Inter-temporal and Inter-Industry Effects of Population Ageing: A General Equilibrium Assessment for Canada

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Abstract. The objective of this paper is to examine the inter-industry and labour market occupational effects of future demographic changes, using a dynamic general equilibrium overlapping-generations model. The model is calibrated along a balanced-growth path, taking into account labour-augmenting (Harrod-neutral) technical progress. It also accounts for heterogeneity at the household level, using 25 occupation-specific earnings profiles. In addition to the impact of slower labour force growth, the model captures the shift in sectoral composition of final demand. The latter is due to different consumption preferences of older individuals. Moreover, a wage curve is introduced to explore the impact of population ageing on the unemployment rate. The simulation results indicate that the growth in real GDP per capita could decline by nearly one percentage point between 2006 and 2050. Besides, the production of services, in percent of total GDP, is projected to increase in the long-run, although the analysis shows more modest changes in production shares than in previous studies. The results also suggest that the equilibrium unemployment rate is likely to decline by more than 2 percentage points in the long run. The impact also varies quite significantly at the occupational level.

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1. Introduction

As demographic projections clearly indicate, Canada and most economically advanced countries are expected to experience a significant decline in population growth as well as an ageing of their workforce. Since labour represents nearly two-thirds of the income share, the anticipated slowing in labour force growth raises important labour market and economic growth challenges.

The objective of this study is to examine the inter-industry and labour market effects of future demographic changes in Canada, using a dynamic general equilibrium model. In addition to the labour supply shock, our analysis takes into account the shift in sectoral composition of final demand. The latter is due to different consumption preferences of older individuals. For example, older households consume more health and travelling services, while younger households consume more education services. A change in the demand structure due to an older population may impact the sectoral composition of production and consequently affect the labour market.

The model used in this research extends the multi-sectoral overlapping-generations (OLG) model of Fougère, Mercenier and Mérette (2007) in four ways. These extensions include: the calibration of the model along a balanced-growth path, taking into account labour-augmenting (Harrod-neutral) technical progress; an increased heterogeneity at the household level with the introduction of 25 occupation-specific earnings profiles according to the National Occupational Matrix (NOC); a wage curve to account for changes in the unemployment rate at the occupational level; and a higher number of generations with various consumption preferences over the life cycle.

Given the underlying structure of the model, the combined supply and demand effects are expected to mitigate the negative impact in some sectors. The intuition behind these impacts is as follows. At the aggregate level, population ageing implies slower labour force growth, which in turn raises labour market pressures, reduces the equilibrium unemployment rate and increases wage pressures. Physical capital becomes relatively more abundant than labour and its relative rental rate declines. According to life-cycle assumption, older households tend to consume more and save less. This pushes the demand for consumption up and its price and lowers savings and investment. At the sectoral level, changes in the composition of final demand and combined changes in wages and in the rate of return to capital will affect the value-added price and the producer price which will in return determine the reallocation of factors across sectors as well as the substitution in consumption. The sector's relative intensity of factor inputs is also an important determining factor. The more labour-intensive an industry is, the more its sector will be negatively affected by rising wage pressures. Alternatively, more capital-intensive industries will benefit from declining relative rental rate of capital. Lastly, the occupations used intensively in the more expanding industries will benefit the most in terms of relative real wages.

The remainder of this paper is divided as follows. Section 2 provides a brief overview of the recent literature which focused on the sectoral and growth implications of population ageing. Section 3 provides a technical description of the model and discusses the calibration procedure. Section 4 describes the implementation of the demographic shock in the context of slowing population growth. Section 5 presents the main simulation results. Section 6 discusses sensitivity analysis. Finally, Section 7 concludes.

2. Literature Review

In this section, we review studies that have examined the impact of population ageing on changes in the composition of demand and the underlying effects on industrial sectors.

Fougère *et al.* (2007), analyze the dynamic and transitional impact of population ageing in Canada at the sectoral and occupational level using a computable overlapping generations model. In their analysis the authors account for both changes in labour supply and in the composition of demand due to a higher proportion of older consumers. The authors find that the negative labour supply shock due to ageing will prevail over the effect of changes in the composition of demand. At the sectoral level, they indicate that the share in total GDP of *Health*, *Finance, Insurance and Real Estate* activities would increase, while the share of *Education*, *Construction* and *Manufacturing* sectors would decrease.

Börsch-Supan (2003) analyses the effects of population ageing on the labour market in Germany. The author claims that the decline in the workforce will be partly offset by an increase in capital intensity and labour productivity through more education and training. He suggests that the shift in the age structure will modify the composition of demands for goods which will have important effects on employment across sectors of the economy. Assuming that the distribution pattern by age remains unchanged in the future, he finds that employment would likely increase in *Health*, *Personal Outfit*, *Energy* and *Housing* sectors, while employment would decrease in the *Food, Beverage and Tobacco*, *Clothing*, *Education*, *Travel and Communication sectors*.

Dewhurst (2006) provides a similar type of analysis for Scotland using an input-output model. The author finds that a shift in the age-structure due to ageing would stimulate final demand for some goods and services such as *Utilities*, *Social work services*, *Health* and *Insurance services* and likely reduce the demand for *Hotels, catering and pubs*, *Letting of dwellings* and *Education.*

More recently, Volz (2008) analyses the sectoral effects of population ageing in Germany. The author uses a static computable general equilibrium (CGE) model which takes into account the same two driving forces: increased labour market pressures due to ageing and consumption demand changes. The findings of this study are similar to the results presented in Fougère *et al.* (2007), with *Health* and *Education* being the two most affected sectors.

On the other hand, Kronenberg and Moeller-Uehlken (2008) examine the impact of demographic changes on infrastructure demand in two regions of Germany using a regional input-output model. They find that changes in the composition of final demand due to ageing may have significant and regionally different impacts on infrastructure demand. The authors suggest that production and expenditure in the sectors of *Energy, Transportation, Package holidays and Education* would increase a lot in the region of

Hamburg, but not necessarily in other parts of Germany. Finally, they underline the importance conducting regional studies.

Finally, Fenton, Heaver and Spencer (2006) used an accounting economic model of Canada, which is integrated to a demographic model, to examine the medium and long-run effects of alternative demographic scenarios on economic growth. In their “base case scenario”, they find that between 2001 and 2021, average annual real GDP and real GDP per capita growth rates would reach 2.7 percent and 1.9 percent, respectively. However, over the 2021-2051 period, growth in real GDP and real GDP per capita would fall to 1.2 percent and 1.0 percent, respectively.

3. Overlapping Generations Model

The analysis uses a life-cycle OLG model of a small open economy which represents an extension of Fougère et al. (2007). There is only one fully endogenous region in the model – Canada – and a reduced form residual rest-of-the-world is introduced to represent international trade. Industrial sectors are indexed by s or ss ($s = 1,...,S$). Labour is distinguished by ten occupational categories denoted $iprof = 1,...,Iprof$. For each occupational category there are five levels of qualifications indexed $iqual = 1,...,Iqual$. At each period in time t there are G ($g = 1,...,G$) generations that coexist, with $gj = 1,...,GJ$ working generations and $gm = GJ + 1,...,G$ retired generations.

Households

The dynamics of the population are represented by 15 finitely-lived Canadian households structured in an Allais-Samuelson overlapping-generations setting. At any period of time we make the assumption that a new generation enters the workforce at the age of 17, retires at the age of 65 and lives until the age of 76. Each period of the model corresponds to 4 years; hence, there are 12 working generations and 3 retired generations. Individuals of less than 17 years of age are assumed to be fully dependent on their parents to whom they constitute no extra burden nor provide any felicity. The household preferences are represented by an isoelastic time-separable utility function which takes the following form:

$$U_t = \frac{1}{1-\theta}\sum_{g=1}^{15}\left(\frac{1}{1+\rho}\right)^g \left(TC_{g,t+g-1}^{1-\theta} + \beta_g^{\ \theta} RBeq_{g,t+g-1}^{1-\theta}\right) \quad , \quad \theta > 0, \beta_{g\neq 15} = 0, \beta_{g=15} > 0 \qquad (1)$$

where $TC_{g,t}$ is total consumption of an individual 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). 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 accumulation of assets by the representative agent is a function of savings and evolves according to:

$$\begin{aligned} Lend_{g+1,t+1} - Lend_{g,t} = {} & (1-\tau_t^k)\, R\mathrm{int}_t\, Lend_{g,t} \\ & + (1-\tau_t^w - cr_t)\, LInc_{gj,t} + (1-\tau_t^w)\, Pens_{g,t} + Inh_{g,t} - Beq_{g,t} \\ & - (1+\tau_t^c)\, Pc_{g,t}\, TC_{g,t} \end{aligned} \qquad (2)$$

where $Lend_{g,t}$ denotes the financial assets accumulated by generation g at time t. $LInc_{g,t}$, $Pens_{g,t}$, $Inh_{g,t}$, $Beq_{g,t}$, τ_t^w, τ_t^k, τ_t^c represent, respectively, labour income, public pension, inheritances, nominal bequests ($Beq_{g,t} = Pc_{g,t}\, Rbeq_{g,t}$), the effective tax rates on labour income, capital income and consumption. $R\mathrm{int}_t$ is the interest rate, and cr_t is the contribution rate to the public pension system, which is modelled as a pay-as-you-go.

Labour income depend on the individual's age-specific earnings profiles (EP_g) which are defined as cubic functions of age g:

$$EP_{itype,iprof,iqual,g} = \gamma_{itype,iprof,iqual,g} + \lambda_{itype,iprof,iqual,g}\cdot g - \psi_{itype,iprof,iqual,g}\cdot g^2 + \varphi_{itype,iprof,iqual,g}\cdot g^3 \qquad (3)$$

where the parameters γ, λ, ψ and φ are positive and specific to each occupation. Labour income by working age group gj at period t is defined as:

$$LInc_{gj,t} = \sum_{\substack{itype\\iprof\\iqual}} w^{qual}_{itype,iprof,iqual,t} \left(1 - u_{itype,iprof,iqual,t}\right) L^{sup}_{itype,iprof,iqual,gj} EP_{gj} AAR_{itype,iprof,iqual,gj,t} \tag{4}$$

where $L^{sup}_{itype,iprof,iqual,gj}$ is the amount of labour services supplied by each age group in each occupation and $u_{itype,iprof,iqual,t}$ the occupation-specific unemployment rate, $w^{qual}_{itype,iprof,iqual,t}$ represents the wage rate and $AAR_{itype,iprof,iqual,gj,t}$ is the average retirement rate which is also occupation and time-specific.

Retirees' pension benefits are proportional to their lifetime labour earnings. The fraction is determined by the pension replacement rate $PensR$, which is the same for all workers. Pension benefits are thus equal to:

$$Pens_{gm,t} = PensR \frac{1}{12} \sum_{gj} LInc_{gj,t-gm+gj} \tag{5}$$

Maximizing households' utility function subject to a lifetime version of the budget constraint represented by equation (2), yields the following first-order conditions for consumption and bequests:

$$TC_{g+1,t+g} = \left(\frac{\left(1 + Rint_{t+g}\left(1 - \tau^{k}_{t+g}\right)\right)}{1+\rho} \cdot \frac{\left(1+\tau^{c}_{t+g-1}\right) P^{Con}_{g,t+g-1}}{\left(1+\tau^{c}_{t+g}\right) P^{Con}_{g,t+g}} \right)^{\left(1/\theta\right)} TC_{g,t+g-1} \tag{6}$$

$$RBeq_{g,t} = \beta_g \; TC_{g,t} \tag{7}$$

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

$$Inh_{gj,t} \; Pop_{gj,t} = \frac{1}{12} \cdot P^{Con}_{gn,t} \; RBeq_{gn,t} \; Pop_{gn,t} \tag{8}$$

where $Pop_{g,t}$ denotes the number of people in age group *g* at period *t*.

Households allocate their aggregate consumption expenditures across the available final goods s; we assume CES preferences. First order conditions impose that:

$$\begin{cases} ConS_{s,g,t} = \alpha_{s,g}^{ConS} \left(\dfrac{P_{g,t}^{Con}}{P_{s,t}} \right)^{\sigma_g^{Con}} TC_{g,t} \\ P_{g,t}^{Con\;1-\sigma_g^{Con}} = \sum_s \alpha_{s,g}^{ConS} P_{s,t}^{\;1-\sigma_g^{Con}} \end{cases} \tag{9}$$

where $ConS_{s,g,t}$ denotes the household's consumption of good s bought at market price $P_{s,t}$; $P_{g,t}^{Con}$ is the household's aggregate consumption price index. 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 $K_{g,t}$ and in bonds $B_{g,t}$ issued by domestic firms and the national government. We assume both assets are perfect substitutes so that the composition of households' wealth is without consequence (except of course on impact after an unexpected shock).

Production

To produce good s in amount $Z_{s,t}$, firms use factors of production and intermediate goods ($XS_{ss,s,t}$) from sectors ss. Production factor inputs include capital services denoted $K_{s,t}^{dem}$ and different types of labour services, different 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, $P_{ss,t}$, the rental rate of capital, $Rent_t$ and wages by type, occupation and level of qualification, $w_{itype,iprof,iqual,t}^{Qual}$. The primary input factors (capital and labour) are mobile across sectors. In each sector, producers have to solve the following problem:

$$\underset{XS_{ss,s,t},K_{s,t}^{dem},L_{s,itype,iprof,iqual,t}^{qual}}{\text{Min}} \sum_{ss} P_{ss,t} XS_{ss,s,t} + Rent_t K_{s,t}^{dem} + \sum_{itype,iprof,iqual} w_{itype,iprof,iqual,t}^{qual} L_{s,itype,iprof,iqual,t}^{qual} \qquad (10)$$

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

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

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

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

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

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

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

Here, Cobb-Douglas technologies are denoted by $CD(.;\alpha)$ parameterized by expenditure shares α. Constant-elasticity-of-substitution production functions are denoted by $CES(.;\alpha,\sigma)$ with share parameters, α and substitution elasticity, σ. The production of output $Z_{s,t}$ is generated by combining intermediate inputs and value added in fixed expenditure shares, in amounts $X_{s,t}$ 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. Associated with each constraint of the firm's cost minimization problem are shadow prices, which are indicated in brackets.

Aggregate labour services is a CES mixture of three types of labour $L_{s,itype,t}^{Type}$, each of these being a different CES combination of occupations $L_{s,itype,iprof,t}^{Prof}$, which themselves result from a CES aggregation of different qualification levels $L_{s,itype,iprof,iqual,t}^{Qual}$. This multilevel CES technology (Figure 1) captures the heterogeneous nature of labour inputs.

The equations and the optimality conditions of the firm's problem are the following:

$$\begin{cases} Z_{s,t} = Sc_s^Z X_{s,t}^{1-\alpha_s^Q} Q_{s,t}^{\alpha_s^Q} \\ P_{s,t}^X X_{s,t} = (1-\alpha_s^Q) P_{s,t} Z_{s,t} \\ P_{s,t}^Q Q_{s,t} = \alpha_s^Q P_{s,t} Z_{s,t} \end{cases} \quad (11)$$

$$\begin{cases} XS_{ss,s,t} = \alpha_{ss,s}^{XS} \left(\dfrac{P_t^X}{P_{ss,t}^c} \right)^{\sigma_s^X} X_{s,t} \\ P_{s,t}^{X\,1-\sigma_s^X} = \sum_{ss} \alpha_{ss,s}^{XS} P_{ss,t}^{c\;1-\sigma_s^X} \end{cases} \quad (12)$$

$$\begin{cases} Q_{s,t} = Sc_s^Q K_{s,t}^{dem\,\alpha_s^K} L_{s,t}^{dem\,1-\alpha_s^K} \\ \mathrm{Re}\,nt_t\, K_{s,t}^{dem} = \alpha_s^K P_{s,t}^Q Q_{s,t} \\ wage_{s,t} L_{s,t}^{dem} = (1-\alpha_s^K) P_{s,t}^Q Q_{s,t} \end{cases} \quad (13)$$

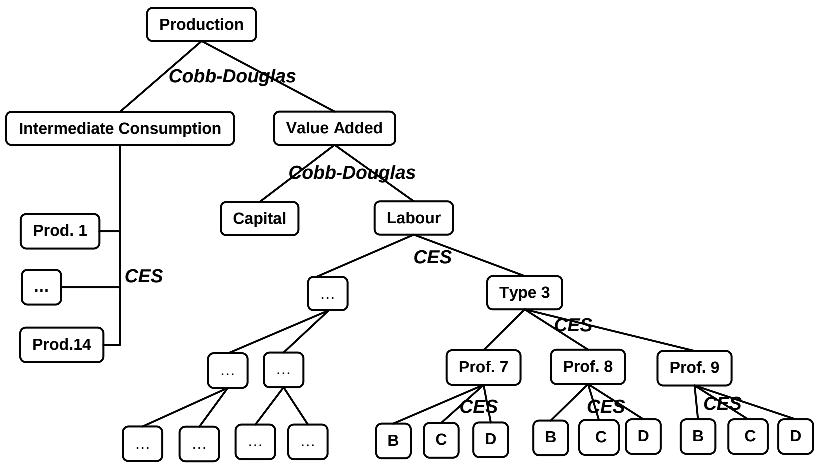
$$\begin{cases} L_{s,itype,t}^{Type} = \alpha_{s,itype}^{Ltype} \left(\dfrac{wage_{s,t}}{w_{s,itype,t}^{Type}} \right)^{\sigma_s^{Ldem}} L_{s,t}^{dem} \\ wage_{s,t}^{\;1-\sigma_s^{Ldem}} = \sum_{itype} \alpha_{s,itype}^{Ltype} w_{s,itype,t}^{Type\;\;1-\sigma_s^{Ldem}} \end{cases} \quad (14)$$

$$\begin{cases} L_{s,itype,iprof,t}^{\Pr of} = \alpha_{s,itype,iprof}^{Lprof} \left(\dfrac{w_{s,itype,t}^{Type}}{w_{s,itype,iprof,t}^{\Pr of}} \right)^{\sigma_{s,itype}^{Ltype}} L_{s,itype,t}^{Type} \\ w_{s,itype,t}^{Type\;\;1-\sigma_{s,itype}^{Ltype}} = \sum_{iprof} \alpha_{s,itype,iprof}^{Lprof} w_{s,itype,iprof,t}^{\Pr of\;\;1-\sigma_{s,itype}^{Ltype}} \end{cases} \quad (15)$$

$$\begin{cases} L_{s,itype,iprof,iqual,t}^{Qual} = \alpha_{s,itype,iprof,iqual}^{Lqual} \left(\dfrac{w_{s,itype,iprof,t}^{\Pr of}}{w_{itype,iprof,iqual,t}^{Qual}} \right)^{\sigma_{s,iprof}^{Lprof}} L_{s,itype,iprof,t}^{\Pr of} \\ w_{s,itype,iprof,t}^{\Pr of\;\;1-\sigma_{s,iqual}^{Lqual}} = \sum_{iqual} \alpha_{s,itype,iprof,iqual}^{Lqual} w_{itype,iprof,iqual,t}^{Qual\;\;1-\sigma_{s,iprof}^{Lprof}} \end{cases} \quad (16)$$

These first-order-conditions provide the optimal demand system for inputs by firms from each sector at each time, conditional on intermediate goods and factor prices, and on output levels.

Figure 1. Nesting in Sectoral Production



Notes: CES: constant elasticity of substitution; B, C, D: qualification levels in the NOC matrix.

Following Blanchflower and Oswald (1994), we assume the presence of equilibrium unemployment on the labour market using a "wage curve" which depicts a negative relation between the real wage and the unemployment rate:

$$w^{Qual}_{itype,iprof,iqual,t} = A_{itype,iprof,iqual} \cdot \left(u_{itype,iprof,iqual,t}\right)^{\varepsilon_{itype,iprof,iqual}} \tag{17}$$

$A_{itype,iprof,iqual}$ and $\varepsilon_{itype,iprof,iqual}$ are occupation-specific and represent, respectively, a scale parameter and the (negative) elasticity of the real wage rate with respect to the unemployment rate. The idea behind this empirical relation is to consider that local unemployment rate in a given region or industry is one of the determinants of the wage rate. Wages on labour markets with lower unemployment rate are higher than wages on labour markets with higher unemployment rates. In our model, we regard as "local" the labour market for a given profession. This in line with Card (1995), who suggested that the efficiency wage theory proposed by Shapiro and Stiglitz (1984) may be seen as a leading contender for explaining the wage curve, where the wage rate for a given occupation is related to the occupation-specific unemployment rate.

Investment

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:

$$\begin{cases} InvS_{s,t} = \alpha_s^{InvS} \left(\dfrac{P_t^{Inv}}{P_{s,t}} \right)^{\sigma^{Inv}} Inv_t \\ P_t^{Inv\ 1-\sigma^{Inv}} = \sum_s \alpha_s^{InvS} P_{s,t}^{\ 1-\sigma^{Inv}} \end{cases} \tag{18}$$

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

$$Kstock_{t+1} = Inv_t + (1 - DepR\ )Kstock_t \tag{19}$$

The one period expected rate of return on a unit of physical capital bought at time $t-1$, denoted $RRet_t$, is thus defined as:

$$RRet_t = \frac{Rent_t + (1 - DepR\ )P_t^{Inv}}{P_{t-1}^{Inv}} \tag{20}$$

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

The Public Sector

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

$$\begin{cases} GovS_{s,t} = \alpha_s^{GovS} \left[\dfrac{P_t^{Gov}}{P_{s,t}} \right]^{\sigma^{Gov}} Gov_t \\ P_t^{Gov 1-\sigma^{Gov}} = \sum_s \alpha_s^{GovS} P_{s,t}^{\ 1-\sigma^{Gov}} \end{cases} \tag{21}$$

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:

$$
\begin{aligned}
& P_t^{Gov} Bond_{t+1} - P_{t-1}^{Gov} Bond_t \\
& = P_t^{Gov} Gov_t + \left\{ Rint_{t-1} \left(\frac{P_t^{Gov}}{P_{t-1}^{Gov}} \right) - 1 \right\} P_{t-1}^{Gov} Bond_t \\
& - \sum_g Pop_{g,t} \left\{ \begin{aligned} & \tau_t^w \left(LInc_{g,t} + Pens_{g,t} \right) + \tau_t^c P_t^{Con} Con_g \\ & + \tau_t^k \left(\frac{Rint_{t-1} P_t^{Gov}}{P_{t-1}^{Gov}} - 1 \right) P_{t-1}^{Gov} B_{g,t} + \tau_t^k \left(RRet_{t-1} - 1 \right) P_{t-1}^{Inv} K_{g,t} \end{aligned} \right\}
\end{aligned} \tag{22}
$$

Pension System

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

$$\sum_{gm} Pop_{gm,t} Pen_{gm,t} = cr_t \sum_{gj} Pop_{gj,t} LInc_{gj,t} \tag{23}$$

External Sector

We make the traditional *Armington* assumption that Canadian and foreign goods are imperfect substitutes in demand. Aggregate domestic demand for good s

$$QQ_{s,t} = \sum_{ss} XS_{s,ss,t} + \sum_g Pop_{t,g} ConS_{s,g,t} + InvS_{s,t} + GovS_{s,t} \tag{24}$$

is a composite of domestically produced and imported goods using a CES function:

$$
\begin{cases}
Dom_{s,t} = \alpha_s^{Dom} \left[\dfrac{P_{s,t}^c}{P_{s,t}} \right]^{\sigma_s^c} QQ_{s,t} \\[2ex]
Imp_{s,t} = \alpha_s^{Imp} \left[\dfrac{P_{s,t}^c}{P_{s,t}^{row}} \right]^{\sigma_s^c} QQ_{s,t} \\[2ex]
P_{s,t}^{c\ 1-\sigma_s^c} = \alpha_s^{Dom} P_{s,t}^{\ 1-\sigma_s^c} + \alpha_s^{Imp} P_{s,t}^{row 1-\sigma_s^c}
\end{cases} \tag{25}
$$

A reduced form rest-of-the-world closes the model with constant prices and income; its demand for Canadian goods is:

$$Exp_{s,t} = Exp_0 \left[\frac{P_{s,t}^{row}}{P_{s,t}} \right]^{\eta_s}, \quad \eta_s > 0. \tag{26}$$

Consistent with the reduced form description of the rest of the world, we assume that it neither borrows nor lends to the national economy, so that trade balances at all *t*:

$$\sum_s P_{s,t}^{row} Imp_{s,t} = \sum_s P_{s,t} Exp_{s,t} \tag{27}$$

Equilibrium Conditions

– Market clearing for goods:

$$Z_{s,t} = Dom_{s,t} + Exp_{s,t} \tag{28}$$

– Labour market

$$\left(1 - u_{itype,iprof,iqual,t}\right) \cdot \sum_{gj} Pop_{gj,t} L_{itype,iprof,iqual,gj}^{\sup} EP_{gj} = \sum_s L_{s,itype,iprof,iqual,t}^{qual} \tag{29}$$

– Capital market

$$Kstock_t = \sum_s K_{s,t}^{dem} \tag{30}$$

– Integrated asset markets:

$$\frac{Rint_t P_t^{Gov}}{P_{t-1}^{Gov}} = RRet_t \tag{31}$$

This completes the models description. It is easy to check that asset markets clear at each *t* by Walras' law:

$$\sum_g Pop_{g,t} Lend_{g+1,t+1} = P_t^{Gov} Bond_{t+1} + P_t^{Inv} Kstock_{t+1} \tag{32}$$

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

4. Model Calibration

Data

The calibration exercise consists to choose behavioural parameters and stock levels so that the model reproduces the data set on flows at a chosen base year. Production activities by sectors have been computed using Statistics Canada's Input-output accounts aggregated to 14 sectors. Table 1 presents the sectoral aggregation which is based on the input-output tables for the year 1999.

Table 1: Industrial sector aggregates

	Related Sectors of the Input-Output Tables
1. Primary	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	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	29 to 31, and 37: residential construction; non-residential construction; repair construction; gross imputed rent.
4. Transport and Storage	32 and 44: transportation and storage; transportation margins.
5. Communication	33: communications services.
6. Wholesaling and Retailing	35 and 36: wholesaling margins; retailing margins.
7. Finance, Insurance and Real Estate Services	38: other finance, insurance and real estate services.
8.Professional Services to Firms and Advertising	60% of 39: business and computer services.
9. Computer and other Services to Firms	40% of 39: business and computer services.
10.Public Administration	34, 48 and 51: other utilities; government sector services; sales of other government services.
11. Education	40: education services.
12. Health	41: health and social services.
13. Accommodation and Leisure Services	42 and 46: accommodation services and meals; travel and entertainment, advertising and promotion.
14. Other Services	43, 47, and 49: other services; non-profit institutions serving households; non-competing imports.

Table 2 presents the distribution of sectoral GDP and factor's shares as calibrated in the CGE model. Among sectors, *Construction*, and most service industries like *Public Administration*, *Health*, *Education*, *Wholesaling & Retails* are very labour-intensive. Their share of labour in value added is at least 70 percent and their share of value added in production represents about 60 percent or more. *Accommodation & Leisure* is also a very labour-intensive industry, although its value added represents only 16.5 percent of production. On the other hand, *Finance, Insurance and Real Estate* and *Primary* industries are the more capital-intensive sectors in the economy.

Table 2: Distribution of Sectoral GDP and Factor's Share

	Value added share	Share of value added in production	Share in value added of	
			Labour	Capital
Primary	3.3	34.4	34.4	65.3
Man. & utilities	20.8	32.0	53.2	46.6
Construction	14.8	66.8	77.3	22.6
Transp. & stor.	2.2	24.4	65.0	34.8
Communication	1.8	42.5	48.6	51.2
Wholesaling & ret.	9.2	59.0	74.0	25.9
Fin., ins., & RS serv.	10.8	55.7	29.6	70.1
Serv. to firms	4.8	75.7	70.2	29.6
Comput. & serv.	3.2	77.4	70.2	29.6
Public. adm.	11.0	69.4	85.6	14.4
Education	3.4	63.4	84.1	15.9
Health	6.6	64.8	70.3	29.6
Accom. & leis.	1.5	16.5	75.0	24.9
Other serv.	6.7	73.4	79.4	20.6

Source: Input-Output Tables, Statistics Canada.

Regarding the specification of labour markets, the categories are defined from the National Occupational Classification Matrix, 2001. Table 3 summarizes the 10 occupational groups and 5 qualification levels of the matrix. The sectoral distribution of employment by occupations and level of qualification are based on the Labour Force Survey. We define three types of sectoral labour demand aggregates: see Appendix 1. For instance, the Type 1 labour aggregate groups Occupations 1, 4, and 10, with Occupation 1 defined as an aggregation of labour Qualification levels 2, 3, and 4. $L^{sup}_{itype,iprof,iqual,gj}$ is an exogenous variable calibrated in the initial steady state equilibrium to ensure that total labour supply -- after taking into account individual's productivity (or earnings) profile, retirement age, unemployment rate and population by age groups -- equals the corresponding occupational labour demand coming from all sectors of the economy.

Table 3: Occupations and Qualification Levels

Occupations	Qualification Levels
1. Business, finance and administration occupations	1. Management occupations
2. Natural and applied sciences and related occupations	2. Occupations that usually require university education
3. Health occupations	3. Occupations that usually require college education or apprenticeship training
4. Occupations in social science, education, government service and religion	4. Occupations that usually require secondary school and/or occupation specific training
5. Occupations in arts, culture, recreation and sport	5. On-the-job training is usually provided for these occupations
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	

Parameterization

The values for the behavioural parameters are reported in Table 4. The estimates for the inter-temporal elasticity of substitution used in applied general equilibrium literature, lie between 0.1 and 1.3 (see Auerbach and Kotlikoff, 1987 and Kenc and Perraudin, 1997). We choose a value a value of 1.0 for the base run scenario. The labour demand substitution elasticities are based on Ciccone and Peri (2005) who report an estimate of the substitution elasticity between high-skilled and low-skilled workers equal to 1.5. In our model, however, we assume a smaller value for the substitution between types of occupations ($\sigma_s^{Ldem} = 0.5$). Within each type of occupation, substitution is somewhat easier ($\sigma_{s,itype}^{Ltype} = 1.5$) but with a smaller value for occupations of type 2 ($\sigma_{s,itype}^{Ltype} = 1.1$) as they are more heterogeneous and knowledge specific. We set $\sigma_{s,itype,iprof}^{Prof}$ to the value of 1.5 so that it is easier for firms to substitute between qualifications within, than across occupations.

Inter-sectoral elasticities of substitution for investment and public consumption are assumed equal to 2.5. Elasticities of substitution for private consumption as well as between the domestic and imported good are fixed to 1.5, the elasticities of substitution between intermediate goods are set equal to 2.0 for all sectors, and the export demand elasticities are set to 5.0 in all sectors.

Table 4. Behavioural and public policy parameters

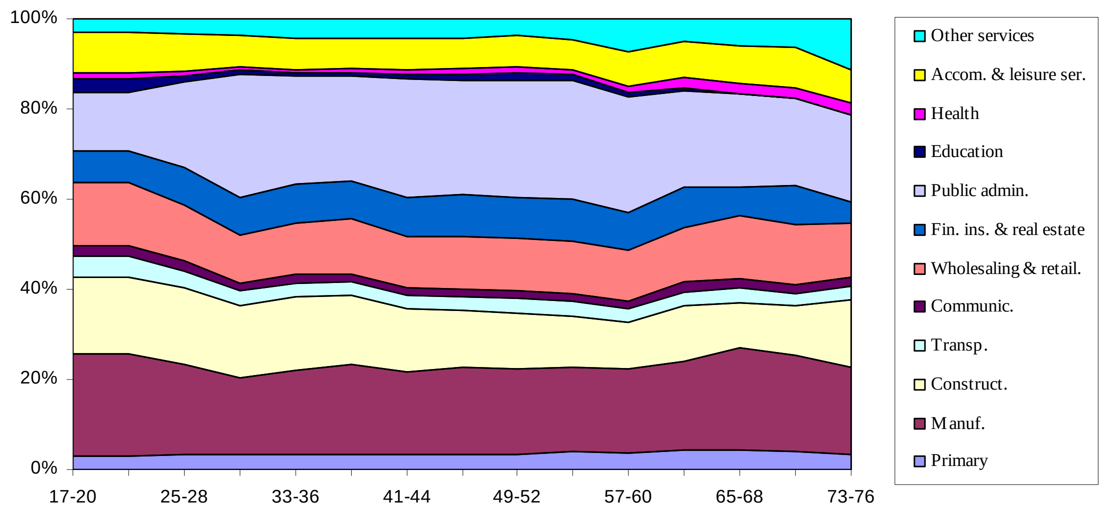
Parameter	**Notation**	**Value**
Inter-temporal elasticity of substitution (logarithmic utility)	$1/\theta$	1.0
Intra-temporal elasticity of substitution	σ_s^{Con}	2.0
Investment substitution elasticity	σ_s^{Inv}	2.5
Government consumption substitution elasticity	σ_s^{Gov}	2.5
Bequest parameter	$BeqR$	0.4
Inheritance rate	$InhR$	1/12
Pension replacement rate	$PensR$	0.5
Elasticity of substitution between labour types	σ_s^{Ldem}	0.5
Elasticity of substitution between labour professions	$\sigma_{s,itype}^{Ltype} \begin{cases} itype=1 \\ itype=2 \\ itype=3 \end{cases}$	1.5 1.1 1.5
Elasticity of substitution between skill levels	$\sigma_{s,itype,iprof}^{Prof}$	1.5
Intermediate demand elasticity of substitution	σ_s^X	2.0
Depreciation rate of physical capital	$DepR$	0.066 (per year)
Elasticity of the export demand function	η_s	5.0
Government debt/GDP		0.761
Public health care/GDP		0.059
Public education/GDP		0.041
Wage tax rate	τ^w	0.325
Capital tax rate	τ^k	0.489
Consumption tax rate	τ^c	0.196

Table 4 also presents the main base year 2000 macroeconomic data used in the calibration. Using the share of education and health care with respect to GDP, government expenditures are divided in four components: health, education, construction and public administration. The values of the elasticity of the real wage rate with respect to the unemployment rate in the wage curve are based on the estimates reported in Decaluwé et al. 2005 (Table 4). Finally, as indicated in introduction, the CGE model is calibrated along a balanced-growth path, taking into account labour-augmenting (Harrod-neutral) technical progress. In the baseline simulation, the exogenous labour productivity growth rate is set equal to the 1996-2006 average of 1.9 percent per year.

Spending Shares by Age

Household consumption preferences are depicted in Figure 1. 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. The spending shares for the 75-84 age group are assumed identical to those of the 65-74 group, as both age groups are incorporated into one single class due to data limitations.

Figure 1. Private spending shares by sector and age groups



As *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 only impact of population ageing on these sectors will be through changes in firm's demand for intermediate goods.

As can be seen from the table, spending shares in most sectors are age-sensitive: household preferences change with age so that consumption baskets vary along the life cycle. For example, spending shares on *Health*, *Primary* goods, *Accommodation and Leisure Services*, as well as on *Other Services* increase with age. On the other hand, spending shares on *Construction* and on *Education* tend to fall later in life. Note, however, that the size of spending shares allocated to education and health is relatively small as it represents private spending only. Middle age households spend relatively more than younger and older households on *Finance, Insurance and Real Estate Services*, as well as on *Public Administration*. The spending share allocated to public administration accounts for direct taxes paid by households and reflects the higher tax burden on middle-age households. Finally, the spending shares for the remaining sectors, including *Manufacturing and Utilities*, *Transportation*, *Communication* and *Wholesaling and Retailing* do not change substantially with age.

Figure 2. Public Expenditure on Health and Education per Age Group (Dollar share per capita)

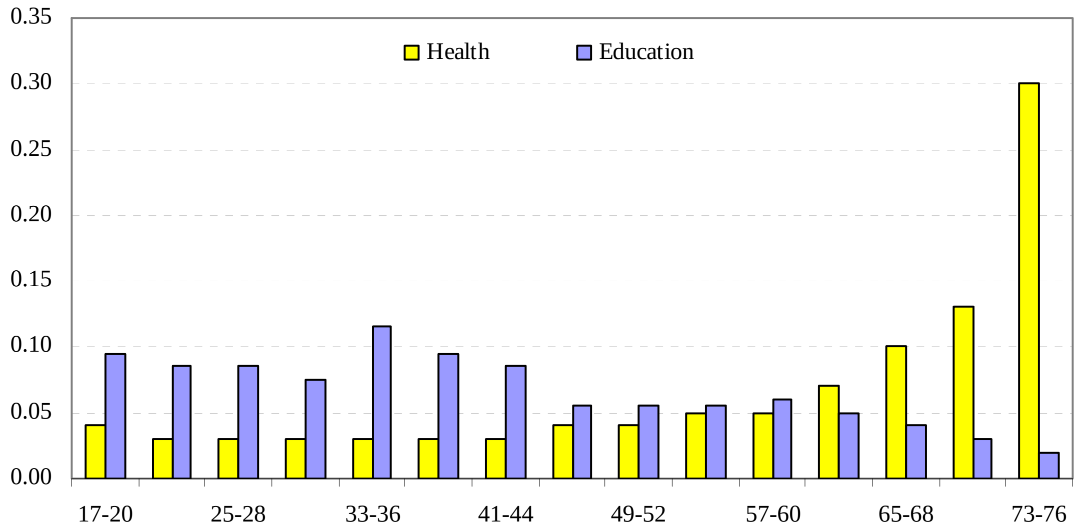
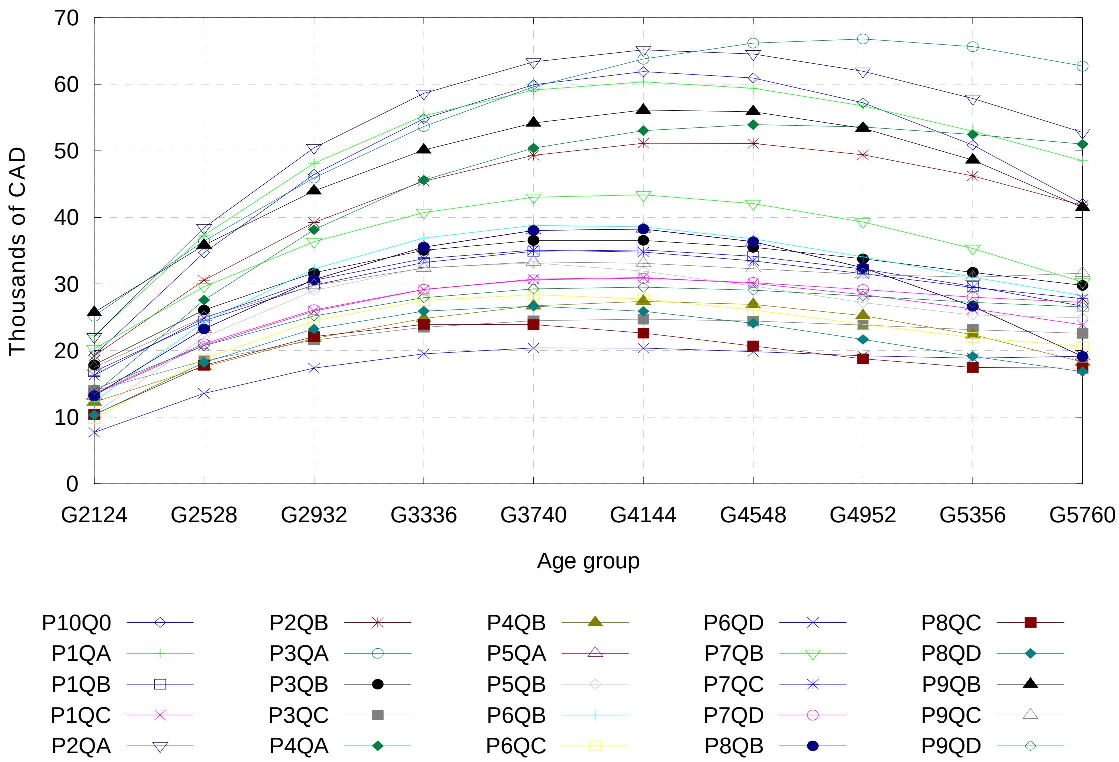


Figure 2 presents the dollar share of public health care and education spending allocated by age group. While education expenditures are higher at younger ages, health care spending is assumed to increase substantially from age 65-74 to 75-84. This reflects the fact that the bulk of health care demand occurs during the last three periods of life. In comparison, the age group 17-20 receives only 4 percent of each dollar spent per capita by the government on health care. Regarding education expenditures the amount spent reaches a maximum for age group 33-36, representing elementary and secondary education subsidies received by individuals as parents.

In the remaining steps of the calibration procedure we determine the life-cycle consumption profile, the time preference parameter and the equilibrium interest rate, 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 similarly, and is assumed to have the same structure for all age groups. Lastly, the calibration of the life-cycle earnings profiles in the initial steady state is based on information from the 2001 Census. Figure 3 presents the distribution of earnings by occupation and by age group.

Figure 3. Age-specific earnings profiles



Retirement Age and Unemployment by Occupation

Table 5 reports the average effective retirement age for the period 2000-2006, the unemployment rate for the year 2006, and the wage curve elasticity. The effective age of retirement is relatively higher for workers in occupations specific to primary industries. By contrast, workers in *Social Sciences, Education, Government and Religion* have the lowest effective age of retirement. Regarding the unemployment rate, the highest value is, again, for the occupations specific to primary industries, while the lowest rate is for health care related occupations.

Table 5. Retirement and unemployment rates and the wage curve elasticity, by occupation

Occupational Group	Skill level	Retirement age	Unemployment rate	Wage curve elasticity
Management Occupations		60.9	1.9	-0.07
Business, Finance and Administration	A	61.4	1.7	-0.06
	B	60.4	3.0	-0.06
	C	60.8	4.2	-0.06
Natural and Applied Sciences	A	62.9	1.7	-0.09
	B	60.2	3.7	-0.09
Health Occupations	A	61.2	0.2	-0.09
	B	59.4	1.2	-0.09
	C	62.3	1.8	-0.09
Social Sciences, Education, Government and Religion	A	58.5	2.6	-0.09
	B	61.8	2.8	-0.09
Art, Culture, Recreation and Sports	A	62.5	2.9	-0.09
	B	61.3	6.0	-0.09
Sales and Services	B	62.1	3.6	-0.07
	C	61.8	5.5	-0.07
	D	63.1	6.3	-0.07
Trades, Transport and Equipment Operators	B	61.7	5.2	-0.11
	C	63.0	5.5	-0.08
	D	62.2	9.9	-0.11
Occupations in Primary Industries	B	67.3	5.8	-0.09
	C	62.3	5.8	-0.07
	D	63.7	22.0	-0.07
Processing, manufacturing and Utilities	B	60.0	3.0	-0.07
	C	61.9	7.5	-0.07
	D	61.1	11.1	-0.07

Source: Labour Force Survey, National Occupation Classification Matrix, Decaluwé et al. (2005), and Lapointe et al. (2006).

5. Simulation of demographic change

In the absence of a demographic shock the model generates the data used in the calibration with a constant economic growth rate and a constant population. This scenario is ignored. Whereas, when the shock is introduced, the model generates a new transition path, called “baseline”. The analysis of the results is based on the computation of changes in growth rates of key economic variables along this new transition path. In what follows we describe the simulation of population ageing in Canada.

Figure 4 depicts the old-age dependency ratio as projected by Human Resources and Skills Development Canada (which takes into account lower birth rates, increased longevity and immigration) for the next four decades. The old age dependency ratio is the population aged 65+ relative to the working-age population. We see that this ratio is expected by demographers to rise from a current level of 20 percent to 40 percent over the next three decades and to remain stable after 2040.

Figure 4. Projected old-age dependency ratio (OADR) and population growth rate

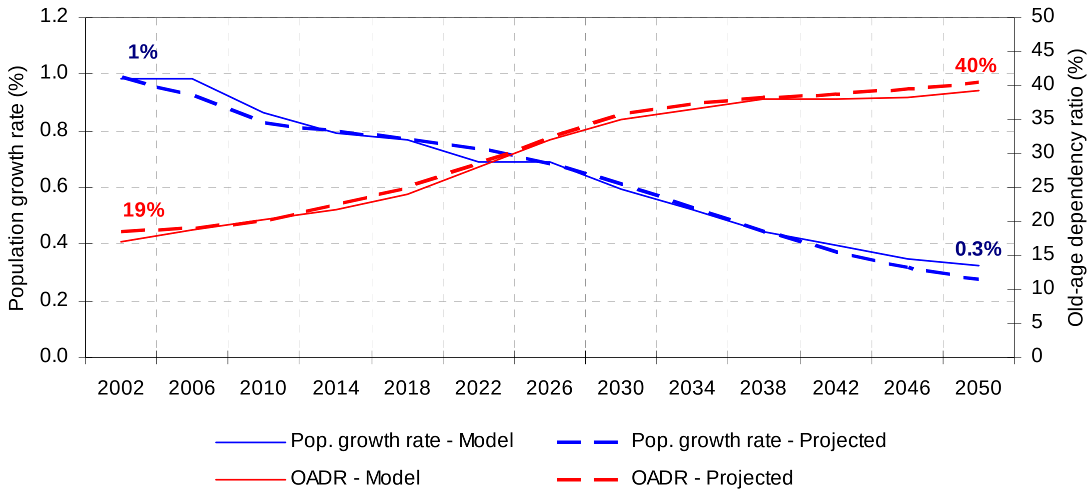


Figure 4 also shows the close approximations used for the simulations. Approximation to HRSDC`s projections are achieved by choosing as best as possible the growth rate of the number of individuals entering the first cohort every year (the fertility rate $\phi_{g,t}$). In addition, future population growth rate is determined by choosing the values of the parameter $\pi_{g,t}$ which may be considered as a survival rate. The simulation of population ageing and the slower population growth rate imply the introduction of the following equations:

$$Pop_{g=1,t+1} = \phi_{g,t} \cdot Pop_{g=1,t} \tag{33}$$

$$Pop_{g+1,t+1} = \pi_{g,t} \cdot Pop_{g,t} \tag{34}$$

In addition to the demographic shock, we assume for all simulations that the government maintains public education and health care expenditures fixed per head in each age group; this implies that there is a budget shift in favor of health care partly at the expense of education when population ages. Public consumption net of health and education expenditures is then allocated to construction and public administration services in the same proportions as in the base run.

5. Simulation Results

In this section, we examine the impact of population ageing at both the aggregate and sectoral levels. We first examine the macroeconomic impact on key economic indicators. This is followed by more detailed results at the sectoral and occupational levels. It is also worth noting that even if the model is characterized by an exogenous growth mechanism (given the assumption of a Harrod-neutral technical progress) the growth rate is endogenous during the transition to the long-run steady state due to the introduction of the demographic changes.

Macroeconomic Impact of Population Ageing

Figure 5 and 6 present the impact of population ageing on the growth in productive capacity measured in both real GDP and real GDP per capita. Figure 5 presents the result over the period 2006 to 2050, while Figure 6 compares historical with projected GDP growth averages.

In the Baseline scenario, the decline in labour force growth due to population ageing would lower the growth in real GDP and real GDP per capita by 1.5 and 0.9 percentage points, respectively, between 2006 and 2050. The decline in real GDP per capita growth rate is less pronounced because population growth rate is slowing too. Comparing historical and projected growth averages, the impact of population ageing over the period 2018-2030 would contribute to reduce growth in real GDP per capita to 2.5 percent, still above the 2.3 percent growth average reached during the 1962-2006 period. After 2030, average growth in real GDP per-capita falls further to 1.5 percent, similar to the 1974-1996 average, a period where the Canadian economy was hit by two world oil crisis and two severe recessions (1981-82, 1990-92).

Table 6 presents a summary of key macroeconomic indicators in annual average percent growth rates. First, over the next few decades, the demographic shock reduces growth in effective labour supply (labour supply adjusted by a relative productivity index represented by the earning profile), which eventually reaches zero by 2038 and turns slightly negative by 2050. On the other hand, growth in effective labour supply per capita is negative over the entire period, as the proportion of older people of lower participation increases relative to the total population. This suggests that the change in effective labour supply per capita would negatively affect the growth in real GDP per capita over the next decades.

Figure 5. Impact on growth in real GDP and real GDP per capita

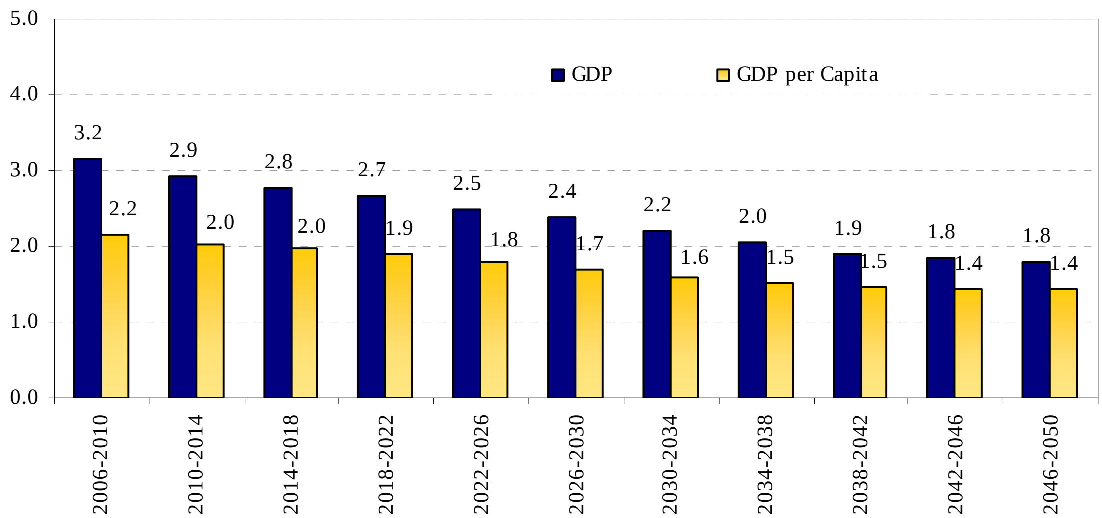
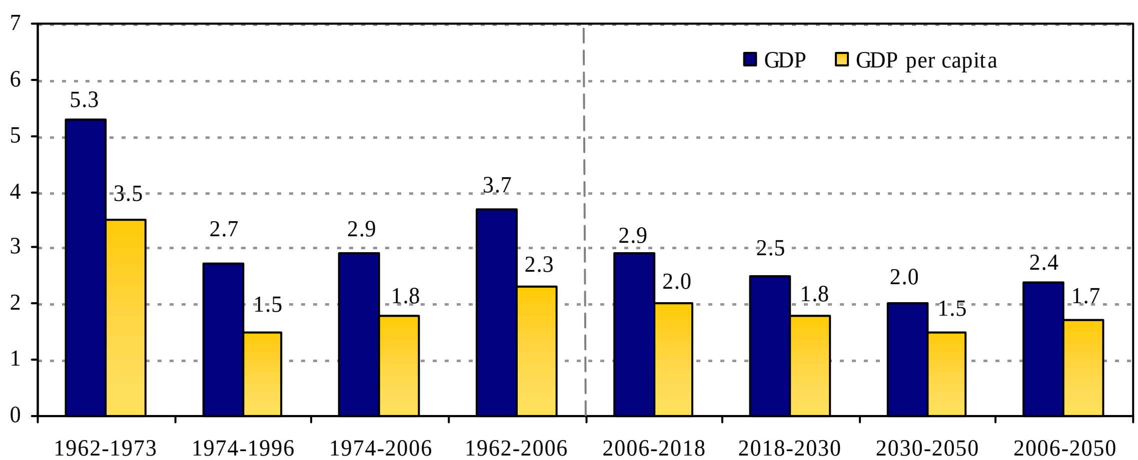


Figure 6. Historical and projected growth in real GDP and real GDP per capita



In contrast, physical capital stock remains a key contributor to economic growth. Annual changes in physical capital stock average more than 3 percent between 2006 and

2020 and stays above 2 percent until 2040. On a per capita basis, physical capital stock grows well above 2 percent until 2026 and declines to 1.3 percent by 2050. Consequently, as physical capital grows faster than effective labour supply, physical capital intensity grows on average by more than 2 percent over the next 40 years. This also may be explained by the rise in relative prices of productive factors (w/r). Increased labour market pressures due to slowing labour force growth reduces the unemployment rate which in turn stimulates real wage growth, while the faster growth in physical capital contributes to reduce its rental rate. Therefore, the combined rise in relative prices of productive factors encourages firms to substitute away from labour and towards physical capital as a factor of production.

Table 6. Summary of macroeconomic results (annual average percent growth rate)

	2010	2018	2026	2038	2050
Real GDP	3.1	2.8	2.5	2.0	1.8
Real GDP per capita	2.1	2.0	1.8	1.5	1.4
Physical capital Stock	3.6	3.2	2.9	2.3	1.6
Physical capital stock per capita	2.6	2.4	2.2	1.7	1.3
Effective labour supply	0.8	0.5	0.3	0.0	-0.1
Effective labour supply per capita	-0.2	-0.3	-0.4	-0.5	-0.4
Physical capital intensity	2.8	2.7	2.6	2.3	1.7
Consumption	3.3	2.8	2.5	2.1	1.9
Consumption to GDP ratio	0.1	0.0	0.1	0.1	0.1
Investment	2.8	2.8	2.3	1.4	1.2
Investment to GDP ratio	-0.4	0.0	-0.2	-0.6	-0.6
Population	1.0	0.8	0.7	0.5	0.4
Interest rate **	-0.3	-0.9	-1.4	-1.9	-1.7
Wage rate *	1.7	5.0	8.4	12.1	12.0
Unemployment rate**	-0.6	-1.6	-2.3	-2.8	-2.7

*Laspeyres index (detrended wage rates); ** Percentage points vs. 2006.

Despite the rise in physical capital intensity, the growth rate of investment spending to GDP ratio is negative due to the reduction in savings. Since the proportion of the older population increases, older households tend to consume more and save less. Therefore, in aggregate, the ratio of consumption to GDP increases, while savings and investment rates decline.

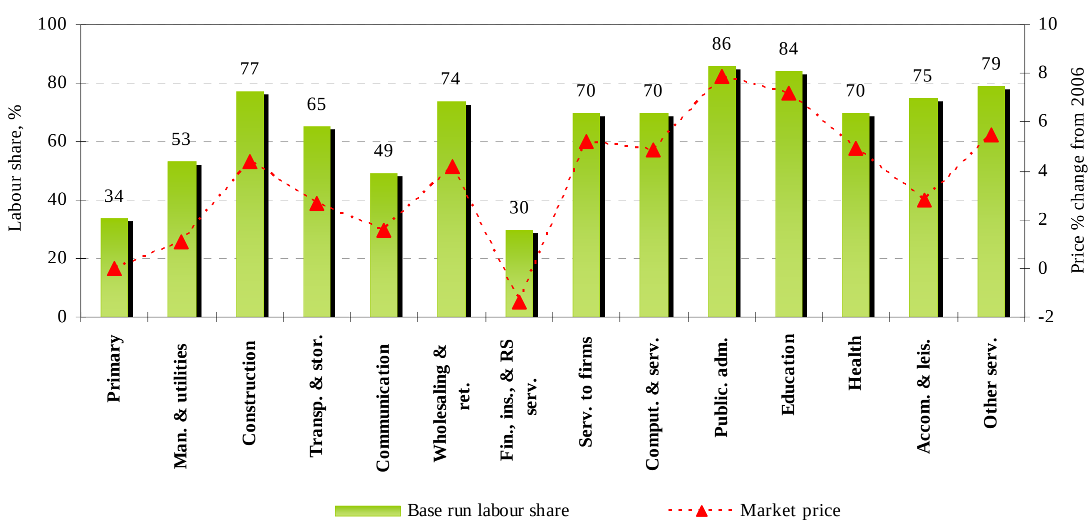
Due to the slower labour force growth, the national unemployment rate declines and real wage pressures increase. From the level achieved in 2006, the unemployment rate would fall by about 2.3 percentage points by 2026 and by about 2.8 percentage points thereafter. This suggests that an "equilibrium" unemployment rate of around 4-5 percent or even lower in Canada over the next two decades is a likely scenario with an ageing population.

Analysis at the Sectoral Level

To well interpret the impact at the sectoral level, it is very important to understand how projected demographic changes will affect both sectoral market prices and sectoral demand. Figure 7 presents the base run sectoral labour share in the model and the long run (2050) impact of population ageing on sectoral market prices relative to 2006. Figure 8 shows the long run impact on sectoral production (detrended) and sectoral market prices relative to 2006.

As it can be seen in Figure 7, the long-run impact of population ageing on sectoral market prices is positively related to sectoral labour shares. This implies that the more labour-intensive the industry, the more it will be hit by rising input costs due to increased labour market pressures. For example, *Public administration* and *Education* are the most labour-intensive industries and accordingly market prices increase the most in these sectors. Conversely, *Finance, Insurance & Real Estate* (*FIRE*) and the *Primary* sectors are very capital-intensive and face very moderate increase in market prices.

Figure 7: Base run sectoral labour share and long-run impact on market prices



On the other hand, Figure 8 shows clearly a negative relationship between changes in sectoral market prices and sectoral output in the long run. Rising production costs limit sectoral growth in more labour-intensive industries. However, the change in the composition of final demand, as older individuals tend to consume more services, compensates the labour-intensive services industries.

Figure 8: Long-run impact on sectoral production and market prices

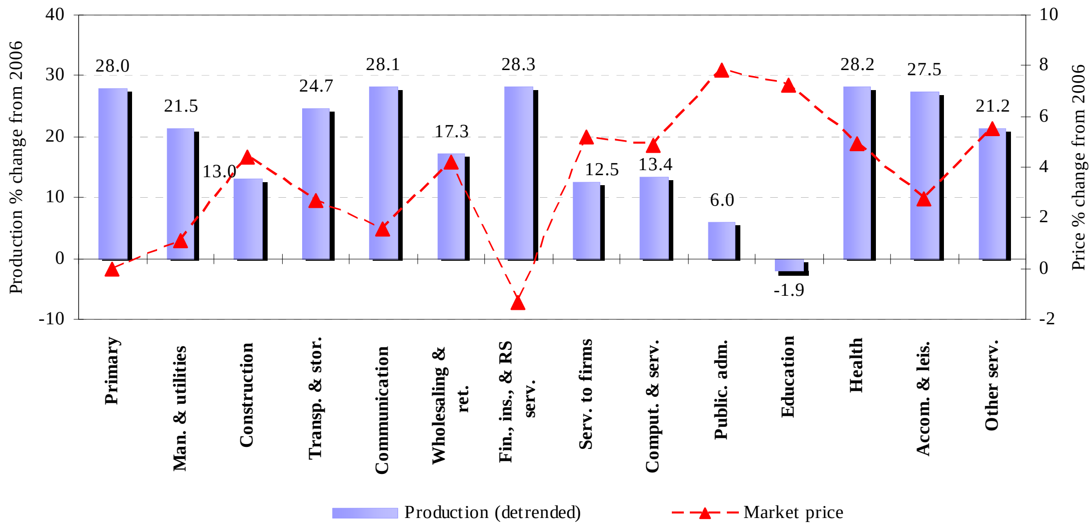


Table 7 presents the average growth impact of population ageing at the sectoral level. According to the results, *FIRE*, *Health*, *Communication*, *Primary* industries, *Accommodation and Leisure Services* and *Transport and Storage* are projected to grow faster, on average, than all sectors combined. In general, above-average growth can be partly explained by the rising demand for goods and services of older households. In addition, the most capital-intensive sectors are the least affected by rising wage costs and are projected to benefit from the reduction in the rental rate of capital.

Health is the most obvious sector benefiting from rising expenditures in health care services due to an older population. On the other hand, the *Health* sector is also very labour-intensive. Therefore, the effect of rising wage costs from health workers partly offsets the effect of rising demand in *Health* services on sectoral growth. In addition, *FIRE* and the *Primary* sector are the two most capital-intensive industries and benefit from the reduction in input costs.

On the other hand, *Education*, *Public administration* and *Construction* are expected to grow slower than the national average, in part because of the negative shift in the composition of private demand. *Education* is the most negatively affected sector, especially between 2006 and 2030 as the proportion of younger individuals is currently falling rapidly and will continue to decline over the next 20 years or so. Accordingly, the demand for education services is projected to grow slower than historically. The *Construction* sector is also negatively affected, since household expenditures on housing is lower among older households. Finally, as indicated earlier, these three sectors are all very labour-intensive. Therefore, they face increased input costs due to rising labour market pressures.

Table 7. Impact of population ageing on sectoral GDP growth (Annual average growth rate)

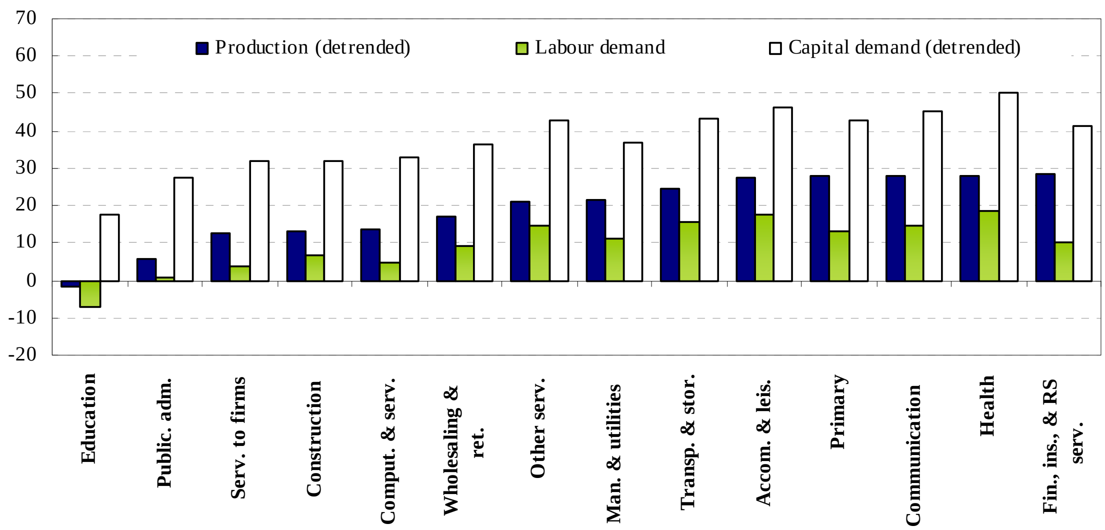
	2006-2018	**2018-2030**	**2030-2050**	**2006-2050**
Primary	3.1	2.7	2.0	2.5
Manufacturing and Public Utility	3.0	2.5	1.9	2.4
Construction	2.8	2.3	2.0	2.3
Transport and Storage	3.1	2.6	2.0	2.5
Communication	3.1	2.7	2.0	2.5
Wholesaling and Retailing	3.0	2.5	1.9	2.4
Finance, Insurance and Real Estate	3.1	2.6	2.0	2.4
Professional Services to Firms	2.9	2.4	1.9	2.3
Computer and other Services to Firms	2.9	2.4	1.9	2.3
Public Administration	2.5	2.3	2.0	2.2
Education	2.3	2.1	1.8	2.0
Health	3.0	2.8	2.2	2.6
Accommodation and Leisure Services	3.1	2.7	2.1	2.5
Other Services	3.0	2.6	2.0	2.5
All Sectors	2.9	2.5	2.0	2.4

Table 8 presents the impact of ageing on the growth of labour and capital demand by sector, while Figure 9 presents the long-run impact of ageing on production (detrended) and factor input reallocation relative to 2006. Growth in capital demand is projected to remain strong across all sectors, while the demand for labour would grow very slowly. On average, labour demand in *Education* is projected to grow negatively, on average over the next decades, while it is projected to stay flat in *Public Administration*. Regarding the remaining sectors, the demand for labour is expected to grow positively but slowly during the 2006-2030 period and remain flat thereafter.

Table 8: Impact of population ageing on labour and capital demand growth by sector
(Annual average percent growth rate)

	Labour Demand				Capital demand			
	2006-2018	2018-2030	2030-2050	2006-2050	2006-2018	2018-2030	2030-2050	2006-2050
Primary	0.7	0.3	0.0	0.3	3.5	3.0	2.1	2.7
Manufacturing and Public Utility	0.7	0.3	-0.1	0.2	3.4	2.9	2.0	2.6
Construction	0.5	0.1	0.0	0.1	3.2	2.7	2.1	2.5
Transport and Storage	0.7	0.4	0.0	0.3	3.5	3.0	2.1	2.7
Communication	0.8	0.4	0.0	0.3	3.5	3.1	2.1	2.8
Wholesaling and Retailing	0.6	0.2	-0.1	0.2	3.4	2.9	2.0	2.6
Finance, Insurance and Real Estate	0.7	0.2	-0.1	0.2	3.5	3.0	2.1	2.7
Professional Services to Firms	0.5	0.1	-0.2	0.1	3.3	2.8	2.0	2.6
Computer and other Services to Firms	0.6	0.1	-0.2	0.1	3.3	2.8	2.0	2.6
Public Administration	0.2	0.0	-0.1	0.0	3.0	2.7	2.1	2.5
Education	0.0	-0.2	-0.2	-0.2	2.7	2.4	1.9	2.3
Health	0.6	0.5	0.2	0.4	3.4	3.2	2.3	2.8
Accommodation and Leisure Services	0.8	0.4	0.0	0.4	3.6	3.0	2.2	2.8
Other Services	0.7	0.3	0.0	0.3	3.5	3.0	2.1	2.7

Figure 9: Long-run impact on factor reallocation (percent change from 2006)



Analysis at the Occupational Level

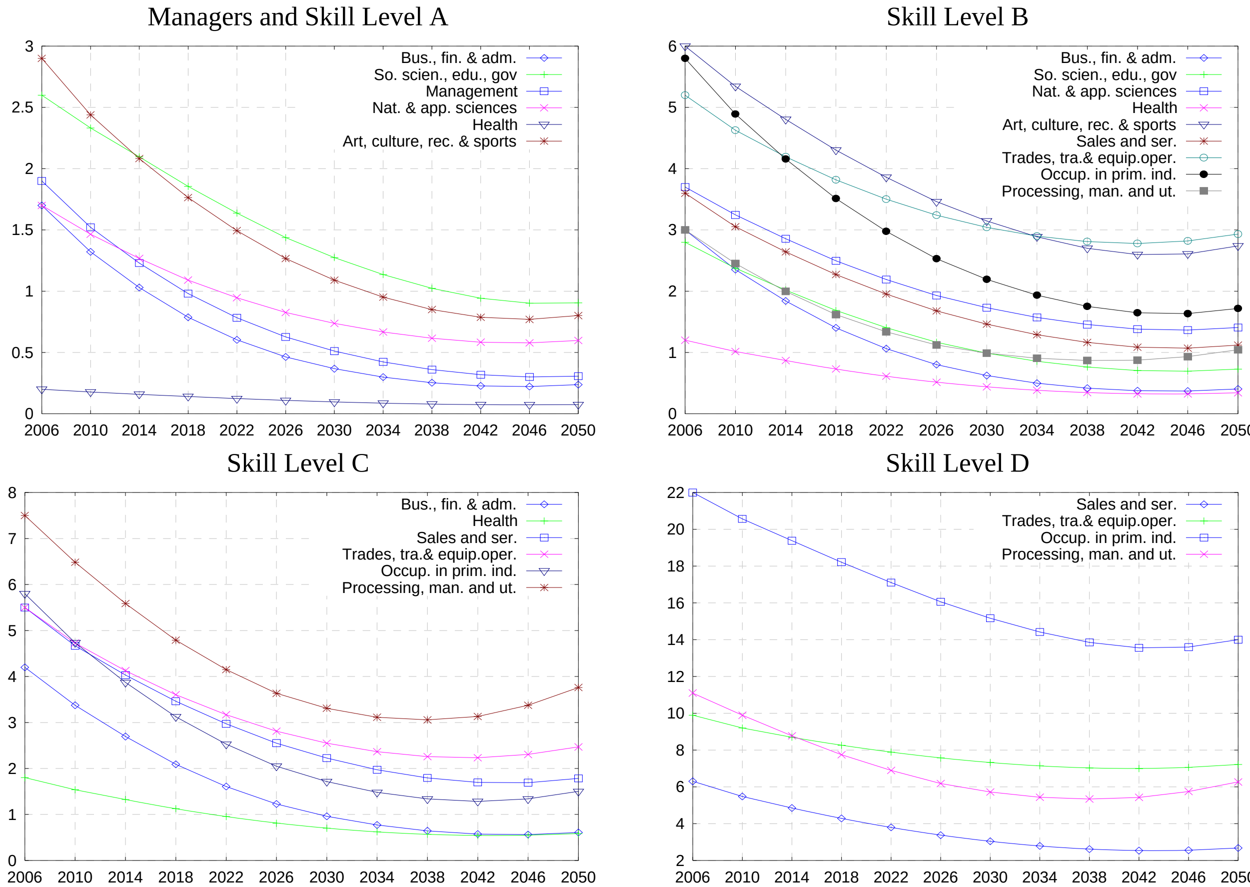
We now focus on the labour market impact at the occupational level. Table 9 and Figure 10 present the impact on the unemployment rate at the occupational level, and Table 10 the impact on the wage rate by occupation.

Changes in unemployment rates reported in Table 9 suggest that labour market effects would vary significantly across the different occupations and skill levels. These changes are determined by the decrease in labour supply as well as changes in sectoral labour demand. The decline in unemployment rates would ultimately represent an additional factor that contributes to the rising pressure on wages.

Table 9: Impact on the unemployment rate by occupation and skill level (percent change from 2006 levels in Table 5)

	Skill level	2010	2018	2026	2038	2050
Management occupations	-	-19.9	-48.4	-67.0	-81.1	-83.8
Business, finance and administration	A	-22.2	-53.7	-72.7	-85.1	-86.0
	B	-21.6	-53.3	-73.3	-86.0	-86.5
	C	-19.7	-50.2	-70.8	-84.6	-85.5
Natural and applied Sciences	A	-13.8	-35.8	-51.4	-63.8	-64.8
	B	-12.3	-32.5	-47.9	-60.6	-62.0
Health occupations	A	-11.0	-29.5	-46.0	-60.0	-62.5
	B	-15.4	-39.1	-57.2	-71.2	-71.4
	C	-14.6	-37.4	-55.1	-68.4	-67.7
Social sciences, education, government and religion	A	-10.3	-28.6	-44.7	-60.6	-65.2
	B	-15.1	-39.8	-58.3	-72.8	-73.9
Art, culture, recreation and sports	A	-15.9	-39.2	-56.3	-70.7	-72.4
	B	-10.9	-28.3	-42.3	-55.0	-54.4
Sales and services	B	-15.2	-36.9	-53.4	-67.7	-68.9
	C	-15.1	-37.1	-53.6	-67.4	-67.5
	D	-13.1	-31.9	-46.5	-58.4	-57.6
Trades, transport and equipment Operators	B	-11.0	-26.6	-37.7	-46.0	-43.6
	C	-14.1	-34.5	-48.9	-58.9	-55.1
	D	-7.1	-16.5	-23.5	-29.0	-27.1
Occupations in primary industries	B	-15.7	-39.4	-56.4	-69.8	-70.4
	C	-18.3	-46.1	-64.7	-76.9	-74.1
	D	-6.5	-17.2	-27.0	-37.0	-36.4
Processing, manufacturing and utilities	B	-18.3	-46.0	-62.6	-71.0	-65.2
	C	-13.5	-36.1	-51.6	-59.3	-49.9
	D	-10.9	-30.2	-44.3	-51.9	-43.5

Figure 10: Impact on the unemployment rate by occupation and skill level



Note: The vertical axis represents unemployment rates in percentage.

As previously stressed, the profession employed mainly in the more expanding industries will benefit the most in terms of real wage rate (Appendix 2). For example, workers in *Business and Finance* occupations would benefit from the expansion of the *Finance and Insurance* sector. This is also the case for *Health* occupations. Overall, occupations with the largest drop in unemployment rate would also experience higher increases in wages. In contrast, the likely negative impact on the labour-intensive *Construction* sector would lead to a relatively smaller decrease in unemployment and pressure on wages for *Trades and Equipment Operators* occupations.

Table 10: Impact on wages (detrended, percent change from 2006)

	Skill level	2010	2018	2026	2038	2050
Management occupations	-	2.1	6.1	10.3	15.7	16.9
Business, finance and administration	A	2.0	6.1	10.3	15.4	15.8
	B	1.9	6.0	10.4	15.8	16.0
	C	1.7	5.6	9.8	15.1	15.5
Natural and applied Sciences	A	1.8	5.4	8.9	12.7	13.0
	B	1.6	4.9	8.2	11.9	12.2
Health occupations	A	1.5	4.5	7.8	11.7	12.4
	B	1.9	5.9	10.1	15.0	15.1
	C	1.9	5.7	9.8	14.2	14.0
Social sciences, education, government and religion	A	1.5	4.4	7.7	11.9	13.2
	B	2.0	6.1	10.4	15.7	16.2
Art, culture, recreation and sports	A	2.1	6.0	10.0	15.0	15.6
	B	1.5	4.3	7.2	10.5	10.3
Sales and services	B	1.7	4.7	7.7	11.4	11.7
	C	1.6	4.6	7.7	11.3	11.3
	D	1.4	4.0	6.6	9.4	9.2
Trades, transport and equipment Operators	B	1.7	4.8	7.5	10.1	9.5
	C	1.7	4.8	7.6	10.5	9.7
	D	1.3	3.3	5.1	6.8	6.5
Occupations in primary industries	B	2.0	6.0	10.0	14.6	14.8
	C	1.9	5.8	9.7	14.0	13.1
	D	0.9	2.6	4.3	6.2	6.1
Processing, manufacturing and utilities	B	1.9	5.8	9.3	12.3	10.8
	C	1.5	4.5	7.4	9.6	8.0
	D	1.3	3.8	6.3	8.3	7.1

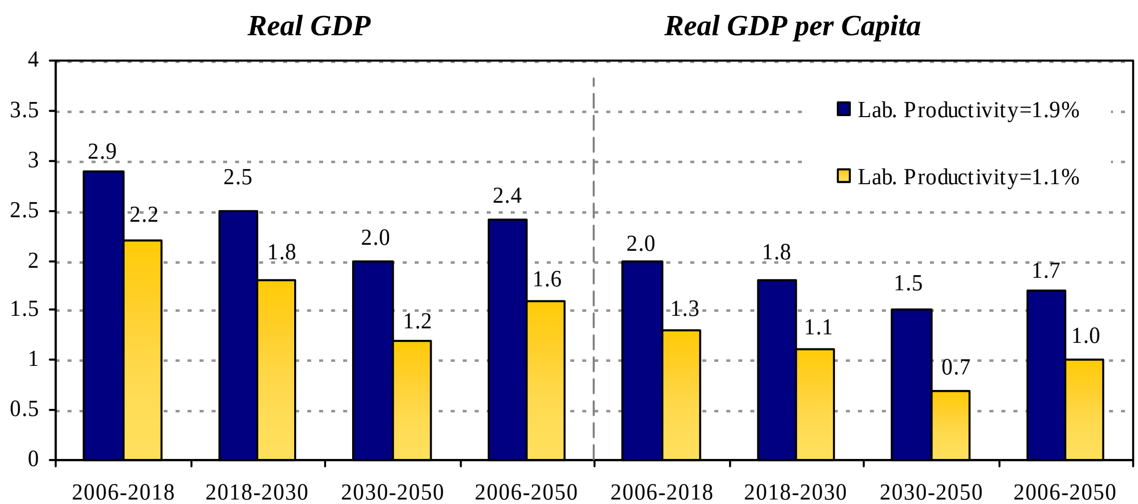
6. Sensitivity Analysis

In Section 3, we discuss the model calibration for our baseline simulation and provide a justification according to the literature for the choice of elasticities and parameter values. In this section, we provide 3 sets of sensitivity analysis to test the robustness of the results. First, we use a lower value for labour productivity growth. Second, we choose a higher value for the inter-temporal elasticity of substitution. Finally, we use higher elasticities of substitution between occupations.

Lower Labour Productivity Growth

In the baseline scenario, we use a value of 1.9 percent for labour productivity growth, corresponding to the 1996-2006 average. In this alternative scenario, we assume that future labour productivity growth will average 1.1 percent, which is equal to the 2000-2006 average. Figure 11 provides a comparison of the impact of a different labour productivity growth assumption on real GDP and real GDP per capita growth rates. Not surprisingly, average growth in real GDP is much lower under the current scenario. However, the long-run drop in real GDP and real GDP per capita remain similar to that under the baseline scenario, since the dominating effect on the economy is the negative labour supply shock.

Figure 11: Impact on growth in real GDP and real GDP per capita under alternative labour productivity assumptions



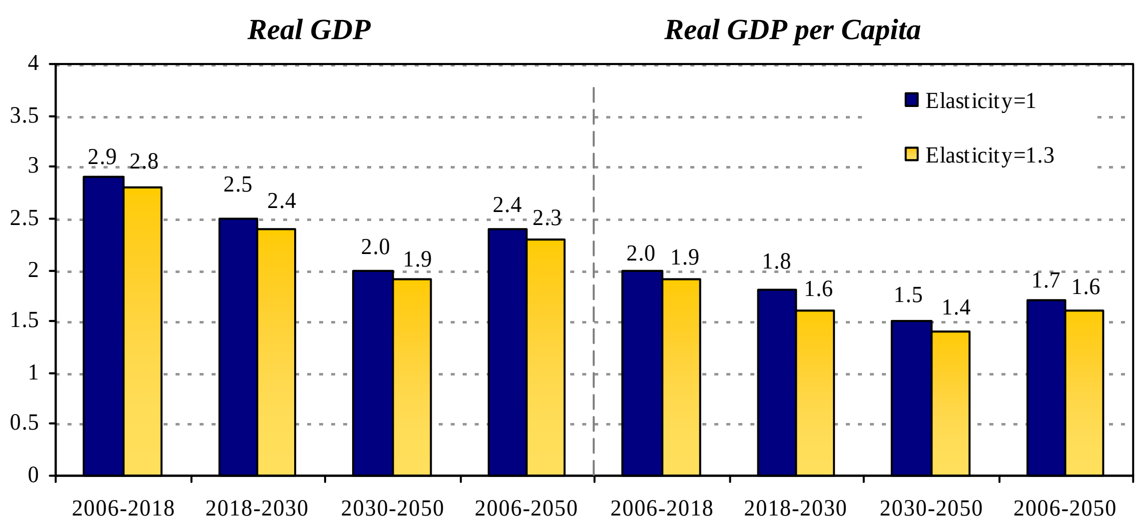
At the sectoral level, the assumption of lower labour productivity growth lowers average real GDP growth, but does not affect the overall decline in real GDP growth between 2006 and 2050. The sectoral ranking is also unchanged. Finally, the impact of population ageing on labour market pressures is somewhat larger with lower growth in labour productivity. Since labour productivity growth is slower, firms need to rely more on labour demand to produce output. Accordingly, the decline in unemployment rate is larger for some occupations and real wage pressures are higher.

Higher Value for the inter-temporal elasticity of Substitution

In the baseline scenario and based on the literature, we have used a value of the inter-temporal elasticity of substitution equal to 1. However, as indicated in Section 3, the highest value found in the literature is 1.3. Therefore, as a second sensitivity test, we have experimented with a value of 1.3.

According to the results in Figure 12, the simulated impact of population ageing on real GDP growth is almost the same as in the baseline. Average GDP or GDP per capita growth rates are about 0.1 percentage point lower with a higher inter-temporal elasticity of substitution. The difference is mainly explained by slower growth in investment and physical capital stock. A higher inter-temporal elasticity of substitution implies that economic agents have a greater preference for current consumption, which leads to a slower growth in savings, investment and capital stock.

Figure 12: Impact on growth in real GDP and real GDP per capita under alternative inter-temporal elasticity of substitution assumptions



Slower growth in physical capital also means slower growth in physical capital intensity, which mitigates the relative scarcity of labour -- after the implementation of the demographic shock-- with respect to physical capital. Consequently, the reduction in the unemployment rate as well as the increase in wages are more moderate than in the baseline scenario. At the aggregate level, the unemployment rate declines by about 2.1

percentage points in the long run, compared to 2.8 percentage points in the baseline scenario, leading to a lower pressure on wages. In the long run, the aggregate wage rate (Laspeyres index) rises by only 8 percent, compared to 12 percent in the baseline.

At the sectoral level, average GDP growth is about 0.1 percentage point lower across all sectors. Regarding the long-run impact on occupational wages, the changes vary between 3.1 and 11.4 percent, compared to 6.1 and 16.9 percent under the baseline scenario. However, the ranking is unchanged.

Higher Value for the elasticity of substitutions in labour CES nesting

As a quick reminder, in the baseline scenario, we assume that the elasticity of substitution between types of occupations $\sigma_s^{Ldem} = 0.5$. Within each type of occupation $\sigma_{s,itype}^{Ltype} = 1.5$, except for type 2 where $\sigma_{s,itype}^{Ltype} = 1.1$. Finally, we set $\sigma_{s,itype,iprof}^{Prof} = 1.5$, assuming that it is easier for firms to substitute between qualifications within than across occupations. In this alternative scenario, we use higher elasticities of substitution: $\sigma_s^{Ldem} = 0.8$, $\sigma_{s,itype}^{Ltype} = \{2, 1.5, 2\}$ and $\sigma_{s,itype,iprof}^{Prof} = 2$.

Under this alternative scenario, the macroeconomic impact of population ageing is similar to the baseline, as key economic indicators are practically unchanged. At the sectoral level, the growth impacts are also unchanged. Finally, there are some small differences on real wages at the occupational level, which are less than ±1.5 percentage points in the long run.

7. Conclusion

This paper examines the inter-industry and labour market effects of future demographic changes using a dynamic general equilibrium overlapping-generations model. The simulation results indicate that growth in real GDP per capita could decline by nearly one percentage point in the long run. As labour force growth is projected to slow very significantly, the unemployment rate would decrease by 2.7 percentage points in the long run, leading to increased pressure on wages (+12 percent on average).

At the sectoral level, production costs would increase more in labour-intensive sectors. Hence, production would expand more in sectors with lower labour share in value-added. This is the case of *Primary* industries, and *Finance, Insurance and Real Estate*. Moreover, the demand effect, which is represented by the change in consumption preferences of older workers as well as the shift in government consumption in favour of the health sector, would mitigate some of the long-run negative effects on labour-intensive service industries such as *Health, Accommodation and Leisure, Other Services* and *Transport and Storage* industries.

Real wage pressures would rise across all occupational groups. Wage pressures in *Management* occupations, *Business, Finance and Administration*, *Health, Social Science and Education* as well as occupations in *Primary* industries would be well above average. In contrast, wage pressures in *Processing, Manufacturing, Sales and Trades* could be well below average.

Finally, we conclude that there are <u>three</u> important structural implications of population ageing for the labour market: 1) the contribution of labour supply (quantity) to economic growth would decline leading to a more important role for physical capital and investment in knowledge in fostering labour productivity (quality); 2) the equilibrium unemployment rate would fall significantly and likely achieve an unprecedented low level; 3) significant distributional effects are expected, and will be caused by rising disparity in occupational unemployment and wage rates. This implies that the distributional impact of population ageing is a very important element to consider in future research.

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Appendix 1. Occupation Types

Labout Type 1

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

Labour 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

Labour 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 demand by sector

			PRI	MAN	CST	TRA	COM	WSR	FIN	SEF	ICS	ADM	EDU	HEA	ARD	OTH
Type 1	Prof 1	Qual 2	8	38	7	5	6	22	101	90	64	36	4	11	9	12
Type 1	Prof 1	Qual 3	27	85	39	30	21	94	150	75	51	98	60	99	16	37
Type 1	Prof 1	Qual 4	22	221	26	57	104	221	203	50	84	149	47	105	24	42
Type 1	Prof 4	Qual 2	2	9		3	2	4	7	61	22	57	545	87	6	37
Type 1	Prof 4	Qual 3	0	1		2			1	22	7	10	31	79	6	12
Type 1	Prof 10	Qual 1	15	192	106	38	31	424	114	32	54	74	65	73	167	48
Type 2	Prof 2	Qual 2	19	113	8	9	19	27	31	92	174	56	16	15	2	5
Type 2	Prof 2	Qual 3	19	105	20	28	13	39	6	55	26	49	9	7	3	4
Type 2	Prof 3	Qual 2	3	2				16	2	1	4	11	3	345		4
Type 2	Prof 3	Qual 3	5	5		1		5			3	3	1	158	1	5
Type 2	Prof 3	Qual 4		1				17			3	3	1	176		4
Type 2	Prof 5	Qual 2	1	20		2	15	2	5	8	13	13	29	7	45	33
Type 2	Prof 5	Qual 3	3	22	1		13	17	3	27	19	16	21	8	59	17
Type 2	Prof 6	Qual 3	5	38	8	6	10	223	125	2	12	83	7	26	218	120
Type 2	Prof 6	Qual 4	9	70	4	33	5	582	6	14	14	33	73	160	274	198
Type 2	Prof 6	Qual 5	7	40	25	14	3	445	34	10	67	23	53	109	381	154
Type 3	Prof 7	Qual 3	33	324	428	86	30	219	5	4	8	21	13	8	7	43
Type 3	Prof 7	Qual 4	26	106	73	321	31	152	3	4	13	16	9	5	18	18
Type 3	Prof 7	Qual 5	1	8	62	8		7		1	2	13			1	2
Type 3	Prof 8	Qual 3	307	4	10	1		2	1	2		2			2	20
Type 3	Prof 8	Qual 4	130	4	1	1		2		1		1	1		3	2
Type 3	Prof 8	Qual 5	26	2	8	1		2	2	1	1	9	3	1	8	19
Type 3	Prof 9	Qual 3	4	143	2	1		5			1	1				2
Type 3	Prof 9	Qual 4	10	776	12	4		34		1	7	1		2	1	19
Type 3	Prof 9	Qual 5	2	175	1			5		1	11			2	1	1

Source: Labour Force Survey, Statistics Canada.