seniors, especially the elderly beyond age 70. The share of capital in the production function is assumed to be 0.28, and the inter-temporal elasticity of substitution is assumed to be 1.5, both parameters consistent with other CGE studies (e.g. Mérette and Georges, 2010). The pension benefit ratio is set to be 35% of total labour income of the current working generations.

As mentioned in Section 2, we introduce an age-dependent rate of time preference, rather than using a constant rate of time preference. In the calibration procedure, this rate is solved endogenously so as to be able to replicate the exogenously given consumption age profile of the NTA methodology (described in Chapter 1). Figure 2.1 shows that the age-dependent rate of time preference required generating the NTA consumption age profile for Canada. This rate increases gradually from young to old, and then declines slightly after age 80 ($g16$). The age-dependent rate of time preference is lower than the rate of return on capital for the young and the middle-age generation which reflects that those generations are more patient than the general financial market (represented by the given five year interest rate, normalized at 1). On the other hand, the seniors have a rate of time preference higher than the rate of return on capital, which implies that they are more impatient than the overall financial market.

5. Simulation Results

Population projection in our model reproduced the UN medium variant scenario.[52] Based on this scenario, total population will increase by 49% as shown in Figure 2.2 for

[52] The UN population projection website is http://esa.un.org/wpp/Excel-Data/population.htm

the period of 2015 to 2080. The projected changes by age groups are fairly different. The senior population will increase by 200% while the youth population will increase by 31% and the working age population will increase even less, by 18%. Given this significant population aging process, we expect a substantial change in the Canadian economy. This section discusses the simulation results of the impacts of demographic changes on the Canadian economy, and several possible policy interventions on the labour market in order to mitigate this impact.

Figure 2.3 shows the simulated change in output, capital stock, and productivity-adjusted labour force with respect to their levels in 2005. The top curve provides the evidence that with older population the capital stock is consistently accumulated during the period from 2005 to 2105. An aging process brings the economy more capital stock because older generations accumulate more assets than younger generations. Higher level of capital stock contributes more to the production, so that the total output increases along the path of capital stock. In addition, the simulation results indicate that the contribution of labour input factor is substantially smaller as a result of the population transition to an aging society.

Higher capital stock accumulated with the aging process brings a lower rate of return on capital. The rate of return drops quickly by 10% from 2015 to 2030 (see Figure 2.4). This significant decline reflects that the capital market is mostly influenced by the asset accumulation of seniors in the next two decades. Thereafter, the projected path of the rate of return is fluctuating around a level about 4% below its benchmark value.

Figure 2.5 shows the path of government spending on age-sensitive (health care and education) and age-neutral (other) programs. The other government spending is increasing at the same rate as the total population, and the government spending on health care and education is age-dependent (see Eq. 21). While education spending should rise with a larger population size of younger generations, younger generations in an aging society increase at a lower rate compared to the overall growth rate of the total population (see Figure 2.2). Therefore, our results show that government spending on education is changing at a lower rate than age-neutral program spending. On the other hand, population aging also brings a larger growth rate of older generation compared to the growth rate of total population. The simulation result shows that health care spending increases by about 150% after a century, which is seven times higher than the growth rate of total population. This shows that the increase of public spending, especially age-sensitive programs on health care, would create serious challenge to the Canadian economy. The government can adjust the wage tax rate to balance its budget constraint. Figure 2.6 indicates that in order to pay the age-sensitive public programs on health care and education, the wage tax rate will need to be raised by 150% by 2055, and 200% by 2105.

The pension system in this model is a defined benefit “pay-as-you-go” scheme. Under this scheme, the retirees’ pension benefits would be fully funded by the contribution of the current working generations. Figure 2.7 shows how the total pension spending evolves during the next century, increasing by 150% after five decades, and close to 250% by 2105. Even if we remove the impact of the growth of total population, the net increase of total pension benefit due to population aging remains high at 115% by 2055, and 200% by 2105. Of course this will increase the pressure on the contribution rate of working generations to fund the pensions. Figure 2.8 shows that the contribution rate needs to increase from the present rate of 10% to about 29% after a century so that pension benefits can be fully funded.

Figure 2.9 shows the projections of percentage change of GDP per capita and consumption per capita. These projections provide evidence that population aging would lower the standard of living with respect to that of 2005. GDP per capita would decline by 15% by 2050, and by 20% by 2105. The decrease of GDP per capita is partly due to the increase of the total population, but a more important cause is the lower proportion of workers due to a changing age structure. In addition, by removing the former factor (the growth of total population), net change of GDP per capita is still at a lower level than in 2005. This suggests that the change in the age structure alone will drop GDP per capita by 5% by 2050, and by 10% after a century. Moreover, population aging also reduces consumption per capita at a much higher rate. For instance, the rate of change in the level of consumption per capita in 2075 is twice as low compared with the rate of change in the GDP per capita.

Population aging increases the scarcity of labour force, relative to capital, therefore, resulting in an increase in the wage rate relative to the rate of return on capital stock. Figure 2.10 shows that the wage rate stays relatively stable over the century (growing at less than 2% during a 100-year period). However, by taking into account the return on capital stock, our results show that the ratio of wage rate relative to the rate of return on capital increases rapidly to 13% by 2030, and then fluctuates around a lower level about 4% after 2030. The pattern of wage rate relative to the rate of return on capital is the mirror image of the change of the rate of return on capital in Figure 2.4.

Given the shortage of labour force, the Canadian government may consider measures that could increase the labour force participation. Figure 2.11 shows the projections under different scenarios of labour force participation along with the benchmark impact of population aging on GDP per capita until 2105. In scenario 1, an increase in the general labour participation rate of individuals between ages 20 to 64 by 10% results in projected GDP per capita increase by the same magnitude. The second scenario is to raise the older workers' (aged 50 to 64) labour force participation rate by

10%. The impact of scenario 2 is much smaller as the GDP per capita would increase by only 3% with respect to the benchmark. Even under scenario 1, maintaining the 2005 standard of living will be extremely difficult after 2025. Finally, current retirement age is roughly 65, but encouraging older workers to remain in the labour force for a longer time can also help in maintaining the living standard. In the late retirement of scenario 3 (i.e. postponing the retirement age from 65 to 70), the projected growth rate of GDP per capita rises by 4% above the benchmark. However, this will still not be sufficient to offset the impact of aging after 2025.

6. Conclusion

This chapter develops a methodology that introduces an age-dependent rate of time preference so as to calibrate an OLG-CGE model on the per capita age profile NTA consumption path derived in Chapter 1. Our findings suggest that the economic challenge from an aging population will be significant. However, the Canadian government may introduce policy that could encourage labour force participation. Our results suggest that even under the most advantageous scenario (of an increase in the general labour force participation rate for ages 20 to 64), maintaining the current standard of living will be extremely difficult after 2025. Nevertheless, such a step would help reduce the economic pressure from population aging. Possible future extensions of this analysis could be the extension to an open economy framework, including the immigration effects.

Appendix for Chapter 2

A.1 Figures

Figure 2.1: Normalized Age-dependent Rates of Time Preference, Canada

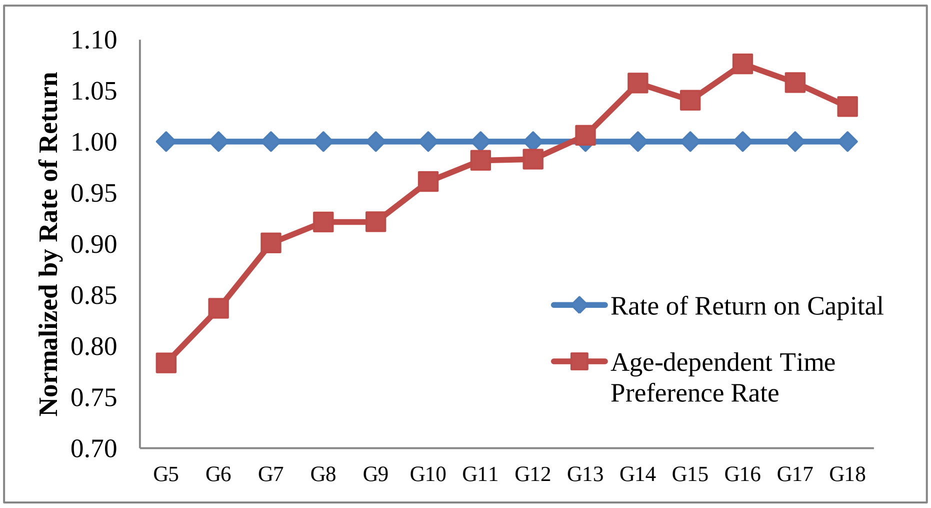


Figure 2.2: Projection of Percentage Changes of Population by Age Groups, Canada, 2015 - 2105

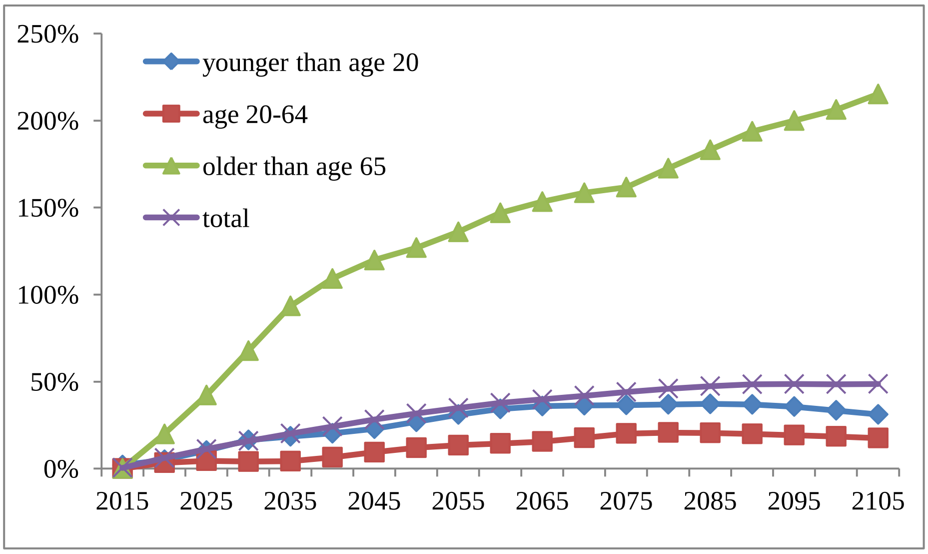


Figure 2.3: Projection of Percentage Changes in Output, Capital Stock and Productivity-adjusted Labour Force, Canada, 2015 - 2105

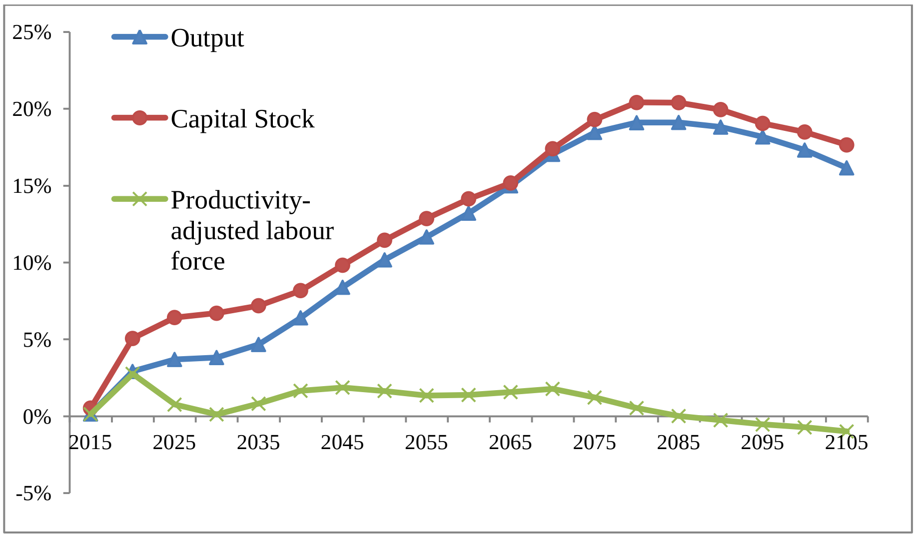


Figure 2.4: Projection of Percentage Changes in Rate of Return, Canada, 2005 - 2105

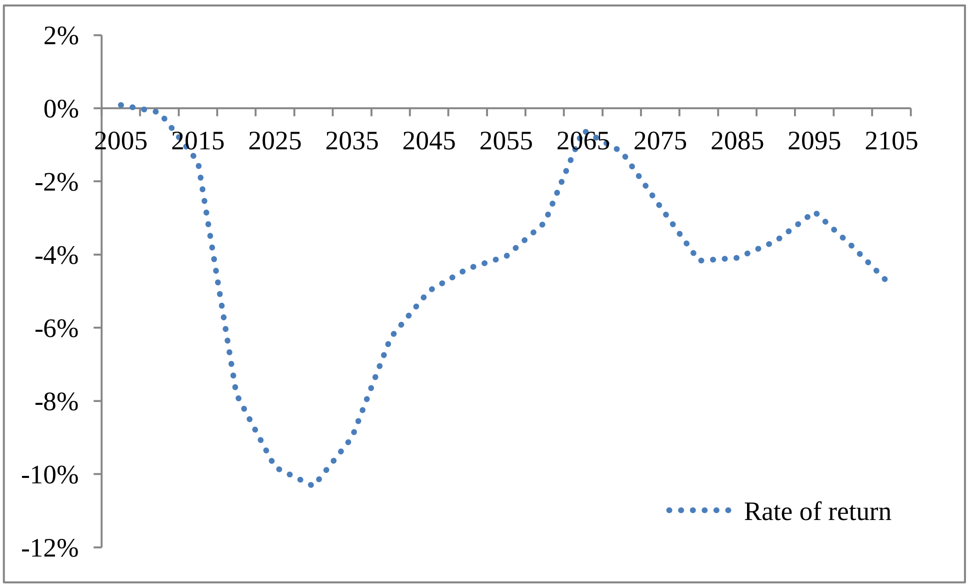


Figure 2.5: Projection of Percentage Changes in Government Spending, Age Sensitive Program (Health Care and Education) and Age-unrelated Program (Other Government Spending), Canada, 2015 - 2105

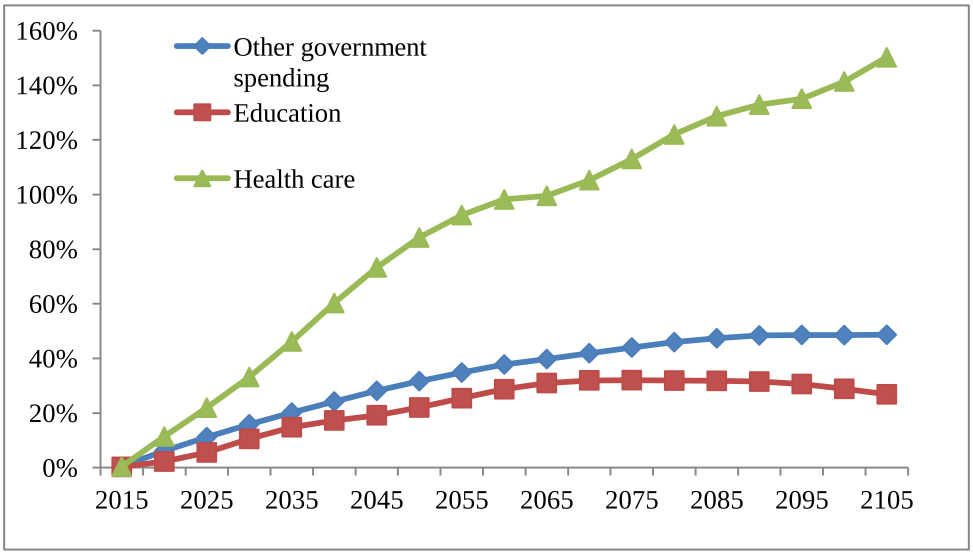


Figure 2.6: Projection of Change of Wage Tax Rate, Canada, 2015 - 2105

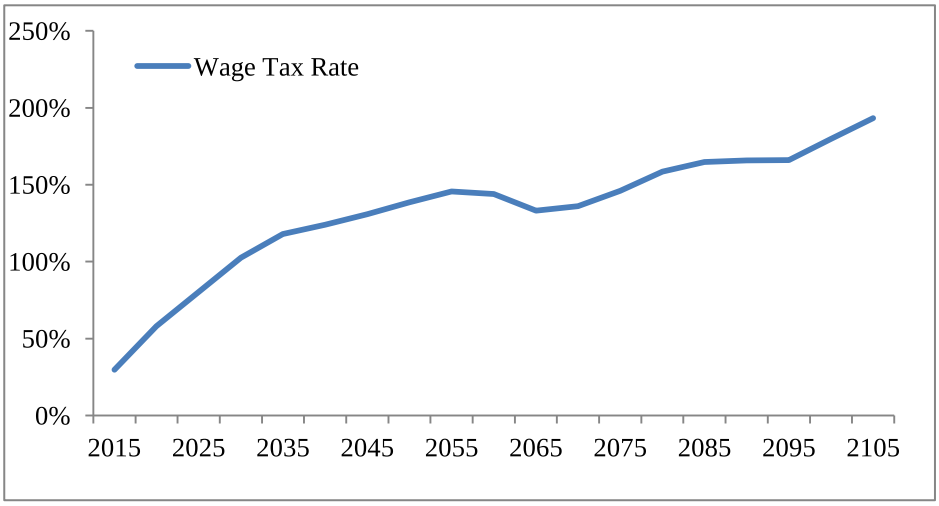


Figure 2.7: Projection of Percentage Changes in Pension Program, Canada, 2015 – 2105

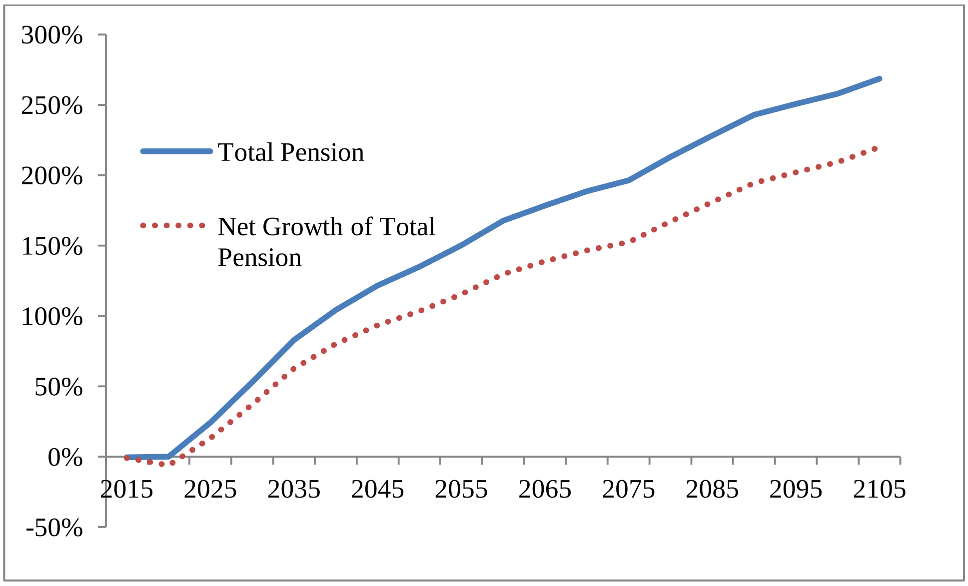


Figure 2.8: Projection of Change in Contribution Rate in Pension Plan, Canada, 2015 - 2105

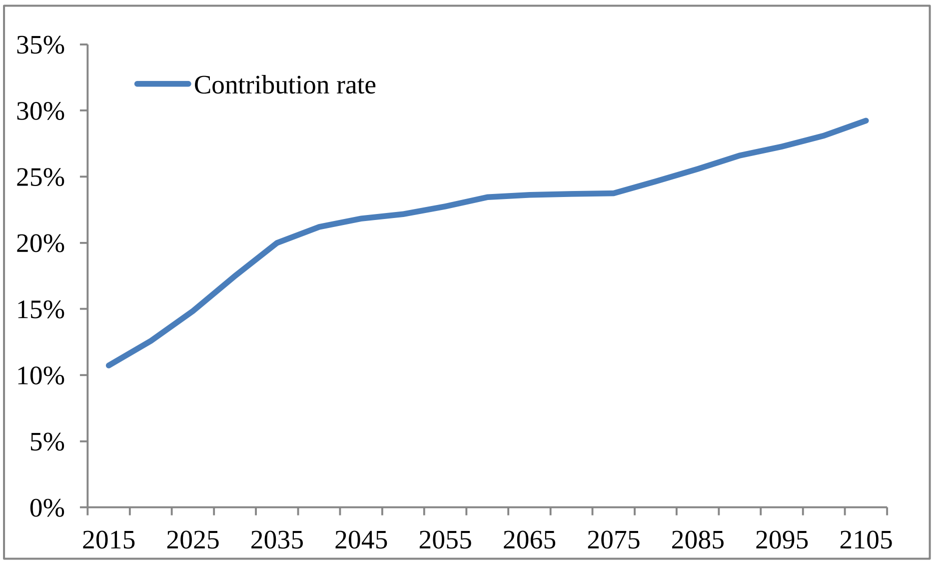


Figure 2.9: Projection of Percentage Change of GDP per Capita, GDP per Capita and Consumption per Capita, Canada, 2015 - 2105

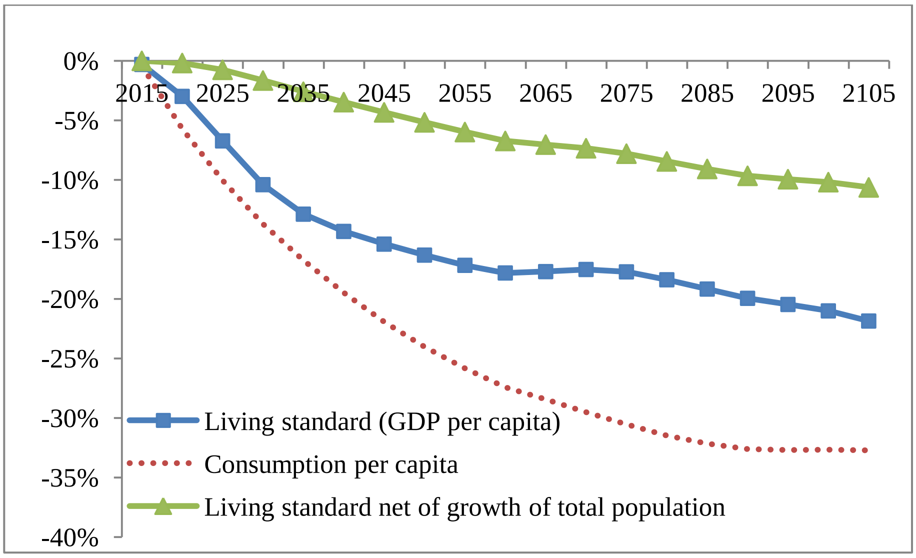


Figure 2.10: Projection of Percentage Change of Wage Rate, and Wage Rate Relative to Rate of Return on Capital, Canada, 2010 - 2105

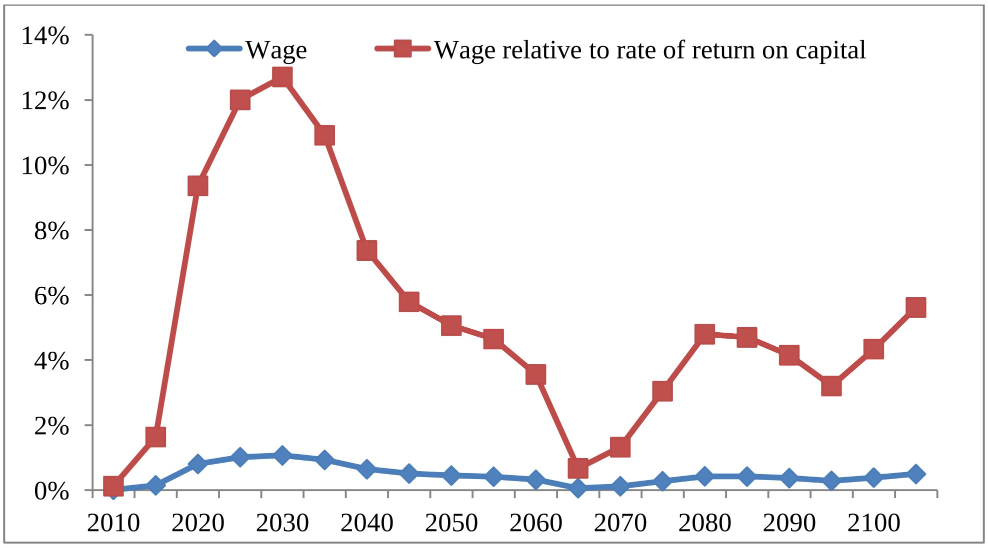
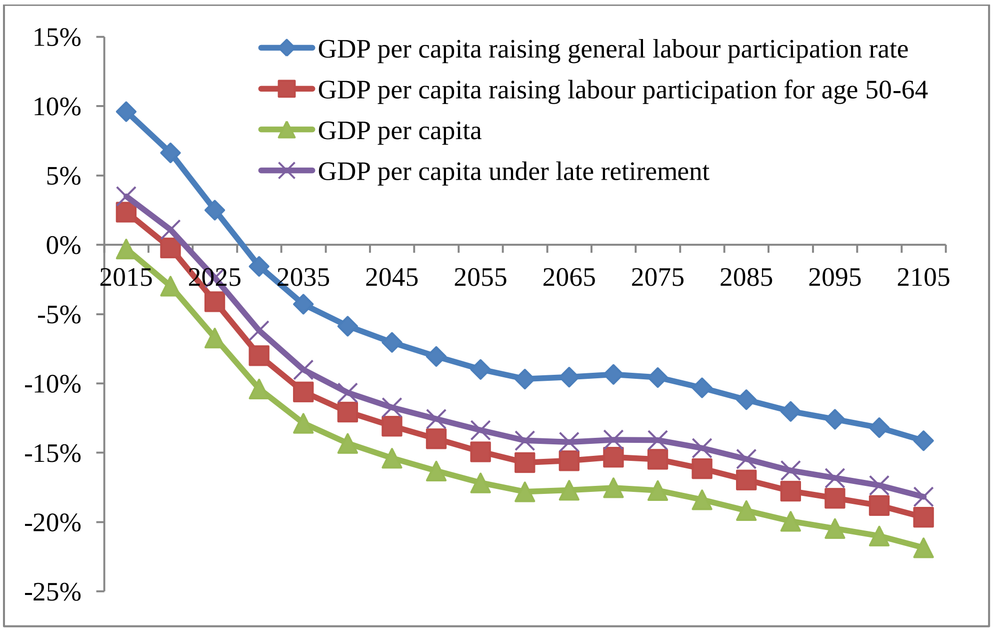


Figure 2.11: Projection of Percentage Change of GDP per Capita by Raising Labour Participation Rate, Canada, 2015 - 2105



A.2 Equations in Household Problem

The utility function for the representative household is:

$$U = \frac{surrate_{t,g}U(Con_{j,t,g})}{1+\tau_{j,g}} + \frac{(surrate_{t,g}surrate_{t+1,g+1})U(Con_{j,t+1,g+1})}{(1+\tau_{j,g})(1+\tau_{j,g+1})} + \cdots + \frac{(surrate_{t,g}surrate_{t+1,g+1} \ldots surrate_{t,g+14})U(Con_{j,t+1,g+14})}{\left(1+\tau_{j,g}\right)\left(1+\tau_{j,g+1}\right) \ldots \left(1+\tau_{j,g+14}\right)}, \tag{A.2.1}$$

where g=(g5,…,g19) so there are 15 generations. Given that the utility function is CES function, the above equation becomes:

$$U = \frac{surrate_{t,g}\left(Con_{j,t,g}\right)^{1-\vartheta}}{(1-\vartheta)\left(1+\tau_{j,g}\right)} + \frac{(surrate_{t,g}surrate_{t+1,g+1})\left(Con_{j,t+1,g+1}\right)^{1-\vartheta}}{(1-\vartheta)\left(1+\tau_{j,g}\right)\left(1+\tau_{j,g+1}\right)} + \cdots + \frac{(surrate_{t,g}surrate_{t+1,g+1} \ldots surrate_{t+14,g+14})\left(Con_{j,t+14,g+14}\right)^{1-\vartheta}}{(1-\vartheta)\left(1+\tau_{j,g}\right)\left(1+\tau_{j,g+1}\right) \ldots \left(1+\tau_{j,g+14}\right)}, \tag{A.2.2}$$

which can be simplified as Eq. (6) step by step. From Eq. (A.2.2), we can take the common term $\frac{1}{(1-\vartheta)}$, so it becomes:

$$U = \frac{1}{(1-\vartheta)}\left[\frac{surrate_{t,g}\left(Con_{j,t,g}\right)^{1-\vartheta}}{\left(1+\tau_{j,g}\right)} + \frac{(surrate_{t,g}surrate_{t+1,g+1})\left(Con_{j,t+1,g+1}\right)^{1-\vartheta}}{\left(1+\tau_{j,g}\right)\left(1+\tau_{j,g+1}\right)} + \cdots + \frac{\left(surrate_{t,g}surrate_{t+1,g+1} \ldots surrate_{t+14,g+14}\right)\left(Con_{j,t+14,g+14}\right)^{1-\vartheta}}{\left(1+\tau_{j,g}\right)\left(1+\tau_{j,g+1}\right)\ldots\left(1+\tau_{j,g+14}\right)}\right]; \tag{A.2.3}$$

$$U = \frac{1}{(1-\vartheta)}\sum_{\gamma=0}^{14}\left[\frac{(\prod_0^\gamma surrate_{t+\gamma,g+\gamma})\left(Con_{j,t+\gamma,g+\gamma}\right)^{1-\vartheta}}{\prod_0^\gamma\left(1+\tau_{j,g+\gamma}\right)}\right]. \tag{A.2.3}$$

Next, we will derive the household budget constraints step by step:

$$surrate_{t,g}(1+CTax_{j,t})P^c{}_{j,t}Con_{j,t,g} + \left(surrate_{t,g}surrate_{t+1,g+1}\right)Hasset_{j,t+1,g+1} = surrate_{t,g}[\left(1-LTax_{j,t} - Contr_{j,t}\right)IncL_{j,t,g} + (1+\left(1-KTax_{j,t}\right)R_{j,t})Hasset_{j,t,g}]; \tag{A.2.4}$$

$$\left(surrate_{t,g}surrate_{t+1,g+1}\right)\left(1+CTax_{j,t+1}\right)P^c{}_{j,t+1}Con_{j,t+1,g+1} + \left(surrate_{t,g}surrate_{t+1,g+1}surrate_{t+2,g+2}\right)Hasset_{j,t+2,g+2} = \left(surrate_{t,g}surrate_{t+1,g+1}\right)[\left(1-LTax_{j,t+1}-Contr_{j,t}\right)IncL_{j,t+1,g+1} + (1+\left(1-KTax_{j,t+1}\right)R_{j,t+1})Hasset_{j,t+1,g+1}]; \tag{A.2.5}$$

...;

$$\left(surrate_{t,g}surrate_{t+1,g+1} \ldots surrate_{t+13,g+13}\right)\left(1+CTax_{j,t+13}\right)P^c{}_{j,t+13}Con_{j,t+13,g+13} + \left(surrate_{t,g}surrate_{t+1,g+1} \ldots surrate_{t+13,g+13}surrate_{t+14,g+14}\right)Hasset_{j,t+14,g+14} = \left(surrate_{t,g}surrate_{t+1,g+1} \ldots surrate_{t+13,g+13}\right)[\left(1-LTax_{j,t+13}-Contr_{j,t}\right)IncL_{j,t+13,g+13} + (1+\left(1-KTax_{j,t+13}\right)R_{j,t+13})Hasset_{j,t+13,g+13} + Pens_{j,t+13,g+13}]; \tag{A.2.6}$$

$$\begin{aligned}&\left(surrate_{t,g}surrate_{t+1,g+1}\dots surrate_{t+14,g+14}\right)\\&\left(1+CTax_{j,t+14}\right)P^{c}{}_{j,t+14}Con_{j,t+14,g+14}\\&+\left(surrate_{t,g}surrate_{t+1,g+1}\dots surrate_{t+14,g+14}surrate_{t+15,g+15}\right)Hasset_{j,t+15,g+15}\\&=\left(surrate_{t,g}surrate_{t+1,g+1}\dots surrate_{t+14,g+14}\right)\\&[\left(1-LTax_{j,t+14}-Contr_{j,t}\right)IncL_{j,t+14,g+14}+(1+\\&\left(1-KTax_{j,t+14}\right)R_{j,t+14})Hasset_{j,t+14,g+14}+\ Pens_{j,t+14,g+14}].\end{aligned}\tag{A.2.7}$$

For g=g5 in Eq. (A.2.4), $Hasset_{j,t,g}=0$; for g=g14,…,g19, $Pens_{j,t+14,g+14}>0$; for g=g19 in Eq. (A.2.7), $Hasset_{j,t+15,g+15}=0$ as this is the last generation to survive. If we rearrange the above equations, they become:

$$\begin{aligned}&Hasset_{j,t+1,g+1}\\&=\left(\frac{1}{surrate_{t+1,g+1}}\right)\Bigg[\left(1-LTax_{j,t}-Contr_{j,t}\right)IncL_{j,t,g}\\&+\underbrace{(1+\left(1-KTax_{j,t}\right)R_{j,t})Hasset_{j,t,g}}_{=0}-\ (1+CTax_{j,t})P^{c}{}_{j,t}Con_{j,t,g}\Bigg];\end{aligned}\tag{A.2.8}$$

$$\begin{aligned}&Hasset_{j,t+2,g+2}\\&=\left(\frac{1}{surrate_{t+2,g+2}}\right)\\&\ \big[\big(1-LTax_{j,t+1}\\&\ -Contr_{j,t+1})IncL_{j,t+1,g+1}\\&\ +\left(1+\left(1-KTax_{j,t+1}\right)R_{j,t+1}\right)Hasset_{j,t+1,g+1}-(1\\&\ +CTax_{j,t+1})P^{c}{}_{j,t+1}Con_{j,t+1,g+1}\big];\end{aligned}\tag{A.2.9}$$

…;

$$\begin{aligned}&Hasset_{j,t+14,g+14}\\&=\left(\frac{1}{surrate_{t+14,g+14}}\right)\left[\left(1-LTax_{j,t+13}-Contr_{j,t+13}\right)IncL_{j,t+13,g+13}\right.\\&+\left(1+\left(1-KTax_{j,t+13}\right)R_{j,t+13}\right)Hasset_{j,t+13,g+13}+\ Pens_{j,t+13,g+13}\\&\left.-\left(1+CTax_{j,t+13}\right)P^{c}{}_{j,t+13}Con_{j,t+13,g+13}\right];\end{aligned}\tag{A.2.10}$$

$$\begin{aligned}&\underbrace{Hasset_{j,t+15,g+15}}_{0}\\&=\left(\frac{1}{surrate_{t+15,g+15}}\right)\left[\left(1-LTax_{j,t+14}-Contr_{j,t+14}\right)IncL_{j,t+14,g+14}\right.\\&+\left(1+\left(1-KTax_{j,t+14}\right)R_{j,t+14}\right)Hasset_{j,t+14,g+14}+\ Pens_{j,t+14,g+14}\\&\left.-\left(1+CTax_{j,t+14}\right)P^{c}{}_{j,t+14}Con_{j,t+14,g+14}\right].\end{aligned}\tag{A.2.11}$$

From the above series of equations, the general expression of household of generation g, where $g = [g5, \dots, g13]$ budget constraint is that:

$$\begin{aligned}&Hasset_{j,t+\gamma+1,g+\gamma+1} \\ &= \left(\frac{1}{surrate_{t+\gamma+1,g+\gamma+1}}\right)\left[\left(1 - LTax_{j,t+\gamma} - Contr_{j,t+\gamma}\right)IncL_{j,t+\gamma,g+\gamma} + (1 \right. \\ &+ \left(1 - KTax_{j,t+\gamma}\right)R_{j,t+\gamma})Hasset_{j,t+\gamma,g+\gamma} + \ Pens_{j,t+\gamma,g+\gamma} \\ &\left. - \left(1 + CTax_{j,t+\gamma,}\right)P^c{}_{j,t+\gamma}Con_{j,t+\gamma,g+\gamma}\right],\end{aligned} \tag{A.2.12}$$

where $\gamma = 0, \dots, 13$. The household budget constraint of the last generation ($g = gn$) is that

$$\begin{aligned}&0 = \\ &\left(1 - LTax_{j,t} - Contr_{j,t}\right)IncL_{j,t,gn} + [1 + \\ &\left(1 - KTax_{j,t}\right)R_{j,t}]Hasset_{j,t,gn} + \ Pens_{j,t,gn} - \left(1 + CTax_{j,t}\right)P^c{}_{j,t}Con_{j,t,gn} \ .\end{aligned} \tag{A.2.13}$$

The expression of inter-temporal household budget constraint over the life-time is that:

$$\begin{aligned}&\frac{\left(surrate_{t,g}\right)(1+CTax_{j,t})P^c{}_{j,t}Con_{j,t,g}}{[1+\left(1-KTax_{j,t}\right)]R_{j,t}} + \dots + \\ &\frac{\left(surrate_{t,g}surrate_{t+1,g+1}\dots surrate_{t+14,g+14}\right)(1+CTax_{j,t+14})P^c{}_{j,t+14}Con_{j,t+14,g+14}}{[1+\left(1-KTax_{j,t+14}\right)]R_{j,t+14}*\dots*[1+\left(1-KTax_{j,t}\right)]R_{j,t}} = \\ &\frac{\left(surrate_{t,g}\right)[\left(1-LTax_{j,t}-Contr_{j,t}\right)IncL_{j,t,g} + \ Pens_{j,t,g}]}{[1+\left(1-KTax_{j,t}\right)]R_{j,t}} + \dots + \\ &\frac{\left(surrate_{t,g}surrate_{t+1,g+1}\dots surrate_{t,g+14}\right)[\left(1-LTax_{j,t+14}-Contr_{j,t+14}\right)IncL_{j,t+14,g+14} + \ Pens_{j,t+14,g+14}]}{[1+\left(1-KTax_{j,t+14}\right)]R_{j,t+14}*\dots*[1+\left(1-KTax_{j,t}\right)]R_{j,t}} \ .\end{aligned} \tag{A.2.14}$$

This equation, Eq. (A.2.14), can be simplified as:

$$\begin{aligned}&\sum\nolimits_{\gamma=0}^{14} \frac{\prod_\gamma surrate_{t+\gamma,g+\gamma}(1 + CTax_{j,t})P^c{}_{j,t+\gamma}Con_{j,t+\gamma,g+\gamma}}{\prod_{\tau=t}^{t+\gamma}[1 + (1 - Ktax_{j,\tau})R_{j,\tau}]} \\ &= \sum\nolimits_{\gamma=0}^{14} \left\{\frac{\prod_\gamma surrate_{t+\gamma,g+\gamma}}{\prod_{\tau=t}^{t+\gamma}[1 + (1 - Ktax_{j,\tau})R_{j,\tau}]}\left[IncL_{j,t+\gamma,g+\gamma} * (1 - Ltax_{j,t+\gamma} \right.\right. \\ &\left.\left. - Contr_{j,t+\gamma}) + Pens_{j,t+\gamma,g+\gamma}\right]\right\}.\end{aligned} \tag{A.2.15}$$

The representative household maximizes the utility, Eq. (A.2.3), subject to the budget constraint, Eq. (A.2.15), and then the Lagrangian function for this problem is:

$$
\begin{aligned}
&L \\
&= \frac{1}{(1-\vartheta)} \sum_{\gamma=0}^{14} [\frac{(\prod_{\gamma} surrate_{t+\gamma,g+\gamma})\left(Con_{j,t+\gamma,g+\gamma}\right)^{1-\vartheta}}{\prod_{\gamma}(1+\tau_{j,g+\gamma})}] \\
&+ \lambda \left\{ \sum_{\gamma=0}^{14} \left\{ \frac{\prod_{\gamma} surrate_{t+\gamma,g+\gamma}}{\prod_{\tau=t}^{t+\gamma}\left[1+\left(1-Ktax_{j,\tau}\right)R_{j,\tau}\right]} \left[IncL_{j,t+\gamma,g+\gamma} \right.\right.\right. \\
&* \left(1 - Ltax_{j,t+\gamma} - Contr_{j,t+\gamma}\right) + Pens_{j,t+\gamma,g+\gamma} \\
&\left.\left.\left. - \left(1 + CTax_{j,t+\gamma}\right) P^{c}{}_{j,t+\gamma} Con_{j,t+\gamma,g+\gamma}\right]\right\}\right\}.
\end{aligned}
\tag{A.2.16}
$$

The first order conditions are:

$$
\frac{\partial L}{\partial Con_{j,t,g}} : \frac{surrate_{t,g}\left(Con_{j,t,g}\right)^{-\vartheta}}{(1+\tau_{j,g})} = \lambda \frac{surrate_{t,g}(1+CTax_{j,t})P^{c}{}_{j,t}}{1+(1-Ktax_{j,t})R_{j,t}};
\tag{A.2.17}
$$

$$
\begin{aligned}
&\frac{\partial L}{\partial Con_{j,t+1,g+1}} : \frac{(surrate_{t+1,g+1} surrate_{t,g})\left(Con_{j,t+1,g+1}\right)^{-\vartheta}}{(1+\tau_{j,g})(1+\tau_{j,g+1})} \\
&\qquad = \lambda \frac{(surrate_{t+1,g+1} surrate_{t,g})(1+CTax_{j,t+1})P^{c}{}_{j,t+1}}{\left[1+\left(1-Ktax_{j,t+1}\right)R_{j,t+1}\right][1+(1-Ktax_{j,t})R_{j,t}]};
\end{aligned}
\tag{A.2.18}
$$

…;

$$
\begin{aligned}
&\frac{\partial L}{\partial Con_{j,t+14,g+14}} : \frac{(surrate_{t+14,g+14} \ldots surrate_{t,g})\left(Con_{j,t+14,g+14}\right)^{-\vartheta}}{\left(1+\tau_{j,g}\right)\left(1+\tau_{j,g+1}\right) \ldots (1+\tau_{j,g+14})} \\
&\qquad = \lambda \frac{(surrate_{t+14,g+14} \ldots surrate_{t,g})(1+CTax_{j,t+1})P^{c}{}_{j,t+1}}{\left[1+\left(1-Ktax_{j,t+14}\right)R_{j,t+14}\right][1+(1-Ktax_{j,t+14})R_{j,t+14}]}.
\end{aligned}
\tag{A.2.19}
$$

Combining these FOC pair-wise:

$$
\frac{\dfrac{(surrate_{t+1,g+1} surrate_{t,g})\left(Con_{j,t+1,g+1}\right)^{-\vartheta}}{(1+\tau_{j,g})(1+\tau_{j,g+1})}}{\dfrac{surrate_{t,g}\left(Con_{j,t,g}\right)^{-\vartheta}}{(1+\tau_{j,g})}}
= \frac{\lambda \dfrac{(surrate_{t+1,g+1} surrate_{t,g})(1+CTax_{j,t+1})P^{c}{}_{j,t+1}}{\left[1+\left(1-Ktax_{j,t+1}\right)R_{j,t+1}\right][1+(1-Ktax_{j,t})R_{t}]}}{\lambda \dfrac{surrate_{t,g}(1+CTax_{t,g})P^{c}{}_{j,t}}{1+(1-Ktax_{j,t})R_{j,t}}}.
\tag{A.2.20}
$$

After simplification the Euler equation is:

$$
\frac{Con_{j,t+1,g+1}}{Con_{j,t,g}} = \{\frac{\left(1+CTax_{j,t}\right)P^{c}{}_{j,t}}{(1+CTax_{j,t+1})P^{c}{}_{j,t+1}} \frac{\left[1+\left(1-Ktax_{j,t+1}\right)R_{j,t+1}\right]}{\left(1+\tau_{j,g+1}\right)}\}^{1/\vartheta};
\tag{A.2.21}
$$

…;

$$\frac{Con_{j,t+14,g+14}}{Con_{j,t+13,g+13}} = \{\frac{\left(1 + CTax_{j,t+13}\right)P^{c}{}_{j,t+13}}{1 + CTax_{j,t+14})P^{c}{}_{j,t+14}} \frac{\left[1 + \left(1 - Ktax_{j,t+14}\right)R_{j,t+14}\right]}{\left(1 + \tau_{j,g+14}\right)}\}^{1/\vartheta}. \tag{A.2.22}$$

The Euler equation can be written as the following, which is Eq. (9) in the main text:

$$\frac{Con_{j,t+\gamma+1,g+\gamma+1}}{Con_{j,t+\gamma,g+\gamma}} = \{\frac{\left(1 + CTax_{j,t+\gamma}\right)P^{c}{}_{j,t+\gamma}}{1 + CTax_{j,t+\gamma+1})P^{c}{}_{j,t+\gamma+1}} \frac{\left[1 + \left(1 - Ktax_{j,t+\gamma+1}\right)R_{j,t+\gamma+1}\right]}{\left(1 + \tau_{j,g+\gamma+1}\right)}\}^{1/\vartheta}. \tag{A.2.23}$$

A.3 Equations in Pension System

The pension benefits are financed by the contribution rates from the current wage earners, which is referred as Eq. (15) in the main text. To better understand Eq. (14) and Eq. (15), we provide further examples: when $gr = g14$ (where g= $[g5, \dots g19]$ so $g14$ is at the 10th position):

$$t - 9 - ord(gr) + ord(gw)$$

$$= \begin{cases} t - 9 - 1 + 1 = t - 9 \; (when\ gr = g14\ and\ gw = g5); \\ t - 9 - 1 + 2 = t - 8 \; (when\ gr = g14\ and\ gw = g6); \\ \dots \\ t - 9 - 1 + 9 = t - 1 \; (where\ gr = g14\ and\ gw = g13); \end{cases} \tag{A.3.1}$$

where $ord(g14)$ is 1 because $gr = g14, \dots g19$; when gr=g15:

$$t - 9 - ord(gr) + ord(gw)$$

$$= \begin{cases} t - 9 - 2 + 1 = t - 10 \; (when\ gr = g15\ and\ gw = g5); \\ t - 9 - 2 + 2 = t - 9 \; (when\ gr = g15\ and\ gw = g6); \\ \dots; \\ t - 9 - 2 + 9 = t - 2 \; (where\ gr = g15\ and\ gw = g13). \end{cases} \tag{A.3.2}$$

The retirees who are at different ages receive different amounts of pension benefits. The right-hand side of Eq. (A.3.1) and Eq. (A.3.2) represents the amount of labour income for calculating the pension benefits.

Chapter 3

9/11 Security Measures and North American Security Perimeter: A Computable General Equilibrium Analysis

1. Introduction on 9/11 and NASP

After the terrorist attack in New York and Washington on September 11th, 2001, the U.S. government heightened security measures at the Canada-U.S. border. Enhanced security procedures have imposed longer waiting time and uncertainties which increase border costs and consequently may adversely affect Canadian exports. The most affected industries are likely to be businesses with "*just-in-time*" inventory strategy and high valued goods and services.[53] For instance, a longer waiting time to cross the border costs more fuel and drivers' hours when export goods are transported by trucks. Huang and Whalley (2008) point out that border delay may also cause higher inventory level, larger warehouses, and additional infrastructures.

To what extent are the incremental costs of delivering goods and people passed in the form of higher prices to the exporting countries? The magnitude of the shortfalls in exports would depend upon the price elasticities of import demand. The declined quantity would also depend on the availability of substitutes in the importing country. Many studies (Goldfarb, 2007; Globerman and Storer, 2006 and 2009; Burt, 2009; Grady, 2009; Alberts, 2008; Goldfarb and Robson, 2003; Hart, 2008; Corcoran, 2008; Gastle and Martyn, 2008; Ryan, 2007) provide examples or econometric evidence on the cost of a "*thickening*" of the border on trade. Rather than bearing these costs, producers might consider changing the location of productions to avoid the border costs. In this case, the post-9/11 security measures may divert foreign direct investment (FDI) away from Canada. Instead, those firms would choose to locate in the United States. All these changes would cause regional and sectoral resource reallocation. Border costs, thus, affect the production decision of suppliers and the investment decisions of investors. In the long term, increasing border costs on the Canada-U.S. frontier could make Canada a

[53] The business with "*just-in-time*" represents a strategy of production which is applied to improve the return of investment by reducing inventory and carrying costs.

less attractive location for investors (Goldfarb, 2003 and 2007).

Some risk-assessed programs have been introduced to mitigate the border costs on exports and facilitate the border-crossing of shipments and travellers, such as Free and Secure Trade (FAST) and NEXUS between U.S. and Canada. The FAST program is designed to enhance border and trade security while pre-screening low-risk truck drivers, carriers and importers (CBSA, 2008a).[54] NEXUS is a program designed to facilitate the border inspection process for travellers between U.S. and Canada. Those low-risk travellers are pre-approved conditional on paying an additional membership fee for a limited time (CBSA, 2008b). While these programs have improved the flow of goods and travellers crossing the U.S.-Canada border, they have not fully solved the issue (Goldfarb, 2007).

Aware of the additional costs resulting from enhanced security measures following 9/11, both governments have discussed the possibility of establishing a North American Security Perimeter (NASP) to remedy these problems. In February 2011, the President of the United States and the Prime Minister of Canada issued a communiqué entitled *Beyond the Border: A Shared Vision for Perimeter Security and Economic Competitiveness.*[55] This was followed by the Action Plan (December 7, 2011). Its objective is to simulate the growth of the economy and other related indicators (i.e. jobs, trade, nation security, law enforcement and long-term partnership, etc.), while setting priorities on the enhancement of the security at the North American Perimeter and reducing security measures at the Canada-U.S. border.

The main contribution of this study is to analyze the counterfactual policy of eliminating the post 9/11 security measures at the Canada-U.S. border while adopting an "external" security perimeter or NASP. Indeed, more than ten years after the introduction

[54] FAST is jointly conducted by Canada Border Services Agency and U.S. Customs and Border Protection.

[55] *Beyond the Border: A Shared Vision for Perimeter Security and Economic Competitiveness* is available at the Government of Canada website http://pm.gc.ca/eng/media.asp?id=3938.

of 9/11 security measures, it might be of interest to evaluate the existing security paradigm and consider alternatives. In this perspective, assessing the cost of the post 9/11 security measures is only one of the elements in gauging the (general equilibrium) benefits of the NASP alternative, as presented in Section 6. This NASP proposal could, at least theoretically, be designed so as to liberalize the post 9/11 security measures and decongest the Canada-U.S. border while possibly shifting these measures (and the associated direct administrative costs) to the external border related with the rest of the world (ROW). However, the NASP proposal does not require (partial or complete) elimination of the pre-9/11 security measures at the Canada-U.S. border to the extent of, say, the borderless zone with common visa and asylum policies that emerged within Europe in 1995 following the Schengen Agreement of 1985 which relies only on external border controls for travellers travelling in and out of the area. Furthermore, we do not envisage changes in the existing regulatory framework of the U.S. Department of Agriculture or the Environmental Protection Agency with respect to inspections at the Canada-U.S. border.

The simulation results presented in Section 6 should, however, be taken as illustrative and not be interpreted literally as an estimate of the impact on the measures envisaged in the 2011 Action Plan. For example, our study does not gauge the impact of other possible measures announced in the Plan such as the harmonisation of product safety and quality regulations. Also, our study does not estimate the North American "security gains" or the "sovereignty erosion" in terms of intelligence data sharing, joint law enforcement and migration procedures, and pre-screening of offshore imports and travellers. According to the "Shared Vision" declaration, some of these aspects are to be examined by two groups, the "Beyond the Border" Working Group and the Canada-U.S. Regulatory Co-operation Council.

As argued above, with current enhanced security measures at the Canada-U.S. border, producers in Canada may prefer to relocate their firms and invest directly in the United States. This may negatively affect the Canadian economy.[56] Under NASP, however, the advantages of investing in Canada would be preserved. Meanwhile, with NASP, producers in the ROW may find it more attractive to invest directly in Canada. This would help the capital market in Canada and help the Canadian economy to grow.

Some studies find that the heightened security inspection at the Canada-U.S. border also diverts Canadian exports to the ROW (Mérette et al., 2008; Georges et al., 2012). On the other hand, eliminating the present enhanced security measures at the Canada-U.S. border would stimulate Canadian exports to U.S., and slow the diversification of Canadian exports to the ROW. Furthermore, implementing NASP would affect the North American economy (i.e. production and investment activities, etc.) through possible increased border securities with the ROW. The magnitude of this effect is uncertain because of the complex relationship of economic activity interactions within the three regions. This paper assesses to what extent the implementation of NASP will benefit Canada and the U.S. by combining econometric analysis and a multi-sectoral and multi-regional computable general equilibrium (CGE) model simulation for nine industry groups.

The rest of the paper proceeds as follows. Section 2 provides an overview of the data which provide evidence of trade pattern changes for the U.S., Canada and the ROW in nine sectors since 2001. Section 3 discusses the econometric evidence focusing on the impact of 9/11 on trade performance across the sectors. Section 4 describes the CGE model which includes FDI decisions. Section 5 discusses modelling NASP in the CGE model. Section 6 presents the simulation results on production, investment and welfare of

[56] U.S. firms might not offset this effect by relocating in Canada because of their larger market.

Canadian, American and the ROW's economies following the implementation of the NASP. Section 7 is the conclusion.

2. Overview of the Trade Data

This section describes how sectoral exports of the three regions have changed since 9/11. Beside the security factor, there are certainly other potential reasons which could also explain the variation of the export flows since 2001, such as the exchange rate or relative price changes. In Section 3, econometric estimates will show more formally whether there exists a significant 9/11 impact in each sector while controlling for other variables.

2.1 Trade Data Analysis in Canadian Sectoral Exports

This section concentrates on the period between 1992 and 2011. A decrease in Canadian exports to the U.S. and an increase in Canadian exports to the ROW have been commonly observed since 9/11 in almost all sectors. Post-9/11 border security measures are a possible factor that might explain this substitution pattern of trade diversification away from the U.S. toward the ROW.

Canadian exports to the U.S. in the agriculture sector (Figure 3.1) remained fairly constant from 1992 to 2011, with a low point in 2004 and a high point in 2008. The Canadian exports to the ROW dropped in 2001, followed by an increase in 2005 and a decrease again during the recent financial crisis of 2008. The increase between 2001 and 2008 was significant. This substitution pattern of Canadian exports to the U.S. and the ROW is more obvious in the food sector (Figure 3.3) as exports to the ROW started to exceed exports to the U.S. in 2006. Security measures after 9/11 seem to have contributed to Canada's diversification of its exports to the ROW. Canadian exports to the U.S. in the textile sector (Figure 3.4) shows a bell-shape curve with the highest point in 2001. In contrast, Canadian exports to the ROW stayed relatively constant in the textile sector.

Again, we observe a possible substitution effect.[57]

In the manufacturing sector, Canadian exports to the ROW increased from 2001 to 2007 but decreased from 2008 to 2009 due to the financial crisis. In contrast, the main direction of Canadian exports to the U.S. has been downward after 2001. Both Canadian exports to U.S. and the ROW declined immediately following 2001 in the automobile sector (Figure 3.7); however, the latter recovered back to the previous level after 2005. This illustrates some scope for substitution. In both technology and service sectors, Canadian exports to U.S. dropped significantly after 2001, and kept a downward but flatter trend after 2003. But exports to the ROW increased from 2001 to 2006 and stayed flat for three years till the financial crisis. Plausibly, the impact of 9/11 may have had a negative influence on Canadian exports to the U.S. and a positive influence on the exports to the ROW. The trends for Canadian exports to the U.S. and the ROW in the transportation sector (Figures 3.12) are similar. The resource sector (Figure 3.2) seems to be an exception in that Canadian exports to the U.S. dropped slightly after 2001 but, thereafter increased simultaneously with Canadian exports to the ROW. This may indicate the lack of substitution in the U.S. for Canadian commodities. In conclusion, in almost all sectors (with the exception of the resource sector) we observe that Canadian exports to the U.S. and the ROW move in the opposite direction.

2.2 Trade Data Analysis in U.S. Sectoral Exports

From Figures 3.13 to 3.21, we observe that U.S. exports to Canada in most sectors have been generally increasing after 2001. This is in contrast with the reduced exports of Canada to the United States.[58]

For example, neither U.S. exports to Canada nor the ROW in the agriculture and

---

[57] As the level of Canadian export to the U.S. is much higher than the one to the ROW, some figures (e.g. Figures 3.4, 3.6, 3.7, 3.9 and 3.11) include two axes (primary and secondary) to give greater details of how each trade flow (for the lower level one) varies across years.

[58] All figures in this section have an added secondary axis to illustrate more clearly changes overtime.

resource sectors (Figures 3.13 and 3.14) dropped after 9/11, except during the recent financial crisis. Instead, U.S. exports to Canada and to the ROW are both in an upward trend. U.S. exports to the ROW in the food sector (Figure 3.15) declined slightly after 2001 while U.S. exports to Canada were consistently increasing from 1992 to 2007. U.S. exports to Canada in the textile sector (Figure 3.16) declined but the decline started before 2001. U.S. exports to the ROW were in an upward trend but it started from 1992, not from 2001. U.S. exports to Canada and to the ROW in the manufacturing sector (Figure 3.17) were both increasing after a small drop in 2001. U.S. exports to the ROW declined only in the first two years following 9/11 in the automobile sector (Figure 3.18). Both trends have been increasing at a similar rate in the service sector. There were decreases in the technology and transportation sectors from 2001 to 2003. But the decline gradually stopped.

In conclusion, Figures 3.1 to 3.12 suggest that the impact of post-9/11 security measures may have stimulated Canada to divert its exports from the U.S. to the ROW. This observation does not apply for the case of exports from the U.S. to Canada, however, as observed in Figures 3.13 to 3.21.

2.3 Trade Volumes among the U.S., Canada and the ROW

Trade volumes between the U.S. and Canada remained stable after 2003 following a small drop between 2001 and 2003 (Figure 3.22).[59] Similarly, trade volumes between the U.S. and the ROW declined in 2002 and 2003 (Figure 3.23). In contrast, trade volume between Canada and the ROW increased after 2001, on the same upward trend observed between 1992 and 2001 (Figure 3.23). The hypothesis is that the 9/11 security measures after 9/11 may have had an impact on trade flows. It must now be tested formally following an econometric methodology.

[59] Trade volume is defined as the summation of the values of imports and exports between Canada and the United States.

3. Econometric Analysis on the impact of 9/11 on exports among Canada, U.S. and the ROW

The examination of trends of exports offers an impression of the likely impact of 9/11 on the exports of goods and services, but disentangling the impact of various factors at play, such as price inflation, demand and supply in each region etc., requires more sophisticated econometric evidence. To recapitulate, Canadian exports to U.S. dropped, but Canadian exports to the ROW increased after 2001 in almost all sectors (except the resource sector). However, U.S. exports to Canada were likely not affected except in the textile and transportation sectors. This section investigates whether and to what extent these patterns of trade across regions and sectors are due to the impact of 9/11 when controlling for other factors in the regression analysis, such as demand factor (GDP), cost factor (relative prices), and supply factor (capacity utilisation rates), as discussed in the Appendix.

3.1 Methodology[60]

The previous studies (Grady, 2009; Globerman and Storer, 2009; Burt, 2009; Feenstra, 2004) applied a gravity model to investigate the impact of post-9/11 security measures on the exports between the U.S. and Canada. The most commonly used methodology in those studies was ordinary least squares (OLS) regression. Inspired by Grady (2009) and Feenstra (2004), the regression equation is written as follows:[61,62,63]

$$\log\left(E_{i,j,s,t}\right) = \beta_0 + \beta_1 \log\left(GDP_{j,t}\right) + \beta_2 log\left(\frac{S\left(\frac{j}{i}\right)_{t-1} P_{i,t-1}}{P_{j,t-1}}\right) + \beta_3 \log\left(E_{i,j,s,t-1}\right) + \beta_4 CUR_{i,s,t} + \beta_5 911_t + \varepsilon_t, \qquad (1)$$

where $E_{i,j,s,t}$ is real region *i*’s exports to region *j* in sector *s* at time *t*; $GDP_{j,t}$ is real

[60] The details of data are in the Appendix.
[61] Feenstra (2004) discusses a version of gravity model of the trade between Canada and U.S.
[62] Note that capacity utilisation is only applied when *i*=CAN, *j*=U.S.; *i*=CAN, *j*=ROW; *i*=U.S., *j*=ROW.
[63] In the papers of Grady (2009), Globerman and Storer (2006 and 2009), and Burt (2009), the revised regression equations are all called gravity models. In our paper, we avoid this name “gravity” because the regression equation does not include the distance term, but the essential feature of gravity model does.

gross domestic product of region *j* at time *t;* $\frac{s\left(\frac{j}{i}\right)_{t-1} P_{i,t-1}}{P_{j,t-1}}$ is the relative cost;[64] $E_{i,j,s,t-1}$ is exports lagged by one period; $CUR_{i,s,t}$ is the capacity utilisation rate in region i; 911_t is the dummy variable for 9/11 at time *t*; ε_t is a random disturbance term.

The relation used specifies that constant dollar exports of a specific sector of region *i* are a function of the real GDP of country *j* (demand of country *j*). The relative cost variable captures the level of prices of goods and services in region *i* relative to the one in region *j* by converting it by the exchange rate, $s\left(\frac{j}{i}\right)$, defined as the quantity of currency *j* for one unit currency of i . The reason why we include the log of dependent variable lagged by one period is to get rid of the trend of region *i*'s exports to region *j* in sector *s*. The capacity utilisation rate in region *i* represents the impact of supply; the dummy variable *9/11* is defined as 0 before 9/11, 1 thereafter, and 0.333 in 2001 to specify that 9/11 only started to affect trade in the last four months of 2001.

Other studies (Globerman and Storer, 2006 and 2009) also use a time-variant dummy variable, which has the advantage to capture the change of impact under 9/11 across years. Nevertheless, it also shares a disadvantage that it may capture the big social or policy events occurring in certain time points. For example, Burt (2009) criticizes that the time-variant dummy variable applied in the study by Golberman and Storer (2009) actually captures the SARS outbreak in Toronto at the end of 2005 because the estimated coefficient of 9/11 appears significantly negative. The relative price term is often included in literature to capture the persistent deviation of prices among regions which reflects that the purchasing power does not hold over an extended period of time due to a "*border effect*" (Harris and Matyas, 2001). The regression equation only includes the capacity utilisation rate variable when analysing Canadian exports to the U.S. and to the

[64] It is ideal to have the specific variable of relative price term in each sector. However, because of the limitation of data, we apply a general (all commodities) relative prices converted by exchange rate instead.

ROW, and U.S. exports to the ROW. There is no need to include the capacity utilisation rate in the regression of U.S. exports to Canada because the size of U.S. economy is ten times as large as the one in Canada. Thus, U.S. exports to Canada only take a small portion of the total U.S. exports and the change in the U.S. capacity utilisation rate will have little impact on U.S. exports to Canada.

The use of logarithms allows the estimated coefficients of GDP and relative price term to be explained as elasticities and the coefficient of the *9/11* dummy variable to be read as a percentage change. All else being equal, the estimated coefficient of $GDP_{j,t}$, β_1, is expected to be positive, which means that the level of exports from region *i* should be higher as the demand of the importing region j is higher. The coefficient of relative cost, β_2, is expected to be negative, that is, the level of exports from region *i* should be lower as the relative price of the exported goods expressed in region j's currency is higher. A positive coefficient of capacity utilisation rate, β_4, indicates that the supply of exports from region i to j should be higher as its production capacity utilization rate CUR_i is higher. A negative coefficient of the dummy variable *9/11* would indicate that tight security measures built at the Canada-U.S. border and the U.S.-ROW border have reduced export flows. However, a positive coefficient of *9/11* would be expected in Canadian exports to the ROW (at least in some sectors) because tight security measures built at the Canada-U.S. border might have diverted trade flows toward the ROW.

As this model includes a number of linear equations, it is normally the case that error terms in different equations would be correlated when a set of equations which has contemporaneous cross-sectional error correlation, it can be analyzed by using the Zellner's seemingly unrelated regression (SUR) system (Zellner, 1962). Each equation in the SUR system is a valid linear equation, and can be estimated separately (i.e. these equations can be estimated one by one through OLS by taking into consideration of the correlation among error terms).

The correlation of error terms could be tested by the Breusch and Pagan (1980) test. The Lagrange multiplier test statistic is as follows:

$$\lambda_{LM} = T \sum_{i}^{m} \sum_{j}^{i-1} {r^2}_{ij} \tag{2}$$

where, m is the number of cross-sectional units, and it is fixed (i.e. nine sectors in our paper); ${r^2}_{ij}$ is the *ij*th residual correlation coefficient; *i* is the equation number (*i*=1,…,*m*); j is the observation index (*j*=1,...,*T*, where T is the total number of observations). The Breusch and Pagan test is distributed $\chi^2(d), where\ d = m(m-1)/2$, under the null hypothesis of independence. The results of the correlation matrix of residuals and the Breusch-Pagan test of independence from Tables 3.2 to 3.7 show that the null hypotheses of all tests are individually rejected. Thus, there is a correlation of the error terms among the equations. Therefore, we apply the SUR system to investigate the impact of 9/11 on the sectoral exports flow among regions, instead of OLS.[65]

3.2 Regression Results

This section provides the SUR regression results as estimated for *i* = Canada, U.S., and ROW. The results are shown for nine categories of exports as well as for the aggregate flow of exports in Tables 3.2 to 3.7 of the Appendix. The most interesting point in this section is to investigate whether the post-9/11 security measures bring a significant impact on the exports among Canada, U.S. and the ROW, and the magnitude of this impact in each sector. Section 2.3 provided an intuition about whether there should be a decrease in exports after 2001 (e.g. Canada to U.S., U.S. to Canada and the ROW, ROW to Canada and U.S.) or an increase in exports (e.g. Canada to the ROW). This section clarifies this issue using econometric evidence. A statistically insignificant coefficient for

[65] Note that there are two circumstances that SUR is equivalent to OLS. The first case is that the error terms are not related; the second case is that the independent variables at the right-hand side of each equation are all the same.

the *9/11* dummy variable indicates that post-9/11 security measures had no effect in that sector.

The econometric evidence illustrates that an enhanced security at the Canada-U.S. border not only directly causes adverse impact on the Canadian exports to the U.S., but also indirectly influences the trade flow of Canada with the ROW which is consistent with the export data discussed in Section 2. As shown in Table 3.1, the influence of 9/11 on the exports from Canada to the U.S., the U.S. to Canada and the ROW, the ROW to Canada and the U.S. is typically negative. For instance, Canadian exports to the U.S. are reduced by 22%, 16.5% and 10.4% in the textile, manufacturing and transportation sectors respectively, and declined even more in the technology (37.8%) and service (49.5%) sectors. U.S. exports to Canada fell by 18.4% in the textile sector, 26.2% in the manufacturing sector, 35.9% in the technology sector, and 20.3% in the transportation sector. However, there is a positive impact from the post-9/11 security measures on Canadian exports to the ROW in the textile (18%) and service sectors (40.9%). Although heightened security measures established at the Canada-U.S. border have lowered Canadian exports to the U.S., they also have caused Canada to diversify some of its exports to other countries. More specifically, even though the U.S. remains Canada's main export partner, the results show that 9/11 has lead to significant increase of Canadian exports to the ROW in the textile and service sectors.

Post-9/11 security measures did not have comparable effect on U.S. exports to the ROW. Indeed, instead of increasing, U.S. exports to the ROW actually decreased. Row 4 in Table 3.1 reports that U.S. exports to the ROW declined by 14.9% in the manufacturing sector, 16.7% in the technology sector, and 15.3% in the transportation sector. Furthermore, as enhanced security measures are geared towards the shipments of goods and travellers entering U.S., it is expected that exports from the ROW to U.S. were negatively affected. Indeed we observe a decrease by 12.3% in the manufacturing sector, 18.7% in the automobile sector, 24.9% in the technology sector, 8.2% in the service sector and 19.7% in the transportation sector (row 6, Table 3.1). Compared with the results in row 4, the negative impact of 9/11 on the ROW exports to the U.S. is relatively larger than the U.S. exports to the ROW, except in the manufacturing sector.

The econometric estimates also illustrate that there is some negative influence of post-9/11 security measures on the exports from the ROW to Canada (e.g. a fall by 26.3% in the technology sector). This finding suggests that there is also an indirect impact on the trade of goods and people from the ROW to Canada as the securities of both countries are tightened up.

The estimated impact of 9/11 security measures shown in Table 3.1 is similar to results of some other studies; however, the findings in certain sectors are much more substantial. Some existing econometric studies suggest that the relevant cost increases due to 9/11 border delays are modest (Taylor et al., 2003, Lee et al., 2008; Moens and Cust, 2008; Burt, 2009). For instance, Moens and Cust (2008) reported that the increased border costs following 9/11 are only about 2 to 3 percent of the total trade. However, other studies (MacPherson and McConnell, 2005; Globerman and Storer, 2006 and 2009; Grady, 2009) suggest that there is a substantial adverse impact on exports due to post-9/11 security measures. For example, in the study of Globerman and Storer (2006), the percentage shortfalls captured by the time variant dummy variable ranges from 8.6% to 25.8% of the total imports by Canada from the U.S., and from 3.9% to 22.8% of the total exports of Canada to the United States. Grady (2009) obtained similar results. It is certainly possible that some existing studies underestimate the impact of 9/11 on exports. The impact of heightened security measures on exports is higher at the margin than at the average, that is, the level of costs generated to incumbents and entrants could be very different. The incumbents can somewhat respond to the border delays and time uncertainties given their better familiarity with existing border crossing procedures and alternative routes; the entrants, however, may not (Globerman and Storer, 2009). The results in Table 3.1 suggest substantial negative impact that has potentially eroded the previous trade impacts from the North American Free Trade Agreement (NAFTA).

4. CGE Model with Wealth Allocation

Only a limited number of studies have used the CGE models to analyse the economic impact of post-9/11 security measures. Studies by Nguyen and Wigle (2009, 2011) use a multi-sectoral and multi-provincial CGE model of the Canadian economy to estimate the impact of post-9/11 security measures on the exports, production, and welfare. It concludes that the previous studies have underestimated the cost of security measures. For instance, Nguyen and Wigle (2009, 2011) show that the aggregate welfare loss should be about ten times the value reported in the study of Walkenhorst and Dihel (2006).

This section describes a multi-region and multi-sector general equilibrium model which includes production and consumption activities, and investment allocation among regions by distinguishing domestic ownership and foreign ownership firms (Petri, 1997; Verikios and Zhang, 2001; Georges et al., 2012). Under a budget constraint, a representative household makes the consumption decision on different commodities produced in different regions by firms of different nationalities. As an investor, this household also makes the investment decision on wealth allocations among regions. We apply the existing model of Georges et al. (2012), and the details of the model follow below. All equations are listed in the Appendix.

4.1 Wealth Allocation

A key characteristic of the model is the determination of FDI investment, or more broadly, the regional allocation of wealth. The investment decision is based on the investor's preference and on the net returns of investment across regions and sectors. The total wealth owned by a representative household with nationality *v* is given exogenously, $TTWEA0_v$. By maximizing the net returns on wealth, this total wealth is allocated across sector *s* and regions *j*. There are three layers in the wealth allocation problem, each using a constant elasticity of transformation (CET) functional form. Hence, we impose an imperfect mobility of capital across regions and sectors, so that the returns on wealth may be different in each region and sector. [66] The allocation of wealth simply depends on the relative return in region *v*, i.e. the higher the relative return, the higher the proportion of total wealth invested in such a region. The first layer (Eq. A.1 and A.2) allocates total wealth owned by a representative household with nationality *v* across sectors *s*. The second layer (Eq. A.3 and A.4) allocates total wealth invested in sector s between domestic, $WEA_{v,v,s}$, and foreign investment, $TWEAF_{v,s}$. The third layer (Eq. A.5, A.6 and A.7) chooses how FDI by nationality of *v* is distributed among subsidiaries located in different countries: $WEA_{v,j,s} = KS_{v,j,s}$.

4.2 Supply Side

There is a representative firm with nationality *v* in each region *j* that produces goods in sector *sd* with a Cobb-Douglas technology (i.e. constant return to scale) using inputs of labour, capital (of nationality *v*), and intermediate goods produced in sector *s*. The representative firm maximizes its profit by choosing the optimal level of output using a marginal cost pricing model (Eq. A.8). Given the Cobb-Douglas functional form, the demand for input is increasing with the price of goods produced and decreasing with factor prices (Eq. A.9, A.10, A.11 and A.12). The demand for intermediate goods is itself a multi-level Leontief function of sectoral goods produced by subsidiaries located in

[66] If the mobility of capital across regions is perfect, the return of wealth should be equal in each region and sector.

different countries (Eq. A.13 and A.14). This makes all intermediate goods complements in the production of goods s.

4.3 Consumption

The representative household in region j earns income from wages, net returns from investment on domestic and foreign markets, tariff revenue collected by government (as household and government accounts are integrated), and tax revenue on capital income from domestic owned and foreign owned firms allocated in region j. The total labour in each region is fixed; therefore, there is no leisure option.

The consumption component in this model is designed as five layers in order to capture the features of multi-nationality, multi-sector and multi-location. The first layer (Eq. A.16 and A.17) illustrates a representative household in region j who maximizes total utility or aggregate consumption, C_j, by choosing different sectoral goods s, $CS_{j,s}$, using a Cobb-Douglas function. The second layer (Eq. A.18, A.19 and A.20) is the choice of consumption between a good produced domestically in j, $CSD_{j,s}$, and an index of foreign goods, $CSF_{j,s}$, imported into j. The third layer (Eq. A.21 and A.22) illustrates how the domestic consumption in sector s is allocated on goods produced by subsidiaries of a different nationality v (but all located in region j), $CSIJV_{v,j,j,s}$, using a constant elasticity substitution (CES) function. The fourth layer (Eq. A.23 and A.24) illustrates that the representative household in region j chooses to consume the imported goods produced in region i, $CSFIJ_{i,j,s}$, by a CES relationship among regions. The last layer (Eq. A.25 and A.26) illustrates that the imported goods which are consumed by the representative household are CES aggregates produced by the subsidiaries with nationality v, $CSFIJV_{v,i,j,s}$.

4.4 Investment Demand

The final demands are composited by the consumption demand and investment demand. The aggregate investment goods in region j are a Cobb-Douglas index of investment goods s produced by firms with nationality v, $IVS_{v,j,s}$ (Eq. A.27 and A.28). The second layer is to locate this investment across each region i, $IVSI_{v,i,j,s}$ (Eq. A.29 and A.30).

4.5 Market Clearing Conditions at Equilibrium

A general equilibrium is established as each representative economic agent's optimum with respect to its budget constraint, and as all markets clear. In factor markets, the labour market (Eq. A.31) is cleared by wage rate to balance demand and supply of labour in each region *j* (i.e. the immobility of labour across regions); the capital market (Eq. A.32 and A.33) is cleared as the rental rate balance the demand and supply of capital in sector *sd* of nationality *v* and region *j* (i.e. no cross-ownership of capital).[67] In the output market (Eq. A.34 and A.35), the price of goods adjusts the total demand of consumption, investment and intermediate goods, and the total supply of goods *s* produced by subsidiary *vo* located in region *j*. At a steady state, investment is equal to the depreciation of the capital stock (Eq. A.36), and a current account equals zero in region *j* (Eq. A.37). Consequently, investment equals national saving.

5. Modeling NASP in a CGE Model

The objective of the NASP is to provide a common security frontier at the North American (Canada-U.S.) periphery, and reduce (or eliminate) the security barriers at the Canada-U.S. border. In other words, the NASP allows for the elimination of security measures at the Canada-U.S. border conditional on the fact that Canada harmonizes its

[67] The no cross-ownership should be reflected in the model as the wealth allocated in region j sector s with nationality v should equal to the capital stock in region *j* sector *s* with the same nationality *v* (i.e. $WEA_{v,j,s} = KS_{v,j,s}$)

security measures with respect to the ROW at the levels imposed by the United States (on the ROW).

How can we model this change of security paradigm? Basically, we use the model described in Section 4 and superimpose a shock that reflects both (1) the elimination of security measures at the Canada-U.S. border, and (2) the harmonization of Canadian security measures imposed on the ROW to the level already imposed by the United States. Jointly, these two steps represent the implementation of a security perimeter at the North American border (NASP). Therefore, implementing NASP involves two concomitant steps and this section presents conceptually how to model these two steps. Note that step 1 cannot be modeled in isolation from step 2, that is, Americans would not allow the elimination of security measures at the Canada-U.S. border if Canada did not at the same time harmonize their security measures with respect to the ROW at the levels required by Americans. However, in order to explain the implementation of the shock in the CGE model, we will discuss both steps sequentially in Section 5. Then Section 6 presents the simulation results of implementing the NASP.

Importantly, we need to stress that to model the NASP, we first need to "calibrate" the impact of the current 9/11 security measures in the sense that their impacts are only *implicitly* present in the current trade flow but they need to be made *explicit*. Sections 5.1 and 5.2 discuss this. Once this is done, implementing the NASP (i.e., implementing a counterfactual policy) comes down to the removal of the (explicitly known) trade effects of the current 9/11 security policies. As this is a general equilibrium exercise, many effects of the NASP will be captured on, say, production, FDI, and welfare, beside the trade flow "reversal" that we should (obviously) expect.

5.1 Modeling the Elimination of Security Measures at the Canada-U.S. Border

In accordance with the above, in order to estimate the impact of eliminating U.S. and

Canadian imposed security measures at the Canada-U.S. border, we first need to (explicitly) estimate the tariff rates that are "equivalent" to the 9/11 security measures (in terms of their impact on bilateral trade between Canada and the United States).

Let us start with the U.S. imposed security measures at the Canadian border. What we need is to obtain the equivalent tariff of these U.S. security measures. We can obtain these (sectoral) tariffs by asking the following question. If the U.S. government had imposed in the early 2000s a protectionist measure (in the form of a tariff barrier on Canadian goods and services) leading to a percentage reduction in Canada's exports as given in Table 3.2 (parameter estimates of the *D*911 dummy variable) (or row 1, Table 3.1), what should have been the magnitude of these (U.S.-imposed) tariffs? This is a complex question that we answer by shocking and simulating the general equilibrium model of Section 4. We impose the *exogenous* percentage change in sectoral real Canadian exports to the U.S. (estimated in Table 3.2) and the model solves *endogenously* for the "equivalent" tariff rates necessary to absorb the trade shock.[68,69] Note that when the sectoral parameter for the *D*9/11 dummy variable is not statistically different from zero (at 10%) in Table 3.2, then the change in exports is exogenously set equal to zero in the model. We also do the same conceptual experiment for the Canadian security measures at the Canada-U.S. border (using, this time, the econometric results given in Table 3.3, or row 2, Table 3.1).

Table 3.13 (rows 1 and 2) provides the equivalent tariffs generated by this methodology. For example, the tariffs equivalent to the post-9/11 U.S. border security measures (row 1) in the sectors of transportation, technology, automobile, and textile are

[68] In modeling terms, the percent change in $EP_{v,can,us,s}$ is exogenously set equal to its estimate given in Table 3.2 (and assumed to be the same for all subsidiaries *v*) while a bilateral equivalent tariff $EqTAR_{v,can,us,s}$ can adjust endogenously to absorb the shock.

[69] Adopting equivalent tariff rates to security measures lead to tariff rents . In our model, these rents are assumed to be distributed to household of the ROW so as to remove the impact that these fictitious rents would have on the welfare analysis of Canada and the United States. Due to the bigger size of the ROW economy, the allocation of these rents to the ROW would have fewer incidences on its welfare analysis.

respectively 25%, 21.1%, 21.5%, and 20.9%, suggesting that activities that depend more on *just-in-time* processes might have been deeply affected. Note first that these are general equilibrium tariffs, which means that they pick up all types of effects including income, terms of trade and allocation effects. Second, these equivalent tariffs are large, which suggests that the 9/11 U.S. security measures must have significantly eroded/offset the trade impact of the tariff preferences obtained by Canada since the 1989 Canada-U.S. Free Trade Agreement (FTA) and NAFTA. Row 2 in Table 3.13 provides the equivalent tariffs of the Canadian security measures imposed (on U.S. goods and services) at the Canada-U.S. border. For instance, the import subsidy (as these are negative tariffs) equivalent to the Canadian security measures are about -16% to -28% in most sectors (e.g. -24.8% in the agriculture sector, -25.5% in the food sector, -16.7% in the textile sector, -28.8% in the automobile sector, and -28.2% in the service sector). The subsidy in the resource sector (-51.5%) is much higher than others. These equivalent tariffs are negative (i.e., these are import subsidies), which reveals the general equilibrium nature of these simulated rates. In order to capture the trade impacts of different security measures, we may need some subsidies to avoid the overshooting of the export targets given in Table 3.1.

As mentioned in the introduction of this section, the use of equivalent tariffs is a calibration trick that makes *explicit* the trade flow impact of the post-9/11 security measures that are only *implicit* in the observed data. Implementing the first step of the NASP (i.e., the elimination of security measures at the Canada-U.S. border) essentially comes down to eliminating these equivalent tariffs. The simulation impact of this is discussed in Section 6.

5.2 Implementing the Harmonisation of Canadian Security Measures with Respect to the ROW at the U.S. Level

As described above, implementing the NASP requires two concomitant steps. Step 1 shows how to conceptually model the existing security measures at the Canada-U.S. border as tariff-equivalent (and how to eliminate them once the NASP is introduced). When analysing the counterfactual policy of implementing the NASP (in Section 6), part of the shock will indeed be the elimination of these security measures at the Canada-U.S. border – in a sense, by setting this computed equivalent-tariff to zero. This, of course, should offset the trade flow impacts of the security measures at the Canada-U.S. border.

Step 2 of the NASP involves the harmonisation of Canadian security measures to the U.S. level with respect to the ROW. This harmonisation step may be presented as a negotiation game between the Canadian and U.S. governments. The negotiation will focus on the equivalent tariffs of existing U.S. security measures with respect to the ROW and the additional efforts needed by Canada to raise their security measures to the U.S. standards (with respect to the ROW). We can imagine the following process based on the econometric estimates given in rows 5 and 6 of Table 3.1. For example, based on row 6, U.S. negotiators may claim that their security measures had the impact of reducing U.S. imports of the ROW transportation services by 19.7%. U.S. negotiators may then claim that Canada should introduce the same security measures so as to reduce Canada's imports of the ROW transportation services by 19.7% as well. Canada will point to U.S. negotiators that their econometric analysis shows that Canadian imports of the ROW transportation services has already been reduced by 12.5% due to security measures. Therefore, to adjust to the security measure levels of the U.S. with respect to the ROW, Canadian additional efforts in terms of security measures should be, at the most, an additional (tariff-equivalent) security measure that will reduce the Canadian import of the ROW transportation services by a further 7.2% (i.e. 19.7% minus 12.5%). Canada would also argue along this line for the automobile sector and thus for an additional effort implying a reduction by 6.3% (i.e., 18.7% minus 12.4%) of their imports of the ROW automobile in order to adjust to U.S. security measure levels with respect to the ROW.

Unfortunately for Canadians, however, U.S. negotiators and their econometricians will probably reply that the Canadian analysis is not correct because the p-value in Table 3.1 indicate that the current trade impact of Canadian security measures on the ROW exports to Canada is statistically insignificant in these sectors. Therefore, it is likely that U.S. negotiators will eventually be able to impose on Canadian negotiators a full scale harmonisation of security measures so as to force a reduction of Canadian imports from the ROW by 18.7% in the automobile sector, and 19.7% in the transportation sector. Similarly, Canada will impose a reduction of Canadian imports from the ROW by 8.2% in the service sector.

The negotiation in the manufacturing sector may also turn as follows. The U.S. would argue that current econometric evidence shows that the ROW exports of manufactured goods to Canada have actually increased by 3.2%. Thus, Canada should increase their security measures with respect to the ROW so as to reduce the imports of manufactured goods by 15.5% (i.e. 12.3% plus 3.2%). However, because the p-value shows that this parameter value is not statistically significant, then, it is likely that the U.S. will simply accept that Canada adjusts to the U.S. security measures by introducing new security measures at the periphery which will have an impact of reducing the ROW export to Canada by 12.3% in the manufacturing sector.

Finally, in the technology sector, both the Canadian and U.S. negotiators will agree with the fact that the impact of security measures has been roughly similar (i.e. 26.3% versus 24.9%) so that no additional effort is needed from both countries in terms of harmonization of security measures.

In conclusion, harmonizing security measures at the North American periphery implies forcing an exogenous reduction in export flow from the ROW to Canada by 19.7% in the transport sector, 18.7% in the automobile sector, 12.3% in the manufacturing sector, and 8.2% in the service sector (see Table 3.12).

Row 3 in Table 3.13 provides the equivalent tariffs that are needed to reduce exports of the ROW to Canada, i.e., the additional equivalent tariffs that Canada must impose on the ROW in order to harmonize their security measures with respect to the ROW at the U.S. levels.

6. General Equilibrium Effects of Implementing NASP

As mentioned in Section 5, the objective of the NASP is to provide a common security frontier at the North American (Canada-U.S.) periphery, and to eliminate the security barriers at the Canada-U.S. border. With the background work described in Section 5, we can now simply implement both steps 1 and 2 concomitantly. According to our modeling strategy, this implies the elimination of the equivalent tariffs computed in rows 1, 2 and 3 of Table 3.13.

Table 3.14 gives us the trade impact of imposing the NASP. Of course, the simulated results for Canadian exports to the U.S. and U.S. exports to Canada should mirror/offset the econometrically estimated trade effects of the 9/11 security measures in Table 3.1. In fact, the numbers reported in rows 2, 11, and 20; 4, 13, and 22; and 7, 16, 25 in Table 3.14 correspond exactly to the negative of the (statistically significant) econometric estimates reported in Table 3.1. For example, the second row (CAN.CAN.US) in Table 3.14 indicates that firms of Canadian nationality located in Canada increased their exports to the U.S. by 37.8% in the technology sector (while Table 3.2 reports that security measures had lowered Canadian exports to the U.S. by 37.8% in the same sector). Furthermore, rows 7, 16, and 25 in Table 3.14 correspond indeed to the sectoral targets imposed by the U.S. on Canada (as given in row 2 of Table 3.1) in order for Canadians to harmonize their security measures with respect to the ROW to the U.S. security levels (with respect to the ROW). Canadian exports to the ROW drop significantly (as shown in rows 3, 12 and 21) and the percentage changes are generally large in each sector. As discussed in Section 2, tighter security measures at the Canada-U.S. border divert Canadian exports to the ROW. Therefore, a removal of the Canada-U.S. border security measures causes significant decline of Canadian exports to the ROW in all sectors. In other words, implementing the NASP would offset some of the observed effects of geographical diversification of Canadian exports to the ROW. For instance, there are major declines in exports to the ROW from Canadian nationality firms located in Canada, such as 33% in the food sector, 40.3% in the textile sector, 32.7% in the technology sector, and 40.9% in the automobile sector. The percentage changes in other sectors are smaller but still significant, such as 19.8% in the agriculture sector, 12.5% in the manufacturing sector, 21.3% in the service sector, and 18.4% in the transportation sector.

As mentioned in Section 5, Canada must also harmonize its security measures with the ROW. This implies a reduction of the ROW exports to Canada by 19.7% in the transportation sector, 18.7% in the automobile sector, 12.3% in the manufacturing sector, and 8.2 in the service sector (see rows 7, 16 and 25). Under the NASP, exports of the ROW to the U.S. do not change much from current level because the essential security changes of North American border are on the Canadian side. Therefore, we observe that the ROW exports to U.S. only slightly change (Table 3.14, rows 8, 17, and 26). Finally the NASP implementation causes a minor decline of U.S. exports to the ROW (Table 3.14, rows 6, 15, and 24). As the change of percentage points of Canadian exports to the ROW declines much more, this illustrates that the NASP would affect the Canadian economy much more than the U.S. economy.

The production by firms of all nationalities (Canada, U.S. and the ROW) located in Canada increases in almost all sectors (see Table 3.15, rows 1, 4, and 7). One of the reasons is that Canadian exports to U.S. increase significantly in the textile, manufacturing, and technology sectors (Table 3.14, rows 2, 11, and 20), which reflect the increase in the demand for these goods. The second reason is that as more capital flows into Canada (Table 3.16, rows 1, 4, and 7), it stimulates the production in Canada as well. The domestic investment by Canadians and FDI by the U.S. and the ROW into Canada all increase. This is due to the perceived gain occurring from the elimination of the Canada-U.S. border security measures and the perceived threat by the ROW that the NASP may become a North American area that will be hostile to trade with the ROW.

With the NASP, Canadian firms located in the U.S. and the ROW produce fewer goods, as shown in Table 3.15 (rows 2 and 3), which is consistent with the results in Table 3.16 (rows 2 and 3) that Canadian wealth is divested from the U.S. and the ROW. This indicates that removing the tight security measures at the Canada-U.S. border induces firms located in Canada to increase their domestic production and exports but to reduce Canadian direct investment abroad. As exporting to the U.S. become easier, Canadian firms located in the ROW produce fewer goods (Table 3.15, row 3) and Canadian investment in the ROW is also reduced (Table 3.16, row 3). The results for U.S.-owned firms are different from those for Canada. Under the NASP, U.S.-owned firms produce more goods in almost all sectors (except the agriculture sector) in Canada (see Table 3.15, row 4). As explained above, the capital market in Canada is favoured after implementing the NASP. Therefore, U.S. households reduce their investment in the ROW and invest more in Canada (Table 3.16, rows 4, 5 and 6). The rate of return on capital is generally much higher in Canada than the one in either U.S. or the ROW, regardless of the nationalities (Table 3.17, rows 1, 4, and 7, and Table 3.18, row 1).

The results above can be summarized as follows: first, Canadian exports (increase) to U.S. and Canadian FDI (decrease) in the U.S. are substitutes; second, Canadian exports (decrease) to the ROW and Canadian FDI (decrease) in the ROW are complements; third, U.S. exports to Canada and U.S. FDI in Canada are complements (both increase); fourth, U.S. exports to the ROW and U.S. FDI in the ROW are complements (both decrease). Why is there a difference between the first (substitutes) and the third (complements) statements? The most plausible reason is that, as a big economy, even a large shock does not affect the U.S. much, while it will affect Canada much more. As the large shocks are all pointing to the Canadian market, the capital market becomes more attractive to domestic and foreign investors. As a "*winner*", Canadian economy is booming so that there are more profits for both producers and investors. Activities in production and investment will be beneficial (complements), resulting in an increase in both U.S. exports and investment in the Canadian economy after the NASP. However, there will be disincentives for Canada to invest their wealth abroad but incentives to export to the U.S. from the Canadian market (substitutes).

Table 3.19 specifically reports the trade performance under the NASP compared to the benchmark scenario. For Canada, total exports increase by 35.4% while total imports increase by 13.2%. For the U.S., the changes of exports and imports are much smaller, 5% and 8.6% respectively. The openness index listed in Table 3.19 is the sum of total exports and imports over GDP. The index measures the importance of international transactions relative to total transactions. The interpretation of this ratio is that the higher the ratio, the larger the influence of trade on domestic activities. Thus, the openness index of Canada increases from 64.9% in the benchmark scenario to 69.7% in the NASP scenario. This reflects that implementing the NASP would enlarge the impact of trade on the Canadian economy. Although the change in this openness index of U.S. is smaller, we can observe that there is also a small increase.

Table 3.20 provides a measure of welfare of implementing the NASP. The welfare gain for Canada is estimated at about 1.8% of GDP, about $19 billion. Welfare impact for the U.S. and the ROW is quite marginal, about 0.3% of the U.S. GDP and -0.2% of the ROW GDP (a decline of welfare in the ROW) respectively. Similar results are found by Walkenhorst and Dihel (2006), who model the impact of post-9/11 border security on the world economy and estimate welfare losses of about 0.2% of GDP for North America and 0.6% of GDP elsewhere (e.g. South Asia). As reported in the study by Nguyen and Wigle (2011), the welfare cost of delay for Canada was 1.8% of GDP, and the welfare loss for Ontario was 2.4% of its GDP due to a border delay cost of 2% on goods and 1% on services.

To investigate the source of changes of EV, we decompose the EV by separating step 1 (i.e. elimination of Canada-U.S. border security measures) and 2 (harmonisation of Canada security measures to U.S. levels with respect to the ROW). Based on Table 3.21, the EV of Canada from step 1 is increased about $27 billion (2.5% of GDP) but it decreases about $8 billion (0.76% of GDP in step 2). The EV of U.S. from step 1 is $32 billion (0.3% of GDP), but slightly decreases by $70 million in step 2. These findings suggest that the harmonisation of Canada security measures to the U.S. levels with respect to the ROW would cause a welfare loss in North America due to the restraining of the imports from the ROW. However, since the gains in welfare from step 1 is much larger, the overall welfare from implementing the NASP increases in both Canada and the United States.

7. Conclusion

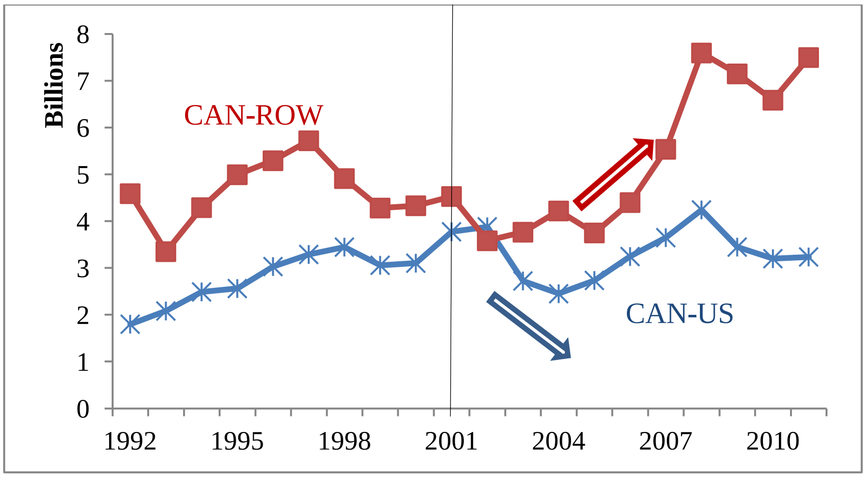
The objective of this paper was to estimate the economic and welfare impact of removing the post-9/11 security measures imposed at the Canada-U.S. border while imposing a NASP. We used a CGE model together with econometric estimates. The current post-9/11 security measures have decreased Canadian exports to the U.S. and increased Canadian exports to the ROW. Our results show that a NASP would reverse these trade flows. Meanwhile, Canada would gain benefits after implementing the NASP because it would be more attractive to the domestic and foreign investors and this would stimulate its economy. Under the NASP, the welfare of Canada is estimated to increase by about 1.8% of GDP (about $19 billion), and the welfare of U.S. is estimated to increase by about 0.3% of GDP (about $32 billion), which suggests that this project merits further discussion by policy makers. Although security measures also apply to people, this model cannot address this relevant issue because of immobility of labour between the U.S. and Canada.[70]

This analysis requires a large number of parameter values as reported in the appendix X. The values of some of those parameters are difficult to find in the literature. Further study would call for a sensitivity analysis and a more complete set of values of those parameters.

Appendix for Chapter 3

A.1 Figures on Trade Data[71]

Figure 3.1: Canadian Exports to U.S. and the ROW in the Agriculture (AGRI) Sector (in 2000 U.S. Dollar)



[70] The model including mobility of labour is discussed in the paper of Dixon et al. (2011).
[71] Data sources are Industry Canada's Trade Data Online, CANSIM, and Bureau of Economic Analysis.

Figure 3.2: Canadian Exports to U.S. and the ROW in the Resource (RESO) Sector (in 2000 U.S. Dollar)

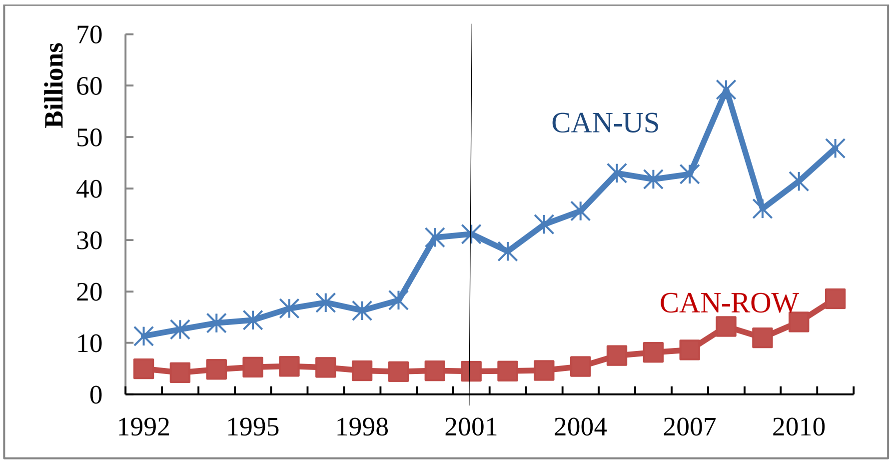


Figure 3.3: Canadian Exports to U.S. and the ROW in the Food (FOOD) Sector (in 2000 U.S. Dollar)

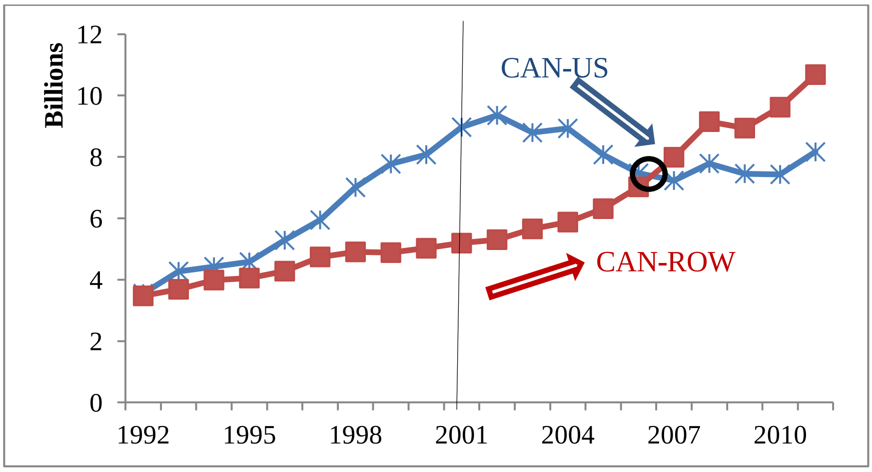


Figure 3.4: Canadian Exports to U.S. and the ROW in the Textile (TEXT) Sector (in 2000 U.S. Dollar)

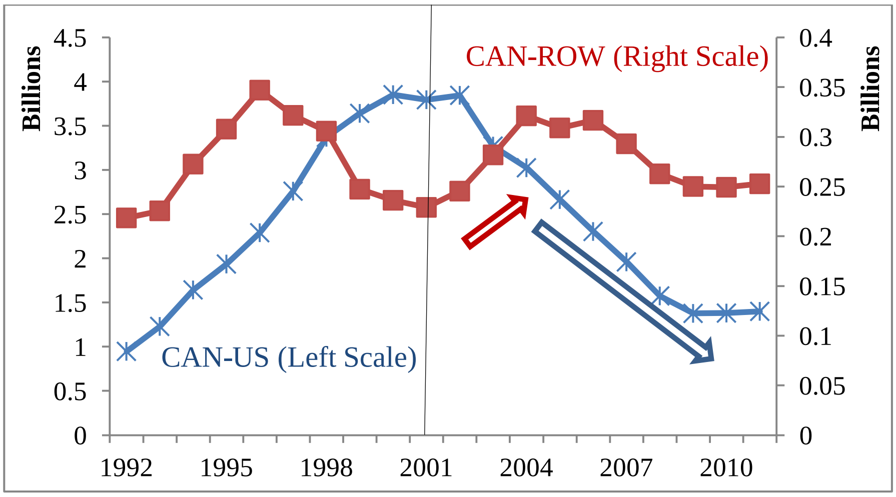


Figure 3.5: Canadian Exports to U.S. and the ROW in the Manufacturing (MANU) Sector (in 2000 U.S. Dollar, with Primary Axis)

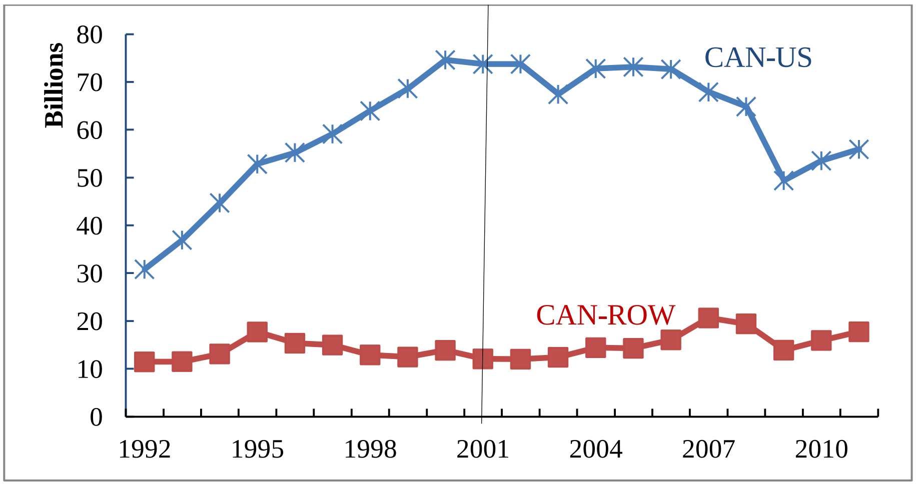


Figure 3.6: Canadian Exports to U.S. and the ROW in the Manufacturing (MANU) Sector (in 2000 U.S. Dollar, with Primary and Secondary Axes)

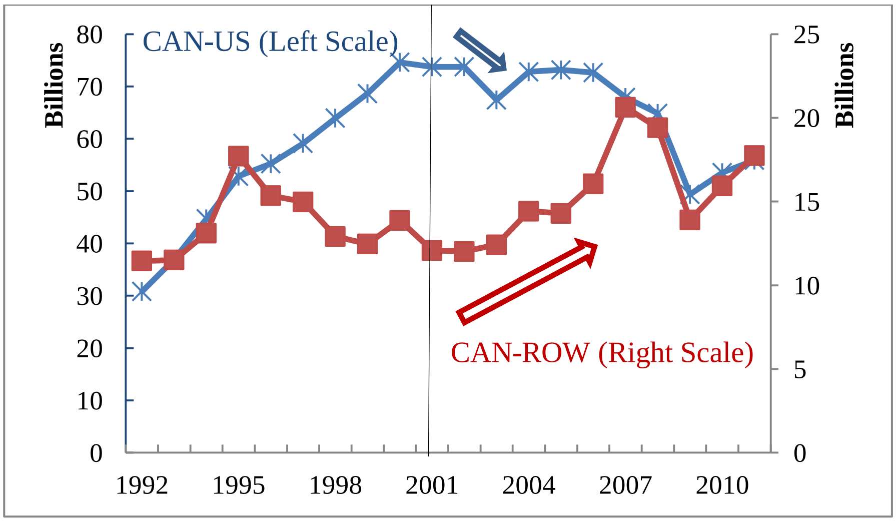


Figure 3.7: Canadian Exports to U.S. and the ROW in the Automobile (AUTO) Sector (in 2000 U.S. Dollar)

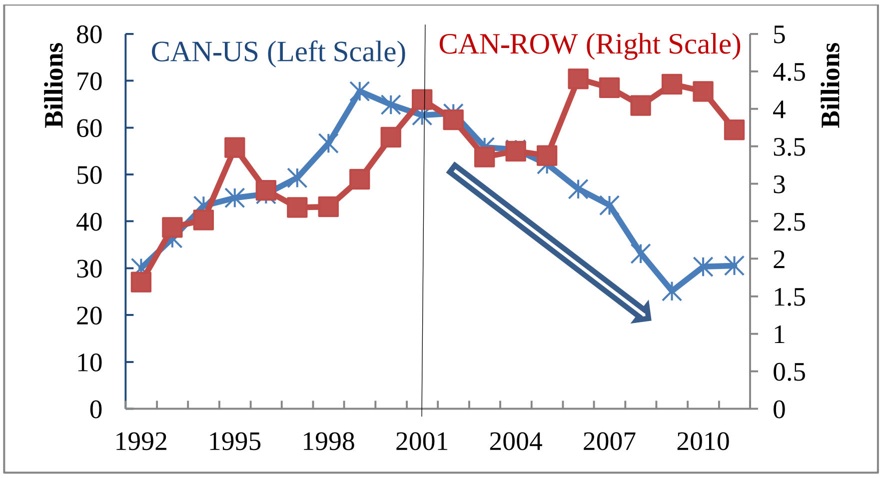


Figure 3.8: Canadian Exports to U.S. and the ROW in the Technology (TECH) Sector (in 2000 U.S. Dollar, with Primary Axes)

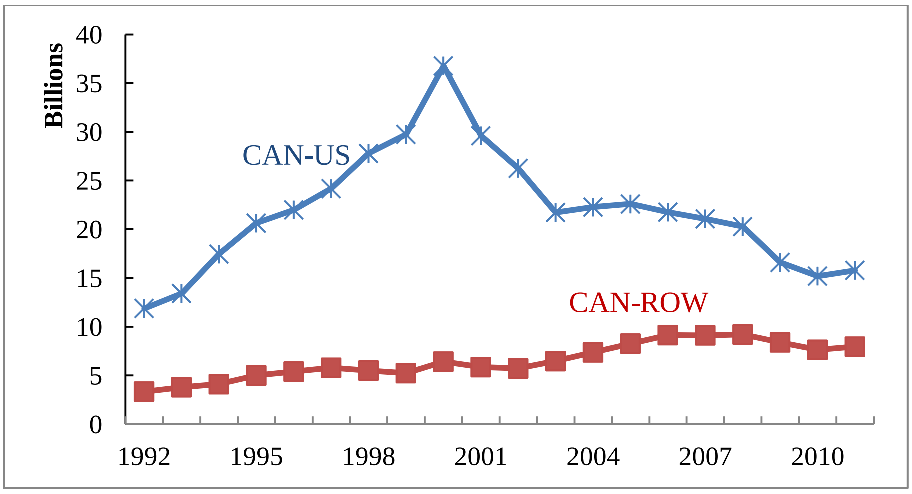


Figure 3.9: Canadian Exports to U.S. and the ROW in the Technology (TECH) Sector (in 2000 U.S. Dollar, with Primary and Secondary Axes)

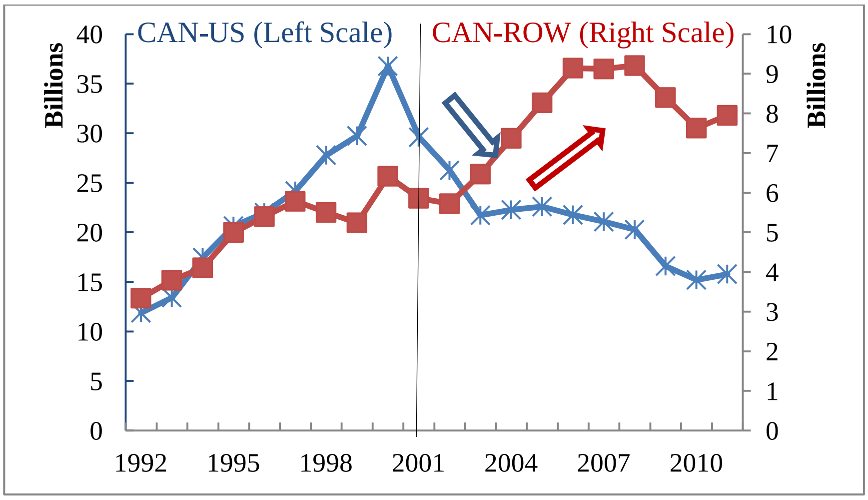


Figure 3.10: Canadian Exports to U.S. and the ROW in the Service (SERV) Sector (in 2000 U.S. Dollar, with Primary Axis)

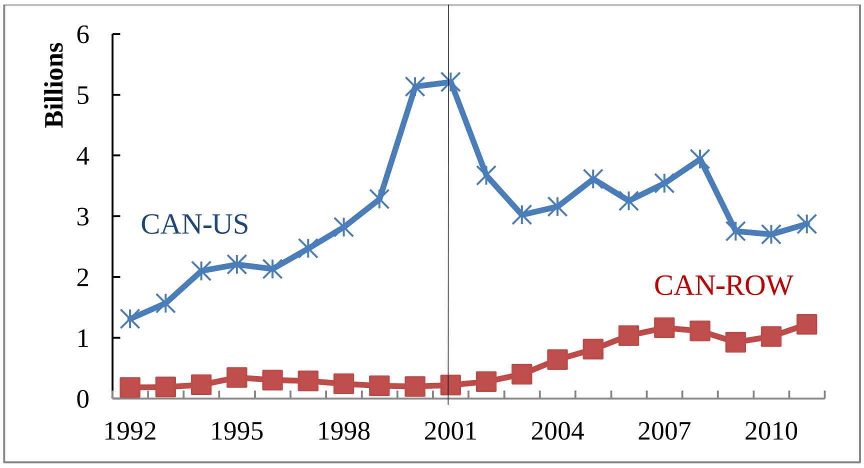


Figure 3.11: Canadian Exports to U.S. and the ROW in the Service (SERV) Sector (in 2000 U.S. Dollar, with Primary and Secondary Axes)

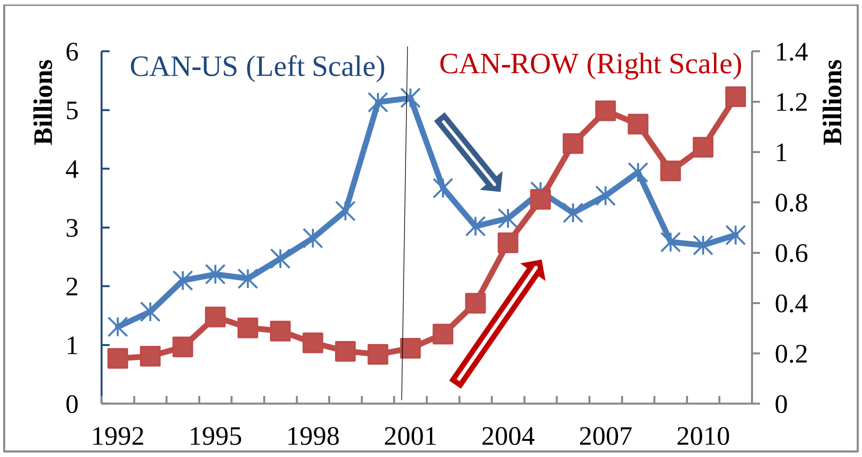


Figure 3.12: Canadian Exports to U.S. and the ROW in the Transportation (TRAN) Sector (in 2000 U.S. Dollar)[72]

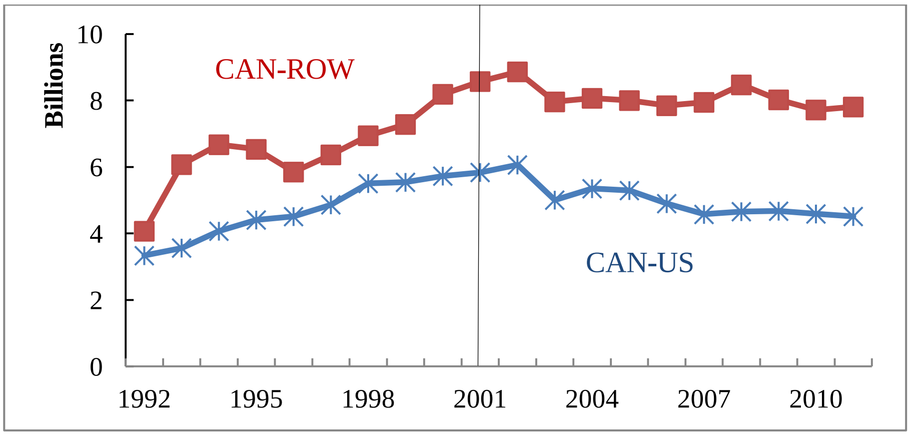
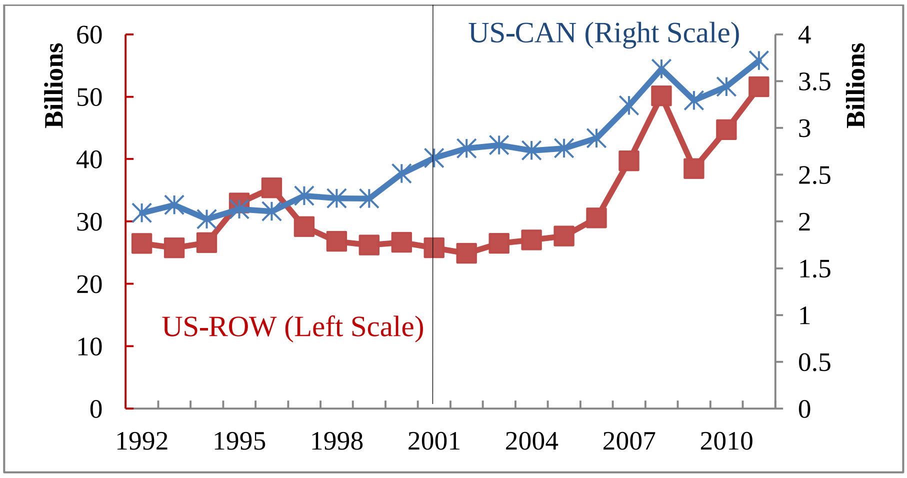


Figure 3.13: U.S. Exports to Canada and the ROW in the Agriculture (AGRI) Sector (in 2000 U.S. Dollar, with Primary and Secondary Axes)



[72] Based on the definitions of NAICS, the sector of transportation includes the delivery of goods and people. The means of transportation include road, rail, water, air and pipeline. National post office service is also included in this sector.

Figure 3.14: U.S. Exports to Canada and the ROW in the Resource (RESO) Sector (in 2000 U.S. Dollar, with Primary and Secondary Axes)

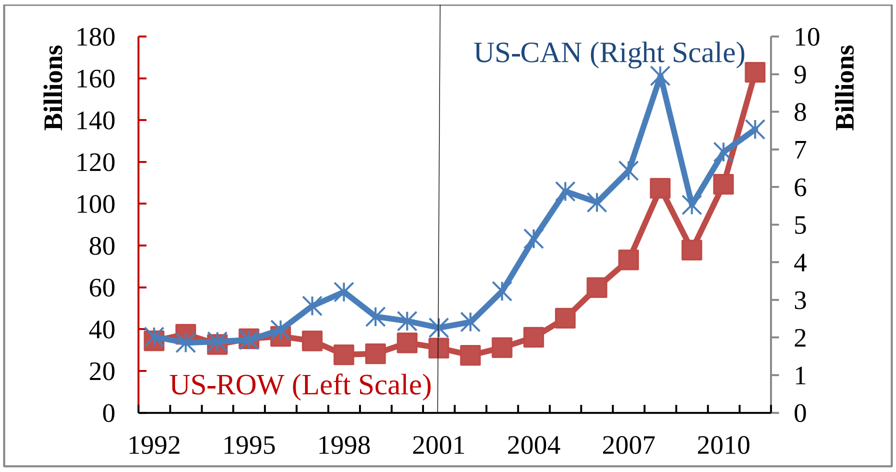


Figure 3.15: U.S. Exports to Canada and the ROW in the Food (FOOD) Sector (in 2000 U.S. Dollar, with Primary and Secondary Axes)

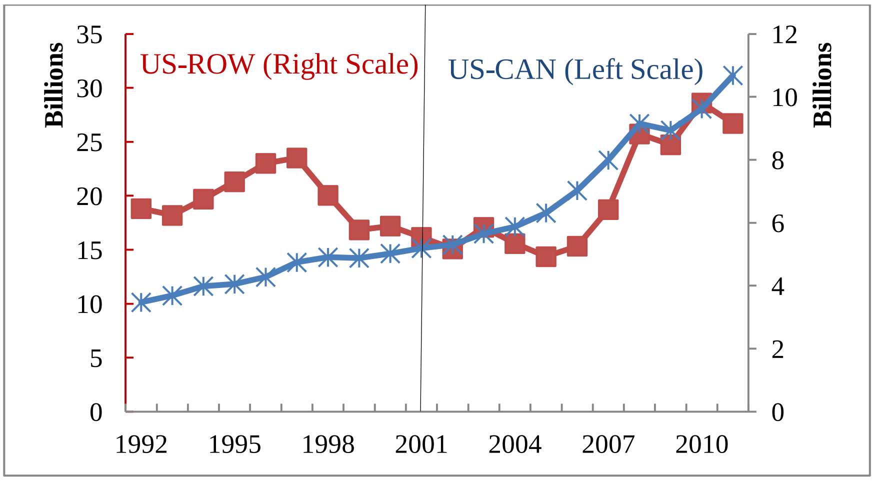


Figure 3.16: U.S. Exports to Canada and the ROW in the Textile (TEXT) Sector (in 2000 U.S. Dollar, with Primary and Secondary Axes)

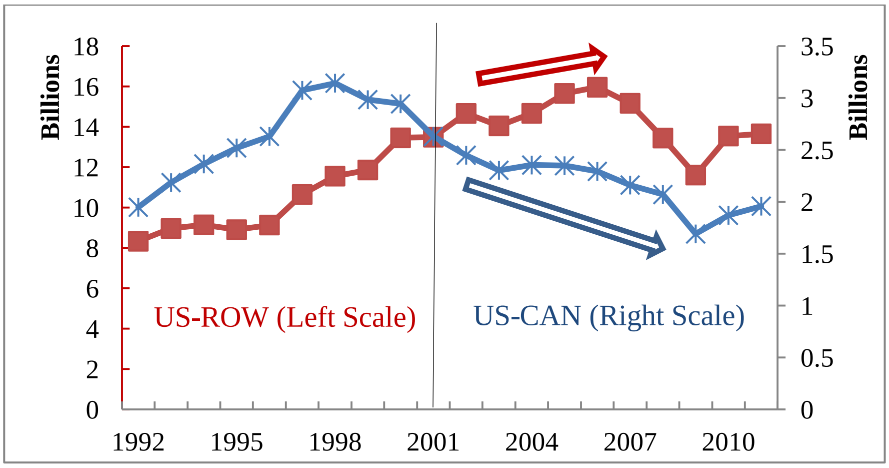


Figure 3.17: U.S. Exports to Canada and the ROW in the Manufacturing (MANU) Sector (in 2000 U.S. Dollar, with Primary and Secondary Axes)

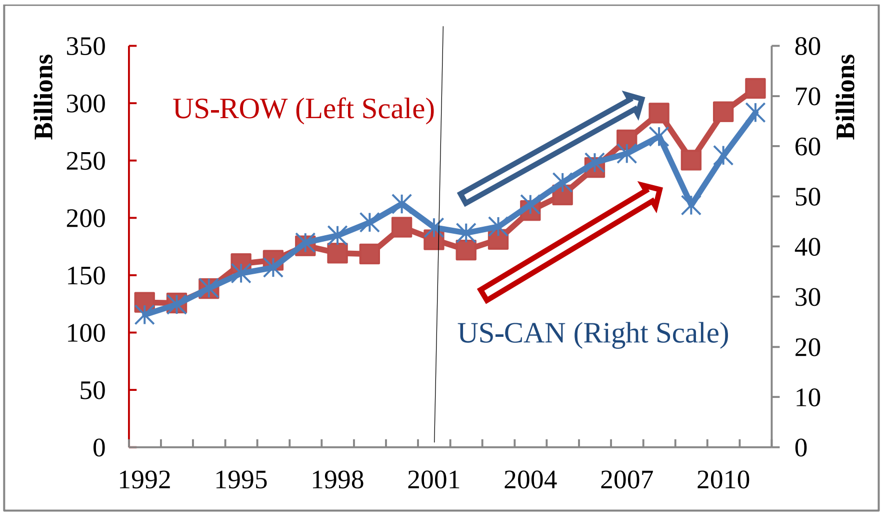


Figure 3.18: U.S. Exports to Canada and the ROW in the Automobile (AUTO) Sector (in 2000 U.S. Dollar, with Primary and Secondary Axes)

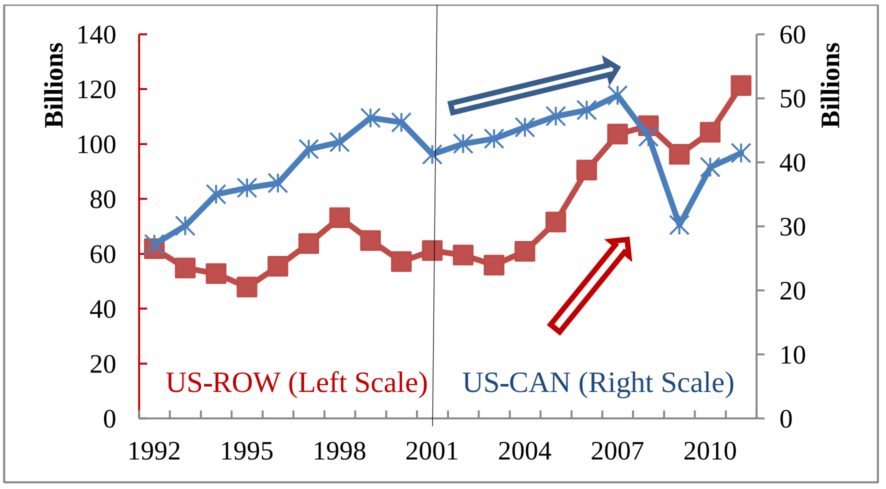


Figure 3.19: U.S. Exports to Canada and the ROW in the Technology (TECH) Sector (in 2000 U.S. Dollar, with Primary and Secondary Axes)

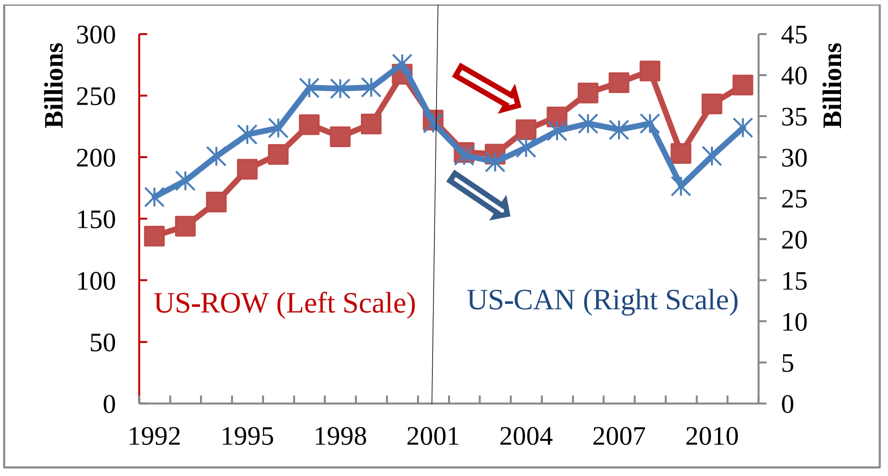


Figure 3.20: U.S. Exports to Canada and the ROW in the Service (SERV) Sector (in 2000 U.S. Dollar, with Primary and Secondary Axes)

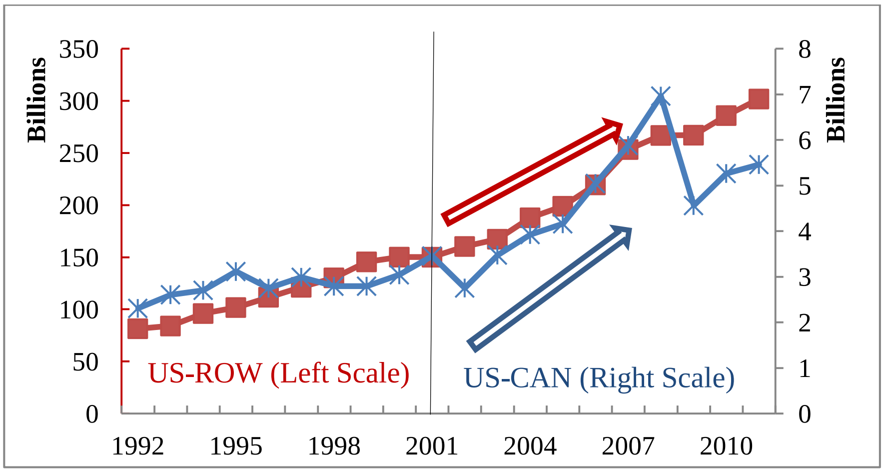


Figure 3.21: U.S. Exports to Canada and the ROW in the Transportation (TRAN) Sector (in 2000 U.S. Dollar, with Primary and Secondary Axes)

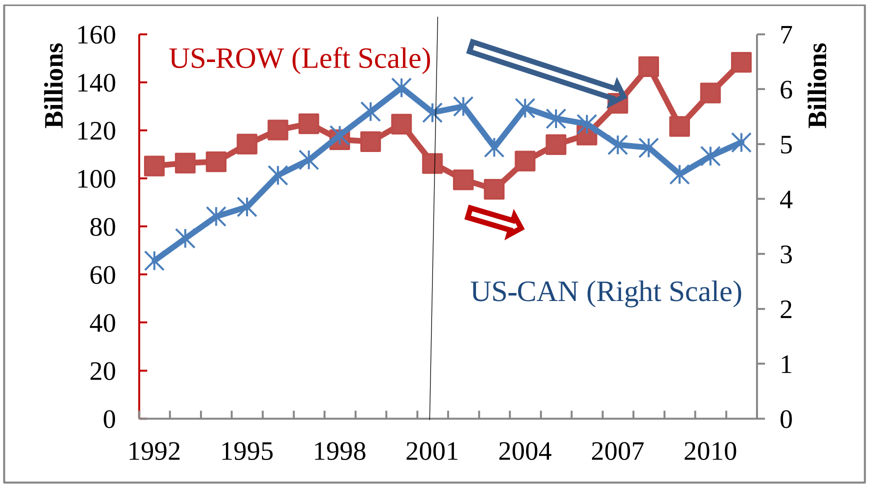


Figure 3.22: U.S.-Canada Volume of Trade (in 2000 U.S. Dollar)

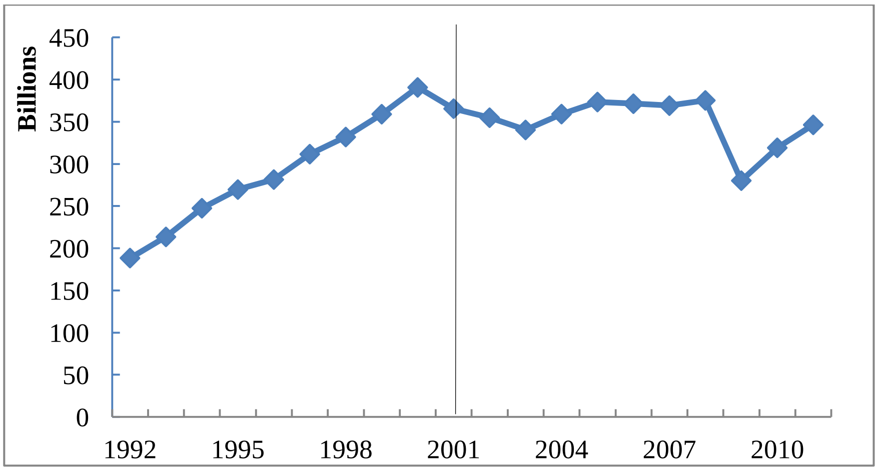
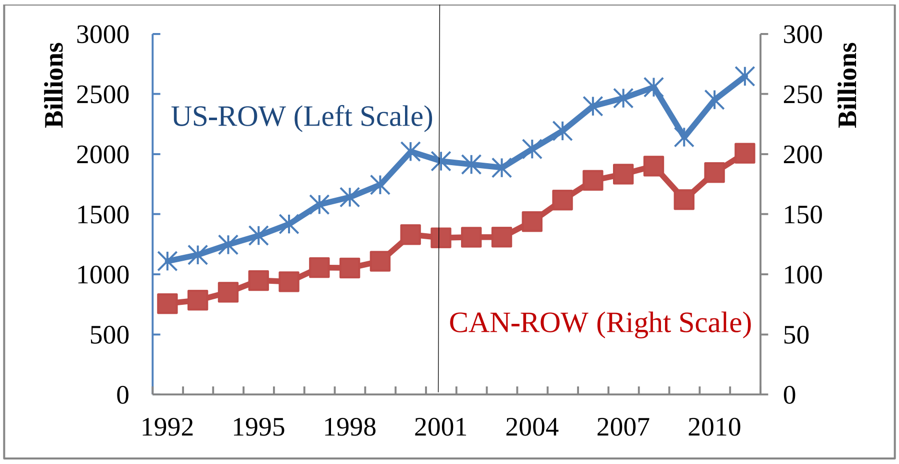


Figure 3.23: U.S.-ROW and Canada-ROW Volume of Trade (in 2000 U.S. Dollar)



A.2 Econometric Analysis

The econometric analysis applies annual data from 1992 to 2011.[73] The data of Canadian exports and imports by industry are from Industry Canada's Trade Data Online (TDO).[74] The industry classification is under North American Industry Classification System (NAICS). The data of the U.S. exports and imports by industry are from the United States International Trade Commission.[75] The industry classification of U.S. exports to the world is by Standard International Trade Classification (SITC). The sectors studied in this paper are agriculture (AGRI), resource (RESO), food (FOOD), textile (TEXT), manufacturing (MANU), automobile (AUTO), technology (TECH), service (SERV) and transportation (TRAN).[76] Because neither NAICS nor SITC include data for transportation services, a supplementary data source for transportation is found in CANSIM for Canada, and Bureau of Economic Analysis (BEA) for the U.S.

Due to the difference between NAICS and SITC, part of the data of U.S. exports under SITC is excluded.[77] The valuation of import is valued by free on board (F.O.B.)

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[73] Some quarterly data series of dependent and some independent variables are missing, thus we work with annual data.
[74] The link of data source is http://www.ic.gc.ca/eic/site/tdo-dcd.nsf/eng/Home.
[75] The link of data source is http://dataweb.usitc.gov/.
[76] The definitions of sectors are fully discussed in the paper of Georges et al. (2012).
[77] The excluded information of U.S. exports by industry defined by SITC is SITC 95, 96, 97, 98 and 99, which are the sectors of coin and low valued items.

and the valuation of exports is valued by free alongside ship (F.A.S.) at the port of exports.[78]

The data source for an effective exchange rate (EER) is from the Bank for International Settlement.[79] EER is calculated as a weighted average across 27 economies.[80] The information of GDP and GDP deflator is obtained from the World Bank. The data source of Canadian capacity utilisation rate is from CANSIM, conducted by Industry Canada; the data for the U.S. capacity utilisation rate is from Industrial Production and Capacity Utilisation, conducted by Board of Governors of the Federal Reserve System.

A.2.1 Regression Results under Seemingly Unrelated Regression (SUR)

Table 3.1: Summary of the Impact of 9/11 on the Exports among Canada, U.S. and the ROW across Sectors

Row	D911	AGRI	RESO	FOOD	TEXT	MANU	AUTO	TECH	SERV	TRAN
1	**CAN-US**	-0.134	0.055	-0.076	-0.220	-0.165	-0.126	-0.378	-0.495	-0.104
	p-value	0.190	0.650	0.188	0.000*	0.000*	0.070***	0.000*	0.000*	0.017**
2	**US-CAN**	-0.002	0.079	-0.012	-0.182	-0.262	-0.123	-0.359	-0.019	-0.203
	p-value	0.972	0.642	0.711	0.004*	0.000*	0.193	0.000*	0.851	0.000*
3	**CAN-ROW**	-0.321	-0.119	0.023	0.180	-0.166	-0.133	0.007	0.409	-0.013
	p-value	0.009*	0.389	0.680	0.011**	0.145	0.133	0.925	0.004*	0.817
4	**US-ROW**	-0.030	-0.015	-0.069	0.015	-0.149	-0.036	-0.167	-0.024	-0.153
	p-value	0.776	0.923	0.534	0.744	0.000*	0.594	0.001*	0.479	0.001*
5	**ROW-CAN**	0.031	-0.023	-0.046	-0.045	0.032	-0.124	-0.263	-0.117	-0.125
	p-value	0.524	0.888	0.188	0.436	0.481	0.157	0.000*	0.168	0.118
6	**ROW-US**	-0.096	0.133	0.005	-0.020	-0.123	-0.187	-0.249	-0.082	-0.197
	p-value	0.022**	0.295	0.941	0.682	0.001*	0.003*	0.000*	0.078***	0.000*

*Note: *= significant at 1%, **=significant at 5%, ***=significant at 10%.*

[78] F.O.B. excludes the import country duties, freight, insurance, and other charges incurred in bringing goods to the port of importation; F.A.S. includes freight, insurance and other charges incurred in taking goods at the port of exportation.
[79] The link of data source is http://www.bis.org/statistics/eer/index.htm.
[80] The 27 economies are Australia, Austria, Belgium, Canada, Chinese Taipei, Denmark, Euro area, Finland, France, Germany, Greece, Hong Kong SAR, Ireland, Italy, Japan, Korea, Mexico, Netherlands, New Zealand, Norway, Portugal, Singapore, Spain, Sweden, Switzerland, United Kingdom, and United States.

Table 3.2: Regression Results for the Log of Canada's Real Export of Goods to the U.S. in Constant Dollar

	AGRI	RESO	FOOD	TEXT	MANU	AUTO	TECH	SERV	TRAN
C	2.780	-5.206	3.349	4.431	8.289	11.298	4.384	-5.578	8.875
	0.385	0.183	0.134	0.019**	0.000*	0.000*	0.052***	0.068***	0.000*
Log of US Real GDP	0.744	2.840	0.625	0.569	1.374	0.422	0.855	1.290	0.851
	0.115	0.000*	0.146	0.137	0.000*	0.092***	0.006*	0.001*	0.003*
Rel. Cost (t-1)	-0.015	0.103	-0.164	-0.580	-0.491	-0.626	-0.273	0.024	-0.330
	0.915	0.360	0.226	0.000*	0.000*	0.000*	0.007*	0.843	0.002*
Exports (t-1)	0.708	0.081	0.721	0.582	0.249	0.398	0.467	0.489	0.341
	0.000*	0.469	0.000*	0.000*	0.000*	0.000*	0.000*	0.000*	0.073***
911	-0.134	0.055	-0.076	-0.220	-0.165	-0.126	-0.378	-0.495	-0.104
	0.190	0.650	0.188	0.000*	0.000*	0.070***	0.000*	0.000*	0.017**
CUR (Can)	-0.039	0.014	-0.034	-0.007	-0.027	-0.005	0.008	0.063	-0.024
	0.139	0.063***	0.032**	0.445	0.000*	0.247	0.183	0.000*	0.033**
R-Square	0.63	0.94	0.95	0.98	0.96	0.94	0.92	0.87	0.89

Note: *= significant at 1%, **=significant at 5%, ***=significant at 10%.

Correlation Matrix of Residuals:

Log of CAN-US Exports	AGRI	RESO	FOOD	TEXT	MANU	AUTO	TECH	SERV	TRAN
AGRI	1								
RESO	0.361	1							
FOOD	0.270	0.059	1						
TEXT	0.083	-0.459	0.348	1					
MANU	0.472	0.323	0.340	0.274	1				
AUTO	0.1523	-0.3324	0.1417	0.281	0.1364	1			
TECH	0.1539	0.1318	-0.226	0.2404	0.4696	0.1012	1		
SERV	0.4173	0.5874	0.0695	0.0101	0.5075	0.2685	0.6591	1	
TRAN	0.3016	-0.0348	0.256	0.4059	0.1825	0.0357	0.1452	0.326	1

Breusch-Pagan Test of Independence: chi2(36)=65.890, Pr=0.0017

Table 3.3: Regression Results for the Log of U.S. Real Export of Goods to Canada in Constant Dollar

	AGRI	RESO	FOOD	TEXT	MANU	AUTO	TECH	SERV	TRAN
C	9.143	5.236	3.021	11.701	12.638	14.948	14.490	13.051	10.489
	0.002*	0.123	0.000*	0.000*	0.000*	0.000*	0.000*	0.000*	0.000*
Log of Can Real GDP	0.679	1.578	0.488	0.175	2.179	0.878	1.013	1.357	1.252
	0.000*	0.018**	0.001*	0.372	0.000*	0.007*	0.000*	0.000*	0.000*
Rel. Cost (t-1)	-0.108	-0.476	-0.165	0.188	-0.069	0.273	0.107	-0.500	0.327
	0.030**	0.019**	0.000*	0.002*	0.139	0.002*	0.074***	0.000*	0.000*
Exports (t-1)	0.374	0.291	0.726	0.408	-0.095	0.153	0.133	0.005	0.163
	0.018**	0.048**	0.000*	0.000*	0.299	0.143	0.088***	0.975	0.205
911	-0.002	0.079	-0.012	-0.182	-0.262	-0.123	-0.359	-0.019	-0.203
	0.972	0.642	0.711	0.004*	0.000*	0.193	0.000*	0.851	0.000*
R-Square	0.95	0.91	0.99	0.88	0.95	0.62	0.72	0.89	0.91

*Note: *= significant at 1%, **=significant at 5%, ***=significant at 10%.*

Correlation Matrix of Residuals:

Log of US-CAN Exports	AGRI	RESO	FOOD	TEXT	MANU	AUTO	TECH	SERV	TRAN
AGRI	1								
RESO	-0.0581	1							
FOOD	0.4659	0.5565	1						
TEXT	0.0761	0.7894	0.6389	1					
MANU	0.1291	0.7026	0.6503	0.8156	1				
AUTO	-0.0032	0.652	0.5828	0.8245	0.7205	1			
TECH	0.0595	0.7349	0.5802	0.8973	0.9408	0.8188	1		
SERV	0.2452	0.4461	0.3975	0.2323	0.4224	0.3768	0.4136	1	
TRAN	-0.2278	0.3246	-0.0154	0.5541	0.4419	0.3481	0.5196	-0.2354	1

Breusch-Pagan Test of Independence: chi2(36)=198.341, Pr=0

Table 3.4: Regression Results for the Log of Canada Real Export of Goods to the ROW in Constant Dollar

	AGRI	RESO	FOOD	TEXT	MANU	AUTO	TECH	SERV	TRAN
C	0.925	-2.716	8.770	12.734	12.859	8.322	5.288	5.550	10.868
	0.805	0.682	0.000*	0.000*	0.000*	0.004*	0.016**	0.209	0.000*
Log of ROW Real GDP	1.832	1.068	0.745	-0.506	0.895	0.085	0.087	-0.642	-0.156
	0.000*	0.055***	0.002*	0.179	0.038**	0.812	0.823	0.299	0.431
Rel. Cost (t-1)	-0.024	0.494	-0.192	-0.084	0.137	0.239	0.089	0.498	0.250
	0.921	0.116	0.072	0.679	0.531	0.189	0.568	0.067***	0.062***
Exports (t-1)	0.317	0.599	0.347	0.642	0.103	0.441	0.671	0.757	0.431
	0.039**	0.001*	0.007*	0.000	0.474	0.004	0.000	0.000*	0.001*
911	-0.321	-0.119	0.023	0.180	-0.166	-0.133	0.007	0.409	-0.013
	0.009*	0.389	0.680	0.011**	0.145	0.133	0.925	0.004*	0.817
CUR (Can)	-0.047	-0.012	-0.014	-0.005	-0.016	0.026	0.011	0.042	0.031
	0.076***	0.581	0.209	0.726	0.310	0.000*	0.102	0.087***	0.002*
R-Square	0.79	0.92	0.91	0.68	0.51	0.79	0.92	0.95	0.80

*Note: *= significant at 1%, **=significant at 5%, ***=significant at 10%.*

Correlation Matrix of Residuals:

Log of CAN-ROW Exports	AGRI	RESO	FOOD	TEXT	MANU	AUTO	TECH	SERV	TRAN
AGRI	1								
RESO	0.2045	1							
FOOD	0.2799	0.5593	1						
TEXT	0.3925	0.4526	0.5239	1					
MANU	0.4879	0.3966	0.4099	0.4771	1				
AUTO	-0.0894	-0.069	0.017	-0.0153	0.2874	1			
TECH	-0.0219	0.273	0.2318	0.3763	0.3938	0.2375	1		
SERV	0.1864	0.5099	0.6958	0.6046	0.6391	0.2482	0.4779	1	
TRAN	-0.3495	-0.1694	-0.1884	-0.5491	-0.3281	0.3517	-0.1565	-0.3117	1

Breusch-Pagan Test of Independence: chi2(36)=97.255, Pr=0

Table 3.5: Regression Results for the Log of US Real Export of Goods to the ROW in Constant Dollar

	AGRI	RESO	FOOD	TEXT	MANU	AUTO	TECH	SERV	TRAN
C	10.303	-0.192	11.461	4.852	6.199	1.753	3.603	-0.567	12.589
	0.015**	0.971	0.008*	0.004*	0.000*	0.439	0.013**	0.482	0.000*
Log of ROW Real GDP	1.001	1.695	0.365	1.191	2.177	1.386	1.176	2.165	0.946
	0.002*	0.002*	0.282	0.000*	0.000*	0.000*	0.000*	0.000*	0.000*
Rel. Cost (t-1)	-0.590	-0.895	-0.539	0.680	-0.148	-0.423	0.450	0.008	-0.252
	0.000*	0.004*	0.002*	0.000*	0.001*	0.000*	0.000*	0.871	0.000*
Exports (t-1)	0.243	0.466	0.476	0.111	-0.068	0.413	0.294	0.160	0.153
	0.043**	0.003*	0.000*	0.042**	0.355	0.000*	0.000*	0.105	0.144
911	-0.030	-0.015	-0.069	0.015	-0.149	-0.036	-0.167	-0.024	-0.153
	0.776	0.923	0.534	0.744	0.000*	0.594	0.001*	0.479	0.001*
CUR (Can)	0.008	0.005	-0.003	0.010	0.006	0.013	0.014	0.006	0.009
	0.155	0.494	0.734	0.000*	0.000*	0.000*	0.000*	0.011**	0.000*
R-Square	0.84	0.93	0.78	0.95	0.99	0.95	0.94	1.00	0.92

*Note: *= significant at 1%, **=significant at 5%, ***=significant at 10%.*

Correlation Matrix of Residuals:

Log of US-ROW Exports	AGRI	RESO	FOOD	TEXT	MANU	AUTO	TECH	SERV	TRAN
AGRI	1								
RESO	0.64	1							
FOOD	0.7179	0.3638	1						
TEXT	-0.7799	-0.5	-0.596	1					
MANU	0.5381	0.0872	0.6414	-0.3059	1				
AUTO	-0.3316	-0.3421	-0.1744	0.4465	-0.2502	1			
TECH	-0.1467	-0.1104	0.0734	0.3878	0.4777	-0.1561	1		
SERV	-0.0726	-0.3208	-0.0914	-0.2562	-0.1712	-0.0311	-0.1874	1	
TRAN	0.6458	0.5289	0.5245	-0.3401	0.4858	-0.2523	0.1253	-0.0522	1

Breusch-Pagan Test of Independence: chi2(36)=108.068, Pr=0

Table 3.6: Regression Results for the Log of the ROW Real Export of Goods to Canada in Constant Dollar

	AGRI	RESO	FOOD	TEXT	MANU	AUTO	TECH	SERV	TRAN
C	1.337	-0.081	10.054	5.679	6.248	1.805	6.678	1.166	4.206
	0.256	0.981	0.000*	0.007*	0.000*	0.356	0.000*	0.502	0.048**
Log of Can Real GDP	-0.090	3.976	1.635	1.037	2.386	1.760	2.818	1.934	0.676
	0.664	0.000*	0.000*	0.000*	0.000*	0.000*	0.000*	0.000*	0.009*
Rel. Cost (t-1)	-0.083	-0.689	-0.165	0.023	-0.132	0.301	0.152	-0.469	0.198
	0.241	0.022**	0.003*	0.781	0.063***	0.018**	0.023**	0.001*	0.115
Exports (t-1)	0.967	-0.134	0.058	0.445	0.076	0.423	-0.052	0.314	0.611
	0.000*	0.524	0.567	0.000*	0.419	0.000*	0.428	0.001*	0.000*
911	0.031	-0.023	-0.046	-0.045	0.032	-0.124	-0.263	-0.117	-0.125
	0.524	0.888	0.188	0.436	0.481	0.157	0.000*	0.168	0.118
R-Square	0.97	0.94	0.99	0.96	0.99	0.95	0.98	0.97	0.84

*Note: *= significant at 1%, **=significant at 5%, ***=significant at 10%.*

Correlation Matrix of Residuals:

Log of ROW-CAN Exports	AGRI	RESO	FOOD	TEXT	MANU	AUTO	TECH	SERV	TRAN
AGRI	1								
RESO	0.3498	1							
FOOD	0.7004	0.1516	1						
TEXT	0.4569	0.1594	0.3869	1					
MANU	0.2855	0.2898	-0.0501	0.4091	1				
AUTO	0.4873	0.2334	0.5341	0.7911	0.2916	1			
TECH	0.0195	0.1554	-0.0867	0.678	0.6623	0.5423	1		
SERV	-0.145	0.0552	0.1025	-0.0287	0.2525	0.0466	-0.0198	1	
TRAN	0.1859	0.2137	-0.1934	0.5409	0.3786	0.5177	0.6534	-0.4126	1

Breusch-Pagan Test of Independence: chi2(36) = 102.373, Pr = 0

Table 3.7: Regression Results for the Log of the ROW Real Export of Goods to U.S. in Constant Dollar

	AGRI	RESO	FOOD	TEXT	MANU	AUTO	TECH	SERV	TRAN
C	-0.146	-2.126	3.597	10.337	4.925	6.287	6.267	-2.183	6.531
	0.945	0.564	0.081	0.000*	0.000*	0.002*	0.000*	0.106	0.003*
Log of US Real GDP	0.638	2.950	1.004	0.910	1.876	1.555	1.750	1.061	0.807
	0.010**	0.000*	0.031**	0.000*	0.000*	0.000*	0.000*	0.000*	0.000*
Rel. Cost (t-1)	-0.092	0.324	0.278	-0.371	-0.448	-0.943	-0.363	-0.035	-0.348
	0.141	0.072**	0.014**	0.000*	0.000*	0.000*	0.000*	0.577	0.000*
Exports (t-1)	0.760	0.017	0.444	0.197	0.162	0.190	0.155	0.701	0.453
	0.000*	0.864	0.020**	0.016**	0.010**	0.000*	0.069***	0.000*	0.000*
911	-0.096	0.133	0.005	-0.020	-0.123	-0.187	-0.249	-0.082	-0.197
	0.022**	0.295	0.941	0.682	0.001*	0.003*	0.000*	0.078***	0.000*
R-Square	0.98	0.94	0.94	0.93	0.99	0.95	0.96	0.99	0.92

*Note: *= significant at 1%, **=significant at 5%, ***=significant at 10%.*

Correlation Matrix of Residuals:

Log of ROW-US Export	AGRI	RESO	FOOD	TEXT	MANU	AUTO	TECH	SERV	TRAN
AGRI	1								
RESO	-0.2114	1							
FOOD	0.1571	-0.1808	1						
TEXT	0.22	0.5236	0.2358	1					
MANU	0.2139	0.5238	0.1672	0.8647	1				
AUTO	0.1864	0.7258	0.1427	0.8676	0.8569	1			
TECH	0.0947	0.3116	0.3826	0.7643	0.677	0.6971	1		
SERV	0.402	-0.2573	0.0469	-0.023	0.2922	0.0881	0.0499	1	
TRAN	0.2989	0.461	0.0999	0.8172	0.8259	0.6986	0.5901	0.154	1

Breusch-Pagan Test of Independence: chi2(36) = 157.197, Pr=0

A.3 Description of Parameters and Variables

Notations of Parameters and Variables	**Description**
Consumption by Representative Household in Region j	
C_j	Basket of Consumption of representative household in region *j*
PC_j	Price of basket of consumption of representative household in region *j*
$CS_{j,s}$	Consumption in sector *s* by representative household in region *j*
$PCS_{j,s}$	Price of consumption in sector *s* by representative household in region *j*
$\rho_{j,s}$	Share of Consumption in sector *s* by representative household in region *j* in basket of consumption in CES function
Domestic Consumption	
$CSD_{j,s}$	Consumption in sector *s* produced domestically and consumed by representative household in region *j*
$PCSD_{j,s}$	Price of consumption in sector *s* produced domestically and consumed by representative household in region *j*
$\eta CSD_{j,s}$	Share of consumption in sector *s* produced domestically and consumed by representative household in region *j* in CES function
Foreign Consumption	
$CSF_{j,s}$	Consumption in sector *s* produced in all foreign regions and consumed by representative household in region *j*
$PCSF_{j,s}$	Price of consumption in sector *s* produced in all foreign regions and consumed by representative household in region *j*
$\eta CSF_{j,s}$	Share of Price of consumption in sector *s* produced in all foreign regions and consumed by representative household in region *j* in CES function
$CSFIJ_{i,j,s}$	Consumption in sector *s* produced in foreign region *i* and consumed by representative household in region *j*
$PCSFIJ_{i,j,s}$	Price of consumption in sector *s* produced in foreign region *i* and consumed by representative household in region *j*
$\eta CSFIJ_{i,j,s}$	Share of consumption in sector *s* produced in foreign region *i* and consumed by representative household in region *j* in CES function
$CSIJV_{v,i,j,s}$	Consumption in sector *s* produced in foreign region *i* by a firm with nationality *v* and consumed by representative household in region *j*
$PSIJV_{v,i,s}$	Price of consumption in sector *s* produced in foreign region *i* by a firm with nationality *v* and consumed by representative household in region *j*
$\eta CSFIJV_{v,i,j,s}$	Share of Consumption in sector *s* produced in foreign region *i* by a firm with nationality *v* and consumed by representative household in region *j* in CES function
$CSIJV_{v,j,j,s}$	Consumption in sector *s* produced domestically in region *j* by a firm with nationality *v* and consumed by representative household in region *j*
$PSIJV_{v,j,s}$	Price of consumption in sector *s* produced domestically in region *j* by a firm with nationality *v* and consumed by representative household in region *j*
$\eta CSDJJV_{v,j,j,s}$	Share of consumption in sector *s* produced domestically in region *j* by a firm with nationality *v* and consumed by representative household in region *j* in CES function
Investment by Representative Household in Region j	
I_j	Total investment demand by region *j*
PI_j	Price of total investment demand by region *j*
$IVS_{v,j,s}$	Investment demand in sector *s* by region *j* produced by a firm with nationality *v*
$PIV_{v,j,s}$	Price of investment demand in sector *s* by region *j* produced by a firm with nationality *v*
$\gamma_{v,j,s}$	Share of investment demand in sector *s* by region *j* produced by a firm with nationality *v* in Cobb-Douglas function
$IVSI_{v,i,j,s}$	Investment demand in sector *s* by region *j* produced by a firm with nationality *v* in a foreign region *i*

$PSIJV_{v,j,s}$	Investment demand in sector *s* produced by a firm with nationality *v* in a foreign region *i*
$\eta IVSI_{v,i,j,s}$	Share of investment demand in sector *s* by region *j* produced by a firm with nationality *v* in a foreign region *i* in CES function
$IVSI_{v,j,j,s}$	Investment demand in sector *s* by region *j* produced domestically in region *j* by a firm with nationality *v*
$PSIJV_{v,j,s}$	Price of investment demand in sector *s* by region *j* produced domestically in region *j* by a firm with nationality *v*
$\eta IVSI_{v,j,j,s}$	Share of investment demand in sector *s* by region *j* produced domestically in region *j* by a firm with nationality *v* in CES function
Production by Representative Producer in Region j	
$OP_{v,j,s}$	Production in sector *s* by a firm with nationality *v* and located in region *j*
$EP_{v,j,i,s}$	Production in sector *s* by a firm with nationality *v*, located in region *j* and exported to region *i*
$EP_{v,j,j,s}$	Production in sector *s* by a firm with nationality *v*, located in region *j* and consumed domestically in region *j*
$PSIJV_{v,j,s}$	Price of production in sector *s* by a firm with nationality *v* and located in region *j*
Input Factors by Representative Producer in Region j	
Labour	
$IL_{v,j,s}$	Input of labour by firm in sector *s* with nationality *v* and located in region *j*
WR_j	Wage rate of labour by firm in sector *s* with nationality *v* and located in region *j*
$\alpha_{ILv,j,s}$	Share of Input of labour by firm in sector *s* with nationality *v* and located in region *j* in Cobb-Douglas function
$m_{v,j,sd}$	Unit cost of production
Capital	
$IK_{v,j,s}$	Input of capital by firm in sector *s* with nationality *v* and located in region *j*
$RR_{v,j,s}$	Rate of return of capital by firm in sector *s* with nationality *v* and located in region *j*
$\alpha_{IKv,j,s}$	Share of Input of capital by firm in sector *s* with nationality *v* and located in region *j* in Cobb-Douglas function
Intermediate Goods	
$II_{v,j,s,sd}$	Input of intermediate goods *s* demanded by firm in sector *sd* with nationality *v* and located in region *j*
$PII_{v,j,s,sd}$	Price of input of intermediate goods *s* demanded by firm in sector *sd* with nationality *v* and located in region *j*
$\alpha_{IIv,j,s,sd}$	Share of input of intermediate goods *s* demanded by firm in sector *sd* with nationality *v* and located in region *j* in a Cobb-Douglas function
$IIVV_{vo,v,i,,j,s,sd}$	Input of intermediate goods *s* produced by firm with nationality *vo* and located in region *i* demanded by firm in sector *sd* with nationality *v* and located in region *j*
$PSIJV_{vo,i,s}$	Price of input of intermediate goods *s* produced by firm with nationality *vo* and located in region *i* demanded by firm in sector *sd* with nationality *v* and located in region *j*
$\eta IIVV_{vo,v,i,,j,s,sd}$	Share of input of intermediate goods *s* produced by firm with nationality *vo* and located in region *i* demanded by firm in sector *sd* with nationality *v* and located in region *j* by a CET function
Asset Owned by Representative Household in region v	
$BOND_v$	Bond owned by representative household in region *v*
WIR	World interest rate
$TTWEA0_v$	Wealth owned by representative household in region *v*
$RTTWEA_v$	Rate of return of capital wealth owned by representative household in region *v*
$TWEA_{v,s}$	Capital wealth invested in sector *s* and owned by representative household in region *v*
$RTWEA_{v,s}$	Rate of return of capital wealth invested in sector *s* and owned by representative household in region *v*
$ETAWEA_{v,s}$	Share of capital wealth invested in sector *s* and owned by representative household in region *v* in CET function

$WEA_{v,v,s}$	Capital wealth of region *v* and invested domestically in sector *s*
$RR_{v,v,s}$	Rate of return of capital wealth invested in sector *s* and owned by representative household in region *v*
$ETAWD_{v,s}$	Share of capital wealth of region *v* and invested domestically in region v and sector *s* in CET function
$TWEAF_{v,s}$	Capital wealth of region *v* and invested in all foreign regions in sector *s*
$RWF_{v,s}$	Rate of return of capital wealth of region *v* and invested in all foreign regions in sector *s*
$ETAWF_{v,s}$	Share of capital wealth of region *v* and invested in all foreign regions in sector *s* in CET function
$WEA_{v,j,s}$	Capital wealth of region *v* invested in sector *s* of foreign region *j*
$RR_{v,j,s}$	Rate of return of capital wealth of region *v* invested in sector *s* of foreign region *j*
$ETAWWEA_{v,j,s}$	Share of capital wealth of region *v* invested in sector *s* of foreign region *j* in CET function
$KS_{v,j,s}$	Capital Supply to sector *s* of region *j* from region *v*
$\sigma FC_{j,s}$	CES elasticity of substitution between domestic region and all foreign regions
$\sigma_{j,s}$	CES elasticity of substitution among all foreign regions
$\sigma FV_{j,s}$	CES elasticity of substitution among all subsidiaries with different nationalities for the imported consumption goods
$\sigma DV_{j,s}$	CES elasticity of substitution among all subsidiaries with different nationalities for domestic consumption
$\sigma TTWEA_{v}$	CET elasticity of transformation of capital wealth of region *v*
$\sigma TWEA_{v,s}$	CET elasticity of transformation of capital wealth of region *v* in sector *s* between foreign investment or domestic investment
$\sigma WEA_{v,s}$	CET elasticity of transformation of capital wealth of region *v* in sector *s* among foreign regions
$LS0_{j}$	Labour supply in region *j*
$REVN_{j}$	Revenue/Gross National Product (GNP) of region *j*
$CUAC_{j}$	Saving minus investment spending
$KT_{v,j,s}$	Tax imposed by region *j* on revenues of capital invested in sector *s* with nationality *v*
$TRF_{v,i,j,s}$	Tariff rate imposed by region *j* on goods in sector *s* and produced by firm with nationality *v* and located in region *i*
$DR_{v,j,s}$	Depreciation rate of capital stock $K_{v,j,s}$
SC_{j}	Scale factor to transfer investment to service of capital

Source: Georges et al. (2012)

A.4 Data and Parameters

The aggregate variables, including trade flows have been calibrated to the GTAP7 database. The ownership ratios, elasticities, and tariff rates are reported in Tables 3.8 to 3.11. The CES elasticity of substitution among subsidiaries with different nationalities for the imported consumption goods, $\sigma FV_{j,s}$, and for the domestic consumption goods, $\sigma FV_{j,s}$, are both equal to 7.0. We assume that these two elasticities are equal given the lack of data availability. The CET elasticity of transformation of capital wealth of region v, $\sigma TTWEA_{v}$, is 1.2, the CET elasticity of transformation of capital wealth of region v

in sector s between foreigh investment or domestic investment, $\sigma TWEA_{v,s}$, is set as 1.3, and the CET elasiticity of transformation of capital wealth of region v in sector s among foreign regions, $\sigma WEA_{v,s}$, equals to 1.4 (Georges et al., 2012). The ownership table was estimated from the recent GTAP-FDI data base (Lakatos and Walmsley, 2010; Boumellasa et al., 2007).[81]

Table 3.8: CES Elasticity of Substitution between Domestic Region and All Foreign Regions ($\sigma FC_{j,s}$)

	AGRI	RESO	FOOD	TEXT	MANU	TECH	AUTO	SERV	TRAN
CAN	2.4	5.1	2.4	3.8	3.1	4.2	3.1	1.9	1.9
US	2.4	5.1	2.4	3.8	3.1	4.2	3.1	1.9	1.9
ROW	2.4	5.1	2.4	3.8	3.1	4.2	3.1	1.9	1.9

Source: Georges et al. (2012)

Table 3.9: CES Elasticity of Substitution among All Foreign Regions ($\sigma_{j,s}$)

	AGRI	RESO	FOOD	TEXT	MANU	TECH	AUTO	SERV	TRAN
CAN	4.9	11.8	4.9	7.6	6.5	8.4	6.3	3.9	3.8
US	4.9	11.8	4.9	7.6	6.5	8.4	6.3	3.9	3.8
ROW	4.9	11.8	4.9	7.6	6.5	8.4	6.3	3.9	3.8

Source: Georges et al. (2012)

Table 3.10: Tariff Rate in Percentage (%)

From	To	AGRI	RESO	FOOD	TEXT	MANU	TECH	AUTO	SERV	TRAN
CAN	**US**	0.6	0.0	3.7	0.0	0.0	4.4	0.0	0.0	0.0
CAN	**ROW**	10.6	0.9	21.9	8.3	2.7	3.1	0	0.0	0.0
US	**CAN**	1.2	0	15.5	0	0	0	0	0.0	0.0
US	**ROW**	11.5	1.5	19.5	6.6	3.4	2.1	2.8	0.0	0.0
ROW	**CAN**	0.8	0.0	13.6	11.9	1.7	0.8	4.1	0.0	0.0
ROW	**US**	3.1	0.2	5.4	9.4	1.4	0.7	1.6	0.0	0.0

Source: Georges et al. (2012)

[81] More details of calibration procedure are discussed in the paper of Georges et al. (2012).

Table 3.11: FDI Ownership Ratio

Nationality	Location	AGRI	RESO	FOOD	TEXT	MANU	TECH	AUTO	SERV	TRAN
CAN	**CAN**	0.998	0.877	0.568	0.921	0.752	0.751	0.798	0.913	0.988
CAN	**US**	0.001	0.013	0.002	0.008	0.028	0.046	0.054	0.004	0.001
CAN	**ROW**	0.001	0.013	0.002	0.008	0.028	0.046	0.054	0.004	0.001
US	**CAN**	0.001	0.114	0.235	0.025	0.163	0.222	0.152	0.052	0.007
US	**US**	0.998	0.972	0.92	0.953	0.903	0.872	0.821	0.923	0.993
US	**ROW**	0.001	0.015	0.078	0.039	0.069	0.082	0.125	0.073	0.006
ROW	**CAN**	0.001	0.009	0.197	0.054	0.085	0.027	0.05	0.035	0.005
ROW	**US**	0.001	0.015	0.078	0.039	0.069	0.082	0.125	0.073	0.006
ROW	**ROW**	0.998	0.972	0.92	0.953	0.903	0.872	0.821	0.923	0.993

Source: Georges et al. (2012)

Table 3.12: Trade Impact of Harmonizing Canadian Security Measures (with respect to the ROW) at the U.S. levels

	AGRI	MANU	AUTO	TECH	SERV	TRAN
Trade Impact of Harmonizing Canadian Security Measures at the U.S. levels	9.6	12.3	18.7	0	8.2	19.7

A.5 Equations

Wealth

The First Level of Wealth Allocation

$$TWEA_{v,s} = ETAWEA_{v,s}\left(\frac{RTWEA_{v,s}}{RTTWEA_{v}}\right)^{\sigma TTWEA_{v}} TTWEA0_{v}; \tag{A.1}$$

$$RTTWEA_{v}^{\;1+\sigma TTWEA_{v}} = \sum_{s} ETAWEA_{v,s} RTWEA_{v,s}^{\;1+\sigma TTWEA_{v}}; \tag{A.2}$$

The Second Level of Wealth Allocation

$$TWEAF_{v,s} = ETAWF_{v,s}\left(\frac{RWF_{v,s}}{RTWEA_{v,s}}\right)^{\sigma TWEA_{v,s}} TWEA_{v,s}; \tag{A.3}$$

$$WEA_{v,v,s} = ETAWD_{v,s}\left(\frac{RR_{v,v,s}}{RTWEA_{v,s}}\right)^{\sigma TWEA_{v,s}} TWEA_{v,s}; \tag{A.4}$$

The Third Level of Wealth Allocation (j≠v)

$$RTWEA_{v,s}^{\;1+\sigma TWEA_{v,s}} = ETAWF_{v,s}\left(RWF_{v,s}\right)^{1+\sigma TWEA_{v,s}} + ETAWD_{v,s}(RR_{v,v,s})^{1+\sigma TWEA_{i,s}}; \tag{A.5}$$

$$WEA_{v,j,s} = ETAWWEA_{v,j,s}\left(\frac{RR_{v.j,s}(1-KT_{v,j,s})}{RWF_{v,s}}\right)^{\sigma WEA_{v,s}} TWEA_{v,s}; \tag{A.6}$$

$$RWF_{v,s}^{\;1+\sigma WEA_{v,s}} = \sum_{j} ETAWWEA_{v,j,s} RR_{v,j,s}^{\;1+\sigma WEA_{v,s}}; \tag{A.7}$$

Supply Side

The First Level of Supply Side

$$\mathrm{PSIJV}_{v,j,sd} = m_{v,j,sd}; \tag{A.8}$$

The Second Level of Supply Side

$$IL_{v,j,sd} = \frac{\alpha_{IL_{v,j,sd}} PSIJV_{v,j,sd} OP_{v,j,sd}}{WR_j}; \tag{A.9}$$

$$IK_{v,j,sd} = \frac{\alpha_{IK_{v,j,sd}} PSIJV_{v,j,sd} OP_{v,j,sd}}{RR_j}; \tag{A.10}$$

$$II_{v,j,s,sd} = \frac{\alpha_{II_{v,j,s,sd}} PSIJV_{v,j,sd} OP_{v,j,sd}}{PII_{v,j,s,sd}}; \tag{A.11}$$

$$\log PSIJV_{v,j,sd} = \alpha_{IL_{v,j,sd}} \log WR_j + \alpha_{IK_{v,j,sd}} \log RR_j + \textstyle\sum_s \alpha_{II_{v,j,s,sd}} \log PII_{v,j,s,sd}\ ; \tag{A.12}$$

The Third Level of Supply Side

$$IIVV_{vo,v,i,j,s,sd} = \eta IIVV_{vo,v,i,j,s,sd}{}^{\sigma_{j,s}} II_{v,j,s,sd} = \eta IIVV_{vo,v,i,j,s,sd} \frac{\alpha_{EI_{v,j,s,sd}} PSIJV_{v,j,sd} OP_{v,j,sd}}{PII_{v,j,s,sd}}; \tag{A.13}$$

$$PII_{v,j,s,sd}{}^{1-\sigma_{j,s}} = \textstyle\sum_i \sum_v \eta IIVV_{vo,v,i,j,s,sd} PSIJV_{vo,i,s}\,; \tag{A.14}$$

Revenue Equation

$$REVN(I) = \textstyle\sum_v \sum_{sd} \alpha_{IL_{v,j,sd}} PSIJV_{v,j,sd} OP_{v,j,sd} + \sum_{vo} \sum_s \sum_j EP_{vo,j,i,s} PSIJV_{vo,j,s}(TRF_{vo,j,i,s} + BDC_{vo,j,i,s}) + \sum_v \sum_{sd} RR_{v,i,sd} WEA_{v,i,sd} KT_{v,i,sd} + \sum_v \sum_{sd} RR_{i,v,sd} WEA_{i,v,sd}\,; \tag{A.15}$$

Consumption

The First Level of Consumption

$$CS_{j,s} = \frac{\rho_{j,s} PC_j C_j}{PCS_{j,s}}; \tag{A.16}$$

$$Log(PC_j) = \textstyle\sum_s \rho_{j,s} \log\left(PCS_{j,s}\right); \tag{A.17}$$

The Second Level of Consumption: Domestic and Foreign Allocation

$$CSD_{j,s} = \eta CSD_{j,s} \left(\frac{PCS_{j,s}}{PCSD_{j,s}}\right)^{\sigma FC_{j,s}} CS_{j,s}; \tag{A.18}$$

$$CSF_{j,s} = \eta CSF_{j,s} \left(\frac{PCS_{j,s}}{PCSF_{j,s}}\right)^{\sigma FC_{j,s}} CS_{j,s}; \tag{A.19}$$

$$PCS_{j,s}{}^{1-\sigma FC_{j,s}} = \left[\eta CSD_{j,s} PCSD_{j,s}{}^{1-\sigma FC_{j,s}} + \eta CSF_{j,s} PCSF_{j,s}{}^{1-\sigma FC_{j,s}}\right]; \tag{A.20}$$

The Third Level of Consumption: Domestic Consumption Allocation

$$CSIJV_{v,j,j,s} = \eta CSDIJV_{v,j,j,s}{}^{\sigma DV_{j,s}} \left(\frac{PCSD_{j,s}}{PSIJV_{v,j,s}}\right)^{\sigma DV_{j,s}} CSD_{j,s}; \tag{A.21}$$

$$PCSD_{j,s}{}^{1-\sigma DV_{j,s}} = \textstyle\sum_v \eta CSDIJV_{v,j,j,s}{}^{\sigma DV_{j,s}} PSIJV_{v,j,s}{}^{1-\sigma DV_{j,s}}\,; \tag{A.22}$$

The Fourth Level of Consumption: Foreign Consumption Allocation

$$CSFIJ_{i,j,s} = \eta \mathrm{CSFIJ}_{i,j,s} \left(\frac{PCSF_{j,s}}{PCSFIJ_{i,j,s}}\right)^{\sigma_{j,s}} CSF_{j,s}; \tag{A.23}$$

$$PCSF_{j,s}{}^{1-\sigma_{j,s}} = \sum_i \eta\mathrm{CSFIJ}_{i,j,s}[PCSFIJ_{i,j,s}]^{1-\sigma_{j,s}}\,; \tag{A.24}$$

The Fifth Level of Consumption

$$CSIJV_{v,i,j,s} = \eta\mathrm{CSFIJV}_{v,i,j,s}\left(\frac{\mathrm{PCSFIJ}_{i,j,s}}{\mathrm{PSIJV}_{v,i,s}(1+TRF_{v,i,j,s})}\right)^{\sigma FV_{j,s}} CSF_{i,j,s}; \tag{A.25}$$

$$\mathrm{PCSFIJ}_{i,j,s}{}^{1-\sigma FV_{j,s}} = \sum_v \eta\mathrm{CSFIJV}_{v,i,j,s}[\mathrm{PSIJV}_{v,i,s}(1+TRF_{v,i,j,s})]^{1-\sigma FV_{j,s}}\,; \tag{A.26}$$

Investment

The First Level of Investment Demand

$$IVS_{v,j,s} = \frac{\gamma_{v,j,s}PI_jI_j}{PIV_{v,j,s}}; \tag{A.27}$$

$$\log PI_j = \sum_v \sum_s \gamma_{v,j,s} PIV_{v,j,s}\,; \tag{A.28}$$

The Second Level of Investment Demand

$$IVSI_{v,i,j,s} = \eta IVSI_{v,i,j,s}{}^{\sigma_{j,s}}\left[\frac{PIV_{v,j,s}}{PSIJV_{v,i,j,s}(1+TRF_{v,i,j,s})}\right]^{\sigma_{j,s}} I_j; \tag{A.29}$$

$$PIV_{v,j,s}{}^{1-\sigma_{j,s}} = \sum_v \eta IVSI_{v,i,j,s}{}^{\sigma_{j,s}}[PSIJV_{v,i,j,s}(1+TRF_{v,i,j,s})]^{1-\sigma_{j,s}}\,; \tag{A.30}$$

Equilibrium Conditions

Labour Market Clearing

$$\sum_v \sum_{sd} \frac{\alpha_{IL_{v,j,sd}} PSIJV_{v,j,sd} OP_{v,j,sd}}{WR_j} = LS0_j; \tag{A.31}$$

Capital Market Clearing

$$\frac{\alpha_{IK_{v,j,sd}} PSIJV_{v,j,sd} OP_{v,j,sd}}{RR_j} = KS_{v,j,sd}; \tag{A.32}$$

$$KS_{v,j,sd} = WEA_{v,j,sd}; \tag{A.33}$$

Goods Market Clearing

$$EP_{vo,i,j,s} = IVSI_{vo,i,j,s} + CSIJV_{vo,i,j,s} + \sum_{sd}\sum_v IIVV_{vo,v,i,j,s,sd}\,; \tag{A.34}$$

$$OP_{vo,i,s} = \sum_j EP_{vo,i,j,s} \tag{A.35}$$

Steady State

$$I_i = \frac{\sum_v \sum_s DR_{i,v,s} KS_{i,v,s}}{SC_i}; \tag{A.36}$$

$$CUAC_j = WIR * BOND_j + REVN_j - C_jPC_j - I_jPI_j = 0. \tag{A.37}$$

A.6 Simulation Results

Table 3.13: Tariff Tax (or Subsidy) Equivalent to Security Measures at the Canada-U.S. and Canada-ROW Borders

		Sectors (S)								
Row number		**AGRI**	**RESO**	**FOOD**	**TEXT**	**MANU**	**TECH**	**AUTO**	**SERV**	**TRAN**
1	TAREQV(CAN, US, S)	15.7	-1.9	17.2	20.9	23.6	21.1	21.5	37.3	25
2	TAREQV(US, CAN, S)	-24.8	-51.5	-25.5	-16.7	4.3	6.4	-28.8	-28.2	-16.1
3	TAREQV(ROW, CAN, S)	25.3	54.1	28.1	26.3	62.4	3	42.8	28.2	56.9

Table 3.14: Percentage Change of Sectoral Trade Flows by Nationality and Locations of Firms and Sectors (%)

Row number	Nationality	From	To	AGRI	RESO	FOOD	TEXT	MANU	TECH	AUTO	SERV	TRAN
1	CAN	CAN	CAN	1.1	1.2	0.1	1.4	1.4	6.1	2.5	0.9	0.7
2	CAN	CAN	US	0.0	0.0	0.0	22.0	16.5	37.8	12.6	49.5	10.4
3	CAN	CAN	ROW	-19.8	-2.3	-33.0	-40.3	-12.5	-32.7	-40.9	-21.3	-18.4
4	CAN	US	CAN	0.0	0.0	0.0	18.2	26.2	35.9	0.0	0.0	20.3
5	CAN	US	US	-3.4	-0.9	-4.0	-2.8	-1.6	-6.7	-6.3	-4.9	-0.9
6	CAN	US	ROW	-3.8	-0.6	-3.4	-3.7	-1.3	-2.1	-1.8	-2.9	-2.6
7	CAN	ROW	CAN	-9.6	0.0	0.0	0.0	-12.3	0.0	-18.7	-8.2	-19.7
8	CAN	ROW	US	-3.8	0.0	-2.1	-2.5	-2.9	-5.3	-6.0	-4.0	-1.8
9	CAN	ROW	ROW	-4.9	-2.8	-5.5	-3.6	-1.8	-0.6	-1.2	-5.9	-3.1
10	US	CAN	CAN	4.6	3.6	6.7	5.9	1.4	-10.8	9.8	7.0	3.2
11	US	CAN	US	0.0	0.0	0.0	22.0	16.5	37.8	12.6	49.5	10.4
12	US	CAN	ROW	-17.9	-2.1	-30.7	-39.4	-12.1	-32.2	-40.3	-19.8	-17.1
13	US	US	CAN	0.0	0.0	0.0	18.2	26.2	35.9	0.0	0.0	20.3
14	US	US	US	0.2	0.1	0.2	-0.7	0.3	-0.1	-0.4	0.1	0.4
15	US	US	ROW	0.1	0.1	0.2	-1.9	-0.5	-2.6	-1.9	-0.6	-0.3
16	US	ROW	CAN	-9.6	0.0	0.0	0.0	-12.3	0.0	-18.7	-8.2	-19.7
17	US	ROW	US	1.3	0.0	2.2	2.1	0.1	3.6	2.1	-0.9	0.7
18	US	ROW	ROW	-0.7	-0.6	-0.8	-0.5	-0.4	0.8	0.0	-0.7	-0.6
19	ROW	CAN	CAN	5.0	5.1	7.3	6.6	4.1	5.3	18.0	7.6	4.7
20	ROW	CAN	US	0.0	0.0	0.0	22.0	16.5	37.8	12.6	49.5	10.4
21	ROW	CAN	ROW	-17.7	-2.1	-30.5	-39.3	-12.1	-32.7	-40.5	-19.6	-17.0
22	ROW	US	CAN	0.0	0.0	0.0	18.2	26.2	35.9	0.0	0.0	20.3
23	ROW	US	US	0.6	0.2	0.6	-0.6	0.2	-2.3	-1.5	0.6	0.5
24	ROW	US	ROW	0.6	0.2	0.6	-1.7	-0.5	-3.5	-2.2	-0.3	0.0
25	ROW	ROW	CAN	-9.6	0.0	0.0	0.0	-12.3	0.0	-18.7	-8.2	-19.7
26	ROW	ROW	US	2.0	0.0	2.7	2.6	0.2	1.7	1.1	-0.5	1.0
27	ROW	ROW	ROW	-0.2	-0.3	-0.2	-0.1	-0.2	-0.1	-0.1	-0.1	-0.2

Table 3.15: Percentage Change of Sectoral Output (%)

Row number	Nationality	Location	AGRI	RESO	FOOD	TEXT	MANU	TECH	AUTO	SERV	TRAN
1	CAN	CAN	-3.6	0.5	-1.4	5.2	4.8	12.6	6.7	1.1	-0.6
2	CAN	US	-3.4	-0.9	-3.9	-2.6	-0.9	-4.2	-5.2	-4.9	-0.9
3	CAN	ROW	-4.9	-2.5	-5.4	-3.5	-1.9	-1.0	-1.7	-5.9	-3.1
4	US	CAN	-0.7	1.9	4.1	8.1	4.8	5.7	8.9	7.1	1.7
5	US	US	0.2	0.1	0.2	-0.5	0.8	0.8	-0.6	0.1	0.4
6	US	ROW	-0.7	-0.5	-0.7	-0.3	-0.4	1.0	0.1	-0.7	-0.6
7	ROW	CAN	-0.4	2.9	4.6	8.6	6.5	12.2	11.3	7.7	3.0
8	ROW	US	0.6	0.2	0.6	-0.4	0.8	-1.0	-1.5	0.6	0.5
9	ROW	ROW	-0.2	-0.2	-0.2	0.1	-0.3	0.1	-0.1	-0.1	-0.2

Table 3.16: Percentage Change of Physical Capital Stock (%)

Row number	Nationality	Location	AGRI	RESO	FOOD	TEXT	MANU	TECH	AUTO	SERV	TRAN
1	CAN	CAN	0.0	1.4	1.4	5.7	5.3	7.6	1.1	3.0	1.9
2	CAN	US	-6.1	-4.1	-6.6	-6.6	-5.4	-7.4	-6.3	-7.0	-5.4
3	CAN	ROW	-7.6	-5.2	-8.1	-7.3	-6.6	-6.0	-6.3	-8.0	-7.1
4	US	CAN	6.5	5.9	9.4	13.2	11.0	9.3	7.5	11.3	8.6
5	US	US	0.1	0.0	0.1	-0.5	0.6	0.5	-0.3	0.1	0.2
6	US	ROW	-1.2	-0.9	-1.2	-0.9	-1.0	-0.1	-0.6	-1.2	-1.1
7	ROW	CAN	7.5	7.1	10.5	14.3	12.9	14.1	9.7	12.5	10.3
8	ROW	US	1.1	0.7	1.1	0.3	1.4	0.3	-0.1	1.3	1.1
9	ROW	ROW	-0.1	-0.1	0.0	0.1	-0.1	0.1	0.1	0.0	-0.1

Table 3.17: Percentage Point Change in Rate of Returns on Physical Capital Stock (%)

Row number	Nationality	Location	AGRI	RESO	FOOD	TEXT	MANU	TECH	AUTO	SERV	TRAN
1	CAN	CAN	0.1	2.0	1.7	6.2	6.2	8.5	8.1	3.8	3.0
2	CAN	US	-8.6	-5.8	-9.4	-9.0	-7.8	-9.7	-10.6	-9.9	-7.8
3	CAN	ROW	-10.2	-7.1	-10.9	-10.0	-8.9	-8.3	-9.0	-10.9	-9.6
4	US	CAN	9.5	8.6	13.4	16.9	14.8	13.0	18.4	16.1	13.0
5	US	US	0.1	0.0	0.1	-0.3	0.5	0.4	-0.5	0.1	0.2
6	US	ROW	-1.2	-1.0	-1.3	-1.0	-1.1	-0.2	-0.8	-1.2	-1.1
7	ROW	CAN	10.6	10.0	14.6	18.1	16.9	18.3	21.1	17.4	14.8
8	ROW	US	1.1	0.7	1.1	0.5	1.3	0.2	-0.2	1.3	1.1
9	ROW	ROW	-0.1	-0.1	0.0	0.1	-0.1	0.1	0.0	0.0	-0.1

Table 3.18: Percentage Point Change in Rate of Returns on Physical Capital Stock in Each Region by Sectors (%)

Row number	Location	AGRI	RESO	FOOD	TEXT	MANU	TECH	AUTO	SERV	TRAN
1	CAN	16.0	13.9	17.6	14.3	12.9	8.4	14.0	17.2	17.7
2	US	1.7	-0.2	0.3	0.0	0.7	0.5	-0.4	-0.7	1.2
3	ROW	0.0	-0.1	0.1	0.2	0.0	0.2	0.1	-0.2	-0.1

Table 3. 19: Evaluation of Trade Performance

Region	% Δ Real Export	% Δ Real Import	Trade Balance Benchmark	Trade Balance	Δ Trade Balance	TOT Benchmark (%)	TOT (%)	% Δ TOT	Openness Index Before NASP (%)	Openness Index After NASP (%)	Δ Openness Index
CAN	35.4	13.2	25428	108590	83162	1.08	1.29	19.6	64.9	69.7	+
US	5.0	8.6	-558526	-647111	-88586	0.66	0.64	-3.4	22.8	24.0	+
ROW	0.5	0.3	533098	538522	5423	1.56	1.57	0.3	8.99	9.04	+

Table 3.20: Measure of Welfare by Hicksian Equivalent Variation (EV) of Implementing NASP (by Million U.S. Constant Dollars)

	Canada	US	ROW
EV	18988	31903	-61572
% of GDP	1.8	0.3	-0.2

Table 3.21: Decomposition of Welfare Impact by Hicksian Equivalent Variation (EV) of Implementing NASP by Step 1 (Elimination of Security Measures only) and Step 2 (Harmonization of Canada Security Measures to U.S. Levels with respect to the ROW only) (by Million U.S. Constant Dollars)

	Canada	US	ROW
EV of Step 1	27113	31973	-68693
% of GDP	2.5	0.3	-0.3
EV of Step 2	-8125	-70	7122
% of GDP	-0.76	0.00	0.03
Net EV	18988	31903	-61572
% of GDP	1.8	0.3	-0.2

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