Immigration and Economic Growth

by

Katerina Lisenkova
National Institute of Economic and Social Research

Marcel Mérette
University of Ottawa

Robert Wright (*)
University of Strathclyde

April 2013

Abstract: This paper provides empirical estimates of the impact of immigration on economic growth. A dynamic overlapping generations computable general equilibrium (OLG-CGE) model is used for this purpose. The basic structure of the model follows in the Auerbach and Kotlikoff tradition. However, the model takes into consideration directly age-specific mortality. This is analogous to "building in" a cohort-component population projection structure to the model, which allows more complex and more realistic demographic scenarios to be considered. The model is calibrated for Scotland. Scotland is an interesting case study since it is likely that both the population and the labour force will decrease in size considerably in the future. In addition, the population is expected to age rapidly over the coming decades. The analysis suggests that modest levels of net-migration, driven by higher levels of immigration, are associated with considerably higher levels of economic growth.

JEL Classification: J11

Keywords: CGE modelling, population ageing, Scotland

(*) Financial support from the Economic and Social Research Council under the grant: "*Developing an OLG-CGE Model for Scotland"*, through the Centre for Population Change, is gratefully acknowledged. Corresponding author: Robert E. Wright, Department of Economics, University of Strathclyde, 130 Rotterow, Glasgow, Scotland, UK, G4 0GE, tel: +44 (0)141-330-5138, email: r.e.wright@strath.ac.uk.

Immigration and Economic Growth

1. Introduction

Population ageing is the shift in the age distribution away from younger age groups (e.g., <20) to older age groups (e.g., 65+), which is caused mainly by long-run below replacement-level fertility. There are a variety of mechanisms by which population ageing can impact on economic growth and the macro-economy more generally (see Borsch-Supan 2003; Weil, 1997). The predominant view is that it will support lower economic growth because it "squeezes" the labour force (mainly people aged 20-64), leading to low (or negative) rates of labour force growth. It is clear that a high-skilled growing labour force is essentially for sustained economic growth. In addition, population ageing causes a shift away from investment to consumption since government expenditure tends to increase to meet the increased demand for pensions and other old age-related benefits. The populations of many high-income countries are ageing very rapidly, and there is some doubt that standard of living increases can be sustained.

It is recognised that managed immigration can be used to meet labour force needs. With immigration it is theoretically possible to increase the size of the labour force thereby counteracting some of the perceived negative consequences of population ageing on economic growth. In this paper examines the impact of immigration on economic growth is evaluated using an over-lapping generations computable general equilibrium (OLG-CGE) model of Scotland. The Scottish context is of particular interest since population decline and labour force decline are not unlikely in the future given past demographic trends. The remainder of this paper is organised as follows. Section 2 outlines the structure of the model. Section 3 discusses how the model is calibrated and gives the data sources. A series of simulations are carried out in Section 4 based on different assumed level of net-migration. A brief Conclusion follows in Section 5.

2. The Model

An OLG-CGE model is mathematical description of an economy using a system of simultaneous equations. As in other general equilibrium models, it is assumed that all the markets, sectors and industries are modelled together with corresponding inter-linkages (unlike "partial equilibrium" models). CGE models tend to be very complex and thus cannot be solved analytically. They are therefore calibrated to "real world" data and rely on solver algorithms that find numerical solutions satisfying all of the model's equations. CGE models are very flexible, and can be used to analyse the macro-economic effects of variety of economic shocks and policies (see Burfisher, 2011; Dixon and Jorgenson, 2012; Fossati and Wiegard, 2001; Hosoe, Gasawa and Hashimoto, 2010).

It is therefore not surprising to find that CGE models have been used to evaluate the impact of population ageing (see Bommier and Lee, 2003; Borsch-Supan, Ludwig and Winter, 2006; Fougère and Mérette, 1999; Fougère, Mercenier and Mérette, 2007; Fougère et al., 2004). The type of CGE model that is best suited to demographic research has an overlapping generations (OLG) structure, introduced by Auerbach and Kotlikoff (1987). An OLG-CGE model is based on an infinite time horizon and inter-temporal optimisation. The household sector consists of several generations living alongside each other at any point in time. In each period the oldest generation "dies", a new youngest generation is "born" and all the generations in-between become a period older. From a demographic point of view, an OLG-CGE model more explicitly allows the interaction of age effects. This is a clear advantage since age is usually a critical variable in the understanding of demographic behaviour

The model presented in this section is designed to analyse the long-term economic and labour market implications of population ageing in Scotland in a context of its tight fiscal relationship with the rest of the UK (RUK). Scotland is modelled as a small open economy. The RUK is not explicitly modelled. It is present in the model mainly to close the government budget constraint and the current account of Scotland. Below we outline the main features of the production, household and government sectors. We also describe the demographic structure of the model. Demographic change is considered as an exogenous shock. It is the difference in these shocks that drive the simulations results.

The model is in the Auerbach and Kotlikoff (1987) tradition and introduces age-specific mortality following Borsch-Supan et al. (2006). It incorporates variation in life expectancy with a perfect annuity market, through which unintentional bequests are implicitly distributed. The theoretical description of this approach was first presented in Yaari (1965). This modification allows precise replication of the population structure from the population projections and dramatically improves the accuracy of demographic shocks.

2.1 Demographic Structure

The population is divided into 21 generations or age groups (i.e., 0-4, 5-9, 10-14, 15-19, …, 100-104). Population projections represent an exogenous shock. In other words, demographic variables such as fertility, mortality (life expectancy) and net-migration are assumed to be exogenous. This is a simplifying assumption given that such variables are likely endogenous and affected by, for example, differences in economic growth. Every cohort is described by two indices.The first is “t”, which denotes time. The second is “g”, which denotes a specific generation or age group.

The size of the cohort, “*Pop*”, belonging to generation “$g+k$” in period “t” is given by two laws of motion:

(1)

$$Pop_{t,g+k} = \begin{cases} Pop_{t-1,g+k+5}\, fr_{t-1} & for\ k = 0 \\ Pop_{t-1,g+k-1}\,(sr_{t-1,g+k-1} + mr_{t-1,g+k-1}) & for\ k \in [1,20] \end{cases}$$

The first law of motion simply implies that the number of children born at time “t” (age group $g+k = g$, i.e. age group 0-4) is equal to the size of the first adult age group ($g+k+5=g+5$, i.e. age group 20-24) at time “t-1” multiplied by the “fertility rate”, “*fr*”, in that period. If every couple on average has two children, the fertility rate is approximately equal to 1 and the size of the youngest generation g at time t is approximately equal to the size of the first adult generation “$g+5$”, one year in the past.

The second law of motion gives the size of any age group “$g+k$” beyond the first generation, g, as the size of this generation a year ago multiplied by the sum of age specific conditional survival rate, “*sr*”, and net migration rate, “*mr*”, at time “t-1”. In this model survival and net migration rates vary across time and age. For the final generation the age group 100-104 (k=20), the conditional survival rate is zero. This means that for the oldest age group at the end of the period, everyone dies with certainty.

With respect to the three main demographic variables—fertility, mortality and net-migration—the model allows them to change over time. Demographic change is assumed to be exogenous. Changes in population size, age-structure and sex-structure are driven by a set of precise assumption relating to future level of fertility, mortality and net-migration. Therefore the modelling of changing demography is integral part of the model. The methodology followed is analogous to "building in" a cohort-component population projection structure to the model. This feature makes it ideal for studying the impact of a variety of what can be termed "demographic shocks", such as different rates of population ageing.

2.1 Production Sector

A representative firm produces at time "*t*" a single good using a Cobb-Douglas technology. The firm hires labour and rents physical capital. The production may be written:

(2) $$Y_t = AK_t^{\alpha} L_t^{1-\alpha}$$

where "Y" is output, "K" is physical capital, "L" is effective units of labour, "A" is a scaling factor and "α" is the share of physical capital in value added. A firm is assumed to be perfectly competitive and factor demands follow from profit maximization:

(3) $$re_t = \alpha A\left(\frac{K_t}{L_t}\right)^{\alpha-1}$$

(4) $$w_t = (1-\alpha)A\left(\frac{K_t}{L_t}\right)^{\alpha}$$

where *"re"* is the rental rate of capital and *"w"* is the wage rate.

In the model there are four types of labour, "*qual" = 1, 2, 3* and *4*. Three are defined in terms of skill-level: "high-skilled workers" (*qual=1),* "medium-skilled workers" (*qual=2)* and "low-skilled workers" (*qual=3).* The fourth type of labour is "non-working individuals" (*qual=4*). Therefore, a firm transforms its demand for labour, "L", into a demand for skills, "L_{qual}", based on a constant-elasticity-of-substitution (CES) function:

(5) $$L_{qual,t} = \varsigma_{qual} \left(\frac{w_t}{w_{qual,t}} \right)^{\sigma^L} L_t$$

where "w_{qual}" is the wage rate for a specific type of skills, "ς" is the share of skill level and "σ^L" is the skill substitution elasticity. The composite wage rate, "w" of the firm's aggregate labour input is related to skill-specific market wages "w_{qual}" by the following optimization expression:

(6) $$w_t^{1-\sigma^L} = \sum_{qual} \varsigma_{qual} w_{qual,t}^{1-\sigma^L}$$

2.2 Household Behaviour

Household behaviour in the model is captured by 21 representative households in an Allais-Samuelson overlapping generations structure representing each of the age groups (as described above). Individuals enter the labour market at the age of 20, retire (on average) at age 65, and die at the latest by age 104. Younger generations (i.e. 0-4, 5-9, 10-14 and 15-19) are fully dependent on their parents and play no active role in the model. However, they do influence the age dependent components of public expenditure such as health and education. An exogenous age/time-variable survival rate determines life expectancy.

Adult generations (i.e. age groups 20-24, 25-29, …, 100-104) optimise their consumption/saving patterns. A household's optimization problem consists of choosing a profile of consumption over the life cycle by maximizing a CES type inter-temporal utility function that is subject to lifetime budget constraint. Inter-temporal preferences of an individual born at time *t* are given by:

(7) $$U = \frac{1}{1-\theta}\sum_{k=0}^{17}\left\{\left[\frac{1}{1+\rho}\right]^{k-1}\Pi_k sr_{t+k,g+k}\left((C_{t+k,g+k})^{1-\theta}\right)\right\} \qquad 0<\theta<1$$

where "*C*" denotes consumption, "ρ" is the pure rate of time preference and "θ" is the inverse of the constant inter-temporal elasticity of substitution. Future consumption is discounted by the probability of survival up to the age "*g+k*". Let "$sr_{t+k,g+k}$" be the age/time-variable conditional survival rate between periods "*t+k*" and "*t+k+1*" and between ages "*g+k*" and "*g+k+1*". Therefore the unconditional survival rate, "*ucs*", up to the age "*g+k*" and period "*t+k*" may be written:

(8) $$ucs = \Pi_k sr_{t+k,g+k},$$

In is important to note that a "period" in the model corresponds to five years and a unit increment in the index, "*k*", represents both the next period, "*t+k*, and, for this individual, a shift to the next age group, "*g+k*".

The household is not altruistic. It does not leave intentional bequests to children. However, it leaves unintentional bequests due to uncertainty of life duration. The unintentional bequests are distributed through a perfect annuity market, as described theoretically by Yaari (1965). This idea was first implemented in an OLG context by Boersch-Supan et al. (2006).

Given the assumption of a perfect annuity market, the household's dynamic budget constraint takes the following form:

(9)

$$HA_{qual,t+1,g+1} = \frac{1}{sr_{t.g}}\left[Y^{L}_{qual,t,g}\left(1-\tau^{L}_{qual,t}-Ctr_{t}\right)+Pens_{qual,t,g}+TRF_{qual,t,g}+\left(1+\left(1-\tau^{K}_{t}\right)Ri_{t}\right)HA_{t,g}-C_{t,g}\right]$$

where "*Ri*" is the rate of return on physical assets, "τ^{K}" is the effective tax rate on capital, "τ^{L}" is the effective tax rate on labour, "*Ctr*" is the contribution to the public pension system, "Y^{L}" is labour income and "*Pens*" is pension benefits. The intuition behind the term "*1/sr*" is that the assets of those who die during the period "*t*" are distributed equally between their peers. Therefore if the survival rate at time "*t*" in age group "*g*" is less than one, then at time "*t+1*" everyone in their group has more assets. That is, they all receive an unintentional bequest through the perfect annuity market.

Labour income is defined as:

(10)

$$Y^{L}_{qual,t,g} = w_{qual,t}EP_{qual,g}LS_{qual,g}$$

where "LS_{qual}" is the exogenous supply of a specific type of labour, where skill is proxied by educational qualifications obtained (as discussed below) . It is assumed that qualification-specific labour income is a function of the individual's age-specific productivity. In turn, it is assumed that these age-specific productivity differences are captured in qualification-specific age-earnings profiles. These profiles, $EP_{qual,g}$, are quadratic functions of age:

(11) $$EP_{qual,g} = \gamma_{qual} + (\lambda_{qual})g - (\psi_{qual})g^2, \gamma, \lambda, \psi \geq 0$$

with parametric values estimated from micro-data (as discussed below). Retirees' pension benefits are assumed to be the same across all generations and qualification groups and stay constant in real terms.

Differentiating the household utility function with respect to its lifetime budget constraint yields the following first-order condition for consumption, commonly known as Euler's equation:

(12) $$C_{qual,t+1,g+1} = \left[\frac{\left[1 + \left(1 - \tau_{t+1}^{K}\right) Ri_{t+1}\right]}{(1 + \rho_{qual})} \right]^{\frac{1}{\theta}} C_{qual,t,g}$$

It is important to note that survival probabilities are present in both the utility function and the budget constraint. Therefore, they cancel each other out and are not present in the Euler's equation.

2.3 Investment and Asset Returns

Migrants in any period are assumed to own the same level of assets the domestic population of the same age and the same skill-level. This implies that when net-migration is positive, migrants' assets add to the stock of capital. Therefore the motion law of capital stock, "*Kstock*", takes into account depreciation and assets of newly arrived migrants:

(14) $$Kstock_{t+1} = Inv_t + (1-\delta)Kstock_t + \sum_{qual} \sum_{g} HA_{qual,t+1,g+1} NM_{qual,t+1,g+1}$$

where "*Inv*" represents investment, "δ" is the depreciation rate of capital, "*HA*" is the level of household assets and "*NM*" is the level of net-migration.

Financial markets are fully integrated implying that financial capital is undifferentiated so that interest rate parity holds. Let "*Ri*" be the rate of return on physical assets. It can be defined as the rental rate minus the depreciation rate:

(15) $$1 + Ri_t = re_t + (1 - \delta)$$

2.4 Government Sector

The Scottish Government receives transfers from the UK Government, "*UKTRF*", and interest income from its assets, "*GA*". Consequently its budget constraint is defined as:

(16) $$\sum_g Pop_{t,g} \left\{ \sum_{iqual} \left(\tau^L_{qual,t} + Ctr_t \right) \left(w_{qual,t} EP_{qual,g} LS_{qual,g} \right) + \tau^C_t \left(P^C_{t,g} C_{t,g} \right) \right\} + Ri_t GA_{t,} + UKTRF_t$$
$$= Gov_t + GovE_t + GovH_t + \sum_g Pop_{t,g} \left(TRF_{t,g} + Pens_{t,g} \right)$$

where "τ^C" is the effective tax rate on consumption, "*GovE*" is public expenditures on education, "*GovH*" is public expenditures on health care and "*Gov*" is public expenditures on other sectors (e.g. transport). The left-hand side of this expressospm equation shows tax revenues from different sources, the interest income from government assets and the transfers received from the UK government. The right hand side of the equation refers to government expenditures and transfers to households. Note that the representative household of generation "*g*" at time "*t*" represents a specific cohort of size "$Pop_{t,g}$". The size of each cohort must be taken into account when computing total tax revenues and transfers to households in a specific period of time. Note that the pension program is part of the overall government budget.

Public expenditures on health and education are age-dependent. They are fixed per person of a specific age. More specifically, "$ASHEPC_g$" is age-specific health expenditure per-person and "$ASEEPC_g$" is age-specific education expenditure per-person. Therefore, total public expenditure in these categories depends not only on the size of the population but also on its age structure:

(17) $$GovH_t = \sum_g Pop_{t,g} ASHEPC_g$$

(18) $$GovE_t = \sum_g Pop_{,t,g} ASEEPC_g$$

Other types of public expenditures, "*GEPC*", are assumed to be age-invariant. That is, they are fixed per-person and hence total expenditure, *"Gov"*, depends only on the size of the total population, *"TPop"*.

(19) $$Gov_t = TPop_t\ GEPC$$

2.5 Market and Aggregation Conditions

The model assumes that all markets are perfectly competitive. The equilibrium condition for the goods market is that Scotland's output, together with return on foreign assets, *"FA"*, and transfers from RUK, must be equal to total demand originating from consumption, investment and government spending:

(20) $$Y_t + Ri_t FA_t + UKTRF_t = \sum_g Pop_{t,g} C_{t,g} + Inv_t + Gov_t + GovH_t + GovE_t$$

The demand for labour of a specific skill-level is equal to the supply of this skill:

(21) $$L_{qual,t} = \sum_g Pop_{t,g} LS_{qual,g} EP_{qual,g}$$

and the stock of capital accumulated in period "*t*" is equal to the demand expressed by a firm:

(22) $$Kstock_t = K_t$$

The capital market is assumed to be in equilibrium. The total stock of private wealth, "*HA*", and government assets, "*GA*", accumulated at the end of period "*t*" must be equal to the value of the total stock of capital and foreign assets at the end of period "*t*":

(23) $$\sum_g Pop_{t,g} HA_{t,g} + GA_t = Kstock_t + FA_t$$

Note that the current account can be derived from this model as the difference between national savings and domestic investment:

(24) $$CA_t = \underbrace{\left(\sum_g Pop_{t+1,g+1} HA_{t+1,g+1} - \sum_g Pop_{t,g+1} HA_{t,g+1} \right)}_{\text{Private Savings}} - \underbrace{\left(Kstock_{t+1} - Kstock_t \right)}_{\text{Domestic Investment}}$$

Alternatively, the current account is either given as the trade balance plus the interest revenues from net foreign asset holdings, or as the difference between nominal GNP (i.e. GDP including interest revenues on net foreign assets) and domestic absorption

3. Calibration

The aggregate side of the model is calibrated using 2006 data for Scotland (where available). The 2006 year is chosen to avoid the effects of the financial crisis, which had a strong negative impact on the performance of the Scottish economy and government finances. The data for demographic shock is taken from the “official” population projections carried out by the *Office of National Statistics* (discussed further below). Population projections are used for calibration of fertility, survival and migration rates used in the model.

Data on public finances and GDP are taken from *2006-07 Government Expenditure and Revenue Scotland Report* (GERS) (Scottish Government, 2008). The estimate used assumes that North Sea revenues are distributed on a geographical share basis. Effective wage income and consumption tax rates are calculated from the corresponding government revenue category and calibrated tax base i.e. total employment income and aggregate consumption. The total amount of pensions and other transfers is taken from the *Department of Work and Pensions, Benefit Expenditure by Country, Region and Parliamentary Constituency*. Based on this information the effective pension contribution rate and the average size of pension benefits are calculated. For effective pension contribution rate calculation it is assumed that the same contribution rate is paid on all wage income. For average size of pension benefits the total amount of pension benefits is divided by the total number of people of pension age. For simplicity it is assumed that both males and females start receiving pension benefits at age 65.

The source of the labour market data is the *Quarterly Labour Force Survey* (QLFS). To avoid single observation biases data for three quarters is used (i.e. Q1:2008, Q1:2009 and Q1:2010). From these pooled data, parameters of the age-specific productivity (earnings) profiles by qualification are estimated. These data are also used to calculate age-specific labour force participation rates and the distribution of the labour force by qualification. For age-specific productivity profiles, Mincer age-earnings regressions are estimated (Mincer, 1958).

There are no Scotland specific estimates of the age structure of government spending on health and education. The estimates used are from the *Canadian National Transfer Accounts* (see Zhang and Mérette, 2011). Figure 1 shows the age profiles of public spending on health and education in Canada in 2006. The majority of education spending occurs between the ages 5-9 and 20-24. Health spending grows slowly until the age of 55-59 when it starts increasing much faster and accelerates after age 75-79. There is no reason to believe that the "shape" of the Scottish profile would be radically different. Capital share of the output (α) is set to 0.3. The (5-year) intertemporal elasticity of substitution ($1/\gamma$) is set to 1.5.

The calibration procedure contains four steps. In the *first step*, available labour market data on the distribution of workers' skill is used to calibrate the composition of the population accordingly. This first step ensures that labour demand equals labour supply for each skill.

The *second step* consists of using the information on output, capital and labour demands and the first-order conditions of the firm problem to calibrate the scaling parameter for the productivity function, plus wage and rental rates.

The *third step* is the most challenging involving equations pertaining to the household's optimisation problem, the equilibrium conditions in the assets and goods markets to calibrate the rate of time preference and government expenditures on sectors other than health and education (*Gov*). In other words, the (5-year) rate of time preference is solved endogenously in the calibration procedure in order to generate realistic consumption profiles and capital ownership profiles per age group, for which no data are easily available. Capital ownership profiles must also satisfy the equilibrium condition on the asset market. Public expenditures on other sectors (*Gov*) is endogenously determined to close the budget constraint of the government and ensures the equilibrium on the goods market. Note that the rate of time preference and the intertemporal elasticity of substitution together determine the slope of the consumption profiles across age groups in the calibration of the model (when the population is assumed to be stable). This is also the slope of the consumption profile of an individual across his lifetime in the simulated model in the absence of demographic shocks or economic growth.

The *fourth and final step* uses the calibration results of the first three steps to verify the model is able to replicate the observed data corresponding to the initial equilibrium. Only when the initial equilibrium is perfectly replicated with the calibration solution can the model be used to evaluate the consequences of demographic shocks associated with population ageing.

4. Results

Let us begin with a discussion of the "official" 2010-based principal population projection for Scotland (National Records of Scotland, 2011). This projection is summarised in Figure 2 which shows the growth rates of key age groups.

According to this projection, by 2106 total population will increase by 22%, the pension age population (65+) will increase by 127%; the children/youth population (<20) will stay constant and the working age population (20-64) will stagnate during this period with an increase of 1%. It is clear from this projection that significant population ageing is expected.

In the simulations carried out in this second, changes in mortality and fertility are the same as in this principal projection. The only demographic variable that changes is the long-run level of net-migration. The simulation period is 100 years. The specific level of net-migration considered are: (1) zero net-migration (natural increase only assumption); (2) +10,000 p.a.; (3) +20,000 p.a.; (4) +30,000 p.a. (5) +40,000 p.a.; and (6) +50,000 p.a. It is worth noting that the current level of net-migration in Scotland is around +20,000. In order to appreciate the possible welfare implication of these different net-migrations scenarios, changes in output per-person (i.e. GDP per-capita) is the key macroeconomic variable of interest.

Figure 3 shows simulated changes in output per-person based on the six scenarios. In all cases, output per-person declines. In the zero net-migration simulation, per-person output loss approaches 20%. It is interesting to note that progressively higher levels of net-migration lead to lower per-person output loss. However, even at a net-migration level of +50,000—over twice the current-level—output loss approaches 15%. It is seem unlikely that higher net-migration driven by higher immigration can be used to counteract the negative welfare consequences of population ageing.

5. Conclusions

This paper developed an overlapping generations (OLG) computable general equilibrium (CGE) model in order to evaluate the macro-economic impacts of population ageing in Scotland. The model is particularly well suited to this task since its OLG structure explicitly allows for the incorporation of ageing effects related to age-specific labour force participation, age-specific productivity differences and age-specific government expenditures. Population ageing is also associated with lower output per-person suggesting that it is welfare reducing. Simulations suggest that higher levels of net-migration—generated by higher levels of immigrations—are associated with less welfare loss. However, even at very high (and unlikely realistic) level of net-migration, output per person still declines over the 100 year simulation period.

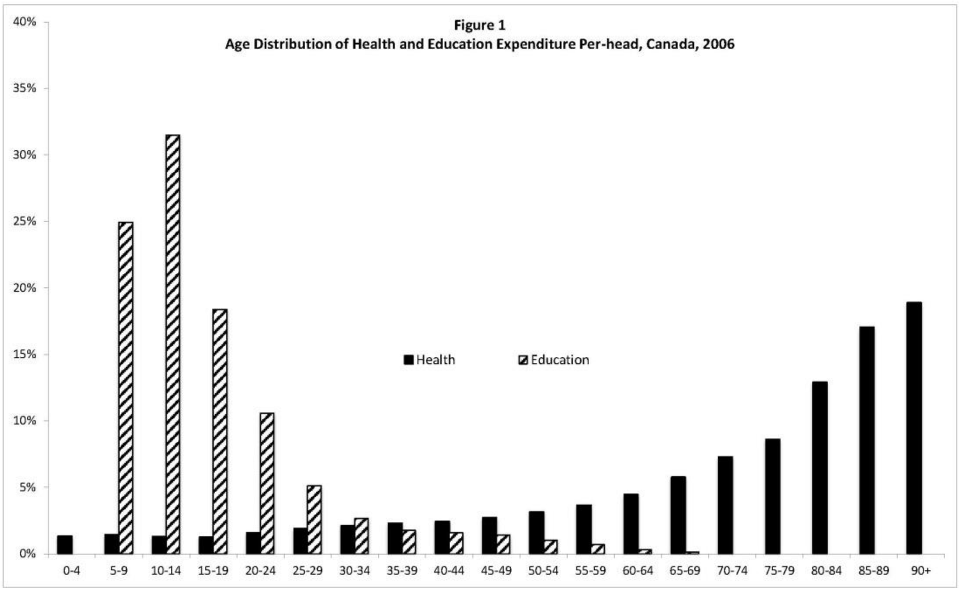
Figure 1
Age Distribution of Health and Education Expenditure Per-head, Canada, 2006
40%
35%
30%
25%
20%
15%
10%
5%
0%
Health
Education
0-4
5-9
10-14
15-19
20-24
25-29
30-34
35-39
40-44
45-49
50-54
55-59
60-64
65-69
70-74
75-79
80-84
85-89
90+

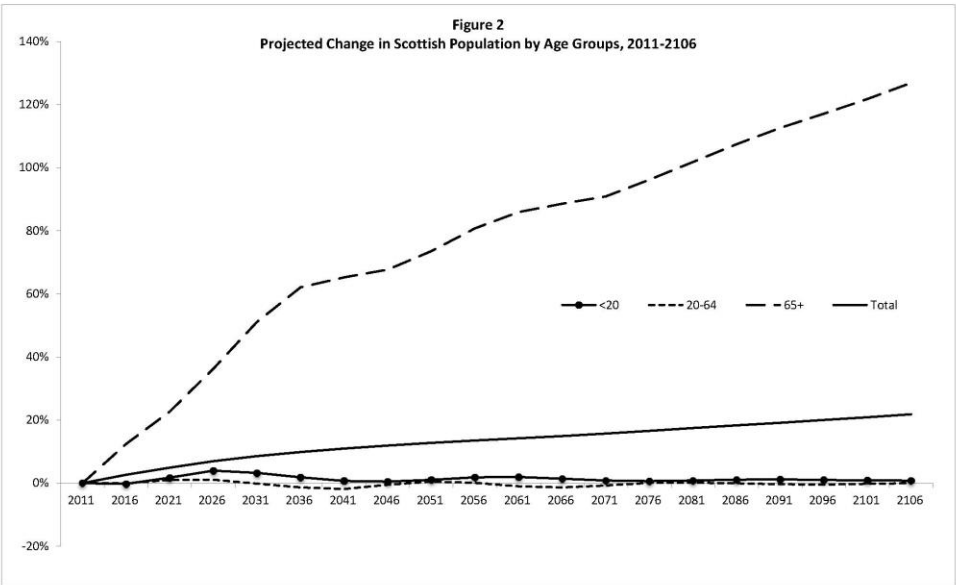
Figure 2
Projected Change in Scottish Population by Age Groups, 2011-2106
140%
120%
100%
80%
60%
40%
20%
0%
-20%
<20
20-64
65+
Total
2011
2016
2021
2026
2031
2036
2041
2046
2051
2056
2061
2066
2071
2076
2081
2086
2091
2096
2101
2106

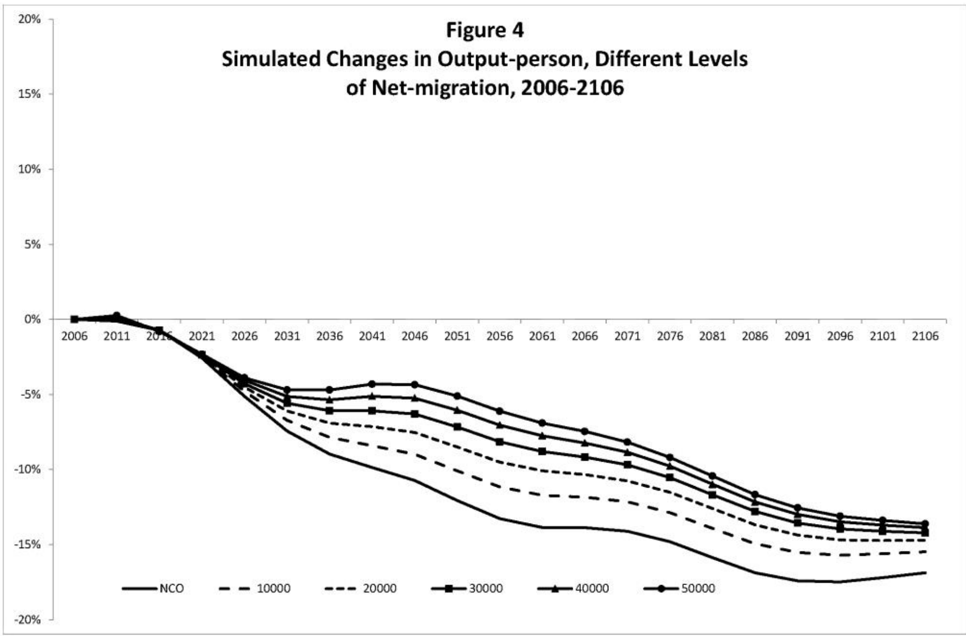
Figure 4
Simulated Changes in Output-person, Different Levels
of Net-migration, 2006-2106
20%
15%
10%
5%
0%
-5%
-10%
-15%
-20%
2006 2011 2016 2021 2026 2031 2036 2041 2046 2051 2056 2061 2066 2071 2076 2081 2086 2091 2096 2101 2106
NCO
10000
20000
30000
40000
50000

References

Auerbach, A. and L. Kotlikoff, (1987), *Dynamic Fiscal Policy*, Cambridge, Cambridge University Press

Bommier, A. and R.D. Lee, (2003), "Overlapping Generations Models with Realistic Demography", *Journal of Population Economics*, vol. 16, pp. 135-160

Boersch-Supan, A., A. Ludwig and J. Winter (2006), "Aging, Pension Reform and Capital Flows: A Multi-Country Simulation Model", *Economica*, vol. 73, pp. 625-658

Boersch-Supan, A., (2003), "Labour Market Effects of Population Ageing", *Labour*, vol. 17 (Special Issue), pp. 5-44

Burfisher, M.E., (2011), *Introduction to Computable General Equilibrium Models*, Cambridge University Press, Cambridge

Dixon, B. and D. Jorgenson, (2012), Handbook of *Computable General Equilibrium Modelling,* North Holland, Amsterdam

Fossati, A. and W. Wiegard, (2001), *Policy Evaluation with Computable General Equilibrium Models*, Routledge, London

Fougère, M. and M. Mérette, (1999), "Population Ageing and Economic Growth in Seven OECD Countries", *Economic Modelling*, vol. 16(3), 411-27

Fougère, M., J. Mercenier and M. Mérette, (2007), "A Sectoral and Occupational Analysis of Population Ageing in Canada Using a Dynamic CGE Overlapping Generations Model", *Economic Modelling* vol. 24, pp. 690-711

Fouugère, M., S. Harvey, M. Mérette and F. Poitras, (2004),"Ageing Population and Immigration in Canada: An Analysis with a Regional CGE Overlapping

Generations Model", *Canadian Journal of Regional Science*, vol. 27, no. 2, pp. 209-236

Hosoe, N., K. Gasawa and H. Hashimoto, (2010), *Textbook of Computable General Equilibrium Modeling: Programming and Simulations*, Plagrave Macmillan, London

Lisenkova, K., P. McGregor, RE. Wright and others, (2010), "Scotland the Grey: A Linked Demographic-CGE Analysis of the Impact of Population Ageing and Decline", *Regional Studies*, vol. 44, no. 10, pp. 1351-1368

Mérette, M. and P. Georgres, (2010), "Demographic Changes and Gains from Globalisation: An Analysis of Ageing, Capital Flows and International Trade", *Global Economy Journal*, vol. 10, no. 3, art. 3

Mincer, J., (1958), "Investment in Human Capital and Personal Income Distribution" *Journal of Political Economy*, vol. 66, no. 4, pp. 281-302.

National Records of Scotland, (2011), *Projected Population of Scotland (2010-based). National Population Projections by Sex and Age, with UK and European Comparisons*, National Records of Scotland, Edinburgh

Scottish Government, (2008), *2006-07 Government Expenditure and Revenue Scotland*, Scottish Government, Edinburgh

Weil, D., (1997), "The Economics of Population Ageing". In: M. Rosenzweig and O. Stark, (eds.), *Handbook of Population Economics*, Volume 1B, North Holland, Amsterdam

Yaari, M. E., (1965), "Uncertain Lifetime, Life Insurance, and the Theory of the Consumer", *Review of Economic Studies*, vol. 32, pp. 137-160

Zhang, and M. Mérette, (2011), "National Transfer Accounts: The Case of Canada", manuscript, University of Ottawa, Ottawa