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PUBLIC PENSION SUSTAINABILITY OPTIONS: THE RELATIVE MERITS OF INCREASING CONTRIBUTION RATES OR SWITCHING TO A FULLY-FUNDED PENSION

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Public Pension Sustainability Options: The Relative Merits of Increasing Contribution Rates or Switching to a Fully-Funded Pension

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Abstract

Many nations are experiencing population aging due to rising life expectancies and declines in fertility. As a result, policymakers are struggling with the sustainability of public pension systems. This paper uses an overlapping generations dynamic equilibrium model to investigate the relative merits of two pension sustainability options. The first option involves increasing the pension contribution rates of workers to ensure sustainability of the typical pay-as-you-go pension system. The second option is the switch to a fully-funded plan, in which the government is required to incur debt to honour existing pension liabilities, with individuals making contributions into the new fully-funded pension system when working, but also paying income taxes to service government debt. The timing of this switch coincides with the baby boom generation entering the old worker stage of life which is consistent with the timing of the current pension reform debate. Simulation results suggest that economies facing no population growth in the future and without technological progress are not better off switching to a fully-funded pension system.

JEL Classification Codes: E21, C68, H55, J26

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1. Introduction

Many nations are concerned with the sustainability of government-run pension systems. For the most part, the pay-as-you-go (PAYGO) pension system is the most common type of pension system, with contributions by workers being used to fund contemporaneous benefits to retirees. These systems were generous to early generations, when life expectancies were relatively low, and as populations and the labour force were growing. However, the sustainability of these systems is in question as a result of the dramatic fall in fertility rates since the post-WWII baby boom, and rising life expectancies.

In Canada, sustained immigration has alleviated some of the impact of these demographic changes, but Figure 1 still shows the striking effect of decreased fertility and population aging. In 1971, almost half of the population of Canada was younger than 25 years of age, and less than ten percent was older than 64 years of age. By the year 2050, the Canadian population is expected to consist of almost equal shares of those aged less than 25, between 25 and 44, between 45 and 64, and older than 64. The ratio of those over 64 to those between the ages of 25 and 64 was less than twenty percent in 1971, and is expected to be fifty percent in 2050. With lower rates of immigration experienced by other nations, the problem is more severe.

The effect of population aging on pension systems can be summarized by the expected change in pension payroll taxes if there is no change in the benefit formula for beneficiaries. The average contribution payroll tax rate in the European Union was found to be 16% at the beginning of the twenty-first century, and it is expected to rise to 27% by 2050 without any further reform (European Union Commission, 2001). Similarly, in the United States, the contribution rate for Social Security would have to rise from 12.4% to 17.8% (Social Security Administration, 2001).

Reform of the existing PAYGO systems could involve gradually decreasing future benefit rates, gradually raising the retirement age, using general tax revenues to fund pension deficits, and also quickly raising contribution rates to partially pre-fund future benefits.

A prominent reform option is to replace PAYGO systems with fully-funded or partially-funded systems. Feldstein (1995) and Feldstein and Samwick (1996) examined a transition from a PAYGO system to a fully-funded system that provides the same level of benefits. They found that there would be positive gains to future generations from a debt-financed transition under the conditions that the marginal product of capital is higher than the rate of aggregate wage growth, and higher than the rate of time discounting, and also that the rate of aggregate wage growth is positive. Since the US experience in the late twentieth century was one of low aggregate wage growth and high rates of return, the authors conclude that a policy shift would be beneficial to the US. However, such a move might not be politically possible since those alive during the transition may experience a welfare reduction, and thus not allow such a policy shift. Both of these works used a partial equilibrium analysis and did not account for the effects of such policy changes on the nation's capital stock, household savings decisions, and interest rates.

Kotlikoff (1995, 1996) simulated the transition from a PAYGO to a privatized system using a general equilibrium overlapping generations model, with no demographic change (constant one percent annual population growth), no technological progress, no intragenerational heterogeneity, and no lifetime uncertainty. He found that efficiency gains were strongest when the benefit-contribution linkage in the PAYGO structure is poor, and when a consumption tax is used to finance the transitional social security benefits. With a poor benefit-contribution linkage, the shift to personal accounts causes agents to supply more labour. When the benefit-contribution linkage is strong and the transition is funded using a proportional income tax, future generations may instead suffer losses. Kotlikoff, Smetters and Walliser (1999) added intragenerational heterogeneity in earnings to the basic modeling framework, and found that privatization can have significant gains in the long run, but that transitional generations can experience welfare losses.

DeNardi, Imrohoroglu and Sargent (1999) commented that demographic change was rarely modeled in general equilibrium models, but could have very dramatic effects on simulation results. They used a dynamic general equilibrium overlapping generations model with uncertain lifetimes, technological progress, and US demographic projections to examine the impact of different reform measures on macroeconomic variables and welfare across generations. The expected costs and funding of Medicare and Medicaid as a result of demographic change were also added to the analysis. Their results indicated that to sustain the social support for the elderly, the payroll tax rate may have to rise as high as sixty percent, or consumption taxes may have to rise to thirty-seven percent. A policy that focuses on increasing the retirement age and the payroll tax rate during the demographic transition is beneficial for future generations, with a relatively small cost to transitional generations. They concluded that the best reform measure would be one which simplifies and strengthens the linkage between an individual's contributions and benefits.

Fehr (2000) extended the basic overlapping generations general equilibrium model to study the impact of a set of PAYGO reforms on the macroeconomy and the welfare of different generations. He incorporated intragenerational heterogeneity, rising life expectancies, and declining fertility into the modeling framework. The reform experiments examined the effect of increasing the retirement age, decreasing benefits, and gradual increases in general taxes to finance pension deficits. He found that strengthening the linkage between benefits and contributions led to efficiency gains, and, it is the baby-boom generation (and in some cases, the following generation) that experience welfare losses as a result of the shift from the status quo, while later generations benefit from the reforms that reduce the burden of the unfunded system.

Butler (2000) examined pension reform of the PAYGO system in a small open economy environment, using a model that incorporated lifetime uncertainty and death bequests. Reform experiments to retain PAYGO features focused on the effects on transitional generations of (i) reducing benefits, (ii) increasing the retirement age, and (iii) increasing the payroll tax, to retain the pay-as-you-go budget balance. In addition, the effects of an increase in the consumption tax to pay for pension deficits, keeping all features of the PAYGO structure constant, was investigated. Butler provided welfare comparisons across reform options for agents of different generations. The results show that consumption taxes provide fewer distortions than payroll taxes. In general, older generations (both current older workers and retirees) prefer tax increases to sustain the pension system instead of benefit reductions, and prefer income tax increases to consumption tax increases, while younger generations at the time of projected reforms have the opposite preferences. In addition, older workers at the time of projected reforms prefer increases in payroll or consumption taxes to increases in the retirement age, while younger workers have the opposite preferences.

Cooley and Soares (1996, 1999) used an overlapping generations model where agents live four periods, and agents face the pension sustainability issue. Will voters dump the PAYGO pension system in favour of a privatized system, or support it? The authors concluded that if voters believed that they could abandon obligations to retirees, the PAYGO system would collapse because generations following the baby-boomers will elect to abandon the system because of the heavy costs associated with supporting the retirement of the baby-boom generation. If voters cannot abandon their obligations to retirees, the system does not collapse because voters want to avoid welfare losses that result from funding benefits for past generations and pre-funding their own pension benefits. If voters are given the option to gradually phase-out the PAYGO system, the only option that is supported by voters is one in which the transition is debt-financed, so that future (non-voting) generations bear a substantial portion of the costs. Servicing the debt with labour taxes is also preferable than consumption taxes to voters. In addition, Conesa and Kruger (1999) indicated that income uncertainty could reduce the support for pension reform from a PAYGO to a fully-funded system, and that an immediate transition is preferable to a gradual transition.

Consistent with different simulation study results, many authors have argued that it is not possible to achieve a Pareto improvement by changing to a fully-funded pension system. Geanakoplos, Mitchell and Zeldes (1998), Sinn (2000), and Breyer (2001) have discounted the oft-cited reasons for the move to fully-funded or partially funded pensions. The PAYGO system essentially transfers income across generations. Introductory generations receive benefits far greater than their contributions, and to pay for these excess benefits, future generations pay an implicit tax as part of their pension contributions to fund the implicit PAYGO pension debt. A transition from a PAYGO to a fully-funded pension system involves converting the implicit PAYGO pension debt into explicit debt, then determining how future generations will service and pay off this debt. Any benefits in moving to a fully-funded system that arise due to a decrease in tax distortions to the labour-leisure and consumption-saving decisions may also be achieved by eliminating such distortions in pension and tax policy while retaining the PAYGO system. The efficiency of the PAYGO system may be improved by directly linking benefits to contributions.

The focus of this paper is on comparing the welfare of generations under two different government pension policy responses to demographic change. The first option is to increase PAYGO pension contribution rates, leaving the benefit structure unchanged. The second option is to immediately shift to a fully-funded pension system, leaving the benefit structure unchanged, and by financing the PAYGO pension obligations at the time of the switch with debt, while the government levies income taxes to cover the interest payments of the debt. This alternative policy option is chosen given the Cooley and Soares (1999) conclusion that a debt-financed transition to a fully-funded pension is preferable to voters, and given the Conesa and

Kruger (1999) assertion that an immediate transition is preferable to a gradual one. The modeling experiments include economies with constant and positive population growth to present baseline simulations to mirror the analyses by Kotlikoff (1995, 1996) and Kotlikoff, Smetters, and Walliser (1999), but also include economies with demographic change as in DeNardi, Imrohoroglou and Sargent (1999), and Fehr (2000), to reflect current population projections that have motivated the pension sustainability and reform debate. Agents in the model economies will also supply labour inelastically, and pension benefits will depend directly on contributions. This is to abstract from issues surrounding the labour-leisure distortion of pension policy that have prompted the critique that governments should reduce these distortions rather than enact a transition from a PAYGO system to a fully-funded system.

2. Modeling Environment

A simple overlapping generations dynamic general equilibrium framework will be used to examine the relative merits of the two different pension sustainability options. Agents live for three periods, with each period corresponding to 20 years. These three periods are defined as follows: In the first period of life, agents are "born" into the economy as young adults; in the second period of life, agents are older workers; and in the third period, agents are no longer working, but are retirees. When working, agents pay mandatory contributions to a pension system as a percentage of wages, and when retired, agents receive benefits at a given rate of their prior employment earnings.

2.1 Population Process

The population of the model economy is defined as follows, where N_{it} denotes the population of that cohort in the i^{th} period of life in time t:

(1) $$N_t = N_{1,t} + N_{2,t} + N_{3,t}.$$

There is no lifetime uncertainty, so that agents live for all three periods. As such, $N_{i+1,t+1} = N_{i,t}$ for i=1,2, and for all t. The population will evolve over time, at the time-varying growth rate, n_t, so that $N_{i,t} = (1+n_t)N_{i,t-1}$

Agents supply e_1 units, and e_2 units, of labour inelastically in the first and second periods of life respectively. At time t, the total labour supply in the model economy is defined as:

(2) $$L_t = N_{1,t}e_1 + N_{2,t}e_2 .$$

2.2 Technology

Production in the economy is deterministic, and is defined by the constant returns to scale production function:

(3) $$Y_t = A_t K_t^{\alpha} L_t^{1-\alpha} .$$

As such, the returns to the factors of production, labour and capital, per unit, are:

(4) $$w_t = (1-\alpha) A_t K_t^{\alpha} L_t^{-\alpha} \text{, and}$$

(5) $$r_t = \alpha A_t K_t^{\alpha-1} L_t^{1-\alpha} - \delta_t .$$

2.3 Government Pension System

The government runs a pay-as-you-go pension system whereby benefits in any period paid to retirees are funded by contributions by workers in that same period. The government imposes a pension contribution rate, $p_{i,t}$, on labour earnings at time t, and pays out benefits to retirees, the amount of which is denoted by b for retirees. These benefit levels will be determined in advance and will be set as a proportion (br) of wage earnings when employed:

(6) $$b_t = br(w_{t-2}e_1 + w_{t-1}e_2) .$$

As such, the pension budget constraint is:

(7) $$N_{1,t} p_{1,t} w_t e_1 + N_{2,t} p_{2,t} w_t e_2 = b_t N_{3,t} .$$

With the PAYGO system, $p_{1,t} = p_{2,t}$. For the purpose of this paper, income taxes will be raised solely for the purpose of managing interest payments on debt following the shift to a fully-funded pension system. Income taxes will be charged on interest income, wage earnings net of pension contributions, and pension benefits, at rate τ_t.

2.4 Preferences

Agents maximize utility over a standard composite good, which can be used for consumption, c, or used as a capital asset in production, a, with time separable preferences, subject to a discount factor β, under the following constraints:

(8) $$U(c,t) = \sum_{i=1}^{3} \beta^{i-1} \log c_{i,t+i-1}, \text{ subject to}$$

(9) $$c_{1,t} = w_t e_1 (1 - p_{1,t})(1 - \tau_t) - a_{1,t},$$

(10) $$c_{2,t+1} = (w_{t+1} e_2 (1 - p_{2,t+1}) + r_{t+1} a_{1,t})(1 - \tau_{t+1}) + a_{1,t} - a_{2,t+1},$$

(11) $$c_{3,t+2} = (r_{t+2} a_{2,t+1} + b_{t+2})(1 - \tau_{t+2}) + a_{2,t+1}$$

(12) $$a_{i,t} \geq 0 \forall i,t.$$

The aggregate level of capital stock held by residents is defined as:

(13) $$K_{d,t+1} = N_{1,t} a_{1,t} + N_{2,t} a_{2,t}.$$

The total amount of capital stock used in production, K_t is equal to the sum of capital held by residents, $K_{d,t}$, and by foreigners, $K_{f,t}$. In the case of a closed economy, K_f is set to zero.

Agents in the model economies have perfect foresight. They perfectly predict the evolution of the population, and of technological progress (A_t), without uncertainty. That is, they can perfectly predict the evolution of wages, the rate of return, premium rates, pension benefits, and other economic variables.

2.5 The Shift to Fully-Funded Pensions

In an economy that wishes to shift from a pay-as-you-go pension system to a fully-funded one, the government will sell new debt equivalent to the pension payout of the pay-as-you-go pension system for retirees who contributed before the switch. With the switch, new pension contributions are invested in capital markets and contribute to the stock of productive capital in the economy. As in the case of the PAYGO pension system, contributions are tax-sheltered, and benefits are subject to income tax when received. If the switch occurs in period T, then the government will raise funds by selling bonds to pay the benefits to the retired in time T:

(14) $$B_T = b_T N_{3,T} = br(w_{T-2} e_1 + w_{T-1} e_2) N_{3,T}$$

Those who were in the second period of life at the time of the switch would have contributed to the pay-as-you-go system when in the first period of life, as well as into the fully-financed system in the second period of life, and those contributions will now be addressed. Let us assume that this cohort is promised benefits under the previous pension system according to their earnings history while under the pay-as-you-go system, along with the market value of their contributions while under the fully-funded pension system:

(15) $$b_{T+1} = br(w_{T-1}e_1) + R_{T+1}p^*_{2,T}w_Te_2 .$$

Then the government needs to raise the first portion of benefits by issuing new debt in time T+1:

(16) $$B_{T+1} = br(w_{T-1}e_1)N_{3,T+1} .$$

In this case, if agents in this generation continue to receive benefits set as a defined proportion of their lifetime earnings, then the premium rate for this generation in their second period of life is:

(17) $$br(w_Te_2) = R_{T+1}p^*_{2,T}w_Te_2 \text{, or } \quad p^*_{2,T} = br / R_{T+1} .$$

Those who were in the first period of life, or as yet unborn, at the time of the switch to the fully-funded pension system in time T, will pay contributions that are invested in capital markets and add to the capital stock for production. These contributions will be set at an equal rate across earnings in the two work periods, and will be defined by $p^*_{1,t} = p^*_{2,t+1}$ for agents that retire in period t+2>T+2. Let agents in this generation also receive benefits set as a defined proportion of their lifetime earnings, so that these agents will receive benefits as follows:

(18) $$b_{t+2} = br(w_te_1 + w_{t+1}e_2) = R_{t+2}(R_{t+1}p^*_{1,t}w_te_1 + p^*_{2,t+1}w_{t+1}e_2) ,$$ with their premium rate set to:

(19) $$p^*_{1,t} = p^*_{2,t+1} = br(w_te_1 + w_{t+1}e_2) / R_{t+2}(R_{t+1}w_te_1 + w_{t+1}e_2)$$

Government debt-service is now addressed. Assume that the government wants to service only interest payments on the two bond issues in perpetuity, so that the level of government debt remains at $D_{T+i} = B_T + B_{T+1}$ for all i>1. In period T+1, it levies taxes on incomes excluding pension contributions and including pension benefits to pay interest payments on the first bond issue. In period T+i, i>1, it levies taxes to pay interest payments on both bond issues. In open economies, foreign capital earnings are also taxed at the same rate.

Since the economies investigated herein are all deterministic without uncertainty, rate of return equality must exist between the two available assets, productive capital and government debt. The aggregate level of capital stock used in production and held by residents is now defined as:

(20) $$K_{d,t+1} = N_{1,t}(a_{1,t} + p^*_{1,t} w_t e_1) + N_{2,t}(a_{2,t} + p^*_{2,t} w_t e_2) - D_t \text{, for } t \geq T.$$

2.6 Computation of Equilibria

The method of computing equilibria for a closed economy is slightly different than that used for an open economy. The method for computing equilibria in the open economy is simpler, and will be described first.

In an open economy, the rate of return on assets is determined exogenously in world capital markets. Capital is assumed to be perfectly mobile. If the amount of domestically-supplied capital is too low (or too high), funds will flow in from abroad (or domestic capital will flow out), until the return to capital equals the world interest rate. The amount of labour is defined in each period given the population process. The steps for computing equilibria are as follows:

1. Eq. (5) is solved for K_t, given the international rate of return, the level of labour, and the production parameters, A, α, and δ, for all values of t;
2. The wage rate is calculated using Eq. (4), for all values of t;
3. The pension contribution rate in Eq. (7) is calculated with predefined values for the benefit levels for retirees, for all values of t;
4. The agents' optimization problem is solved recursively as defined by Eqs. (8-12), for all values of i = 1 to 3, and all values of t;
5. The optimal levels of asset holdings over time are used to calculate the level of domestic capital stock holdings over time, using Eq. (13).
6. The difference between the level of capital used in production and the level of domestic asset holdings in the open economy is equal to foreign-held capital stock in any given time period.

The method of solving equilibria in the closed economy differs slightly from that described above. In step 1, initial guess values for K_t are defined, and are then used to calculate the rates of return, r_t, in Eq. (5). Steps 2 through 5 do not change. In step 6, however, the value of foreign-held capital stock is zero for the closed economy.

If the values of domestic capital stock holdings from step 5 do not equal the guess values for the capital stock from step 1, then the guess values for the capital stock are updated, and the procedural steps are repeated until the calculated values of capital stock in step 5 are equivalent to the previous guess values in step 1.

To calculate the transition to fully-funded pension systems, the two bond issues in Eqs (14) and (16) are calculated along with the new pension contribution rates defined in Eqs (17) and (19), and the required income tax rates to finance interest payments on the pension debt in step 3. Step 5 is adjusted so that the level of capital stock is calculated using Eq (20).

3. Model Calibration

In order to conduct the simulation experiments, the model must be calibrated for the population processes, technology, preferences, and for the government pension system.

3.1 Population Processes

Two separate population processes will be examined in both open and closed economy settings. The first will be one with a constant population growth rate, to serve as a baseline for comparison with previous work that did not model demographic change (Kotlikoff, 1995, 1996, Kotlikoff, Smetters and Walliser, 1999). The second will be one defined by a process intended to mirror that experienced, and expected to be experienced, in Canada: an initial steady state with constant growth, followed by a one-generation decline in the birth rate corresponding to that experienced over the 1926-1945 period, subsequently followed by a one-generation baby-boom over the 1946-1965 period, then followed by no growth (baby bust).

The population growth rate in the first steady state in both population processes is set to 0.5, which is approximately 2.0% on an annual basis. For the first process, the population is always in this steady state of constant growth. For the second population process, the first steady state is followed by a one-generation decline in the growth rate for the generation born during the interwar period: the growth rate for this generation is set to 0.35 (corresponding to 1.5% annually). This generation enters the labour force over the 1951-1970 period and is in the 25-44 age category as of 1971. The baby-boom generation (born over the 1946-1965 period) is 1.75 times bigger than the preceding generation, which corresponds to an annual increase of almost three percent, and is in the 25-44 age category at the 1991 census. The baby boom generation is all retired by the 2031 census period. Figure 2 shows the differences in the age-composition of the population given this second population process, and the Canadian population at census points. Note that the model economies fail to replicate the smaller size of the cohort of retirees in years before 2011; this is because the model economies do not incorporate lifetime uncertainty and rising life expectancies. The implications of this will be discussed later.

Agents are endowed with age-dependent efficiency units. For young workers, e is normalized to 1. For older workers, e is set to 1.1, so that older workers earn wages that are ten percent higher than those of young workers. In 2003, the average earnings of Canadian male workers was $38,400 for those aged 25 to 34, $50,500 for those aged 35 to 44, $55,600 for those aged 45 to 54, and $42,700 for those aged 55 to 64 (Statistics Canada CANSIM Table 202-0407). The ratio of earnings of older workers to younger workers is about 1.1. In the US, the median level of earnings was $39,595 for males aged 25 to 44 , and $47,978 for males aged 45 to 64 in 2003 (US Census Bureau, 2004). The ratio of earnings of older workers to younger workers in the US was 1.2.

3.2 Technology, Preferences, and Pension Benefits

The share of income to capital is set to 0.3, following the estimate reported in Abel et al (2006: 57) and Auerbach and Kotlikoff (1998: 7). The depreciation rate is set to 0.71, which corresponds to the annual estimate of 6% by Stokey and Rebelo (1995). For the purpose of this paper, total factor productivity is held constant following convention in Kotlikoff (1995, 1996), Kotlikoff, Smetters and Walliser (1999), Cooley and Soares (1996, 1999), Fehr (2000) and Butler (2000). The discount factor (β) is set to 0.785, to approximate the annual figure of 0.988 (Cooley and Soares, 1999). In Canada, the public pension system payed a maximum annual benefit of $9,770 in 2004, which is approximately equal to 20% of average earnings of workers aged 45 to 64 (OSFIC, 2004: 50; Statistics Canada CANSIM Table 202-0407). Since workers in the model economies work two periods and receive benefits in one period, the model economy government operates the pension system so that benefits received by retirees are equal to 10% of lifetime employment earnings (*br* = 0.1). The interest rate in the open economy setting is set so that the rate is within the range of interest rates given the closed economy results. In the initial steady state, the open economy is operating under a capital account surplus (foreign capital flows in). In the final steady state, the economy is operating under a capital account deficit.

The time of the immediate transition to a fully-funded pension is when generation 33 (the first baby-bust generation) enters the workforce (*T*=33). This is also the period when the baby-boom generation is in the older worker stage of life, which is consistent with the current phase of the demographic transition.

4. Simulation Results

The results of the simulation exercises under constant population growth in both open and closed economy settings are presented in Tables 1 and 2. The results for the open economy with demographic change are presented in Tables 3 and 4. The results under the closed economy setting with demographic change are presented in Tables 5 and 6.

4.1 Economies with Constant Population Growth

The open economy results are examined first because factor prices do not change over the demographic cycle, which makes it easier to pinpoint and separate the beneficial effects from negative effects (the effect of changing wages and interest rates add another dimension to the analysis of closed economy results). For an open economy with constant population growth, certain and unchanging lifetimes, and no technological change, there is no demographic change to alter the economy from the steady state, so that all generations of the model economy under the maintained PAYGO system receive the same level of wages, interest rates, pension contribution rates, benefit rates, and lifetime utility. Table 1 shows the results for an open economy transition from a PAYGO to a fully-funded pension system, with constant population growth. The initial steady-state results for generations 26 through 31 are identical to the results for subsequent generations if there was no change from the PAYGO pension system. The shift to the fully-funded system begins at time 33, when generation 33 enters the labour force as young workers. The shift to a fully-funded system requires bond issues to pay for the promised benefits of the retired under the PAYGO system, with interest payments to be financed with income taxes. Generations 32 through 36 are worse off with the shift to full-funding because of the pension debt taxation burden that offsets any beneficial effects of lower contribution rates. Later generations are better off under the fully funded system because of the lower contribution rate required to provide equal benefits, and also due to the ever falling taxation burden of the pension debt as the population continues to grow.

Table 2 presents the results for the simulation exercise of a closed economy with constant population growth and a transition to a fully-funded pension system when generation 33 enters the labour force. Note again that without any change to the PAYGO pension system, all generations experience the same factor prices, pension premium rates and benefits, and lifetime utility so that all generations are equally well-off and in a steady state equilibrium. In Table 2, Generations 30 and earlier are in this first steady state. Generation 31 is affected by the switch since the rate of return on their assets falls in the last period of their lifetimes, and leads to lower consumption in that final stage of life. Similarly, Generation 32 is adversely affected by the drop in interest rates, but also faces new income taxes in the final period of their lives. Interestingly, Generation 33 is better off because it benefits from lower pension contribution rates, higher wage rates when working, and higher interest rates in the final period of life, which more than offset the effect of income taxes during their second and third periods of life. Generations 34 through 37 are all adversely affected by the shift to full-funding due to the debt servicing burden, but later generations are better off with the shift since the pension debt burden decreases as the population continues to grow.

These results confirm Kotlikoff's findings that, in model economies with constant and positive population growth, a shift from a PAYGO system to a fully-funded system can be welfare-improving for unborn generations, and that there may be tax-deferral policies for the transitional generations that can make all generations better off. A convincing argument may be made that a shift to full-funding can make all generations better off with appropriate transitional policies under the scenario of constant and positive population growth. However, these experiments do not tackle the major problem that nations are expected to face as the dependency burden of the elderly on the labour force increases. The PAYGO system faces the sustainability issue because of demographic change. How would a shift to a fully-funded system affect generations in the presence of demographic change? Tables 3 through 6 present the results of the simulation experiments for economies that experience demographic pressures similar to those currently experienced by many nations, in particular, a baby-boom followed by a baby-bust.

4.2 Open Economies with Demographic Change

Table 3 presents the results for an economy under the PAYGO system. Notice that generation 30 is worse off than preceding generations since they pay a higher premium rate in their second period of work, because the labour force growth rate has declined with the entry of generation 31 into the labour force. Generations 31 and 32 pay slightly higher premium rates in both work periods than generations in the first steady state. Generation 33 (the first baby-bust generation) pays a much higher premium rate in the second period of life as the baby-boom generation exits the labour force and receives pension benefits. All future generations pay pension premium rates under the PAYGO system of 10% of wages, which causes a lower level of utility in the second steady state than when compared to the first, when the population was growing. In the second steady state with no population growth, consumption in all three periods is lower than for generations in the first steady state with positive and constant population growth. The results also show that foreign capital dependency falls as the population growth rate slows. Savings of generations under no growth are much better able to fund capital requirements than when the labour force is growing.

Table 4 shows the results for the transition to a fully-funded pension system. Again, the pension system switch occurs when generation 32, the baby-boomers, enter the second period of work. Generation 32 is worse off under the switch to a fully-funded pension system than continuing under the PAYGO system because they now have to pay income taxes in the third period of life to finance interest payments on pension debt. The first and second baby-bust generations are better off with the switch than without since they pay lower pension contribution rates under the new system, that are more than enough to offset income taxes that are paid to service pension debt during their lifetimes. However, subsequent generations (35 and higher) are worse off with the switch to full-funding than under the PAYGO system because the negative effect of income taxes dominates the positive effects of lower pension contribution rates. Since the population does not grow, the economy settles into a steady state with an income tax rate of 6.3% to service interest payments on the pension debt in perpetuity.

4.3 Closed Economies with Demographic Change

Tables 5 and 6 present the results when a closed economy is subject to demographic change. In closed economies, generations are affected by changes in pension contribution rates and incomes taxes, as well as by changes in factor prices. The effect of the demographic transition on the model economy that retains the PAYGO pension system is shown in Table 5. Generation 28 experiences a small boost in utility due to higher interest rates in the final period of life (when $t = 30$). Conversely, generation 29 experiences a decline in welfare primarily due to much lower interest rates in their final period of life. Generation 30 receives a welfare improvement with higher wages in the second stage of life, and higher interest rates in the third period of life. Later generations experience declines in welfare compared to earlier generations (numbered less than 28) in the first steady state, primarily as the result of increasing pension contribution rates and declining rates of return on assets that are only partially offset by increases in wages. In the closed economy simulation, the demographic transition causes agents to consume more in the first period of life, and less in the last two periods of life, when compared to those agents living in the first steady state equilibrium.

The simulation results for the model economy with a shift to a fully-funded system during the demographic transition are presented in Table 6. The results for generations up to 30 are unchanged from Table 5. Generation 31 is worse off under the shift to a fully-funded plan because of the lower rate of return in the third period of life under the shift than under a PAYGO system. This is due to the increase in savings by baby-boomers in the first period of life with the shift. Generation 32 (the baby-boom generation) is also worse off with a pension system shift. Consumption is lower in all three periods for baby-boomers if the pension system shifts to a fully-funded system in their second period of life (when compared to a continuing PAYGO system). The negative effect of lower interest rates and higher pension contribution rates more than offsets the positive effect of higher wages for the baby-boom generation. Generations 33 and 34 are the winners from the transition policy investigated for this paper. They experience the positive effects of lower pension contribution rates that overshadow any effects from changing factor prices and debt servicing costs when compared to the scenario of maintaining a PAYGO system. Generations following generation 34 are worse off under a transition than maintaining the status quo because the negative effects of income taxation to service the pension debt burden are greater than any positive effects from lower pension contribution rates.

4.4 Discussion

To summarize the simulation results, it has been show that economies with constant and positive population growth can improve the welfare of unborn generations with a transition to a fully-funded pension system. Generations living during and immediately following the transition are generally adversely affected given the transitional policy simulated for this paper, but if future generations are much better off, it may be possible to develop transitional policies to compensate transitional generations and make all generations better off than under a PAYGO system. However, once demographic changes that reflect current demographic projections are included in the experiments, generations may be better off retaining the PAYGO structure than attempting to shift to a fully-funded pension system, because of the costs of servicing a debt-financed pension shift. No population growth means that the per capita costs of debt servicing will not decline in the future, and these costs overshadow the positive effects of lower contribution rates. A comparison of the open economy and closed economy results for transitional generations (in particular, the baby-boom and first baby-bust generations) reveals that agents in the closed economy experience larger reductions in welfare than their open economy counterparts because of changing factor prices during the demographic transition. However, future generations in closed economies are better off than their open economy counterparts since changing factor prices have buffering effects after the completion of the demographic transition.

The model economies investigated herein offer benefit rates that may appear low to readers. These benefit rates are intended to mirror replacement rates in Canada. In comparison, Social Security pays about twice the benefits to retirees in the US. Simulations with the benefit rate increased do not significantly alter the comparative results for model economies under a continued PAYGO system versus a shift to full-financing. However, when the replacement rate is too high (*br* = 0.4) in model economies, the incentive to privately save is lower, and the pension debt upon the switch to full-funding is so high, that there is not enough savings domestically to provide capital and also purchase the government bond issues for outstanding PAYGO obligations in closed economies.

The modeling results should be taken with some caution due to modeling simplifications. Most importantly, the model economies do not incorporate: (i) changes in life expectancies; (ii) improvements in technology or human capital; (iii) earnings heterogeneity and uncertainty; or (iv) lifetime uncertainty and bequests. Although these are limitations, their omission does allow a simple comparison of the changes in welfare across generations as a result of the fertility transition, and the proposed shift in pension policy, all else equal. The implications of these omissions are briefly noted below, and are left for a more thorough examination in future work.

First, the model economies do not incorporate changes in life expectancies. As a result, the ratio of retirees to workers and the PAYGO contribution rate are overstated for periods before time period 33 when the first baby-bust generation enters the workforce, as compared to actual Canadian population figures and projections up the year 2011 (see Figure 2). Similarly, the model economy PAYGO rate may be understated for future generations if life expectancies continue to rise. As a result, early generations in the model economies pay rates that are higher, and later generations may pay rates that are lower, than their real life counterparts. This would mean that the PAYGO pension burden is projected to be somewhat higher than in the model economies investigated herein. This is a consequence of the increasing ratio of retirement years to working years, as people live longer, and in some cases, work fewer years (earlier retirement and/or delayed entry into the workforce with more years of schooling). However, increasing life expectancies would require higher contribution rates for both the PAYGO and fully-funded pension plans if the retirement age is held constant.

Second, the model economies do not incorporate technological progress or increases in human capital. DeNardi, Imrohoroglou and Sargent (1999) incorporated annual technical progress of 1.6% in their projections for the US economy. For Canada over the 1981 to 2001 period, total factor productivity grew at an average annual rate of 1.0% (Abel et al, 2006: 58). However, earnings of workers were stagnant over this period (Statistics Canada CANSIM Table 202-0407), and low-wage earners who are most reliant on public pension systems faced declining real wages over this time. Incorporating technical progress into the model would lower the PAYGO pension contribution rate, since retiree benefits are based on their lifetime earnings, and contribution rates are based on workers' earnings which would be higher than those of their predecessors. In addition, generations would achieve higher levels of welfare than the preceding generation as a result of higher wages due to technological progress. Future generations would be better able to deal with higher contribution rates in the PAYGO system with demographic change, but would also be better able to deal with income taxes as a result of the shift to a fully-funded pension system. Since higher rates of population growth would make the shift to a fully-financed pension system more attractive than continuing a PAYGO system for future generations, so too would higher rates of technological progress. There may be threshold rates of growth in population and/or technological progress beyond which a switch to full-financing is welfare-improving, and below which economies should retain the PAYGO pension system.

Third, the model economies do not incorporate earnings heterogeneity and uncertainty. Since some PAYGO pension systems (including the Canada Pension Plan) have upper limits on total annual contributions and benefits, low earning agents would have high contribution and benefit rates as a proportion of wage earnings, and low levels of private wealth, while high earning agents would have low contribution and benefit rates as a proportion of wage earnings. Model economies with earnings heterogeneity would have agents with varying pension contribution and benefit rates. Incorporating earnings heterogeneity may not make a significant difference in the simulation results, since model economies without earnings heterogeneity, but with different pension contribution and benefit rates, yield similar results in both open and closed economies for PAYGO pensions versus a pension shift to full-funding.

Fourth, model economies do not include lifetime uncertainty and bequests. As a result, there is no transfer wealth across generations. Lifetime uncertainty alters the consumption and savings pattern of agents as they weigh the expected probability of being alive and needing to consume in the future against consuming in earlier periods. Bequests would increase the level of assets of inheritors and also alter their consumption patterns.

There have been many different reform options discussed by policymakers to alleviate the burden of the pension system for future generations. In Canada, following a review of CPP program in the mid-1990s, the legislated rate was steadily increased from 6.00% in 1997 to 9.90% in 2003 and held at that rate thereafter, in order to build up the CPP trust account and prevent future increases in the premium rate, given population projections into the middle of the twenty-first century. This policy change responds to three distinct issues. First, it alleviates the pension burden of the large baby-boom generation on future generations. Second, it strengthens the contribution-benefit linkage with individuals living longer lifetimes and receiving pension benefits longer than their predecessors. Third, this response is in line with the argument made by Sinn (2000). If the baby-boom generation and those that follow invest fewer resources into the next generation by raising fewer children than their predecessors, then these generations should be making higher contributions into their pensions while working. The savings made through lower child-rearing costs should be compensated by higher pension contributions in order to maintain their expected pension payout. If the model economies with a continuing PAYGO structure were subjected to early rises in contribution rates to pre-fund benefits, the baby-boom generation and the first baby-bust generation would suffer welfare losses due to higher contribution rates, to the benefit of future generations. Upon casual inspection of the modeling results in Tables 2 and 5, this may improve intergenerational equity in the open economy case, but exacerbate intergenerational inequity in the closed economy case, further harming the relative position of the baby-boom and the first baby-bust generation, relative to future generations. A more thorough analysis of this issue is also left for future work.

5. Conclusion

Many nations are facing the public pension sustainability issue as a result of the dramatic decline in fertility rates since the 1960s, and rising life expectancies. Contribution rates in the pay-as-you-go pension system will have to increase if other aspects of the system are not reformed. One popular reform option in policy circles is to shift to a fully-funded pension system. This paper has used an overlapping generations dynamic general equilibrium model to evaluate two competing reform options: raising contribution rates within the PAYGO structure, and shifting to a fully-funded system using debt-finance and income tax debt service. Simulation results suggest that, in model economies with population growth and no technological progress, a shift to a fully-funded pension system improves the welfare of future generations when compared to a sustained PAYGO structure as in Kotlikoff (1995, 1996) and Kotlikoff, Smetters and Walliser (1999). However, in model economies that experience a demographic transition to no population growth, and without technological progress, maintaining a PAYGO pension system is preferable to a switch to full-funding for future generations.

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Table 1: Simulation Results for the Open Economy Shift to a Fully-Funded Pension System with Constant Population Growth

Generation Or Time	**Relative Cohort Size**	$\overline{U}_i$	$c_{1,t}$	$c_{2,t+1}$	$c_{3,t+2}$	$p_{1,t}$	$p_{2,t+1}$	$b_{3,t+2}$	$a_{1,t}$	$a_{2,t+1}$	$K_{d,t} / K_t$	τ_t	w_t	R_t
26	0.1975	0.0000	0.2381	0.3271	0.4494	0.0538	0.0538	0.0746	0.0980	0.2142	0.8880	0.0000	0.3553	1.7500
27	0.2963	0.0000	0.2381	0.3271	0.4494	0.0538	0.0538	0.0746	0.0980	0.2142	0.8880	0.0000	0.3553	1.7500
28	0.4444	0.0000	0.2381	0.3271	0.4494	0.0538	0.0538	0.0746	0.0980	0.2142	0.8880	0.0000	0.3553	1.7500
29	0.6667	0.0000	0.2381	0.3271	0.4494	0.0538	0.0538	0.0746	0.0980	0.2142	0.8880	0.0000	0.3553	1.7500
30	1.0000	0.0000	0.2381	0.3271	0.4494	0.0538	0.0538	0.0746	0.0980	0.2142	0.8880	0.0000	0.3553	1.7500
31	1.5000	0.0000	0.2381	0.3271	0.4494	0.0538	0.0538	0.0746	0.0980	0.2142	0.8880	0.0000	0.3553	1.7500
32	2.2500	-0.0103	0.2365	0.3249	0.4506	0.0538	0.0571*	0.0746	0.0996	0.2178	0.8880	0.0000	0.3553	1.7500
33	**3.3750**	**-0.0037**	**0.2358**	**0.3270**	**0.4541**	**0.0421***	**0.0421***	**0.0746**	**0.1045**	**0.2203**	**0.8939**	**0.0000**	**0.3553**	**1.7500**
34	5.0625	-0.0357	0.2327	0.3231	0.4471	0.0421*	0.0421*	0.0746	0.1001	0.2151	0.9088	0.0220	0.3553	1.7500
35	7.5938	-0.0291	0.2340	0.3238	0.4469	0.0421*	0.0421*	0.0746	0.0978	0.2142	0.8667	0.0251	0.3553	1.7500
36	11.3906	-0.0098	0.2363	0.3262	0.4495	0.0421*	0.0421*	0.0746	0.0983	0.2152	0.8920	0.0167	0.3553	1.7500
37	17.0859	0.0030	0.2379	0.3278	0.4513	0.0421*	0.0421*	0.0746	0.0987	0.2159	0.9228	0.0112	0.3553	1.7500
38	25.6289	0.0115	0.2389	0.3289	0.4524	0.0421*	0.0421*	0.0746	0.0989	0.2163	0.9473	0.0074	0.3553	1.7500
39	38.4434	0.0171	0.2396	0.3296	0.4532	0.0421*	0.0421*	0.0746	0.0991	0.2166	0.9636	0.0050	0.3553	1.7500
40	57.6650	0.0209	0.2400	0.3301	0.4537	0.0421*	0.0421*	0.0746	0.0992	0.2168	0.9744	0.0033	0.3553	1.7500
41	86.4976	0.0234	0.2403	0.3304	0.4541	0.0421*	0.0421*	0.0746	0.0992	0.2170	0.9817	0.0022	0.3553	1.7500
42	129.7463	0.0251	0.2405	0.3306	0.4543	0.0421*	0.0421*	0.0746	0.0993	0.2170	0.9865	0.0015	0.3553	1.7500
43	194.6195	0.0262	0.2407	0.3307	0.4544	0.0421*	0.0421*	0.0746	0.0993	0.2171	0.9897	0.0010	0.3553	1.7500
44	291.9293	0.0269	0.2408	0.3308	0.4545	0.0421*	0.0421*	0.0746	0.0993	0.2171	0.9918	0.0007	0.3553	1.7500
45	437.8939	0.0274	0.2408	0.3309	0.4546	0.0421*	0.0421*	0.0746	0.0993	0.2172	0.9933	0.0004	0.3553	1.7500
46	656.8409	0.0277	0.2409	0.3309	0.4546	0.0421*	0.0421*	0.0746	0.0993	0.2172	0.9942	0.0003	0.3553	1.7500

Notes: The shift to full-funding occurs at time 33, when Generation 33 is in the first period of life. Pension contribution rates under the fully-funded system are denoted with *. $\overline{U}_i$ denotes the lifetime value of utility relative to the steady-state level, given Eq (8): $\overline{U}_i = U_i - U_{26}$. The ratio of debt to domestic wealth is 20.5% and 23.1% in periods 33 and 34 respectively.

Table 2: Simulation Results for the Closed Economy Shift to a Fully-Funded Pension System with Constant Population Growth

Generation Or Time	Relative Cohort Size	U_i^*	$c_{1,t}$	$c_{2,t+1}$	$c_{3,t+2}$	$p_{1,t}$	$p_{2,t+1}$	$b_{3,t+2}$	$a_{1,t}$	$a_{2,t+1}$	K_t / K_{t-1}	τ_t	w_t	R_t
26	0.1975	0.0000	0.2257	0.3279	0.4765	0.0538	0.0538	0.0725	0.1010	0.2183	1.5000	0.0000	0.3452	1.8509
27	0.2963	0.0000	0.2257	0.3279	0.4765	0.0538	0.0538	0.0725	0.1010	0.2183	1.5000	0.0000	0.3452	1.8509
28	0.4444	0.0000	0.2257	0.3279	0.4765	0.0538	0.0538	0.0725	0.1010	0.2183	1.5000	0.0000	0.3452	1.8509
29	0.6667	0.0000	0.2257	0.3279	0.4765	0.0538	0.0538	0.0725	0.1010	0.2183	1.5000	0.0000	0.3452	1.8509
30	1.0000	0.0000	0.2257	0.3279	0.4765	0.0538	0.0538	0.0725	0.1010	0.2183	1.5000	0.0000	0.3452	1.8509
31	1.5000	-0.0013	0.2257	0.3280	0.4754	0.0538	0.0538	0.0725	0.1009	0.2182	1.5000	0.0000	0.3452	1.8509
32	2.2500	-0.0135	0.2247	0.3256	0.4739	0.0538	0.0545*	0.0725	0.1020	0.2222	1.4999	0.0000	0.3452	1.8510
33	**3.3750**	**0.0088**	**0.2250**	**0.3274**	**0.4867**	**0.0383***	**0.0383***	**0.0727**	**0.1074**	**0.2256**	**1.5061**	**0.0000**	**0.3457**	**1.8465**
34	5.0625	-0.0272	0.2197	0.3266	0.4787	0.0382*	0.0382*	0.0725	0.1060	0.2220	1.5176	0.0238	0.3469	1.8338
35	7.5938	-0.0434	0.2209	0.3238	0.4671	0.0390*	0.0390*	0.0723	0.0999	0.2177	1.4529	0.0283	0.3436	1.8687
36	11.3906	-0.0218	0.2259	0.3258	0.4631	0.0398*	0.0398*	0.0727	0.0994	0.2174	1.5240	0.0186	0.3452	1.8512
37	17.0859	-0.0030	0.2302	0.3273	0.4603	0.0405*	0.0405*	0.0732	0.0991	0.2172	1.5329	0.0121	0.3475	1.8277
38	25.6289	0.0123	0.2336	0.3285	0.4587	0.0410*	0.0410*	0.0736	0.0992	0.2173	1.5333	0.0079	0.3498	1.8043
39	38.4434	0.0228	0.2359	0.3294	0.4577	0.0413*	0.0413*	0.0739	0.0993	0.2173	1.5239	0.0051	0.3514	1.7876
40	57.6650	0.0299	0.2374	0.3300	0.4570	0.0415*	0.0415*	0.0741	0.0994	0.2173	1.5166	0.0034	0.3526	1.7761
41	86.4976	0.0345	0.2385	0.3303	0.4566	0.0417*	0.0417*	0.0743	0.0994	0.2174	1.5111	0.0022	0.3534	1.7685
42	129.7463	0.0376	0.2392	0.3306	0.4563	0.0418*	0.0418*	0.0744	0.0994	0.2174	1.5074	0.0015	0.3539	1.7634
43	194.6195	0.0397	0.2396	0.3308	0.4561	0.0418*	0.0418*	0.0744	0.0995	0.2174	1.5049	0.0010	0.3542	1.7601
44	291.9293	0.0410	0.2399	0.3309	0.4560	0.0419*	0.0419*	0.0745	0.0995	0.2174	1.5032	0.0006	0.3545	1.7578
45	437.8939	0.0419	0.2401	0.3309	0.4559	0.0419*	0.0419*	0.0745	0.0995	0.2174	1.5021	0.0004	0.3546	1.7564
46	656.8409	0.0425	0.2403	0.3310	0.4558	0.0419*	0.0419*	0.0745	0.0995	0.2174	1.5014	0.0003	0.3547	1.7554

Notes: The shift to full-funding occurs at time 33, when Generation 33 is in the first period of life. Pension contribution rates under the fully-funded system are denoted with *. $\overline{U}_i$ denotes the lifetime value of utility relative to the steady-state level, given Eq (8): $\overline{U}_i = U_i - U_{26}$. The ratio of debt to the capital stock is 19.5% and 22.1% in periods 33 and 34 respectively.

Table 3: Simulation Results for the Open Economy under a PAYGO Pension with Demographic Change

Generation Or Time	**Relative Cohort Size**	U_i^*	$c_{1,t}$	$c_{2,t+1}$	$c_{3,t+2}$	$p_{1,t}$	$p_{2,t+1}$	$b_{3,t+2}$	$a_{1,t}$	$a_{2,t+1}$	$K_{d,t} / K_t$	τ_t	w_t	R_t
26	0.1975	0.0000	0.2381	0.3271	0.4494	0.0538	0.0538	0.0746	0.0980	0.2142	0.8880	0.0000	0.3553	1.7500
27	0.2963	0.0000	0.2381	0.3271	0.4494	0.0538	0.0538	0.0746	0.0980	0.2142	0.8880	0.0000	0.3553	1.7500
28	0.4444	0.0000	0.2381	0.3271	0.4494	0.0538	0.0538	0.0746	0.0980	0.2142	0.8880	0.0000	0.3553	1.7500
29	0.6667	0.0000	0.2381	0.3271	0.4494	0.0538	0.0538	0.0746	0.0980	0.2142	0.8880	0.0000	0.3553	1.7500
30	1.0000	-0.0031	0.2378	0.3267	0.4488	0.0538	0.0571	0.0746	0.0983	0.2138	0.8880	0.0000	0.3553	1.7500
31	1.3500	-0.0056	0.2376	0.3264	0.4483	0.0571	0.0546	0.0746	0.0974	0.2136	0.9436	0.0000	0.3553	1.7500
32	2.3625	-0.0042	0.2377	0.3266	0.4486	0.0546	0.0571	0.0746	0.0982	0.2137	0.8606	0.0000	0.3553	1.7500
33	2.3625	-0.0487	0.2334	0.3206	0.4404	0.0571	0.1000	0.0746	0.1016	0.2090	1.0055	0.0000	0.3553	1.7500
34	2.3625	-0.1148	0.2270	0.3119	0.4284	0.1000	0.1000	0.0746	0.0927	0.2022	1.4399	0.0000	0.3553	1.7500
35	2.3625	-0.1148	0.2270	0.3119	0.4284	0.1000	0.1000	0.0746	0.0927	0.2022	1.3778	0.0000	0.3553	1.7500
36	2.3625	-0.1148	0.2270	0.3119	0.4284	0.1000	0.1000	0.0746	0.0927	0.2022	1.3466	0.0000	0.3553	1.7500
37	2.3625	-0.1148	0.2270	0.3119	0.4284	0.1000	0.1000	0.0746	0.0927	0.2022	1.3466	0.0000	0.3553	1.7500
38	2.3625	-0.1148	0.2270	0.3119	0.4284	0.1000	0.1000	0.0746	0.0927	0.2022	1.3466	0.0000	0.3553	1.7500
39	2.3625	-0.1148	0.2270	0.3119	0.4284	0.1000	0.1000	0.0746	0.0927	0.2022	1.3466	0.0000	0.3553	1.7500
40	2.3625	-0.1148	0.2270	0.3119	0.4284	0.1000	0.1000	0.0746	0.0927	0.2022	1.3466	0.0000	0.3553	1.7500
41	2.3625	-0.1148	0.2270	0.3119	0.4284	0.1000	0.1000	0.0746	0.0927	0.2022	1.3466	0.0000	0.3553	1.7500
42	2.3625	-0.1148	0.2270	0.3119	0.4284	0.1000	0.1000	0.0746	0.0927	0.2022	1.3466	0.0000	0.3553	1.7500
43	2.3625	-0.1148	0.2270	0.3119	0.4284	0.1000	0.1000	0.0746	0.0927	0.2022	1.3466	0.0000	0.3553	1.7500
44	2.3625	-0.1148	0.2270	0.3119	0.4284	0.1000	0.1000	0.0746	0.0927	0.2022	1.3466	0.0000	0.3553	1.7500
45	2.3625	-0.1148	0.2270	0.3119	0.4284	0.1000	0.1000	0.0746	0.0927	0.2022	1.3466	0.0000	0.3553	1.7500
46	2.3625	-0.1148	0.2270	0.3119	0.4284	0.1000	0.1000	0.0746	0.0927	0.2022	1.3466	0.0000	0.3553	1.7500

Note: $\overline{U}_i$ denotes the lifetime value of utility relative to the steady-state level, given Eq (8): $\overline{U}_i = U_i - U_{26}$.

Table 4: Simulation Results for the Open Economy Shift to a Fully-Funded Pension with Demographic Change

Generation Or Time	Relative Cohort Size	U_i^*	$c_{1,t}$	$c_{2,t+1}$	$c_{3,t+2}$	$p_{1,t}$	$p_{2,t+1}$	$b_{3,t+2}$	$a_{1,t}$	$a_{2,t+1}$	$K_{d,t} / K_t$	τ_t	w_t	R_t
26	0.1975	0.0000	0.2381	0.3271	0.4494	0.0538	0.0538	0.0746	0.0980	0.2142	0.8880	0.0000	0.3553	1.7500
27	0.2963	0.0000	0.2381	0.3271	0.4494	0.0538	0.0538	0.0746	0.0980	0.2142	0.8880	0.0000	0.3553	1.7500
28	0.4444	0.0000	0.2381	0.3271	0.4494	0.0538	0.0538	0.0746	0.0980	0.2142	0.8880	0.0000	0.3553	1.7500
29	0.6667	0.0000	0.2381	0.3271	0.4494	0.0538	0.0538	0.0746	0.0980	0.2142	0.8880	0.0000	0.3553	1.7500
30	1.0000	-0.0031	0.2378	0.3267	0.4488	0.0538	0.0571	0.0746	0.0983	0.2138	0.8880	0.0000	0.3553	1.7500
31	1.3500	-0.0056	0.2376	0.3264	0.4483	0.0571	0.0546	0.0746	0.0974	0.2136	0.9436	0.0000	0.3553	1.7500
32	2.3625	-0.0155	0.2357	0.3238	0.4514	0.0546	0.0571*	0.0746	0.1002	0.2200	0.8606	0.0000	0.3553	1.7500
33	**2.3625**	**-0.0305**	**0.2315**	**0.3228**	**0.4553**	**0.0421***	**0.0421***	**0.0746**	**0.1088**	**0.2263**	**1.0146**	**0.0000**	**0.3553**	**1.7500**
34	2.3625	-0.1126	0.2222	0.3135	0.4422	0.0421*	0.0421*	0.0746	0.1065	0.2186	1.4767	0.0343	0.3553	1.7500
35	2.3625	-0.1547	0.2183	0.3080	0.4345	0.0421*	0.0421*	0.0746	0.1006	0.2141	1.3060	0.0628	0.3553	1.7500
36	2.3625	-0.1547	0.2183	0.3080	0.4345	0.0421*	0.0421*	0.0746	0.1006	0.2141	1.2442	0.0628	0.3553	1.7500
37	2.3625	-0.1547	0.2183	0.3080	0.4345	0.0421*	0.0421*	0.0746	0.1006	0.2141	1.2236	0.0628	0.3553	1.7500
38	2.3625	-0.1547	0.2183	0.3080	0.4345	0.0421*	0.0421*	0.0746	0.1006	0.2141	1.2236	0.0628	0.3553	1.7500
39	2.3625	-0.1547	0.2183	0.3080	0.4345	0.0421*	0.0421*	0.0746	0.1006	0.2141	1.2236	0.0628	0.3553	1.7500
40	2.3625	-0.1547	0.2183	0.3080	0.4345	0.0421*	0.0421*	0.0746	0.1006	0.2141	1.2236	0.0628	0.3553	1.7500
41	2.3625	-0.1547	0.2183	0.3080	0.4345	0.0421*	0.0421*	0.0746	0.1006	0.2141	1.2236	0.0628	0.3553	1.7500
42	2.3625	-0.1547	0.2183	0.3080	0.4345	0.0421*	0.0421*	0.0746	0.1006	0.2141	1.2236	0.0628	0.3553	1.7500
43	2.3625	-0.1547	0.2183	0.3080	0.4345	0.0421*	0.0421*	0.0746	0.1006	0.2141	1.2236	0.0628	0.3553	1.7500
44	2.3625	-0.1547	0.2183	0.3080	0.4345	0.0421*	0.0421*	0.0746	0.1006	0.2141	1.2236	0.0628	0.3553	1.7500
45	2.3625	-0.1547	0.2183	0.3080	0.4345	0.0421*	0.0421*	0.0746	0.1006	0.2141	1.2236	0.0628	0.3553	1.7500
46	2.3625	-0.1547	0.2183	0.3080	0.4345	0.0421*	0.0421*	0.0746	0.1006	0.2141	1.2236	0.0628	0.3553	1.7500

Notes: The shift to full-funding occurs at time 33, when Generation 33 is in the first period of life. Pension contribution rates under the fully-funded system are denoted with *. $\overline{U}_i$ denotes the lifetime value of utility relative to the steady-state level, given Eq (8): $\overline{U}_i = U_i - U_{26}$. The ratio of debt to domestic wealth is 19.2% and 24.2% in periods 33 and 34 respectively.

Table 5: Simulation Results for the Closed Economy under a PAYGO Pension with Demographic Change

Generation Or Time	Relative Cohort Size	U_i^*	$c_{1,t}$	$c_{2,t+1}$	$c_{3,t+2}$	$p_{1,t}$	$p_{2,t+1}$	$b_{3,t+2}$	$a_{1,t}$	$a_{2,t+1}$	K_t / K_{t-1}	τ_t	w_t	R_t
26	0.1975	0.0000	0.2257	0.3279	0.4765	0.0538	0.0538	0.0725	0.1010	0.2183	1.5000	0.0000	0.3452	1.8509
27	0.2963	0.0000	0.2257	0.3279	0.4765	0.0538	0.0538	0.0725	0.1010	0.2183	1.5000	0.0000	0.3452	1.8509
28	0.4444	0.0002	0.2257	0.3279	0.4767	0.0538	0.0538	0.0725	0.1010	0.2183	1.5000	0.0000	0.3452	1.8509
29	0.6667	-0.0136	0.2259	0.3283	0.4648	0.0538	0.0539	0.0725	0.1008	0.2175	1.5000	0.0000	0.3452	1.8509
30	1.0000	0.0053	0.2289	0.3240	0.4772	0.0539	0.0564	0.0730	0.0977	0.2154	1.4990	0.0000	0.3452	1.8517
31	1.3500	-0.0108	0.2257	0.3325	0.4600	0.0564	0.0553	0.0727	0.1044	0.2197	1.4784	0.0000	0.3499	1.8033
32	2.3625	-0.1134	0.2331	0.3226	0.3840	0.0553	0.0559	0.0732	0.0907	0.2050	1.4681	0.0000	0.3429	1.8764
33	2.3625	-0.0734	0.2582	0.3074	0.3693	0.0559	0.0911	0.0775	0.0760	0.1906	1.4340	0.0000	0.3540	1.7627
34	2.3625	-0.0256	0.2622	0.3150	0.3772	0.0911	0.0969	0.0802	0.0858	0.1947	1.2988	0.0000	0.3828	1.5164
35	2.3625	-0.0418	0.2607	0.3122	0.3751	0.0969	0.1001	0.0801	0.0833	0.1927	0.9838	0.0000	0.3810	1.5305
36	2.3625	-0.0445	0.2599	0.3122	0.3753	0.1001	0.1001	0.0801	0.0836	0.1928	1.0060	0.0000	0.3817	1.5253
37	2.3625	-0.0471	0.2595	0.3119	0.3751	0.1001	0.1001	0.0800	0.0833	0.1927	0.9939	0.0000	0.3810	1.5307
38	2.3625	-0.0474	0.2594	0.3119	0.3751	0.1001	0.1000	0.0800	0.0833	0.1927	0.9992	0.0000	0.3809	1.5313
39	2.3625	-0.0475	0.2594	0.3119	0.3751	0.1000	0.1000	0.0800	0.0833	0.1927	0.9994	0.0000	0.3808	1.5318
40	2.3625	-0.0475	0.2594	0.3119	0.3751	0.1000	0.1000	0.0800	0.0833	0.1927	1.0000	0.0000	0.3808	1.5318
41	2.3625	-0.0475	0.2594	0.3119	0.3751	0.1000	0.1000	0.0800	0.0833	0.1927	1.0000	0.0000	0.3808	1.5319
42	2.3625	-0.0475	0.2594	0.3119	0.3751	0.1000	0.1000	0.0800	0.0833	0.1927	1.0000	0.0000	0.3808	1.5318
43	2.3625	-0.0475	0.2594	0.3119	0.3751	0.1000	0.1000	0.0800	0.0833	0.1927	1.0000	0.0000	0.3808	1.5318
44	2.3625	-0.0475	0.2594	0.3119	0.3751	0.1000	0.1000	0.0800	0.0833	0.1927	1.0000	0.0000	0.3808	1.5318
45	2.3625	-0.0475	0.2594	0.3119	0.3751	0.1000	0.1000	0.0800	0.0833	0.1927	1.0000	0.0000	0.3808	1.5318
46	2.3625	-0.0475	0.2594	0.3119	0.3751	0.1000	0.1000	0.0800	0.0833	0.1927	1.0000	0.0000	0.3808	1.5318

Note: $\overline{U}_i$ denotes the lifetime value of utility relative to the steady-state level, given Eq (8): $\overline{U}_i = U_i - U_{26}$.

Table 6: Simulation Results for the Closed Economy Shift to a Fully-Funded Pension with Demographic Change

Generation Or Time	**Relative Cohort Size**	U_i^*	$c_{1,t}$	$c_{2,t+1}$	$c_{3,t+2}$	$p_{1,t}$	$p_{2,t+1}$	$b_{3,t+2}$	$a_{1,t}$	$a_{2,t+1}$	K_t / K_{t-1}	τ_t	w_t	R_t
26	0.1975	0.0000	0.2257	0.3279	0.4765	0.0538	0.0538	0.0725	0.1010	0.2183	1.5000	0.0000	0.3452	1.8509
27	0.2963	0.0000	0.2257	0.3279	0.4765	0.0538	0.0538	0.0725	0.1010	0.2183	1.5000	0.0000	0.3452	1.8509
28	0.4444	0.0002	0.2257	0.3279	0.4767	0.0538	0.0538	0.0725	0.1010	0.2183	1.5000	0.0000	0.3452	1.8509
29	0.6667	-0.0136	0.2259	0.3283	0.4648	0.0538	0.0539	0.0725	0.1008	0.2175	1.5000	0.0000	0.3452	1.8509
30	1.0000	0.0053	0.2289	0.3240	0.4772	0.0539	0.0564	0.0730	0.0977	0.2154	1.4990	0.0000	0.3452	1.8517
31	1.3500	-0.0126	0.2257	0.3325	0.4585	0.0564	0.0553	0.0727	0.1044	0.2196	1.4784	0.0000	0.3499	1.8033
32	2.3625	-0.1347	0.2318	0.3196	0.3791	0.0553	0.0666*	0.0733	0.0921	0.2063	1.4680	0.0000	0.3429	1.8765
33	**2.3625**	**-0.0477**	**0.2591**	**0.3073**	**0.3829**	**0.0521***	**0.0521***	**0.0778**	**0.0770**	**0.2004**	**1.4428**	**0.0000**	**0.3546**	**1.7565**
34	2.3625	0.0081	0.2576	0.3210	0.4004	0.0503*	0.0503*	0.0799	0.1003	0.2102	1.3154	0.0212	0.3850	1.5005
35	2.3625	-0.0479	0.2509	0.3130	0.3940	0.0499*	0.0499*	0.0791	0.0917	0.2050	0.9303	0.0428	0.3767	1.5632
36	2.3625	-0.0506	0.2492	0.3137	0.3953	0.0496*	0.0496*	0.0789	0.0933	0.2058	0.9979	0.0428	0.3765	1.5651
37	2.3625	-0.0580	0.2482	0.3128	0.3946	0.0496*	0.0496*	0.0787	0.0924	0.2053	0.9854	0.0439	0.3748	1.5783
38	2.3625	-0.0590	0.2480	0.3128	0.3947	0.0495*	0.0495*	0.0787	0.0925	0.2053	0.9984	0.0440	0.3747	1.5797
39	2.3625	-0.0600	0.2478	0.3127	0.3947	0.0495*	0.0495*	0.0786	0.0924	0.2053	0.9981	0.0441	0.3745	1.5815
40	2.3625	-0.0602	0.2478	0.3127	0.3947	0.0495*	0.0495*	0.0786	0.0924	0.2053	0.9996	0.0441	0.3744	1.5818
41	2.3625	-0.0604	0.2477	0.3127	0.3946	0.0495*	0.0495*	0.0786	0.0924	0.2053	0.9997	0.0442	0.3744	1.5820
42	2.3625	-0.0604	0.2477	0.3127	0.3946	0.0495*	0.0495*	0.0786	0.0924	0.2053	0.9999	0.0442	0.3744	1.5821
43	2.3625	-0.0604	0.2477	0.3127	0.3946	0.0495*	0.0495*	0.0786	0.0924	0.2053	1.0000	0.0442	0.3744	1.5821
44	2.3625	-0.0604	0.2477	0.3127	0.3946	0.0495*	0.0495*	0.0786	0.0924	0.2053	1.0000	0.0442	0.3744	1.5821
45	2.3625	-0.0604	0.2477	0.3127	0.3946	0.0495*	0.0495*	0.0786	0.0924	0.2053	1.0000	0.0442	0.3744	1.5821
46	2.3625	-0.0604	0.2477	0.3127	0.3946	0.0495*	0.0495*	0.0786	0.0924	0.2053	1.0000	0.0442	0.3744	1.5821

Notes: The shift to full-funding occurs at time 33, when Generation 33 is in the first period of life. Pension contribution rates under the fully-funded system are denoted with *. $\overline{U}_i$ denotes the lifetime value of utility relative to the steady-state level, given Eq (8): $\overline{U}_i = U_i - U_{26}$. The ratio of debt to capital stock is 19.1% and 26.5% in periods 33 and 34 respectively.

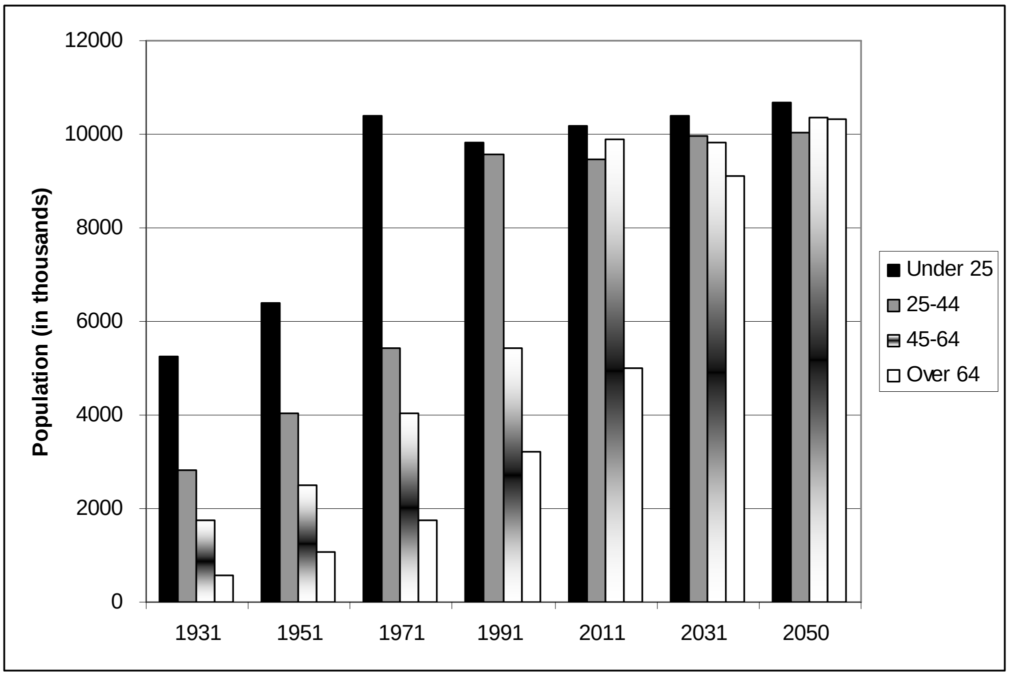

Figure 1: Canadian Population by Age-Groups, Selected Census Years
Sources: Statistic Canada CANSIM Tables 075-0013, 051-0001, and US Census Bureau, International Data Base projections.

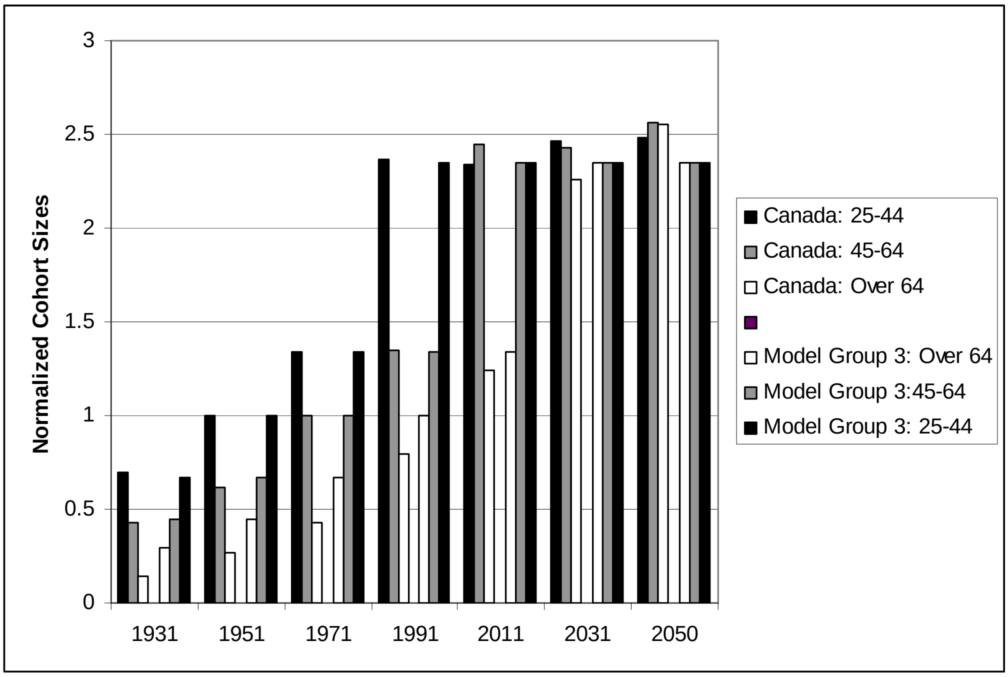

Figure 2: Comparison of Calibrated Population Shares and Canadian Population Shares

Note: All cohort sizes are relative to the size of the 25-44 age cohort in 1951.