Skills Research Initiative
Initiative de recherche sur les compétences

Population Ageing in Canada: A Sectoral and Occupational Analysis

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Acknowledgments

Abstract

The Canadian population is expected to age at an exceptional pace over the next decades which could lead to profound structural changes on the product market, on labour markets and financial markets. It may also lead to sectoral, occupational and skill pressures on the labour market. This paper's key objective is to quantify the sectoral dynamic and transitional impacts of population ageing arising from the combination of two important structural changes that will affect the Canadian economy and the labour market. The first is the negative labour supply shock that will arise from slower labour force growth. The second is the change in the composition of consumption demands due to an increase in the proportion of older consumers. The analysis is done using a sectoral and occupational computable general equilibrium model with overlapping generations. The paper's key findings indicate that the negative labour supply shock will largely dominate. However, there will also be some significant sectoral compositional shifts due to final demand changes. In particular, the sectoral share of health services in total GDP may increase by near 50% between 2000 and 2050. It is also estimated that real wages may need to increase twice as fast in health occupations as in the rest of the economy to prevent shortages in health occupations. In addition, finance, insurance and real estate may also benefit to a certain degree over the next 20 years from the composition change in final demand. On the other hand, the combined sectoral contribution of education, construction, manufacturing, and wholesaling and retailing to GDP may fall by 3.3% of GDP between 2000 and 2050. This in turn would reduce wage pressures in processing and manufacturing occupations and in trades.

Résumé

Il est prévu que la population canadienne va vieillir à un rythme exceptionnel au cours des prochaines décennies, ce qui pourrait entraîner des changements structurels profonds dans le marché des biens, le marché du travail et les marchés financiers. Cela pourrait également entraîner des pressions importantes sur le marché du travail au niveau sectoriel, professionnel et selon les compétences. Le principal objectif de cette étude consiste à quantifier l'impact dynamique de transition sectoriel du vieillissement démographique, provenant de la combinaison de deux changements structurels importants qui vont affecter l'économie canadienne et le marché du travail. Le premier est le choc d'offre de travail négatif provenant d'une croissance plus faible de la population active. Le second est le changement dans la composition de la demande de consommation causée par la hausse de la part des consommateurs plus âgés. L'analyse est effectuée à l'aide d'un modèle calculable d'équilibre général à générations imbriquées comportant des secteurs industriels et des professions. Les principaux résultats de l'étude indiquent que le choc d'offre de travail va dominer les effets provenant de la demande. Toutefois, il y aura également quelques changements de composition sectoriels importants dû aux changements dans la demande finale. En particulier, la part sectorielle des services de santé dans le PIB total pourrait augmenter de près de 50% entre 2000 et 2050. Les salaires réels dans les professions de la santé pourraient également devoir augmenter deux fois plus rapidement que dans le reste de l'économie afin de prévenir des pénuries de main-d'œuvre dans ce secteur. De plus, le secteur de la finance, assurance et immobilier pourrait aussi profiter dans une certaine mesure, au cours des 20 prochaines années, du changement dans la composition de la demande finale. D'un autre côté, la contribution sectorielle combinée de l'éducation, la construction,

fabrication et commerce de gros et de détail pourrait diminuer de 3,3% du PIB entre 2000 et 2050. Cela aurait pour conséquence de réduire les pressions salariales dans les professions liées à la transformation, la fabrication ainsi que dans les métiers.

1. Introduction

It is now well recognized that over the next decades, the composition of the Canadian population will undertake a profound transformation. Over the period 2011 to 2031, it is projected that the population will age at an exceptional pace. This may result in a relative scarcity of workers and lead to sectoral, occupational and skills labour market pressures, a key concern for HRSDC.

The literature on population ageing in Canada counts a large number of academic studies either using partial or general equilibrium methodologies. However, most of the work done so far has either focused on the demographic (Moore and Rosenberg 1991, Denton and Spencer 1999, Carrière, 2000), macroeconomic (Billings *et al.*, 1998, Fougère and Mérette 2000a, 2000b, 2000c, Mérette, 2002) or public finance implications of population ageing (Murphy and Wolfson 1991, Wolfson and Murphy, 1997, Office of the Auditor General, 1998, King and Jackson 2000, Robson, 2001). To our knowledge, very little work has considered examining the combination of supply and final demand channel effects from population ageing in a general equilibrium framework. Moreover, little is known about the sectoral and labour market implications of population ageing at the occupational and skill levels.[2]

In a recent report for Human Resources and Skills Development Canada, Mercenier, Mérette and Harvey (2003) developed a computable general equilibrium model (CGE), calibrated on Canadian data with detailed features on regions, sectors and occupations. The model has been used to explore the potential sectoral and occupational implications of anticipated changes on the composition of final demand in the economy.

The model Mercenier, Mérette and Harvey (MMH) is composed of six Canadian regions (plus an aggregate rest-of-the-world), six different age groups within each region, fourteen industrial sectors of activity, and some twenty-five occupational groups differentiated by ten occupational groups (skill-types) and five qualification levels.[3] Simulation experiments were conducted taking into consideration the projected re-composition of the population of the six Canadian regions to estimate the resulting change in consumption patterns from the six age groups, and their consequences on the sectors and locations of economic activity, as well as their occupations. However, because of the large numerical size of the model, relative to available computational capacity, simulation exercises were run by imposing steady state assumptions on the four decades (2010, 2020, 2030, 2040) investigated. Moreover, as the paper's objective was to investigate the effects arising from consumption demand changes, the productive capacity of each region was controlled by keeping supplies of labour and capital constants.

[2] On the final demand channel, Börsch-Supan, 2001 is one notable exception for Germany. The study provides a shift-share analysis of changes in the mix of goods consumed by age.
[3] The calibration of the occupational groups is based on the National Occupational Classification System. Please note that for modeling purposes, managers are considered as both an occupational group and a level of qualification.

However, MMH simulation results can only be considered a crude approximation of the potential sectoral impact of population ageing as by nature the expected demographic change is a transitional phenomenon and the steady state equilibrium will not be reached within the next 50 years. Therefore, to well capture the transitional path between very distant steady-states of the economy through both supply and demand perspectives, a fully dynamic framework is necessary by incorporating to the model the factors of transition and accumulation such as savings, physical and human capital.

In this paper, we upgrade the MMH model by incorporating a fully dynamic framework to the CGE model and investigate the sectoral and occupational impact of population ageing by accounting for both supply and demand shocks. The supply effect takes the form of a decline in the labour force due to an ageing workforce, whereas the demand effect refers to the structural change in final demand that follows the composition change of the population.

As in MMH, the dynamic model used in this paper features fourteen industrial sectors and twenty-five occupations. However, given that the model structure is highly disaggregated, incorporating a dynamic framework dramatically raises the numerical complexity to resolve the model. Therefore, to mitigate some of the numerical challenges, we concentrate at this stage on a national version of the model. Finally, as explained in more detail in Section 4, for calibration purposes, the number of overlapping generations has been raised from six to seven.

In the model, labour is differentiated at the aggregate level by three different types (high, medium and low labour demand elasticity of substitution), ten occupational groups, and five levels of qualification. However, labour supply remains exogenous and is identically supplied across households. Since long-term labour supply projections by occupation and level of qualification are not available, the only labour supply alteration effect across the twenty-five occupations comes from differences in the effective age of retirement by occupation. The projected labour supply shock is very large, but should not generate significantly different sectoral or occupational effects. On the other hand, the projected shift in the composition of final demand due to ageing, although not as dramatic as the labour supply shock, is expected to generate more significant inter-sectoral and occupational effects.

The restructuring of final demand is expected to benefit some sectors of activity and hurt others across the country. This, in turn, will affect the occupational characteristics of labour demand in the Canadian labour market. One can expect that the sectoral and occupational consequences of population ageing will affect the relative sectoral performance of the economy.

The paper is divided as follows. Section 2 provides some context on the labour market implications of population ageing. Section 3 gives a detailed description of the model. Section 4 describes the data, discusses the calibration procedure and reports the projected old-age dependency ratio in Canada by decade. Section 5, reports and discusses the simulation results. Section 6 concludes and suggests a direction for future research.

2. Labour Market Effects of Population Ageing

As the economy faces a relative decline in the prime age labour force and the older workforce gradually transits towards retirement, this will generate profound structural changes on the product market, the labour market and financial markets. On the labour market side, we can think of at least two channels of influence affecting the direction of labour market flows. The first and most obvious channel is workforce ageing, which will lead to a relative scarcity of workers and possibly to increased labour market pressures.

In a simple model with homogeneous labour and capital, Auerbach and Kotlikoff (1987) and Hamermesh (1993) demonstrate that the relative scarcity of labour caused by population ageing will lead to an increase in wages and a decline in the return to capital. If however, the degree of substitution among and within workers and between the different groups of workers and capital is different, then the net effects are less clear. According to Hamermesh (2001), the evidence suggests that there is substantial substitution between workers at different ages, which implies that a decline in the relative supply of prime-age workers would raise their wage, providing incentives for employers to increase the demand for older workers and immigrants. However, there is not enough information in the literature to provide an indication about the magnitude of these effects.

In addition, on the workforce ageing channel, Kuhn (2003) argues that with an older labour force, a greater share of turnover will involve older workers. However, according to Abe et al. 2002, the older Canadian workforce tends to be less mobile than younger workers. This suggests that population ageing may increase costs to the Canadian economy simply because lower labour mobility of an older workforce may impede the economy to more rapidly adapt to exogenous shocks.

The second channel of effect is the final demand channel, which results from the fact that consumption behaviour change with increasing age. Older people consume a different mix of goods and services than younger individuals. For example, older households consume more health services, prescription drugs, traveling services, while younger households consume more education services for their children, etc. A change in the consumption mix due to an older population may significantly impact the sectoral composition of production and consequently affect labour market flows.

To assess the likely impact of ageing-induced consumption changes, Börsch-Supan (2001) provides a shift-share analysis of the age-specific distribution of consumption across different groups of goods for Germany. Assuming that the distribution pattern by age remains unchanged in the future, he calculates that employment would likely increase in the health sector, personal outfit, energy and housing, while employment would decrease in the food, beverage and tobacco, clothing, education, travel and communication and other household goods.

Although this analysis is very useful, it can be argued that a simple shift-share analysis only provides a partial analysis of the final demand effects. As argued by Kuhn (2003), to provide a more elaborate analysis requires input-output considerations, since the change in consumption patterns will also influence the demand for intermediate goods by industries, which

is not captured in a shift-share analysis. We also need to account for the relative price effects associated with changes in demand. If the demand for certains goods increases, this will raise the price for those goods and consumption will not rise as much as a shift-share analysis would predict. Finally, we must consider that each year, younger people enter the labour market while older people leave. The effect of overlapping generations must then be considered to evaluate these effects on labour market flows.

3. Description of the Model

In this section, we first provide a non-technical summary of the model structure. This is followed by a more detailed technical description with the equations and variables.

3.1 Non-Technical Model Description Summary

As mentioned in introduction, the CGE model presented in this paper is an extension of the MMH model. It represents the Canadian economy plus an aggregate rest-of-the world. The main distinction with MMH is that this model is fully dynamic and the regions of Canada are aggregated into one single region. The model is composed of 14 industrial sectors, each producing one differentiated goods (or service) imperfectly substitutable with other sectoral goods.

Sectoral production technologies are represented by Cobb-Douglas production functions, where sectoral goods and services are produced with factors of production (labour and capital) and intermediate input goods. The aggregate intermediate input is a CES mix of market goods produced across industries in Canada and the rest of the world.

Labour is composed of 25 occupations, combining 10 large occupational groups and five levels of qualification. Labour is also composed by types to distinguish occupational demand with high, medium or low elasticity of substitution. Aggregate labour services are also defined as CES combinations of labour types, occupational category and level of qualification.

The household dynamic is characterized by an overlapping generations framework. At each period in time, a eldest generation dies and is replaced by a new generation. Each adult individual has perfect foresight, living 7 periods, each periods corresponding to 10 years. The working life begins at age 15, ends at 64 and individuals die at 84.

Each generation optimizes a CES type inter-temporal utility function of consumption and bequest subject to lifetime income. The household optimization problem consists of choosing the consumption and savings pattern. Savings can be allocated between domestic physical capital ownership titles and bonds issued by firms and the government. Similarly, consumption goods are allocated towards the 14 available final goods according to household preferences represented in the CES function. Bequests are distributed equally across working generations as inheritances at the end of each generation's lifetime.

The government issues bonds to finance its public debt and to satisfy its budget constraint. The government taxes labour income, capital income and consumption expenditures

and spends on public expenditures, health care, education and interest payments on the public debt. The government also manages the public pension system, which is represented by a simple pay-as-you go pension scheme and financed by contribution rates on labour income.

Finally, the regional allocation of sectoral goods is assumed differentiated in demand by their geographic origin (Canada versus rest-of-the-world). The Canadian consumer optimally chooses the basket of domestically and internationally produced goods in each sector. In fact, the rest of the world only serves to close the model and is described as a reduced form. We assume that it neither borrows nor lend internationally, so that the Canadian balance of payments always remains in equilibrium.

3.2 Technical Model Description and Structure

3.21 Preliminaries on sets and indices

There is only one fully endogenous region in the model (Canada) and a reduced form residual rest-of-the-world indexed *row* in a subset denoted *RoW*. The set of all regions is denoted *II* and indexed by *ii* or *jj* ($ii = 1,...,II$). We have $II = I \cup RoW$, where here *I* is singular and represents Canada.[4]

For Canada, there are *S* industrial sectors indexed by *s*, *ss* ($s = 1,...,S$). Labour is distinguished by ten occupational categories denoted by *Iprof* ($iprof = 1,..., Iprof$). Each occupational category is composed of five level of qualification, *Iqual* ($iqual = 1,..., Iqual$) and three labour types *Itype* ($itype = 1,..., Itype$) to distinguish the occupational groups according to the degree of substitutability (high, medium and low labour demand elasticity of substitution).

At each period in time (time is indexed *t*) there are *G* ($g = 1,...,G$) generations that coexist, with *gj* ($gj = 1,..., GJ$) working generations and *gm* ($gm = GJ + 1,...,G$) retired generations.

3.22 Producers s of region j at time t

To produce good *s* in amount $Z_{s,t}$, producers use factors of production and intermediate input goods from sectors *ss*, the latter in amount $X_{ss,s,t}$. Production factor inputs include capital services denoted K_t^{dem} and different types of labour services by occupation and level of qualification, $L_{s,itype,iprof,iqual,t}^{Qual}$. Each input is bought at market prices, including the price of intermediate goods, $P_{ss,t}^X$, the rental rate of capital, $\text{Re}\,nt_t$ and wages by type, occupation and level of qualification, $w_{itype,iprof,iqual,t}^{Qual}$. The primary input factors (capital and labour) are assumed mobile across sectors. Producers therefore have to solve the following problem:

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[4] The notations used in the description of the model are chosen so as to ease the reading, in parallel, of the computer code using GAMS.

(1) $\quad \underset{XS_{ss,s,t}, K_{s,t}^{dem}, L_{s,itype,iprof,iqual,t}^{Qual}}{\textbf{Minimize}} \quad \sum_{ss} P_{ss,t} XS_{ss,s,t} + \text{Re}\,nt_t K_{s,t}^{dem} + \sum_{\substack{itype \\ iprof \\ iqual}} w_{itype,iprof,iqual,t}^{Qual} L_{s,itype,iprof,iqual,t}^{Qual}$,

subject to the following set of embedded constraints that characterize the firm's technology:

(2) $\qquad Z_{s,t} = CD(X_{s,t}, Q_{s,t}; Sc_{s,t}^Z, \alpha_s^Q)$ $\qquad\qquad\qquad\qquad$ $(P_{s,t})$

(3) $\qquad X_{s,t} = CES(XS_{ss,s,t}; \alpha_{ss,s}^{XS}, \sigma_s^X)$ $\qquad\qquad\qquad\qquad$ $(P_{s,t}^X)$

(4) $\qquad Q_{s,t} = CD(K_{s,t}^{dem}, L_{s,t}^{dem}; Sc_{s,t}^Q, \alpha_s^K)$ $\qquad\qquad\qquad\quad$ $(P_{s,t}^Q)$

(5) $\qquad L_{s,t}^{dem} = CES(L_{s,itype,t}^{Type}; \alpha_{s,itype}^{Ltype}, \sigma_s^{Ldem})$ $\qquad\qquad\qquad$ $(wage_{s,t})$

(6) $\qquad L_{s,itype,t}^{Type} = CES(L_{s,itype,iprof,t}^{\Pr of}; \alpha_{s,itype,iprof}^{Lprof}, \sigma_{s,itype}^{Ltype})$ $\qquad\qquad$ $(w_{s,itype,t}^{Type})$

(7) $\qquad L_{s,itype,iprof,t}^{\Pr of} = CES(L_{s,itype,iprof,iqual,t}^{Qual}; \alpha_{s,itype,iprof,iqual}^{Lqual}, \sigma_{s,iprof}^{\Pr of})$ $\qquad$ $(w_{s,itype,iprof,t}^{\Pr of})$

Here, Cobb-Douglas functions are denoted by $CD(.;Sc,\alpha)$ parameterized by the scaling parameter Sc and expenditure shares α. Constant-elasticity-of-substitution functions are denoted by $CES(.;\alpha,\sigma)$ with share parameters, α and substitution elasticity, σ. The production of output $Z_{s,t}$ is a combination of intermediate inputs and value added output in fixed expenditure shares of amount $X_{s,t}$ and $Q_{s,t}$, respectively. The aggregate intermediate input is itself a CES mix of market goods in quantities $XS_{ss,s,t}$. The value added is produced using $K_{s,t}^{dem}$ and $L_{s,t}^{dem}$ amounts of capital and aggregate labour services with fixed expenditure shares. Aggregate labour services is a CES mixture of different types of labour $L_{s,itype,t}^{Type}$, each of these being a different CES combination of occupations $L_{s,itype,iprof,t}^{\Pr of}$, which themselves result from a CES combination of different qualification levels $L_{s,itype,iprof,iqual,t}^{Qual}$. This multilevel CES aggregation structure captures the heterogeneous nature of labour inputs. Associated with each constraint of the firm's cost minimization problem are shadow prices, which are indicated in brackets. Mercenier, Mérette and Harvey (2003) present a schema of the technological constraint plus the optimality conditions for the firm.

3.23 Household g of region j at time t

An Allais-Samuelson overlapping generations framework characterizes households, so that the model is based on the life-cycle theory of savings. Each adult individual lives seven periods of ten years, retiring after five periods. In each period, the eldest generation dies and a new generation enters the labour force, which implies that at any point in time seven generations are alive. The working life begins at age 15; younger children are assumed to be fully dependent on

their parents to which they constitute no extra burden nor provide any felicity. Individuals have perfect foresight and fully retire from the labour force at age 64 and die at age 84. A newborn generation's problem consists of maximizing an inter-temporal utility function of consumption and bequest subject to a lifetime income in a first step. The utility function is time-separable with the following CES form:

$$(8) \quad U_t = \frac{1}{1-\theta} \sum_{g=1}^{7} \left(\frac{1}{1+\rho}\right)^g \left(Con_{g,t+g-1}^{1-\theta} + \beta_g^{\theta} RBeq_{g,t+g-1}^{1-\theta}\right) \quad \theta > 0, \beta_{g \neq 7} = 0, \beta_{g=7} > 0 \;,$$

where $Con_{g,t}$ is consumption of an individual living in region j of age group g at time t, ρ the pure rate of time preference, θ the inverse of the inter-temporal elasticity of substitution, β_g a constant parameter and $RBeq_{g,t}$ denotes bequests (in real terms). This equation states that the welfare of an individual is a weighted sum of 7 periods of consumption from age group $g=1$ at period t to age group $g=7$ at $t+6$, plus the (positive) utility to bequest for $g=7$ in period $t+6$. Leisure does not enter into the utility function since individual's labour supply is assumed to be exogenous. The bequest specification follows Blinder (1974) and gives rise to inter-generational transfers in addition to public old-age pension benefits. The specification of the utility function implies that the felicity from bequest is independent of the present value of cash receipts extending beyond the death of the current generation.

Assuming no borrowing constraints and perfect capital markets, the present value of household wealth is the discounted sum of lifetime labour income $LInc_{g,t}$ net of taxes but inclusive of public old-age pensions $Pens_{g,t}$ and inheritances $Inh_{g,t}$:

$$(9) \quad W_t = \sum_{g=1}^{7} \left(\frac{1}{1+R\,\mathrm{int}_{t+g-1}\left(1-\tau^K\right)}\right)^t \left(LInc_{g,t+g-1}(1-\tau^w_{t+g-1} - CtR_{t+g-1}) + \right.$$
$$\left. (1-\tau^w_{t+g-1})Inh_{g,t+g-1} + Pens_{g,t+g-1}\right) ,$$

where $R\,\mathrm{int}_t$ is the rate of interest, τ^K and τ^w are effective tax rates on capital and labour income respectively, and CtR_t is the contribution rate to the Canadian public pension system, which is modelled as a pay-as-you-go.

Labour income depends on the individual's age-dependent productivity (earnings) profile (EP_g) which is defined as a quadratic function of age g:

$$(10) \quad EP_g = \gamma + \lambda g - \psi g^2, \quad \gamma, \lambda, \psi \geq 0,$$

with parametric values chosen to ensure that the maximum is reached between mid-life and retirement. Labour income by working age group gj at period t is defined as:

$$(11) \quad LInc_{gj,t} = \sum_{\substack{itype \\ iprof \\ iqual}} w^{qual}_{itype,iprof,iqual,t} L^{sup}_{itype,iprof,iqual,gj,t} EP_{gj} AAR_{itype,iprof,iqual,gj,t},$$

where $L^{sup}_{itype,iprof,iqual,gj,t}$ is the amount of labour services supplied and $AAR_{itype,iprof,iqual,gj,t}$ the average age of retirement, also specific to occupations and time.

Retirees's pension benefits are proportional to their lifetime labour earnings. The fraction is determined by the pension replacement rate *PensR* that applies identically everywhere in Canada. Pension benefits are thus equal to:

$$(12) \quad Pens_{gm,t} = PensR \frac{1}{5} \sum_{gj} LInc_{gj,t-gm+gj}.$$

Differentiating the household's utility function with respect to its lifetime budget constraint yields the following first-order conditions for consumption and bequests:

$$(13) \quad Con_{g+1,t+g} = \left[\frac{\left(1 + R\,int_{t+g}\left(1 - \tau^K_{t+g}\right)\right)}{1+\rho} \frac{\left(1+\tau^{Con}_{t+g-1}\right)P^{Con}_{g,t+g-1}}{\left(1+\tau^{Con}_{t+g}\right)P^{Con}_{g,t+g}} \right]^{\left(1/\theta\right)} Con_{g,t+g-1},$$

$$(14) \quad RBeq_{g,t} = \beta_g Con_{g,t}.$$

Bequests are distributed at the end of each generation's lifetime (generation *gn*), equally across working generations *gj* as inheritances:

$$(15) \quad Inh_{gj,t} Pop_{gj,t} = \frac{1}{5} P^{Con}_{j,gn,t} RBeq_{gn,t} Pop_{gn,t},$$

where $Pop_{g,t}$ denotes the number of people living by age group *g* at period *t*. The population growth rate is treated as exogenous. Note that $Inh_{g,t}$ is defined in current prices.

In a second optimization step, households must allocate their consumption expenditures across the available final goods *s*; we again assume a CES aggregator. First order conditions impose that:

$$(16) \quad \begin{cases} P^{Con}_{g,t}{}^{1-\sigma^{Con}_g} = \sum_s \alpha^{ConS}_{s,g} P_{s,t}{}^{1-\sigma^{Con}_g} \\ \\ ConS_{s,g,t} = \alpha^{ConS}_{j,s,g} \left[\frac{P^{Con}_{g,t}}{P_{s,t}} \right]^{\sigma^{Con}_g} Con_{g,t} \end{cases},$$

where $ConS_{s,g,t}$ denotes the household's consumption of good s, and $P_{s,t}$ the consumer price. Note that, because the composition of consumption baskets varies across generations—for example, older generations consume more health services than younger ones,—the aggregate consumer price index is generation dependent.

Households invest in physical capital $Kij_{g,t}$ and in bonds $Bij_{g,t}$ issued by firms and the government. Because we assume that all assets are perfect substitutes and traded on fully integrated international markets, the composition of households' wealth is without consequence, except on impact after an unexpected shock.

3.24 Investors of region j at time t

Capital goods are built using an investment technology that also allows for substitution between different market goods; choosing the optimal constituting mix, we get the following conditions:

$$(17) \quad \begin{cases} P_t^{Inv \, 1-\sigma^{Inv}} = \sum_s \alpha_s^{InvS} P_{s,t}^{\, 1-\sigma^{Inv}} \\[2mm] InvS_{s,t} = \alpha_s^{InvS} \left[\dfrac{P_t^{Inv}}{P_{s,t}} \right]^{\sigma^{Inv}} Inv_t \end{cases} .$$

The stock of physical capital broadens with investment Inv_t, but narrows with depreciation at constant rate $DepR$:

$$(18) \quad Kstock_{t+1} = Inv_t + (1 - DepR)Kstock_t .$$

The one period expected rate of return on a unit of physical capital bought at time $t-1$, denoted $R\operatorname{Re}t_t$, is then defined by the following expression:

$$(19) \quad R\operatorname{Re}t_t = \frac{\operatorname{Re}nt_t + (1 - DepR)P_t^{Inv}}{P_{t-1}^{Inv}} ,$$

that is, as its expected real rental price net of depreciation augmented by anticipated capital gains.

3.25 The government at time t

The government taxes labour and capital incomes, as well as consumption expenditures. Government spending includes government consumption, Gov_t and interest payments on the debt. Government consumption spending is allocated across sectors using a CES aggregator:

(20) $\quad P_t^{Gov\,1-\sigma^{Gov}} = \sum_s \alpha_s^{GovS} P_{s,t}^{1-\sigma^{Gov}}$

(21) $\quad GovS_{s,t} = \alpha_s^{GovS} \left[\dfrac{P_t^{Gov}}{P_{s,t}} \right]^{\sigma^{Gov}} Gov_t$

To satisfy its budget constraint when tax revenues come short of expenditures, the government issues new bonds. Accordingly, the budget constraint of the government is:

(22)
$$P_t^{Gov} Bond_{t+1} + \sum_g Pop_{g,t} \left\{ \tau_t^w \left(LInc_{g,t} + Pens_{g,t} \right) + \tau_t^{Con} P_t^{Con} Con_g + \right.$$
$$\tau_t^K \left(\frac{R\,int\,J_{t-1} P_t^{Gov}}{P_{t-1}^{Gov}} - 1 \right) P_{t-1}^{Gov} Bij_{g,t} + \tau_t^K \left(R\,Ret_{t-1} - 1 \right) P_{t-1}^{Inv} Kij_{g,t} \right\}$$
$$= P_t^{Gov} Gov_t + \left(\frac{R\,int\,J_{t-1} P_t^{Gov}}{P_{t-1}^{Gov}} \right) P_{t-1}^{Gov} Bond_t$$

Pay-as-you-go pension benefits are financed by contribution rates on wage earnings:

(23) $\quad \sum_{gm} Pop_{gm,t} Pen_{gm,t} = CtR_t \sum_{gj} Pop_{gj,t} LInc_{gj,t}$

3.26 Canada's foreign trade in goods at time t

All agents within Canada make use of a composite good indexed *s*, which is priced at $P_{j,s,t}^c$. The aggregate demand for this good is defined by adding-up all individual demands:

(24) $\quad \sum_{ss} XS_{s,j,ss,t} + \sum_g Pop_{j,t,g} ConS_{j,s,g,t} + InvS_{j,s,t} + GovS_{j,s,t}$,

where *j* here represents the region of Canada. We make use of the traditional Armington assumption to allocate this demand between Canada and the rest-of-the-world. That is, even though individual producers are microscopic price takers, goods of sector *s* are assumed differentiated in demand by their geographic origin. A Canadian fictitious importer accordingly chooses the optimal basket of domestic and international goods in each sector, using a $CES(E_{ii,j,s,t}; \alpha_{ii,j,s}^E, \sigma_{j,s}^c)$ aggregator. The price $P_{j,s,t}^c$ can then be expressed as a function of each supplying Canada and rest-of-the-world's producer price $P_{ii,s,t}$ (where *ii* refers here to Canada or rest-of-the-world):

(25) $\quad P_{j,s,t}^{c\,1-\sigma_{j,s}^c} = \sum_{ii} \alpha_{ii,j,s}^E P_{ii,s,t}^{1-\sigma_{j,s}^c}$

and the associated demand system is:

$$(26) \quad E_{ii,j,s,t} = \alpha^E_{ii,j,s} \left[\frac{P^c_{j,s,t}}{P_{ii,s,t}} \right]^{\sigma^c_{j,s}} \left\{ \sum_{ss} XS_{s,j,ss,t} + \sum_g Pop_{j,t,g} ConS_{j,s,g,t} + InvS_{j,s,t} + GovS_{j,s,t} \right\}$$

3.27 The rest of the world at time t

The rest of the world only serves to close the model and is described by a reduced form; its prices and income are exogenously held constant. Its demand for region i's (Canada) good s therefore depends on the region's sectoral competitiveness:

$$(27) \quad E_{i,row,s,t} = Sc^E_{i,row,s} \left[\frac{P_{row,s,t}}{P_{i,s,t}} \right]^{\eta_s} \qquad \eta_s > 0$$

Consistent with the reduced form description of the rest of the world, we assume that it neither borrows nor lends internationally, so that its trade with the Canadian economy is calibrated as balanced at all t:

$$(28) \quad \sum_s \sum_{ii} P_{ii,s,t} E_{ii,row,s,t} = \sum_s P_{row,s,t} \sum_{ii} E_{row,ii,s,t}$$

3.28 Equilibrium conditions

- Market clearing for goods:

$$(29) \quad Z_{s,t} = \sum_{ii} E_{ii,s,t}$$

- Full employment of labour:

$$(30) \quad \sum_{gj} Pop_{gj,t} L^{sup}_{itype,iprof,iqual,gj} EP_{gj} = \sum_s L^{qual}_{s,itype,iprof,iqual,t}$$

- Full employment of capital:

$$(31) \quad Kstock_t = \sum_s K^{dem}_{s,t}$$

- Fully integrated asset markets:

$$(32) \quad \frac{R \operatorname{int} J_t P^{Gov}_{t+1}}{P^{Gov}_t} = R \operatorname{Re} t_{t+1}$$

This completes the models description. It is easy to check that the model implies asset market clearing at each t:

$$(33) \quad \sum_g Pop_{g,t} Lend_{g+1,t+1} = P_t^{Gov} Bond_{t+1} + P_t^{Inv} Kstock_{t+1}$$

Prices of the rest of the world are chosen as numéraire.

4. Data and Calibration

Calibrating the model to a base year data set consists of fitting a macroeconomic long run steady state consistent with detailed microeconomic observations underlying individual optimal choices. The challenge is in fact to build a Social Accounting Matrix (SAM) constrained on the preference patterns of the different age groups, the sectoral production, as well as the distribution of labour by type, occupational group and level of qualification. The SAM must also be consistent with macroeconomic aggregates such as output, consumption, investment, and data on international trade flows. In addition, since the model is dynamic and characterized by an overlapping generations structure with perfect foresight, the calibration procedure must ensure that decisions are inter-temporal consistent, that is, that consumption and savings decisions at the individual level are consistent with inter-temporal prices. Moreover, the amount of total savings generated by aggregating individual consumption decisions must be consistent with existing stocks of assets. As one can expect, macroeconomic and microeconomic data come from different sources. In the following, we describe the data sources and explain the calibration procedure.

4.1 Industrial Sectors

The model comprises two regions: Canada (CAN) and a second, residual region, the Rest-of-the-World (*RoW*). The international trade flows data are taken from the 1999 Interprovincial and International Trade Flows Matrix calculated by Statistics Canada.[5] These tables report trade flows for more than 50 sectors. The model contains 14 sectors and Table 1 summarizes the aggregation rule applied to the large Statistics Canada Table.

Intermediate demand by firms is taken from Statistics Canada's input-output tables. Similarly to trade flow data, an aggregation of sectors is operated on the input-output tables to make them consistent with the model's sectors. Table 1 in Appendix 1 of Mercenier, Mérette and Harvey (2003) summarizes the link between the sectoral disaggregation adopted in the model and that available in the input-output tables.

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[5] Statistics Canada, Systems of National Accounts, Input-Output Division, Table 386-0001.
[6] More details about other adjustments made to the Statistics Canada data can be found in Mercenier, Mérette and Harvey (2003).

4.2 Labour Market

One of the original elements of the model is its specification of labour into several occupation and qualification categories. The categories are defined from the National Occupational Classification Matrix 2001. Table 2 summarizes the 10 occupational groups and 5 qualification levels of the matrix. The sectoral allocation of the various occupations and qualification levels are taken from the Labour Force Survey. The composition of labour demand and the elasticities of substitution across occupations and level of qualification are "guestimated" based on information available from Lavoie and Therrien (1999). The matrix is sparse, that is, it displays a large number of zero cells. We take advantage of this by defining three different types of sectoral labour demand aggregates: see Appendix 1. For instance, labour of Type 1 aggregates Occupations 1, 4, and 10, Occupation 1 is defined as an aggregation of labour Qualification levels 2, 3, and 4. As one expects, the substitution possibilities are smaller between labour types than within each type. Substitution possibilities are in turn smaller between qualifications within each occupation (see Table 4 for values of elasticities of substitution).

Table 1: Industrial Sectors in CGE Model

	Model Acronym	Related Sectors of the Inter-provincial Trade Flow Matrix
1. Primary	PRI	1 to 8: grain; other agricultural products; forestry products; fish, sea foods and trapping products; metal ores and concentrates; mineral fuels; non-metallic minerals; services incidental to mining.
2.Manufacturing and Public Utility	MAN	9 to 28, and 45: meat, fish, and dairy products; fruit, vegetables and other food products, feeds; soft drinks and alcoholic beverages; leather, rubber and plastic products; textile products; hosiery, clothing and accessories; lumber and wood products; furniture and fixtures; wood pulp, paper and paper products; printing and publishing; primary metal products; other metal products; machinery and equipment; motor vehicles, other transportation equipment and parts; electrical, electronic and communication products; non-metallic mineral products; petroleum and coal products; chemical, pharmaceuticals and chemical products; other manufactured products; operating office, cafeteria, and laboratory supplies.
3. Construction	CST	29 to 31, and 37: residential construction; non-residential construction; repair construction; gross imputed rent.
4. Transport and Storage	TRA	32 and 44: transportation and storage; transportation margins.
5. Communication	COM	33: communications services.
6. Wholesaling and retailing	CGD	35 and 36: wholesaling margins; retailing margins.
7. Finance, insurance and real estate services	FAI	38: other finance, insurance and real estate services.
8.Professional services to firms and publicity	SEP	60% of 39: business and computer services.

9. Computer and other services to firms	ICS	40% of 39: business and computer services.
10. Public administration	ADM	34, 48 and 51: other utilities; government sector services; sales of other government services.
11. Education	EDP	40: education services.
12. Health	SAN	41: health and social services.
13. Accommodation and leisure services	HRD	42 and 46: accommodation services and meals; travel and entertainment, advertising and promotion.
14. Other services	AUT	43, 47, and 49: other services; non-profit institutions serving households; non-competing imports.

Table 2: Occupations and Qualification Levels

Occupations
1. Business, finance and administration occupations
2. Natural and applied sciences and related occupations
3. Health occupations
4. Occupations in social science, education, government service and religion
5. Occupations in arts, culture, recreation and sport
6. Sales and services occupations
7. Trades, transport and equipment operators and related occupations
8. Occupations specific to primary industry
9. Occupations specific to processing, manufacturing and utilities
10. Management
Qualification Levels
1. Management occupations
2. Occupations that usually require university education
3. Occupations that usually require college education or apprenticeship training
4. Occupations that usually require secondary school and/or occupation specific training.
5. On-the-job training is usually provided for these occupations

4.3 Model Parameters

Table 3 reports relevant base year (2000) data. Public debt includes provincial and federal government's debts. Public health care spending to GDP, public education spending to GDP, the wage income tax rate, the capital income tax rate, and the tax rate on consumption are aggregate calculations of regional data used by Mercenier, Mérette and Harvey (2003).

Table 3: Model Parameters and Exogenous Variables

Government Debt/GDP	.761
Public Health Care/GDP	.059
Public Education/GDP	.041
Wage tax rate (τ^w)	.325
Capital tax rate (τ^K)	.489
Consumption tax rate (τ^{con})	.196

Table 4 below reports key behavioural parameter values. The value of the inter-temporal elasticity of substitution is 0.175, which is slightly lower than the value of 0.25 used by Auerbach and Kotlikoff (1987). Inter-sectoral elasticities of substitution for private and public consumption, as well as for investment are assumed equal to 2.5. The pension replacement rate *PenR* is set to 0.30, the bequest parameter *BeqR* to 0.40 whereas the inheritance rate *InhR* equals 0.20 as private bequests are assumed equally distributed among the working age population. The various labour demand substitution elasticities ($\sigma_{j,s}^{Ldem}$, $\sigma_{j,s,itype}^{Ltype}$, $\sigma_{j,s,iqual}^{Lqual}$) are inferred from Lavoie and Therrien (1999).[7] Observe that the elasticity of substitution between types of occupations is rather small ($\sigma_{j,s}^{Ldem}$=0.5) and is relatively higher across occupations within each type: $\sigma_{j,s,itype}^{Ltype}$ >1. It is assumed that it is relatively more difficult for firms to substitute among occupations of type 1 than among occupations of type 3. As occupations of type 2 are more heterogeneous and knowledge specific, the elasticity of substitution is assumed to be the smallest of all three types. Consequently, the elasticity of substitution for *itype* = 1 occupation is set to 2.0, whereas the elasticities for *itype* = 2 and *itype* = 3 are 1.3 and 2.5 respectively. As it is reasonable to assume that the elasticity of substitution across qualifications (that is, within each occupation) is greater than across occupations; we set $\sigma_{j,s,iqual}^{Lqual}$ equal to 3.0 for all occupations.

The elasticity of substitution between intermediate goods ($\sigma_{j,s}^X$) is set equal to 2.0 for all sectors. The calibrated annual interest rate is equal to 3.8 percent; which is the rate necessary to generate large enough life-cycles savings to match data on stocks of physical capital and on government bonds in the Canadian economy.[8] Finally, the calibrated depreciation rate is equal to 5.1 percent, whereas export price elasticities (η_s) to the RoW are set to 5.0 in all sectors.[9]

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[7] In this study, Lavoie and Therrien (1999) examine the role of computers in the transformation of the employment structure and estimate labour demand functions by skills.

[8] In their pioneer computable OLG work, Auerbach and Kotlikoff (1987) use an interest rate equal to 7.3 percent.

[9] As is clear from the model description, the RoW plays no role here other than to match base year data; therefore, adopting high export price elasticity values is both realistic and consistent with the model structure.

Table 4: Behavioural Parameters

$1/\theta$	.175
$\sigma_{j,s}^{Con}$	2.5
$\sigma_{j,s}^{Inv}$	2.5
$\sigma_{j,s}^{Gov}$	2.5
$BeqR$	0.4
$InhR$	0.25
$PensR$	0.3
$\sigma_{j,s}^{Ldem}$	0.5
$\sigma_{j,s,itype}^{Ltype}, \quad itype = 1$	2.0
$\sigma_{j,s,itype}^{Ltype}, \quad itype = 2$	1.3
$\sigma_{j,s,itype}^{Ltype}, \quad itype = 3$	2.5
$\sigma_{j,s,iprof}^{Prof}$	3.0
$\sigma_{j,s}^{X}$	2.0
$R\,int$	.038
$DepR$	.051
η_s	5.0

4.4 Spending Shares by Age

Household preferences are allowed to vary along the lifecycle. Table 5 reports the spending shares for the seven age groups in the model. The expenditure share by age group are equal to unity. The spending shares for the 75-85 age group are assumed identical to the 65-74 age group as both age groups are incorporated into one single group in the MMH model.

The spending shares have been calculated using the 1999 Survey of Household Spending from Statistics Canada. Based on information from the survey, goods and services are aggregated into the 14 industrial sectors of the model. It must be noted that since *professional services to firms* and *computer and other firm services* are pure services to firms, their consumer spending share is equal to zero for all age group. Firms absorb all these services as input costs. Therefore, the impact of population ageing on these sectors will come indirectly through changes in firm's demand for intermediate goods.

Table 5: Private Spending shares by age groups (%)

Age-group	15-24	25-34	35-44	45-54	55-64	65-75	75-85
Primary	2.9	3.2	3.3	3.5	3.9	3.8	3.8
Manufacturing and Utilities	22.8	18.4	19.2	19.0	19.1	20.8	20.8
Construction	16.8	16.5	14.8	12.2	11.5	12.7	12.7
Transportation	4.6	3.2	3.0	3.1	3.1	2.9	2.9
Communication	2.5	1.9	1.7	1.6	1.8	2.1	2.1
Wholesaling and Retailing	14.0	11.3	11.8	11.6	11.7	12.7	12.7
Finance, Insurance and Real Estate	6.9	8.4	8.6	9.4	8.6	6.2	6.2
Public Administration	13.0	24.2	24.5	26.0	24.4	19.4	19.4
Professional Services to Firms	0	0	0	0	0	0	0
Computer and other Firm Services	0	0	0	0	0	0	0
Education	3.1	1.0	0.7	1.3	0.8	0.1	0.1
Health	1.1	0.8	1.1	1.3	1.6	2.6	2.6
Accommodation and Leisure Services	9.1	7.2	6.8	6.8	7.5	8.0	8.0
Other Services	3.0	3.7	4.4	4.1	5.9	8.7	8.7
Total	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**

It can also be shown that spending shares in some sectors are age-sensitive. For example, spending shares on health, primary goods, accommodation and leisure services and other services increase with age. On the other hand, spending shares on construction and education decline with age. Note, however, that the size of spending shares allocated to education and health is relatively small in Table 5 as it represents private spending only. Education and health care services are publicly funded for the most part.

Middle age households spend relatively more than younger and older households on finance, insurance and real estate services and public administration. The spending share allocated to public administration accounts for direct taxes paid by households. It follows a concave shape along the lifecycle, reflecting the higher tax burden on middle-age households. The demand for public administration services is equivalent in the model to government expenditures. Finally, the spending shares for the remaining sectors, including manufacturing and utilities, transportation, communication and wholesaling and retailing does not change substantially by age.

Using the share of education and health care with respect to GDP reported in Table 3, government expenditures are split into four: health, education, construction and public administration, which is the residual. By this desegregation, we capture the real nature of current

government expenditures. It does not, however, make these expenditures sensitive to changes in the composition of the population. We will discuss this issue further below.

Table 6 reports the dollar share of public health care and education spending allocated by age group (hence the row-sum equals unity). The distribution for health care is calibrated slightly differently from Mercenier, Mérette and Harvey (2003) at the end of a person's life. In this paper, the distribution of health care spending during retirement age is assumed to more than double from age 65-74 to 75-84. This reflects the fact that the bulk of health care demand occurs during the last three years of life. In comparison, the age group 15-24 receives 3% only of each dollar spent per capita by the government on health care. It is oubious from this table that health care spending are concentrated among the older age groups.

The expenditure pattern of education follows a completely different path. The age group 15-24 receives 26% of each dollar spent on public education per capita. The amount spent reaches 40% for age group 25-34, representing elementary and secondary education subsidies received by the parents' children. Public expenditures on education declines thereafter, nearing zero during retirement.

Table 6: Public Expenditure on Health and Education per Age Group
(Dollar share per capita, %)

Age-group	15-24	25-34	35-44	45-54	55-64	65-74	75-84
Health	3.0	3.0	7.0	9.0	11.0	27.0	40.0
Education	26.0	40.0	20.0	7.0	5.0	1.0	1.0

The burden of calibration rests mainly on the demand side, to ensure a general equilibrium at the base year. This step determines the life-cycle consumption profile, the consumers' rate of time preference, as well as government expenditures other than health care and education. Once the aggregate variables are correctly calibrated to a base year and are consistent with a steady state equilibrium, the sectoral structure of consumption baskets by age is adjusted to be consistent with aggregate consumption. The structure of wealth portfolios is determined in a similar fashion. We assume the same structure for all age groups.

Once a balanced social accounting matrix is constructed, the calibration of the share parameters (the various αs) of technology and preferences is a trivial matter. However, the structure of labour demands by sector, occupation and level of qualification is quite complex. To have an idea of the absolute and relative size of labour units demanded by sector, the calibrated share parameters on labour demand are shown in Appendix 2. The sectoral composition of labour demand by occupation and level of qualification plays a determining role in the model and on the interpretation of results.

4.5 Effective Age of Retirement by Occupation

In Canada, although the entitlement age for receiving old age security (OAS) pension benefits is 65, the average effective age of retirement in Canada is well below 65.[10] Compared to the 1970s and early 1980s where the average age of retirement was near 65, it has declined more or less steadily since to stabilize in 1997 and achieve 61 in 2001.[11]

However, over the period 1996-2001, the effective age of retirement has varied quite significantly across workers by industry and occupation. Table 7 provides information on the effective age of retirement for the period 1996-2001 by large occupational groups. Since no valuable information is available at the two-digit level, we impose the same retirement age by skill level. As shown in the table, the effective age of retirement remained very high across workers in occupations unique to primary industries, around age 66. This is explained in good part by agriculture workers. By contrast, workers in social sciences, education, government and religion have the lowest effective age of retirement, averaging 57 during the 1996-2001 period. For the remaining occupational groups, the effective age of retirement ranges from 60.3 for business, finance and administration to 62.4 for trades, transport and equipment operators.

4.6. Demographic Projections

Table 8 below reports the old-age dependency ratio as projected by Human Resources and Skills Development Canada (HRSDC). We also present the approximations made by the model. The statistics are reported for the next four decades. The matching of HRSDC`s projections are achieved by choosing appropriately the growth rate of the number of individuals belonging to the first age group of the model. The old age dependency ratio is the population aged 65+ relative to the working-age population. As shown the table, according to the demographic projection, the old-age dependency ratio is expected to rise from 18% in 2000 to 40% in 2040, so more than double over the next 40 years.

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[10] For more information on the methodology used to measure the age of retirement, see Gower (1997).
[11] See Fougère *et al.* (2004) for more details on historical retirement trends .

Table 7: Effective Age of Retirement by Occupation, 1996-2001 Average[12]

Occupational Group	Skill level	Retirement age
Management Occupations		60.4
Business, Finance and Administration	A	60.3
	B	60.3
	C	60.3
Natural and Applied Sciences	A	60.6
	B	60.6
Health Occupations	A	61.0
	B	61.0
	C	61.0
Social Sciences, Education, Government and Religion	A	57.4
	B	57.4
Art, Culture, Recreation and Sports	A	61.8
	B	61.8
Sales and Services	B	62.0
	C	62.0
	D	62.0
Trades, Transport and Equipment Operators	B	62.4
	C	62.4
	D	62.4
Occupations in Primary Industries	B	66.3
	C	66.3
	D	66.3
Processing, manufacturing and Utilities	B	61.4
	C	61.4
	D	61.4

Source: Labour Force Survey, National Occupation Classification Matrix

Table 8: Old-Age Dependency Ratio (%)

Years	2000	2010	2020	2030	2040
HRDC	18.4	20.4	27.6	37.1	40.4
Model	18.2	22.7	28.4	35.5	42.4

5. Simulation Results

As mentioned in the introduction, the paper's key objective is to analyze the dynamic effects of population ageing arising from the combination of two important structural changes that will affect the Canadian economy and the labour market. The first is a relative decline in labour supply. The anticipated decline in the supply of labour will affect potential output both

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[12] Please note that within each occupational group, we assume that the effective age of retirement is the same by skill level. The reason is that the quality of data is questionable at the two digit level.

directly as labour is a factor of production, but also indirectly as physical capital becomes relatively more abundant than effective units of labour. Therefore, capital investment to equip new workers becomes of less necessity. Also, although MMH assumed that the labour force attachment is homogeneous across occupations, in this paper, we introduce some heterogeneity regarding retirement age. As indicated in Table 7, the effective retirement age by occupational group is assumed to remain unchanged from the 1996-2001 average.

The second important structural shock is the change in the composition of consumption demand. As shown in MMH, this change will have a much smaller sizable impact on GDP than the labour supply shock. However, as relative private and public consumption needs evolve with age, the impact will differ across sectors. In other words, consumption demand changes will lead to relative inter-sectoral effects, which will result in relative wage differential across occupations through changes in firms' labour demand.

Population ageing will also generate increased pressures on government spending through health expenditures (see Table 6). However, this will be partly offset by reducing pressures from education spending. To remain consistent with this observation, we assume for all simulation experiments that the the Canadian government maintains public education and health care expenditures constant per head by age group; so it essentially allocates more resources to health care and less to education when population ages. With this assumption, we can easily compute the necessary change in the allocation of government expenditures towards health care and education for the decades to come, using the numbers in Table 6 and the demographic projections; the residual is allocated to construction and public administration services in the same proportions as in the base year so as to maintain total public spending constant in real terms.[13] Note that in absolute terms, the reallocation is five to eight times larger for public administration than for construction.

As suggested in Tables 5 and 6, population ageing is expected to increase consumption demands for health services, primary goods, finance, insurance and real estate services, accommodation and leisure services and other services, but reduce demands for education and construction. We now turn to the simulation experiments.

5.1 Macroeconomic Impact

Table 9 below reports the impact of population ageing on key macroeconomic indicators. The results are presented in percentage changes with respect to the initial steady state solution. As shown in the Table, real GDP per capita is projected to increase somewhat until 2020, but to decrease sharply thereafter, reaching -10.8% by 2050. This result is fully consistent with most aggregate CGE models with overlapping generations, which predict a decline in GDP per capita relative to a scenario with no ageing.[14] The decline in real per-capita GDP is due to two main factors. The first is the labour supply shock due to population ageing. Effective units of labour,

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[13] The adjustment we impose on the sectoral allocation of governments' expenditures is certainly conservative since it neglects to take into account the growing political influence of older generations, likely to affect the preferences of the government.

[14] See for example, Hviding and Mérette (1998), Fougère and Mérette (2000b), Mercenier and Mérette (2002), Fougère et al. (2003) and Fougère et al. (2004).

which combine a measure of quantity and quality of labour (productivity), increase initially as baby boomers achieve their most productive working years. The productivity of old and young workers is relatively smaller than that of middle-age workers which explains this result. This is followed by a decline in effective units of labour as the proportion of older workers increases and the baby boom generation reaches retirement. The second factor which explains the decline in real per-capita GDP is the fall in real investment. This drop is the result of the slower growth in the arrival of new workers, which leads to a rise the ratio of physical capital to effective units of labour and reduces the need for firms to invest in physical capital. The investment/GDP ratio falls by 7.7% in 2010 and 27% by 2050, while the share of investment in total GDP falls by near 5 percentage points, from 12.7% to 8% by 2050. The investment decline is only slightly offset by the relative increase of private consumption as the ratio of consumption with respect to GDP increases slightly during the period 2000 to 2050. The rate of interest behaves as in more aggregate models; that is it declines between 2000 and 2050 because of the relative abundance of capital.

On the fiscal side, the wage income tax rate increases relative to the initial steady state, to maintain the ratio of public debt to GDP unchanged. As we keep government expenditures constant per capita, the wage income tax rate reacts mostly to changes in government revenue and increased pressures coming from public expenditures on health care. The tax rate increases slightly during the first two decades investigated, but increases substantially after 2020 because of the decline in the revenue coming from the labour income tax base.

Table 9: Impact of Population Ageing on Key Macroeconomic Indicators
(Percentage changes with respect to initial steady state)

	2000	*2010*	*2020*	*2030*	*2040*	*2050*
GDP per capita (%)	0.0	1.6	1.8	-0.4	-5.0	-10.8
Effective labour supply (%)	0.0	2.6	-0.8	-10.6	-24.1	-37.0
Investment/GDP (%)	0.0	-7.7	-13.8	-22.0	-31.3	-37.1
Share in Investment/GDP (% point)	0.127	0.118	0.110	0.099	0.089	0.080
Private consumpt./GDP (%)	0.0	1.2	1.8	2.2	2.2	1.6
Share in Consumption/GDP (% point)	0.680	0.688	0.692	0.695	0.695	0.691
Rate of interest (% point)	0.0	-0.4	-0.7	-0.8	-0.6	-0.2
Capital-Labour Ratio (%)	0.0	9.7	18.4	25.1	25.5	19.8
Wage tax rate (% point)	0.0	1.5	2.0	3.6	7.1	11.6

5.2 Sectoral Impact of Population Ageing

We now turn our attention to the simulation results at the sectoral level. As mentioned earlier, the sectoral effects of population ageing are a combination of both supply and demand factors. The supply effect is driven by the decline in the effective supply of labour and investment, while the demand shock arises from age-sensitive preferences over specific goods. The demographic shock imposed on the benchmark year 2000 is equivalent to a change in household preferences at the aggregate level, combined with a sectoral re-allocation of public expenditures, which reflects new government priorities due to the change in the composition of the population. Please note that the results reported in Table 10 present the share of sectoral output in total GDP. An increase in output share for an industrial sector implies that this sector will grow faster than the rest of the economy as a result of population ageing.

As can be seen from Table 10, the sectoral share of *health* increases by near 50% between 2000 and 2050, from 4.8% to 7% of total GDP, which is enormous. The other sectors benefiting (although substantially less than *health*) are *finance, insurance and real estate*, and *communication*. On the other hand, *manufacturing and utilities, construction, education* and *wholesaling and retailing* significantly lose relative to total GDP. This is due to a combination of final demand and intermediate demand changes. For *education*, the negative impact of ageing due to final demand changes is partially offset by an increase in intermediate demand from the health sector. For the *construction* sector, the negative final demand effect is exacerbated by a negative change in intermediate demand coming from the *manufacturing* sector. *Professional services to firms* and *computer and other firm services* are also somewhat negatively affected mainly because of the negative shock in intermediate demand coming from *manufacturing* and *construction*.

To illustrate the relative importance of intermediate demand factors, according to Table 5, we would anticipate significant gains from the *primary* sector, *accommodation and leisure services* and *other services,* although as can be seen from Table 10, their sectoral share of output changes very modestly. This is partly explained by negative intermediate demand changes from *manufacturing*, *construction* and *wholesaling and retailing*, which affect these sectors.

Table 10: Sectoral Impact of Population Ageing
(Share of Sectoral Output in Total GDP)

Sectors\Years	2000	2010	2020	2030	2040	2050
Primary	0.034	0.034	0.035	0.035	0.035	0.034
Manufacturing and Utilities	0.220	0.219	0.218	0.216	0.213	0.208
Construction	0.156	0.154	0.151	0.148	0.146	0.146
Transportation	0.021	0.021	0.021	0.021	0.022	0.022
Communication	0.017	0.018	0.018	0.019	0.019	0.019
Wholesaling and Retailing	0.096	0.095	0.094	0.092	0.091	0.090
Finance, Insurance and Real Estate	0.113	0.117	0.120	0.121	0.120	0.116
Professional Services to Firms	0,050	0,049	0,049	0,048	0,047	0,047
Computer and other Firm Services	0,033	0,033	0,032	0,032	0,031	0,031
Public Administration	0,098	0,097	0,097	0,099	0,102	0,106
Education	0.036	0.034	0.032	0.030	0.030	0.031

Health	0.048	0.051	0.055	0.060	0.065	0.070
Accommodation and Leisure Services	0.014	0.014	0.014	0.015	0.015	0.015
Other Services	0.064	0.064	0.064	0.064	0.065	0.066

5.3 Sectoral and Occupational Wages

In the model, labour markets are perfectly competitive and labour supplies are exogenous. As population ages, the relative scarcity of workers translates into changes in relative wages. Table 11 reports the impact of the demographic shock on average sectoral wage rates. The numbers reported in the table can be interpreted as per unit of (effective) labour cost paid by the representative sectoral firm in the economy.

As expected, wage rates increase in all sectors with respect to the initial steady state. However, each sector of the economy has a specific labour demand structure by occupation and level of qualification. Therefore, the wage difference across sectors reflects the sectors' specific structure of labour demands. Over the first 20 years, the wage impact does not differ much from sector to sector. By 2020, the sectoral wage increase ranges from 7.6% in *construction* to 8.7% in the *primary* sector (just above health with 8.4%). Over the longer run, the differential in sectoral wage increase differs somewhat more, but nevertheless remains relatively modest. By 2040, the sectoral wage increase ranges from 10.4% in *construction* to 12.8% in the *health* sector. This suggests that at the sectoral level, supply factors significantly dominate demand factors. Moreover, the relatively small sectoral difference in wages can also be explained by the fact that although there is no occupational labour mobility (workers cannot move from one occupation to another), within each occupation there is perfect labour mobility across industries. One needs to go at a more disaggregated level (occupations and level of qualification) to observe more substantial differences on wages.

Table 11: Sectoral Wage Rates, (Percent Change Relative to Initial Steady State)

Sectors\Years	2010	2020	2030	2040	2050
Primary	4,7	8,7	11,8	12,3	10
Manufacturing and Utilities	4,3	7,9	10,6	10,8	8,5
Construction	4,1	7,6	10,1	10,4	8,3
Transportation	4,3	7,9	10,7	11,1	9,1
Communication	4,3	8,1	11,2	11,9	10,2
Wholesaling and Retailing	4,3	8,1	11,1	11,8	9,9
Finance, Insurance and Real Estate	4,4	8,3	11,5	12,3	10,7
Professional Services to Firms	4,3	8,1	11,3	12,1	10,6
Computer and other Firm Services	4,3	8,1	11,2	12	10,3
Public Administration	4,4	8,2	11,4	12,3	10,7
Education	4,4	8,2	11,4	12,3	10,8
Health	4,4	8,4	11,8	12,8	11,4
Accommodation and Leisure Services	4,3	8,2	11,3	12	10,3
Other Services	4,3	8,2	11,3	12,1	10,4

Labour is also distinguished in the model by ten different occupations and five levels of qualification including managers (see again Table 2). Table 13 below reports the percent change in real wage with respect to the initial steady state by occupation and level of qualification. Not surprisingly, real wage pressures due to ageing are positive across all occupations over the next fifty years. This again reflects the fact that the supply shock, which takes the form of a relative decline in labour, dominates the inter-sectoral and inter-occupational effects. However, the latter effects are large enough to generate some disparity among occupations. For instance, the most rapid wage increase are in health occupations, where the demand for labour in the health sector is the most intensive. Real wages in health occupations increase by about 17% on average by 2040-2050, which is almost twice as much as the other occupational groups. The least rapid wage increases are in occupations specific to processing, manufacturing and utilities, as well as trades, transport and equipment operators. This is explained by slower output growth in manufacturing and construction industries.

Table 13: Wage Indices by Type, Profession and Qualification

Professions	Skill level	2010	2020	2030	2040	2050
Management Occupations		4.3	7.9	10.8	11.3	9.4
Business, Finance and Administration	A	4.4	8.2	11.3	12.0	10.2
	B	4.4	8.3	11.5	12.5	11.0
	C	4.5	8.4	11.7	12.7	11.1
Natural and Applied Sciences	A	4.2	7.9	10.9	11.6	9.9
	B	4.2	7.9	10.9	11.7	10.1
Health Occupations	A	5.2	10.3	15.0	17.6	17.4
	B	5.2	10.2	14.8	17.1	16.5
	C	5.2	10.3	14.9	17.3	16.9
Social Sciences, Education, Government & Religion	A	4.2	8.0	11.5	12.9	12
	B	4.4	8.4	12.0	13.4	12.4
Art, Culture, Recreation and Sports	A	4.4	8.4	11.8	12.8	11.4
	B	4.3	8.1	11.2	12.1	10.6
Sales and Services	B	4.5	8.6	12.0	13.2	11.8
	C	4.3	8.1	11.2	11.9	10.2
	D	4.3	8.1	11.0	11.6	9.8
Trades, Transport and Equipment Operators	B	4.0	7.2	9.5	9.4	7.1
	C	4.3	7.9	10.6	10.9	8.7
	D	4.0	7.2	9.6	10.0	8.2
Occupations in Primary Industries	B	4.8	9.0	12.2	12.5	9.9
	C	5.0	9.4	12.7	13.1	10.4
	D	4.3	8.1	11.3	12.3	11.0
Processing, manufacturing and Utilities	B	4.3	7.9	10.4	10.1	7.2
	C	4.2	7.9	10.3	10.1	7.1
	D	4.2	7.8	10.3	10.0	7.1

8. Conclusion

Over the next several decades, the Canadian population is expected to age at an exceptional pace, which could lead to profound structural changes on the product market, on labour markets and on financial markets. This paper's key objective is to analyze the dynamic effects of population ageing arising from the combination of two important structural changes that will affect the Canadian economy and the labour market. The first is a relative decline in labour supply. The second is the change in household consumption preferences as the population ages. The analysis is done using a dynamic sectoral and occupational CGE model with overlapping generations.

The results suggest that although the labour supply shock largely dominates the final demand shock, changes due to population ageing will also have significant inter-sectoral and occupational effects. The source of these effects is a complex combination of factors that include differences in household consumption baskets of goods over the lifecycle, government fiscal policy choices, the technology structures (value added coefficient shares and intermediate demand), the labour demand structure associated with each sector of the economy and retirement age heterogeneity across occupations.

More specifically, at the sectoral level, the results suggest that the demand for health services will be such that the production of health may grow well above all other sectors, leading to increased real wage pressures in health occupations. Moreover, other industries may also benefit to a certain extent from the composition change in final demand such as finance, insurance and real estate as well as communication to some extent. The composition change in consumption may also lead to a significant decline in the demand for construction, manufacting, education and wholesaling and retailing services. This in turn would reduce wage pressures in processing and manufacturing occupations and in trades.

Finally, in term of future direction for research, work is currently underway to introduce endogenous labour and human capital investment decisions to the regional OLG model (this is a separate version of the model and more aggregated than the sectoral version of the model used in this paper). Once this step is completed, we can consider the possibility of introducing endogenous labour supply to this model as well. But before considering these more complex additions to the model, some small changes at the margin would be worth considering. These include: 1) moving down from 10-year age groups to five-year age groups; 2) Introduce multi-factor productivity with differences across industries based on observed trends, which implies that the sectoral CGE model would generate a steady state equilibrium with economic growth; 3) Make a distinction between traditional and ICT capital as the model already includes the industrial sectors that produce ICT intermediate goods. These additions, would make the model more flexible to capture the effects of structural changes, like demographics, technology changes, growing and declining industries, innovation and R&D investment. The model could also be used to undertake long-term economic projections at the sectoral and occupational levels.

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Appendix 1. Occupation Types

TYPE 1						
Profession 1				Profession 4		Profession 10
Qual. 2	Qual. 3	Qual. 4	Qual. 5	Qual. 2	Qual. 3	Qual. 1

TYPE 2								
Profession 2		Profession 3			Profession 5		Profession 6	
Qual. 2	Qual. 3	Qual. 2	Qual. 3	Qual. 4	Qual. 2	Qual. 3	Qual. 3	Qual. 4	Qual. 5

TYPE 3								
Profession 7			Profession 8			Profession 9		
Qual. 3	Qual. 4	Qual. 5	Qual. 3	Qual. 4	Qual. 5	Qual. 3	Qual. 4	Qual. 5

Appendix 2. Labour demands by sector.

			PRI	MAN	CST	TRA	COM	CGD	FAI	SEP	ICS	ADM	EDP	SAN	HRD	AUT
Type1	PROF1	QUAL2	7.8	38.4	7.1	4.8	5.7	21.9	101	89.6	64.3	35.9	3.9	10.6	8.7	11.5
Type1	PROF1	QUAL3	27.2	84.6	38.7	30.1	20.9	94.1	149.9	75.2	50.9	97.7	59.5	99.3	15.7	36.8
Type1	PROF1	QUAL4	22.4	221.4	26.2	56.7	104.1	220.6	202.5	49.6	84	148.5	46.7	105.4	24.3	42.4
Type1	PROF4	QUAL2	2.2	9.3	0.4	3	1.9	4.3	6.7	60.5	22.3	57.2	545.1	87.2	5.8	36.5
Type1	PROF4	QUAL3	0.4	0.7	0.1	1.7	0.2	0.2	0.8	22	7.1	10	30.7	79.3	5.7	12.2
Type1	PROF10	QUAL1	15.3	191.5	105.9	38.4	31.4	423.9	113.9	31.7	53.9	73.5	64.5	73	166.8	48
Type2	PROF2	QUAL2	19.3	113.1	7.5	9.1	18.7	27	30.6	91.9	174.4	55.9	16.2	14.6	1.8	4.6
Type2	PROF2	QUAL3	19	104.7	20.2	28.2	13.2	38.7	5.9	54.8	26.3	49.1	9.3	6.5	3.4	4.4
Type2	PROF3	QUAL2	2.5	2.1	0.3	0.1	0.1	16.3	2.1	1.1	3.9	10.9	2.6	344.9	0.3	3.8
Type2	PROF3	QUAL3	4.5	5.1	0.1	0.7	0	5.1	0.1	0.1	2.5	3.3	0.6	157.8	0.7	4.7
Type2	PROF3	QUAL4	0	0.6	0.2	0	0	17.4	0	0.4	3.3	2.6	0.7	175.5	0.1	3.5
Type2	PROF5	QUAL2	1.4	19.5	0	1.5	14.6	2.4	4.6	7.7	13.1	12.7	28.8	7.3	44.8	32.6
Type2	PROF5	QUAL3	2.5	22.4	1.2	0.1	13.2	16.5	3.3	27	19	16.1	20.6	7.5	58.8	17.4
Type2	PROF6	QUAL3	5	37.5	8.2	6.3	10.1	223.4	124.8	2.2	12.3	82.9	7.4	25.7	217.5	119.8
Type2	PROF6	QUAL4	9	70.3	3.7	32.8	5.4	582.3	5.7	14.3	13.8	33.4	73.2	160.3	273.6	197.7
Type2	PROF6	QUAL5	7.2	39.9	24.8	14.3	3.1	444.9	34	9.9	66.7	23.1	52.8	108.8	381.2	153.8
Type3	PROF7	QUAL3	32.9	323.9	428.3	86.1	29.8	219.3	5	3.8	8.3	21.1	12.8	8.2	6.9	43.4
Type3	PROF7	QUAL4	26.2	105.8	73	321.2	30.8	151.7	2.6	3.7	13.1	15.5	8.5	4.7	18.2	18.3
Type3	PROF7	QUAL5	1.3	8	62	8.4	0.2	7.3	0.4	1.3	1.8	13.3	0.1	0.4	0.7	1.8
Type3	PROF8	QUAL3	307.1	3.5	9.6	1.2	0	1.7	0.5	1.5	0.1	1.6	0.3	0.2	1.6	20.2
Type3	PROF8	QUAL4	130.2	4.3	1	0.6	0	1.7	0.2	0.7	0.3	1.3	0.8	0.4	2.8	1.7
Type3	PROF8	QUAL5	26.4	2.4	8.3	0.8	0	2	1.6	0.6	0.7	9.2	2.5	0.9	8.4	18.5
Type3	PROF9	QUAL3	3.7	142.5	1.5	0.7	0	4.6	0.2	0	0.8	0.6	0	0.1	0.3	1.8
Type3	PROF9	QUAL4	9.7	776.4	12.1	4.1	0.4	33.9	0.1	1.3	6.6	1.3	0.4	2	0.7	19
Type3	PROF9	QUAL5	1.7	174.7	0.8	0.4	0.2	4.6	0	0.5	10.5	0	0	2.1	0.5	1.2