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The Dynamic Fiscal Effects of Demographic Shift: The Case of Australia

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The Case of Australia*

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Abstract

In this paper, we develop a small open economy, overlapping generations model that incorporates non-stationary demographic transition paths to study the dynamic fiscal effects of demographic shift in Australia. Our main results are summarised as follows. *First*, the demographic shifts towards population ageing lead to a change in the tax base from labor income to capital/asset income and consumption. The effect on income tax revenue is non-linear along the transition paths. *Second*, the changes in demographic structure cause substantial increases in old-age related spending programs including health, aged care and pensions. Significant adjustments in other government expenditures and taxes will be required to finance the larger old-age related benefits in the future. In particular, the government will have to either cut other expenditures by around 32 percent or increase consumption taxes by 28 percent by 2050 to finance these benefits. *Third*, the increase in survival rates, rather than the decline in fertility rates, is the main driving factor behind these fiscal costs. *Fourth*, increases in fertility and immigration are not effective solutions to such budget challenges.

Keywords: Demographic Transition, Ageing, Overlapping Generations, Dynamic General Equilibrium, Fiscal Policy

JEL Classification: H2, J1, C68

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1 Introduction

Australia, like most other developed countries, has an ageing population, which is attributed to falling mortality and, especially, fertility rates in the past. Projected mortality improvements in the next few decades imply further ageing of Australia's population, which is also expected to increase due mainly to net migration inflows. Such fundamental demographic changes will have potentially vast macroeconomic implications and place increasing demands on government spending in the form of old-age related benefits. Fiscal reform will inevitably form part of the overall policy response to demographic change, but formulating an optimal policy response requires a solid understanding of how the evolution of such demographic factors affects individual behavior, market equilibrium, macroeconomic aggregates and government budget operations. In this paper, we study the economic effects of the dynamic evolution of the demographic structure for the Australia economy. Our main goals are to quantify the fiscal challenge caused by demographic shift and to isolate the quantitative importance of each demographic factor.

To that end, we develop a small open economy version of computable overlapping generations (OLG) models that were pioneered by Auerbach and Kotlikoff (1987). This class of models has been used by many researchers worldwide to analyse the economic effects of population ageing – see, for example, Fehr (2000), Nishiyama (2004), Kotlikoff *et al.* (2007), Fehr *et al.* (2008) and Braun and Joines (2014). The model we use for our analysis is an extension of the small open economy, OLG model for Australia that was developed by Kudrna and Woodland (2011). Their model consists of overlapping generations of households and production, government and foreign sectors and incorporates the essential features of the Australian taxation and income retirement systems, including the means tested age pension.

There are two fundamental extensions made here. First, their model is extended to incorporate non-stationary demographic paths consistent with the expected ageing of the Australian population via a demographic model. Specifically, we use the Australian Productivity Commission's MoDEM 2.0 assumptions about future fertility, mortality and net immigration rates to create a range of demographic projections for the Australian population over the next 100 years from our demographic model.[1] We then use these non-stationary demographic paths in our simulations of the economic model. Second, in order to better focus on the fiscal implications of such demographic shift, we extend the specification of the OLG model by incorporating a detailed disaggregation of age-related government expenditures. As a result, our model allows us to simulate the differential impacts of population ageing on such age-related expenditures as education, health care,

[1] See Cuxson *et al.* (2008) for detailed documentation of MoDEM 2.0.

family benefits and age care as well as the publicly provided age pension.

We apply our model to quantify the economic effects of demographic shift in Australia, focusing on the fiscal implications. Demographic shift in Australia increases the proportion of the elderly in the population and decreases the population shares of working cohorts. These changes in the population age distribution alter the general equilibria over a long period of time and our model provides the platform for simulating these changes. Our approach is to maintain assumptions about the policy environment and the structure of the economic model over the simulation period. This enables us to focus solely on the endogenous impact of the exogenous projected changes in the demographic structure of the population on the general equilibrium for the economy and behaviour of households, firms and governments.

Our simulation results provide conclusions regarding a range of outcomes. First, demographic shift in Australia affects various macroeconomic variables. Changes in the population age distribution towards older ages negatively impact labour supply and output but increase assets and consumption, all in per capita terms. We find that per capita GDP decreases 6.2 percent by 2050 as a result of the future demographic shift. This contraction reduces investment opportunities in the domestic economy and leads to increased capital outflows. Second, demographic shift affects the fiscal position of the government over time, with significant changes in the tax base. Tax revenues move in favour of asset incomes and consumption and away from labour earnings.

Third, the projected larger proportion of older Australians leads to significant expansions in old-age related government expenditure programs. Our simulation results indicate that the percentage increases in the sizes of health care, aged care and pension programs by 2050 are 24.5, 125.9 and 62.7 percent, respectively, creating a fiscal challenge. In order to finance such substantial increases in age related benefits, the government will have to cut non-age related expenditures and/or increase taxes substantially during the demographic transition. Specifically, we find that a 32 percent cut in non-age related expenditures or a 28 percent increase in the consumption tax rate is required for the government budget to be balanced in 2050.[2]

Fourth, we quantify the relative importance of the increase in longevity vs. the decline in fertility embodied in the demographic change. Our decomposition results indicate that the main driving force behind the increased fiscal costs is the increase in survival rates rather than the decline in fertility rates. Furthermore, our results lead to the conclusion

[2]In interpreting these results, note that we assume away non-demographic factors (e.g., medical progress) and policy changes that are to be implemented in near future (e.g., increases in the superannuation contribution rate and in the age pension age) that may have significant implications for economic aggregates.

that higher fertility and increased immigration are not effective solutions to deal with the increasing fiscal burden of old-age related government spending programs, since their fiscal effects are estimated to be rather small.

Our paper is related, and makes contributions, to several strands of the literature on population ageing. First, our paper is related to a growing literature analysing the fiscal effects of population ageing in advanced economies, such as Nishiyama (2013) for the US and Imrohoroglu *et al.* (2013) and Braun and Joines (2014) for Japan.[3] Our paper extends these studies to the context of a small open economy with the focus on Australia that has quite different taxation and retirement income systems from those in the United States and other OECD countries.[4] Moreover, our model is distinguished from these papers by incorporating a broader range of age-related programs including education, health care, family benefits, age pension, and aged care. This permits considerable variation in government outlays in our simulations, and we demonstrate that population ageing results in quite different fiscal effects across age-related programs. We highlight the pressing problems associated with health care and aged care programs and show that ageing causes an adverse effect on public education expenditure.

Second, our paper is connected to the strand of literature that examines the implications of demographic change by its source, including fertility and survival rate changes. The macroeconomic effects of improved survival rates and longevity are analysed, for example, by Kotlikoff (1989), Fehr *et al.* (2008), Kulish *et al.* (2010) and Zhang and Zhang (2005) using general equilibrium models. While Bloom *et al.* (2003) provide empirical evidence that lifespan extension should induce higher labour supply, delayed retirement and greater saving, the ageing effect on capital deepening is simulated to be subdued because of the increased tax and social security contribution rates required to balance government budgets (Auerbach and Kotlikoff, 1987, Miles, 1999, and Fehr, 2000), with Kotlikoff *et al.* (2007) and Fehr *et al.* (2008) even finding capital shallowing. The effects of fertility changes on the government budget, savings, living standards and growth rates has been analysed by a number of researchers, with the findings being inconclusive. Guest and McDonald (2000, 2002) and Guest (2006) find that greater social expenditures by the

[3]Fiscal effects are not the only aspect of interest in macroeconomic studies of population ageing. For example, Abel (2003) and Poterba (2004) use such models to examine impacts upon rates of return to assets, while Brooks (2002) and Borsch-Supan *et al.* (2006) are concerned with asset allocation and impacts on international capital flows.

[4]First, there is no specific labour income tax on the workers' side in Australia; labour income is taxed together with asset income under the progressive personal income taxation. Second, the first pillar of Australia's retirement income policy is the age pension, which is means tested and financed through general taxation revenues. Third, there is no publicly provided earnings-related retirement income scheme such as the US social security system. The second pension pillar in Australia is a privately managed superannuation guarantee scheme that is compulsory and fully funded by employer contributions. The taxation and retirement income systems are discussed in more detail in the model and calibration sections.

Australian Government arising from low fertility rates would not occur until after 2040, with minimal increases in taxation, and higher future living standards. On the other hand, simulations of lower fertility rates in Europe and Japan by Fehr *et al.* (2008) result in lower labour supply and generate significant increases in social security tax rates. Our main contribution to this strand of literature is to decompose the dynamic fiscal effect of population ageing by these two sources of ageing – increased longevity and lower fertility. By doing so, we are able to determine their relative importance in the Australian context. Our simulation results show that changes in survival rates (longevity) are the main driving force behind such a pressing fiscal challenge, with fertility changes being of secondary importance.

Third, we contribute to the literature on the role of immigration. Higher immigration of young and skilled workers is often seen as a way to mitigate the negative economic effects of population ageing on the government budget. This view is supported by Guest and McDonald (2000, 2001), who show that the fiscal and economic effects of higher net immigration are positive for a small open economy like Australia. However, Fehr *et al.* (2004) show that the effects of higher immigration are far less significant for a large economy such as the United States; even a significant increase in skilled immigration will do little to alter capital shortages, tax hikes and wage falls caused by population ageing. Our paper contributes to this strand of literature by considering the role of immigration in mitigating the negative fiscal effects of ageing for Australia. Our results lead to the conclusion that an increase in immigration is not an effective long-run solution to the population aging problem.

Finally, we contribute directly to the literature analysing the economic and fiscal effects of population ageing in Australia. Guest and McDonald (2001, 2002) and Guest (2006) used a Ramsey model with no inter-generational heterogeneity among households, while Kulish *et al.* (2010) abstract from the fiscal effects of demographic change, which are the focus of our paper. The core models for fiscal projections and policy analyses by the Federal Treasury (Australian Government, 2010) and the Productivity Commission (Productivity Commission, 2005 and 2013) are micro-simulation models, which abstract from behavioral responses. Accordingly, we provide an alternative analytical tool for policy analysis in Australia comprising a large-scale life-cycle, general equilibrium model that incorporates behavioural responses by agents, essentials of the tax and retirement systems and a government fiscal constraint. We demonstrate that there are significant projection errors when abstracting from modelling behavioural responses of households.

The rest of the paper is organised as follows. In the next section, we provide a description of our general equilibrium OLG model. Section 3 reports on the calibration and presents the resulting parameter values. The economic and fiscal effects of the baseline demographic transition are dealt with in Section 4. Section 5 isolates the role of demographic factors and examines the implications of higher fertility and immigration. Section 6 is devoted to a sensitivity analysis of alternative ageing scenarios as well as several modifications of the model. Section 7 offers some concluding remarks.

2 Model

The small open economy model that we apply to analyse the implications of demographic shift in Australia builds on Kudrna and Woodland (2011) and extends this study by incorporating a richer fiscal structure and non-stationary demographic paths. The model features inter-temporal general equilibrium with overlapping generations that allows for life-cycle saving, consumption and labour supply responses of households to a projected demographic change as well as to numerically evaluate macroeconomic and fiscal implications. The model comprises (i) a household sector populated with overlapping generations of utility maximising households, (ii) a production sector with profit maximising firms, (iii) a government sector described by a balanced public budget, and (iv) a foreign sector with an international budget constraint.

The fiscal structure and retirement income policy are modeled to closely correspond with the actual policy settings in Australia. Taxes imposed on households and firms generate revenues for the government, which are used to fund public expenditures, including age-related spending on education, health and aged care, pension and family benefits. The model also incorporates the major aspects of the two publicly-stipulated pillars of Australia's retirement income policy – the means tested age pension and fully funded mandatory superannuation.

In this section, a brief algebraic description of the demographic model is provided, followed by a description of each of the sectors of our economic model.

2.1 Population dynamics

The model economy is populated by overlapping generations of households. In every time period t, there are 101 generations aged 0 to 100 years, but we assume that only adult households aged 21 years and over ($a = 21, .., 100$) make economic decisions. Denoting $N_{a,t}$ as the size of a cohort of age a in time t, the total population is a sum of all cohorts alive in period t and so given by $P_t = \sum_{a=0}^{100} N_{a,t}$. The cohort share of the entire population at any point in time t is given by $\mu_{a,t} = \frac{N_{a,t}}{P_t}$.

The population dynamics in our model are driven by the sex-specific and age-dependent fertility, mortality and immigration rates. Even though we do not formally distinguish between sexes, we model the influences of sex-related factors on the dynamics of population ageing. That is, we assume that a cohort of age a in time t consists of male individuals $\left(N_{a,t}^{m}\right)$ and female individuals $\left(N_{a,t}^{f}\right)$, so that $N_{a,t} = N_{a,t}^{m} + N_{a,t}^{f}$. The size of each gender-specific cohort evolves over time. In each year t, the number of persons of gender g $(g = m, f)$ at age a, $N_{a,t}^{g}$, is recursively given by

$$N_{a,t}^{g} = \begin{cases} \left(1 - d_{a,t}^{g}\right) \cdot N_{a-1,t-1}^{g} + M_{a,t}^{g}, & \text{for } a > 0, \\ \omega^{g} \sum\limits_{a=15}^{49} N_{a,t}^{f} f_{a,t}, & \text{for } a = 0, \end{cases}$$

where the term $\left(1 - d_{a,t}^{g}\right) \cdot N_{a-1,t-1}^{g}$ denotes the last year's survivors, $d_{a,t}^{g}$ is the sex-specific mortality rate and $M_{a,t}^{g}$ denotes the number of net immigrants at age a in year t. The number of newborn males and females, $N_{0,t}^{g}$, is a function of age-specific fertility rates $f_{a,t}$ of females aged between 15 and 49 years in year t, with the terms ω^{m} and ω^{f} defining the birth shares of male and female newborns.[5]

The population dynamics depend on the evolution of age-specific fertility, mortality and net immigration rates. The assumptions for these vital rates and the constructed demographic scenarios are discussed in detail in the next section on calibration.

2.2 Households

The economic decisions made by adult households follow the lifecycle theory of consumption and saving. In particular, households optimally choose paths of their consumption, c, and leisure, l, at each age $(a = 21, .., 100)$ given their preferences, time and budget constraints. The timing of full retirement from workforce is also endogenous in our framework. Preferences are represented by the inter-temporal utility function, which is given for a generation who begins economic life at date t by

$$U_{t} = \frac{1}{1 - 1/\gamma} \sum_{a=21}^{100} S_{a,i} \left(1 + \beta\right)^{21-a} \left[\left(c_{a,i}\right)^{(1-1/\rho)} + \alpha_{a} \left(l_{a,i}\right)^{(1-1/\rho)}\right]^{\frac{1-1/\gamma}{1-1/\rho}}, \qquad (1)$$

where the subscript i is defined as $i = a + t - 21$. The parameters include the inter-temporal elasticity of substitution, γ, the intra-temporal elasticity of substitution, ρ, the leisure distribution parameter, α_{a}, and the rate of time preference, β. The term $S_{a,i}$

[5] This description of the population dynamics is based on Fehr and Habermann (2006). Similarly to Kotlikoff *et al.* (2007) and Fehr and Habermann (2006), our economic model does not distinguish between immigrants and the native population on the household side, meaning that the economic behaviour of immigrants is exactly the same as that of native-born households.

denotes unconditional survival probabilities.

The expected lifetime utility function is maximised subject to a lifetime budget constraint that can be expressed as period by period asset accumulations

$$
\begin{aligned}
A_{a,t} - A_{a-1,t-1} &= rA_{a-1,t-1} + w_t e_a(1 - l_{a,t}) + AP_{a,t} + SA_{60,t} + SP_{a,t} \\
&\quad + FB_{a,t} + B_t - T(y_{a,t}) - (1 + \tau^c)\, c_{a,t}. \qquad (2)
\end{aligned}
$$

The left-hand side of Equation (2) denotes household saving, which equals the sum of interest income, $rA_{a-1,t-1}$, labour earnings, $w_t e_a(1 - l_{a,t})$, age pension, $AP_{a,t}$, superannuation payouts, $SA_{60,t}$ and $SP_{a,t}$, family benefits, $FB_{a,t}$, and bequest receipts, B_t, minus the sum of income taxes, $T(y_{a,t})$, and consumption expenditures, $(1 + \tau^c)\, c_{a,t}$. Labour earnings are the product of labour supply, $1 - l_{a,t}$, and the hourly wage, $w_t e_a$, where w_t is the market wage rate and e_a is the age-specific earnings ability variable. The labour supply is required to be non-negative, $1 - l_{a,t} \geq 0$, which implies that leisure, $l_{a,t}$, cannot exceed available time endowment, which is normalised to one; when $l_{a,t} = 1$, the household does not work. Households pay the consumption tax at the rate of τ^c and the progressive income tax from their taxable income, $y_{a,t} = rA_{a-1,t-1} + w_t e_a(1 - l_{a,t}) + AP_{a,t}$, that comprises interest income, labour earnings and the age pension.[6] There are no annuity markets, with the assets of those who die being equally redistributed as accidental bequests, B_t, to all surviving adults. We follow Gokhale *et al.* (2001) by abstracting from any bequest motives.

The Australian age pension, $AP_{a,t}$, is means tested, that is, the pension is paid to households of age pension age ($a \geq 65$) only if they satisfy the following income test.[7] Let p denote the maximum age pension that the government is committed to pay to pensioners provided that their assessable income does not exceed the income threshold, IT_1. The maximum pension, p, is then reduced at the income taper rate, θ, for every dollar of assessable income above IT_1. Algebraically, the age pension benefit can be written as

$$
AP_{a,t} = \begin{cases} p & \text{if } \widehat{y}_{a,t} \leq IT_1 \\ p - \theta\left(\widehat{y}_{a,t} - IT_1\right) & \text{if } IT_1 < \widehat{y}_{a,t} \leq IT_2 \\ 0 & \text{if } \widehat{y}_{a,t} > IT_2 \end{cases}, \qquad (3)
$$

[6] We do not model directly housing, but, in order to closely target actual income tax revenues and age pension expenditures, we calculate the age-specific fraction of owner-occupied housing in total net worth, ϕ_a, from the 2009-10 wealth data (ABS, 2011). It is further assumed that the interest income generated by that fraction of assets is exempt from personal income taxation and the pension means test.

[7] We consider only the income test. Although currently about one third of part-age pensioners have their pension reduced due to the asset test, the assessable assets of pensioners are never high enough in the model for the asset test to be binding. Note that for the given interest rate and the means test parameters (i.e., taper rates and thresholds), it can be shown that the income (asset) test is binding for lower (higher) assessable assets.

where assessable income $\widehat{y}_{a,t} = rA_{a-1,t-1} + 0.5 \times w_t e_a(1 - l_{a,t})$ includes interest income and half of labour earnings, and IT_1 and IT_2 denote the lower and upper bound thresholds for the assessable income.[8]

The model also incorporates the main features of the Australian second retirement income pillar known as the superannuation guarantee. The superannuation guarantee is a privately managed and fully funded system that mandates employers to make superannuation contributions into each employee's superannuation fund. Accordingly, we assume that each producer pays these contributions for households aged 21 to 60 years at the after-tax contribution rate, $(1 - \tau^s)\, cr$, from their labour income, $w_t e_a(1 - l_{a,t})$, to the superannuation fund. The contributions are added to superannuation assets, $SA_{a,t}$, which earn investment income at the after-tax interest rate, $(1 - \tau^r)\, r$. The stock of superannuation assets accumulates in the fund until age 60, when households receive lump-sum payouts, $SA_{60,t}$, and the superannuation accumulation ceases. The superannuation asset accumulation during $a \leq 60$ can be expressed as

$$SA_{a,t} = [1 + (1 - \tau^r)\, r]\, SA_{a-1,t-1} + [(1 - \tau^s)\, cr]\, w_t e_a(1 - l_{a,t}), \tag{4}$$

where τ^r is the earnings tax rate, τ^s denotes the contribution tax rate and cr is the mandatory contribution rate. We further assume that working households aged 60 years and over are paid mandatory contributions directly into their private assets account, denoted by $SP_{a,t}$ in equation (2).[9] The payment of these contributions is given by

$$SP_{a,t} = (1 - \tau^s)\, cr \cdot w_t e_a\, (1 - l_{a,t})\,, \text{ for } a > 60 \text{ and } 1 - l_{a,t} > 0. \tag{5}$$

2.3 Firms

The production sector consists of a large number of perfectly competitive firms that are represented by a single producer. The representative producer demands capital, K_t, and labour, L_t, to produce a single all purpose output, Y_t, according to the technology described by the standard CES production function

$$F(K_t, L_t) = \kappa \left[\varepsilon K_t^{(1-1/\sigma)} + (1 - \varepsilon) L_t^{(1-1/\sigma)}\right]^{[1/(1-1/\sigma)]}, \tag{6}$$

where κ is the productivity constant, ε denotes the capital intensity parameter and σ is the elasticity of substitution in production. Capital formation is subject to adjustment

[8] A further explanation on how the income test of the age pension works is provided in Appendix B, where Figure A2 shows the association between the age pension payment and assessable income.

[9] This is consistent with post-July 2007 policy, which allows such contributions by seniors to be immediately removed tax free from the superannuation fund.

costs given by

$$C(I_t, K_t) = \frac{\psi}{2}\frac{I_t^2}{K_t}, \tag{7}$$

which are assumed to be quadratic in net investment, I_t, where ψ is the adjustment cost coefficient.

The producer maximises the present value of all future profit payments discounted at the world interest rate, r, subject to the capital accumulation equation, as described by

$$\begin{array}{cc} \max\limits_{\{K_t,\ L_t,\ I_t\}} & \sum\limits_{t=0}^{\infty} \frac{1}{(1+r)^t} \left[\left(1-\tau^f\right)\pi_t\right] \\ \text{s.t.} & K_{t+1} = I_t + (1-\delta)\, K_t, \end{array} \tag{8}$$

where $\pi_t = F(K_t, L_t) - C(I_t, K_t) - I_t - (1+cr)w_t L_t$ denotes the firm's profit at time t, τ^f stands for the corporation tax rate and δ is the capital depreciation rate. The first-order necessary conditions from the profit maximisation problem (8) may be solved for the producer's inter-temporal demands for labour, capital and investment and the Lagrange multiplier, q_t, which also represents the market price for capital, given the time profile for wage rate, w_t, and the interest rate, r.

2.4 Government

The government sector is modeled as follows. The consolidated government issues new debt, ΔD_t, and collects taxes from individuals and firms, Tax_t, in order to finance government final consumption expenditures, G_t, interest payments on its debt, rD_t, and social transfer payments to individuals TR_t:

$$\Delta D_t + Tax_t = G_t + rD_t + TR_t. \tag{9}$$

The government total tax revenue, Tax_t, is collected from taxing household income, Tax_t^Y, and consumption, Tax_t^C, superannuation, Tax_t^S, and from imposing corporate taxes on the firm's annual profit, Tax_t^F. These revenues can be expressed as

$$\begin{aligned} Tax_t^Y &= \textstyle\sum_{a=21}^{100} T(y_{a,t})N_{a,t}, \\ Tax_t^C &= \textstyle\sum_{a=21}^{100} \tau^c c_{a,t} N_{a,t}, \\ Tax_t^S &= \textstyle\sum_{a=21}^{60} \left[\tau^s cr \cdot w_t e_a^i (1-l_{a,t}^i) + \tau^r r S A_{a-1,t-1}^i\right] N_{a,t}, \\ Tax_t^F &= \tau^f \pi_t, \end{aligned}$$

where $N_{a,t}$ is the size of cohort aged a and π_t is the firm's profit in period t.

The government's final consumption expenditures, G_t, consist of expenditures on education, health and aged care and government purchases of other goods and services. The government purchases of other goods and services are non-age related expenditures that are expressed in per capita terms and denoted as $\overline{G}_t$. The average age-specific expenditures on education, edu_a, (which are only spent on children aged 0 to 20 years), health care , hc_a, and aged care, ac_a, are assumed to be constant over time. The government's final consumption expenditures can be expressed as

$$G_t = \overline{G}_t \cdot P_t + \sum_{a=0}^{20} edu_a N_{a,t} + \sum_{a=0}^{100} hc_a N_{a,t} + \sum_{a=65}^{100} ac_a N_{a,t}. \tag{10}$$

The model accounts for the following two government transfers to individuals: age pension payments and family benefits. The age pension payments, $AP_{a,t}$, are endogenous in the model and, as already mentioned, these payments are received only by eligible households aged 65 years and over that satisfy the means test (see Equation (3)). The age- and time-specific family benefits, $FB_{a,t}$, are assumed to be exogenous and to be received by households between ages 21 and 60 years.[10] The government's transfer payments are

$$TR_t = \sum_{a=65}^{100} AP_{a,t} N_{a,t} + \sum_{a=21}^{60} FB_{a,t} N_{a,t}. \tag{11}$$

We further assume a balance government budget with no government debt, that is, $\Delta D(t) = rD(t) = 0$ in Equation (9). Although the consolidated Australian government budget was in a deficit of about 2.5 percent of GDP in 2009-10, the current Australian government is committed to balanced budgets in the future. We use the non-age related government expenditure, $\overline{G}_t$, to balance the government budget during the demographic transition.[11]

2.5 Foreign sector

We assume a small open economy model specification with perfect capital mobility, where the domestic interest rate, r, is exogenous and equal to the world interest rate.[12] When domestic savings fall short of the domestic capital, foreign capital will be employed thus

[10] The family benefits are given by $FB_{a,t} = fb_a v_t$, where fb_a is age-specific family benefit and v_t is the index of the ratio of children to adults that is set to one in 2010.

[11] In the sensitivity analysis section, we examine the effects of population ageing by adjusting the consumption tax rate as an alternative policy instrument to balance the government budget.

[12] This assumption is relaxed in Section 6, where we allow the interest rate to adjust to the changes in the foreign debt to output ratio as one of our robustness checks.

adding to foreign debt. The accumulation of net foreign debt, FD_t, can be expressed as

$$FD_{t+1} - FD_t = TB_t - rFD_t, \tag{12}$$

where TB_t is the trade balance and rFD_t represents the interest payments on net foreign debt. The constraint in (12) equates capital flows on the left-hand side with the current account on the right-hand side.

2.6 Competitive equilibrium

The endogenous variables in the model are determined such that all agents make their choices optimally. Households maximise their lifetime expected utility function (1) subject to the budget constraint (2), while the producer chooses labour and capital inputs, along with investment, to maximise discounted profits given by (8). The government balances its budget (9) in every time period by adjusting its non-age related expenditures.

Competitive equilibrium further requires that all markets clear in every time period. That is, demand for labour by the producer equals the labour supply across households, the market value of the capital stock equals total (domestic plus foreign) assets, and the supply of goods by producers equals the sum of demands by households, firms for investment, government and foreigners (net trade balance):

$$\begin{aligned} L_t &= \textstyle\sum_{a=21}^{100} e_a(1-l_{a,t})N_{a,t}, \\ q_tK_t &= \textstyle\sum_{a=21}^{100} A_{a-1,t-1}N_{a,t} - FD_t, \\ Y_t &= \textstyle\sum_{a=21}^{100} c_{a,t}N_{a,t} + I_t + G_t + TB_t. \end{aligned} \tag{13}$$

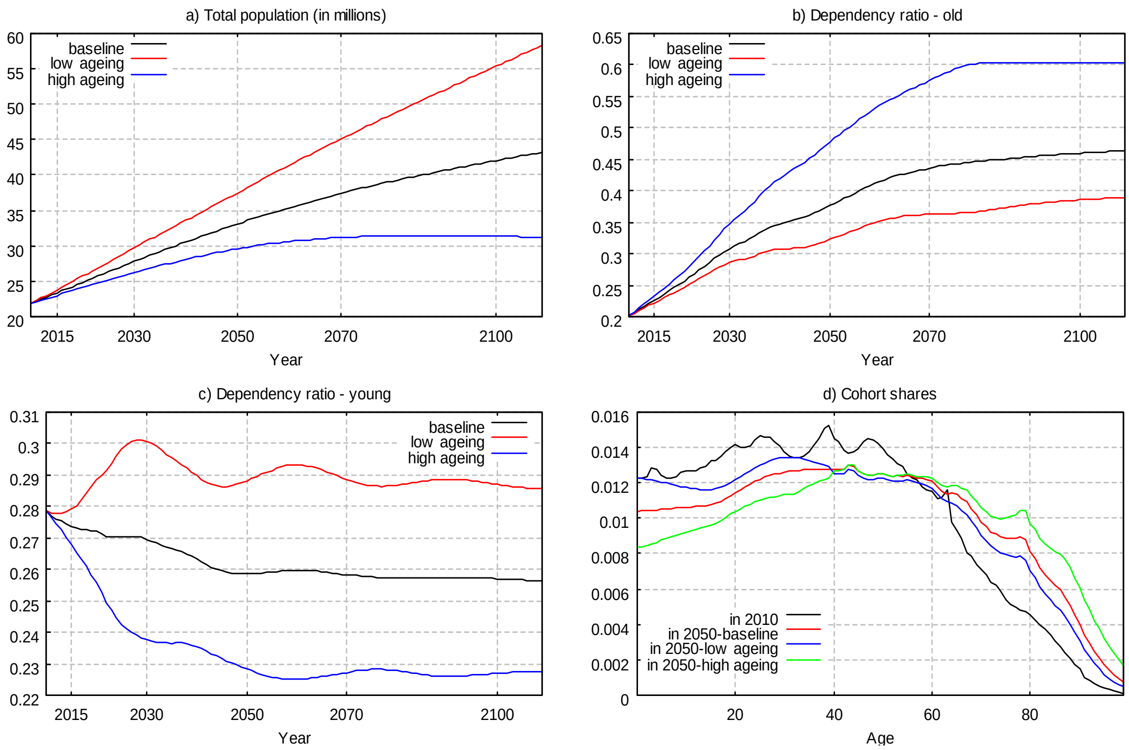
3 Calibration

We assume year 2010 to be the base year for our economic calculations and use actual cohort sizes and mortality rates in that year to compute an artificial steady state. The computation of that steady state is performed to calibrate the model economy and to obtain initial asset holdings for each age cohort in 2010. While some of the model parameters are calibrated to reproduce calibration targets in 2010 (most of the production function parameters and the government tax and expenditure adjustment parameters), other parameters are either taken from related literature (most of the utility function parameters) or match actual policy settings in 2009-10 (age pension parameters). Population projections and the parameter values of the economic model are discussed in detail below.

3.1 Population dynamics

We construct several projection scenarios for the evolution of demographic structure in Australia in next 100 years. The starting point of our population projections is Australia's population structure (i.e., actual cohort sizes and shares) in 2010. The population projection model outlined in the previous section is then fitted with assumed future fertility, survival and net immigration rates from Productivity Commission's MoDEM 2.0.[13] Finally, the future cohort sizes and cohort shares in the total population generated by each demographic projection scenario are then used in our economic model to draw out the macroeconomic and fiscal implications of demographic shift.

Figure 1: Baseline and alternative demographic projections - key population statistics



Notes: Projections are based on MoDEM 2.0 input data for fertility, survival and net immigration rates. Baseline projection assumes medium rates; Low (high) ageing scenario assumes high (low) fertility and net immigration and low (high) survival rates.

Baseline projection. Our baseline population projection is the most likely scenario that uses the medium values of future fertility, survival and net immigration rates. In particular, the baseline projection assumes (i) the total fertility rate (i.e., sum of age-specific fertility rates, $f_{a,t}$) to decrease from 1.8 to 1.7 babies per woman by 2018; (ii)

[13] MoDEM 2.0 is a population projection program that forecasts population for Australia over the period of 2008-2056, given different assumptions about fertility, mortality and migration rates over time. The program can be accessed on Productivity Commission's website: http://www.pc.gov.au/research/commissionresearch/nationalreformagenda/modem/modem2. See Cuxson *et al.* (2008) for detailed documentation of MoDEM 2.0.

annual net immigration (i.e., sum of age-specific immigration, $M_{a,t}$) of 177,000 people; and (*iii*) the medium survival rates $(1 - d^g_{a,t})$ to generate a life expectancy at birth that increases from 79 years in 2010 to 88.2 years by 2053 for males and from 84 years in 2010 to 90.8 years by 2053 for females.[14]

Population statistics for the baseline projection in Figure 1 indicate that by 2050, *a*) the total population increases to over 33 million, *b*) the old-age dependency ratio exceeds 0.37, and *c*) the youth dependency ratio declines below 0.26. The ageing of Australia's population is also depicted by the changes in future cohort shares (Figure 1*d*), showing greater projected shares of older cohorts in the total population in 2050, compared to their actual shares in 2010.

Alternative ageing projections. The two alternative ageing scenarios presented here use different values of future fertility, survival and net immigration rates from those used in the baseline projection. The aim is to account for two extreme demographic developments – low and high ageing. The "low ageing" scenario combines high fertility and net immigration and low survival, while the "high ageing" scenario combines low fertility and net immigration and high survival. The low (high) fertility case assumes that the total fertility rate declines (increases) to 1.5 (1.9) babies per woman by 2018. The low (high) survival case uses survival rates that increase life expectancy at birth to 85.3 years (93.8 years) for males and to 89 years (95.8 years) for females by 2053. Finally, low (high) net immigration assumes 117,000 (237,000) net immigrants.

Figure 1 shows that the low ageing scenario is also a high population scenario, with the total population size reaching 38 million by 2050 and over 55 million by 2100. Compared to the baseline projection with the medium vital rates, the low ageing scenario leads to a greater proportion of younger age groups, while the high ageing scenario results in a greater share of the elderly in the population. Under the high ageing scenario, greater (smaller) shares of older (younger) age groups result in a significantly higher old-age dependency ratio, which increases to 0.48 by 2050 and to 0.6 in 2100. This is due mainly to greater longevity. In contrast, the fertility increases in the low ageing scenario are behind the increased youth dependency ratio.

3.2 Household, firm and market structure

Table 1 reports the values of the main parameters of the model. The values of the utility function and production parameters are standard in the literature. The inter-temporal elasticity of substitution is set to 0.3, as in Kudrna and Woodland (2011). Following Fehr

[14]MoDEM 2.0 assumes that total fertility and the survival rates remain constant after 2018 and after 2053, respectively.

et al. (2008), the intra-temporal elasticity is substitution is set to 0.4, which generates labour supply elasticity with respect to the wage rate of around 0.5. The subjective rate of time preference, β, is set 0.02 to generate the capital output ratio K/Y of 3 (ABS, 2010a) in the base year.[15] Similarly to Fehr (2000), the leisure intensity parameter, α_a, is age-specific and chosen to be 2 up to age 55, after which its value increases at a constant rate to 2.5 at age 100.

Table 1: Values of the model parameters

Description	Value	Source
Utility function		
Inter-temporal elasticity of substitution	0.3	Literature
Intra-temporal elasticity of substitution	0.4	Literature
Subjective rate of time preference	0.02	Calibrated
Leisure parameter [a]	2-2.5	Literature
Technology		
Production constant	0.897	Calibrated
Elasticity of substitution in production	0.987	Calibrated
Capital share	0.45	Data
Depreciation rate	0.071	Calibrated
Adjustment cost parameter	2.242	Calibrated
Age pension		
Maximum age pension p.a. (in $100,000)	0.1747	Data
Income test threshold (in $100,000)	0.0398	Data
Income reduction rate	0.5	Data
Superannuation		
Mandatory contribution rate	0.09	Data
Contribution tax rate	0.15	Data
Earnings tax rate	0.075	Data
Taxation		
Statutory consumption tax rate [GST]	0.1	Data
Statutory corporation tax rate	0.3	Data
Income tax function	-	Estimated

Notes: [a] Leisure parameter is 2 up to age 55 and then it increases at a constant rate to 2.5 at age 100.

The technology constant, $\kappa = 0.857$, is calibrated to reproduce the market wage rate, w, which is normalised to one in 2010. The capital depreciation rate, δ, is set 0.07 to target the investment rate I/K of 0.09 (ABS, 2010a). The elasticity of substitution in production, $\sigma = 0.981$, and the capital intensity parameter, $\varepsilon = 0.45$, are calibrated via the producer's first order profit-maximisation conditions to match the interest rate and national account data for factor shares. The time endowment is normalised to unity and the adjustment cost parameter, $b = 2.27$, is calibrated such that the adjustment costs

[15] The values of the calibration targets including the capital to output ratio, investment rate and foreign assets to capital ratio are five year averages ending in June 2010 taken from ABS (2010a).

account for about 10 percent of investment in 2010.[16]

The age-specific earnings ability variable (or efficiency profile) is based on the econometric estimates of the wage function for males with 12 years of schooling by Reilly *et al.* (2005). As Reilly at al. consider only workers aged 15-65, we further assume that wages after age 65 decline at a constant rate to reach zero at age 90 to avoid positive labour supply at very old ages.

The exogenous interest rate, r, is assumed to be 5 percent. We also set the equilibrium condition for the capital market such that 81 percent of the domestic capital stock come from household savings, with the remaining 19 percent funded through net foreign debt. This reflects the net foreign ownership of about 19 percent of Australia's capital stock, averaged over five years ending in June 2010 (ABS, 2010a).

3.3 Government

We calibrate the model to match composition of government expenditures and tax revenues observed from the Australian data averaged over five years ending in June 2010.

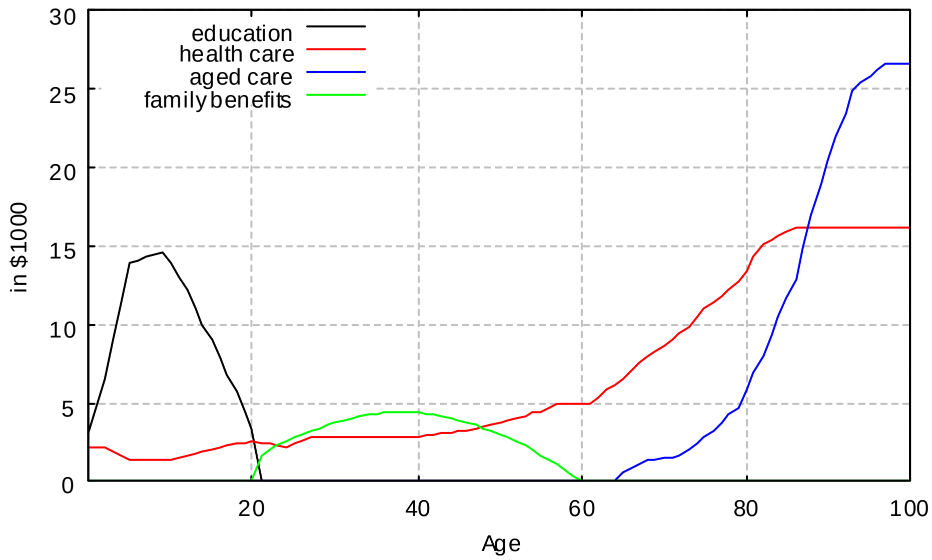
Pension. The age pension, AP_a, is endogenous and depends on assessable income of households. We use the actual values in 2010 for the age pension parameters, including the maximum pension rate, p, the income threshold, IT, and the income taper rate, θ. Similarly, the superannuation parameters that include the mandatory contribution rate, cr, the contribution and fund's investment tax rates denoted by τ^s and τ^r match the actual values in 2010.

Other age-related expenditures. Government expenditures on health care, hc_a, aged care, ac_a, education, edu_a, and family benefits fb_a are age-related and exogenous in our model. We derive these average age-specific government expenditures from various data sources. In particular, the average age-specific public health and aged care expenditures and education expenditures are taken from the Productivity Commission (2013), while the age profile for the family benefits is derived from the 2010 HILDA survey.[17] Figure 2 plots the profiles of the exogenous average public expenditures that are expressed in units of $\$1,000$.

[16]Note that the chosen values of the production function parameters result in a steady state q-value (i.e., the price of capital) of 1.14, which is very close to an equilibrium q-value of 1.13 found in the empirical study by Oliner *et al.* (1995).

[17]To smooth the family benefit profile, the function, $fb_a = \lambda + \lambda_1 a + \lambda_2 a^2$, is estimated, using the average age-specific expenditures from the 2010 HILDA data.

Figure 2: Age-specific public expenditures



Notes: Health care, aged care and education expenditure profiles are taken from Productivity Commission's (2013) report and deflated at a 3 percent rate to year 2010; Family benefits profiles are derived from 2010 HILDA individual data set.

Note that, in order to match the exact sizes of government expenditures in percent of GDP, we introduce adjustment parameters for health care expenditures, f_{hc}, education expenditures, f_{edu}, aged care, f_{ac}, age pension, f_{ap}, and family benefits, f_{fb}. We adjust the values of these parameters replicate the actual ratio of each expenditure to GDP taken from ABS (2010b).

Taxes. There is no specific labour income tax on the workers' side in Australia. Labour earnings are taxed together with asset or interest income and the age pension under the personal income taxation, which is progressive. We use a differentiable approximation function of the 2009-10 Australian personal income tax schedule, which is denoted by $T(y_a)$ in Equation (2).[18] The statutory consumption and corporation tax rates ($\overline{\tau}^c$ and $\overline{\tau}^f$) are set to their actual values in June 2010, that is, 10 percent and 30 percent, respectively.

Similarly to the government expenditures, we introduce tax adjustment parameters, f_{itax}, f_{ctax}, f_{stax}, and f_{ftax}, which are calibrated to replicate the actual ratio of each tax revenue to GDP taken from ABS (2010c). We summarise the calibrated values of the adjustment parameters along with the calibration targets in Table 2. Note that the optimisation problems faced by households and firms and the tax revenues and expenditures in the government budget constraint in the previous section would need to be adjusted so that each tax rate and transfer payment are multiplied by the corresponding adjustment parameter. For example, as the consumption tax adjustment parameter is 1.46 (see

[18]The comparison of the approximated income tax function with the actual income tax schedule is depicted by Figure A3 in Appendix B. The figure shows that the two functions are very similar.

Table 2), the effective consumption tax rate, τ^c, in Equation (2) amounts to 14.6 percent ($\tau^c = \overline{\tau}^c \cdot f_{ctax}$).[19]

Table 2: Calibrated adjustment parameters for government indicators

Description	Value	Target (% of GDP)
Adjustment parameters		
Health care [a]	1.06	6.20
Education [a]	1.30	5.10
Aged care [b]	0.83	0.80
Age pension [b]	0.99	2.80
Family benefits [b]	1.40	2.50
Income taxes [a]	1.05	11.50
Superannuation taxes [a]	0.70	0.80
Corporation taxes [a]	0.97	5.50
Consumption taxes [a]	1.46	7.50

Notes: Data for Australia are taken from ABS (2010b, 2010c); [a] Data for Australia are averages over 2006-10; [b] Data for Australia are for June 2010.

3.4 Method of computation and model performance

We start by computing the initial steady state to calibrate some of the model's parameters and to derive the initial asset distribution across the generations existing in 2010. Taking as given the model parameters and the demographic variables (i.e., the cohort sizes, $N_{a,t}$, and survival rates, $1 - d_{a,t}$), we then solve the model over transition paths for the baseline and alternative population projection scenarios. It should be pointed out that demographic change in our framework is assumed to be unanticipated by households. In 2011, existing cohorts endowed with initial assets learn unexpectedly about improved future life expectancies and start adjusting their lifecycle behaviour.

The transition period spans the period from 2011 to 2300 and can be divided into the following three sub-periods: (*i*) the 2011-2100 period – the demographic projection period derived from the population model outlined in Section 2; (*ii*) the 2101-2200 period – the adjustment period to reach a stable population by setting the number of births to be constant after 2100; and (*iii*) the 2201-2300 period – additional 100 years for the model reach a final steady state.

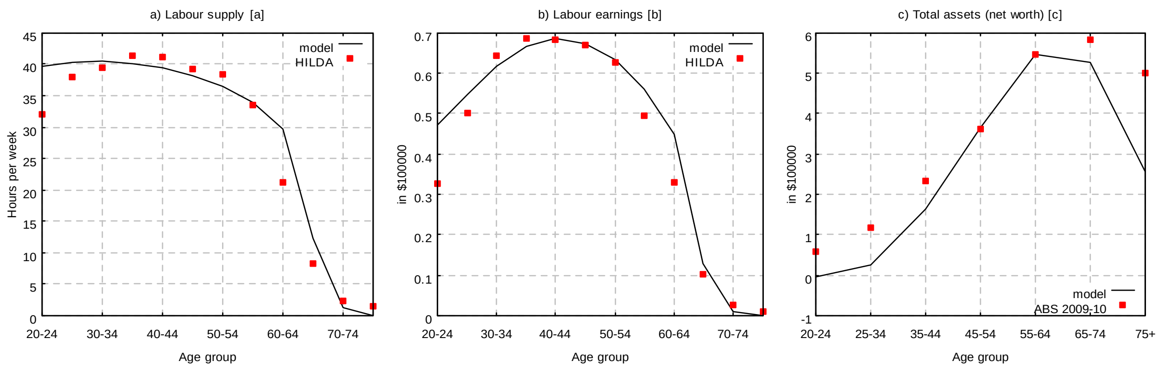
We use the GAMS software to compute the solutions for all our economic simulations. The exact steps that we carry out to solve for the steady state and the transition paths are described in Kudrna and Woodland (2011). In brief, the iterative Gauss-Seidel computational method suggested by Auerbach and Kotlikoff (1987) is applied. The algorithm

[19]This effective tax rate generates the consumption tax revenue that includes not only the GST revenue with the GST rate of 10 percent but also receipts from excise taxes.

involves choosing initial values for some endogenous variables and then updating them by iterating between the production, household and government sectors until convergence.

We now report on some of the key model-generated results at both the household and aggregate levels for the base year of 2010. Specifically, Figure 3 provides comparisons for the life-cycle profiles for labour supply, labour earnings and total assets. The actual cross-sectional data for average labour supply and average annual labour earnings are derived from the 2010 HILDA survey for males (Wooden *et al.*, 2002), while the actual age-specific assets are based on ABS (2011) data for net worth in 2009-10.[20] The model life-cycle profiles for average labour supply and labour earnings are shown to be close both in shapes and levels to the actual cross-sectional data in 2010. The actual assets are above the model-generated assets at the early stages of the life-cycle and especially at older ages. Our model abstracts from any bequest motives and so older households draw down their savings at retirement to fund their consumption and eventually end up with zero assets, should they survive until the assumed maximum age of 100 years.

Figure 3: Comparison of life-cycle data in 2010



Notes: [a] HILDA data points of average labour supply are derived from 2010 individual data set for males; [b] HILDA rata points of average annual labour earnings are derived from 2010 individual data set for males; [c] Average age-specific assets (net worth) are derived from ABS (2011) for fiscal year of 2009-10 and adjusted for the household size, using the equivalence scale suggested by Citro and Michael (1995, p.178).

The comparison of selected macroeconomic variables and government indicators in 2010 is presented in Table 3. The results for the components of aggregate demand reveal that the model replicates the key Australian aggregates fairly well. The positive trade balance generated by the model, which has been negative in Australia for some time, is due to the targeted negative foreign assets position and our assumption of dynamic efficiency with the exogenous interest rate greater than population growth rate. Given the use of the adjustment parameters for government expenditures and tax revenues, the displayed government indicators match exactly the actual data.

[20]Note that the ABS data are provided for household assets. We used the equivalence scale suggested by Citro and Michael (1995, p.178) to convert the given net worth of average households to an average net worth per person.

Table 3: Comparison of the model solution for 2010 with Australian data

Variable	Model	Australia
Expenditures on GDP (percent of GDP)		
Private consumption [a]	51.13	55.50
Investment [a]	26.85	25.40
Government consumption [a]	20.00	20.46
Trade balance [a]	2.01	-1.36
Government indicators (percent of GDP)		
Health expenditure [a]	6.20	6.20
Education expenditure [a]	5.10	5.10
Aged care expenditure [b]	0.80	0.80
Age pension expenditure [b]	2.80	2.80
Family benefits [b]	2.50	2.50
Personal income taxes [a]	11.50	11.50
Corporation taxes [a]	5.50	5.50
Superannuation taxes [a]	0.80	0.80
Consumption taxes (GST and excise) [a]	7.50	7.50

Notes: Data for Australia are taken from ABS (2010b, 2010c); [a] Data for Australia are averages over 2006-10; [b] Data for Australia are for June 2010.

4 Quantifying the effects of demographic shift

We now present the simulation results for the baseline demographic transition of our model. As mentioned, the results are driven only by the assumed processes of future fertility, survival and net immigration and the resulting changes in the age structure of Australia's population. Therefore, we abstract from possible effects of any non-demographic factors (e.g., impact of technological advance in medicine on health care expenditures) and from any changes in government policies (e.g., the recently legislated increases in superannuation contribution rate from 9 to 12 percent and the gradual increases in the age pension eligibility age to 66 in 2018 and 67 in 2023). We further assume that non-age related public expenditures adjust to balance the government budget.[21,22] The changes in this budget-balancing policy instrument will then represent the size of the fiscal costs arising from an ageing of Australia's population.

The effects of future demographic developments on macroeconomic and fiscal variables are determined directly by the demographic changes (i.e., future changes in cohort shares and sizes displayed in Section 3) and by the implications of demographic shift for the life-cycle behaviour of households.[23] We first point out the main life-cycle implications of the

[21] The reason for this assumption is to avoid the policy influence from government budget adjustments on household behaviour, which is not affected by changes in non-age related expenditures.

[22] This assumption of the model is altered in Section 6.

[23] In the appendix, we present the effects of the baseline demographic transition that assume no behav-

projected demographic shift and then proceed with the discussion of the macroeconomic and fiscal effects.

4.1 Behavioural responses

We begin with behavioural responses to demographic shift. It is documented in the previous literature that changes in fertility and survival rates result in significant impacts on the economic behaviour of households.[24] First, there is a direct effect on the life-cycle behaviour of households through improvements in survival probabilities that change the effective rate of discount (i.e., rate of time impatience) and longevity. Reduced effective discount rates are expected to have positive effects on consumption at older ages. Households also tend to work more and accumulate larger assets in younger ages to fund consumption over longer years in retirement. In addition, in our general equilibrium framework, there are indirect effects on household behaviour, triggered by population ageing, as households react to general equilibrium factor price adjustments, tax adjustments and bequest redistributions.[25]

The implications for selected age-specific variables in 2010 and in the two transitional years of 2015 and 2050 are plotted in Figure 4.[26] In particular, the figure includes the graphs showing the values of labour supply, consumption, total assets and the age pension across cohorts of different ages. As expected, households in 2015 adjust their behaviour to improved future life expectancies by working more and consuming less relative to working hours and consumption spending in 2010. These labour and consumption adjustments gradually lead to a greater asset accumulation. During the demographic transition, the increased assets are shown to generate a dominating income effect, with declining labour supply and increasing consumption across all age cohorts in 2050 relative to the profiles in 2015. The changes in asset accumulation also affect age pension payments received by eligible households. Specifically, Figure 4*d* shows reduced age pension payments in 2050, caused by the means testing of increased investment incomes generated by larger total assets at older ages.

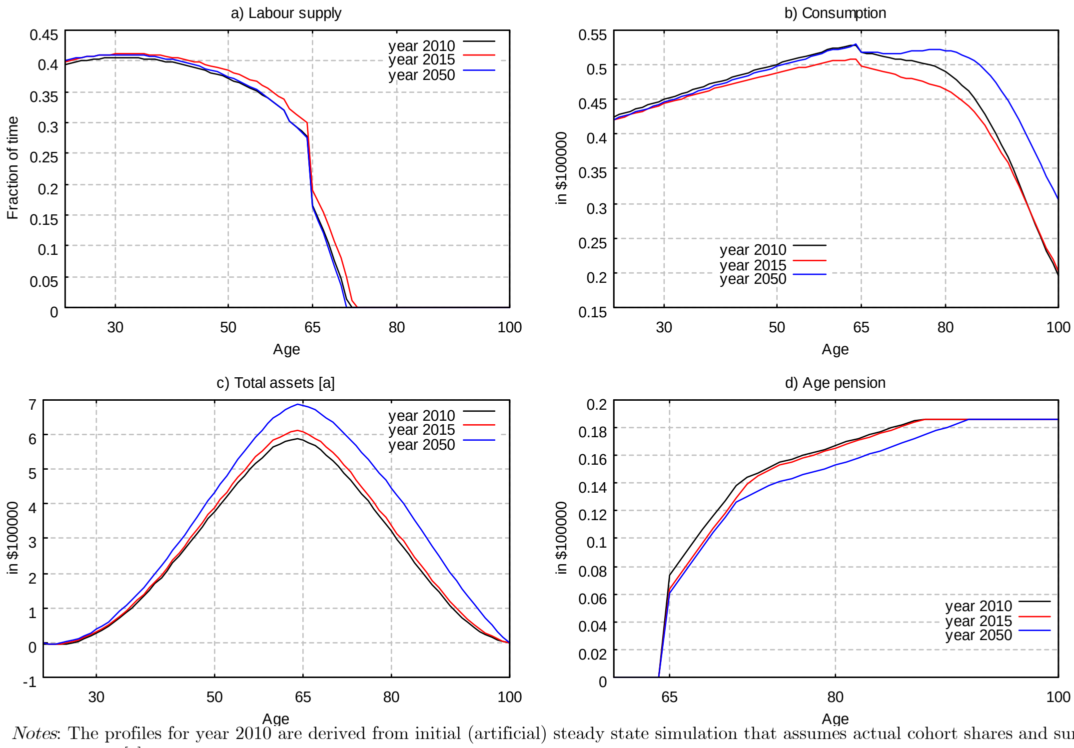
ioural responses of households to demographic shift.

[24] The simulation results presented in the appendix demonstrate the importance of accounting for the behavioural adjustments, which are shown to mitigate negative implications of population ageing for macroeconomic aggregates and the budgetary situation for the government.

[25] There is an increase in accidental bequests because of larger asset accumulations, but the increase is partly offset by smaller proportions of older deceased households as the age-specific mortality rates decline over the transition.

[26] Recall that the results for 2010 are obtained from the artificial steady state computation that applies actual cohort shares and survival rates in that year.

Figure 4: The effects of baseline demographic transition on life-cycle household variables



Notes: The profiles for year 2010 are derived from initial (artificial) steady state simulation that assumes actual cohort shares and survival rates in 2010; [a] Total assets include superannuation and ordinary private assets, with superannuation assumed to be received at age 60.

4.2 Macroeconomic aggregates

We now quantify the implications for macroeconomic variables. The effects of the baseline demographic transition on macroeconomic aggregates are presented in Table 4. To facilitate our exposition, we report percentage changes in the selected per capita variables relative to their values in 2010.

We start with the effects on the labour markets. Our results indicate that the baseline demographic shift causes an increase in per capita labour of 2.67 percent by 2015. The logic behind this result is that the working population born before 2010 increases their worked hours to respond to unanticipated longevity shocks. However, in the medium and long terms, direct demographic effects with smaller shares of the working-age population dominate the life-cycle behavioural effects, generating decreases in per capita labour supply of 7.05 percent by 2050 and 11.65 percent by 2100. The wage rate initially falls due to increased supply of labour, but because of capital deepening (i.e., the capital stock decreasing slightly less than labour supply), the wage rate is somewhat higher for most of the transition path, compared to the wage rate in 2010. Notice that the small open economy assumption with the exogenous interest rate limits the wage rate effects, so they are rather small.

Table 4: Macroeconomic effects of baseline demographic transition
(Percentage changes in the selected macro variables relative to 2010)

Variable		2015	2030	2050	2100
Labour supply	%	2.67	-2.69	-7.05	-11.65
Wage rate	%	-0.84	0.07	0.13	0.33
Domestic assets	%	6.93	25.12	38.22	43.33
Capital Stock	%	0.77	-2.53	-6.79	-11.00
Asset price	%	-0.81	-1.61	-1.92	-2.26
Gross domestic product (GDP)	%	2.24	-1.98	-6.22	-10.58
Gross national product (GNP)	%	3.32	2.30	0.60	-2.39
Consumption	%	-1.22	3.13	7.23	9.76
Investment	%	-6.69	-15.33	-21.36	-27.24

Notes: Variables are expressed in per capita terms except for wage rate and asset price.

Table 4 shows that domestic total assets increase significantly over the transition, rising 38 percent by 2050 and 43 percent by 2100. These increases in asset holdings are driven by the increases in household savings, i.e., larger asset holdings of households as displayed in Figure 4*c*, and by an increasing proportion of the elderly with large assets holdings in the total population. Interestingly, such extra domestic savings/asset holdings do not flow into the domestic production sector. Instead, domestic savings are invested in international financial markets. The main reason is that decreases in labor supply resulting from ageing lead to a lower demand for capital in the domestic market. That is, in the small open economy framework, the effects on aggregate labour supply to a large extent determine the effects on other production variables such as the capital stock and output. In order to clear the capital market these excess savings flow to international financial markets. We also observe declines in the asset price (the price of capital stock in our model) as the population ages.

Our results also indicate a substantial increase in average consumption. Specifically, the increase in per capita consumption is 7.23 percent by 2050 and 9.76 percent by 2100 relative to its 2010 value. The increases in per capita consumption are due to increased household consumption at older ages (e.g., see Figure 4*b*) and the changes in cohort shares of the middle age and older population. The changes in GDP per capita are similar to those in per capita labour supply, with per capita GDP decreasing 6.2 percent by 2050. National product or GNP, which includes interest payments on foreign debt, is positively affected compared to GDP because of large decreases in foreign debt.[27]

[27] It should be noted that all aggregate variables increase significantly over the transition path as a result of a growing total population. For example, GDP (i.e., aggregate output) increases 42 percent by 2050 and aggregate domestic assets more than double by 2050.

4.3 Fiscal implications

One of our main goals is to quantify the fiscal effects of demographic shift. These effects for the baseline demographic transition are reported in Table 5 as (i) percentage changes in the per capita government indicators relative to the base year of 2010 and (ii) in percent of GDP.

As expected, old-age government expenditures increase significantly due to an increasing proportion of older cohorts in the population in the future, while government spending on education and families, which is addressed to younger cohorts, declines. More specifically, our results indicate that the increases in the size of health care, aged care and pension programs in 2050, relative to 2010, are 24.5, 125.9 and 62.7 percent, respectively. Meanwhile, the decreases in the size of education and family benefits programs are 16.42 and 15.88 percent by 2050, respectively.

Behavioral changes in response to demographic shift result in structural changes in tax revenues. There is a shift in the tax base from labour earnings to asset incomes and consumption. The effects on tax revenues are non-linear and vary along the transition paths. In particular, the income tax revenue increases in the medium run due to larger average asset incomes. However, the income tax revenue decreases in the long term because of the declines in per capita labour supply and smaller average incomes. The income tax revenue is about 2.1 percent smaller in 2100 than it was in 2010. In addition, corporate tax receipts also increase in the short and medium run, increasing about 6.4 and 2.7 percent by 2015 and 2030 respectively, but fall in the long run, by about 5.1 percent in 2100, as a result of smaller average output and profits. Moreover, the consumption tax becomes more important as increased average consumption generates a larger consumption tax revenue. Consumption tax revenue will increase almost 10 percent by 2100 relative to 2010.

Yet, demographic shift will create an unprecedented fiscal challenge for Australia in years to come. In order to finance such substantial increases in age-related benefits, the government will have to cut other expenditures or increase taxes during the demographic transition. To quantify the total fiscal cost, we assume that the government adjusts non-age related expenditures to balance its budget every period. This is labeled as other expenditures in Table 5. Note that this government budget balance assumption results in no fiscal distortion to household behaviour in our model.

Table 5: Fiscal effects of baseline demographic transition

Variable	(% change relative to 2010)				(Percent of GDP)			
	2015	2030	2050	2100	2015	2030	2050	2100
Government expenditures								
Health care	2.24	12.80	24.45	34.65	6.20	7.13	8.23	9.34
Aged care	5.37	45.67	125.92	190.72	0.82	1.19	1.93	2.60
Age pension	4.48	35.23	62.70	93.35	2.86	3.86	4.86	6.05
Education	-3.50	-9.91	-16.42	-20.78	4.81	4.69	4.55	4.52
Family benefits	-1.89	-7.97	-15.88	-20.91	2.40	2.35	2.24	2.21
Other expenditures [a]	7.75	-9.38	-31.89	-58.04	8.33	7.30	5.74	3.71
Government tax revenues								
Income taxes	3.73	3.04	0.80	-2.11	11.67	12.09	12.36	12.59
Corporation taxes	6.43	2.66	-1.04	-5.13	5.73	5.76	5.80	5.84
Consumption taxes	-1.22	3.13	7.23	9.76	7.25	7.89	8.58	9.21
Superannuation taxes	0.19	-3.88	-6.44	-10.85	0.78	0.78	0.80	0.80

Notes: [a] These represent non-age related expenditures that are assumed to balance the budget.

We find that the decline in non-age related government expenditure is 31.9 percent by 2050 and almost 60 percent by 2100.[28] These cuts pay for the substantial increases in old-age related expenditures with public health care spending rising to 9.34 percent of GDP in 2100, the aged care expenditure from 0.8 percent to 2.60 percent of GDP in 2100 and the age pension expenditure to over 6 percent of GDP in 2100. The displayed decreases in public spending on education and families do not prevent cuts in other non-age related expenditures. These expenditures, as a percentage of GDP, decrease from 8.4 percent in 2010 to 5.74 percent by 2050 and further to 3.71 percent by 2100. Overall, the assumed budget-equilibrating instrument declines by almost 3 percentage points of GDP by 2050 and further 2 percentage points of GDP by 2100 relative to our base year of 2010.

It is worth noting that our results for age-related expenditures differ to some extent from the forecast by the Productivity Commission (2013). According to their forecasts, by 2050 government expenditures on aged care increase to 2.2 percent of GDP (from 0.8 percent of GDP in 2011-12), on health increase to 9.8 percent of GDP (from 6.5 percent of GDP in 2011-12), on age and service pensions increase to 3.7 percent of GDP (from 2.7 percent of GDP in 2011-12), and on education decrease to 4.9 percent of GDP (from 5.4 percent of GDP in 2011-12). Total spending on age-related expenditure in their projections is expected to rise by 5.9 percentage points of GDP by 2050, which compares to our increase of 4.5 percentage points of GDP in these expenditures between 2010 and 2050.

The differences between our paper and Productivity Commission's report are due to different modelling approaches and assumptions. First, in the Productivity Commission's

[28] The total government consumption actually increases, because the final public consumption also includes increased health and aged care expenditures.

report, the health care costs increase not only due to the changes in demographics but also because of their assumed annual growth rate in these expenditures that is more than 0.6 percent higher than the GDP growth rate. Second, their projections also account for the effects of several policy changes on age pension expenditures, including the gradual increase in the mandatory superannuation contribution rate from 9 to 12 percent and the increases in the age pension age to 66 in 2018 and to 67 in 2023. In contrast, we abstract from these structural changes and policy responses to focus on the fiscal effects that are purely driven by demographic shift. Third, in the Productivity Commission's report, all tax revenues are assumed to grow at the GDP growth, while the effects on tax revenues in our paper are endogenously driven by the implications for life-cycle household behaviour and the changes in cohort shares in the population. The fiscal pressure, measured in terms non-age related expenditures, is smaller in our paper, compared to Productivity Commission's (2013) estimates due partly to higher total tax revenues.[29]

5 Understanding the role of demographic factors

In this section, we contribute to the literature on the effects of demographic change by its source, by shedding light on the role of each of demographic factors for our baseline results. We first investigate the effects of the separate changes in fertility and survival rates (life expectancy) to determine the main driver of the results. We next examine the role of increasing fertility and net immigration, which are often cited as solutions to the fiscal burden arising from population ageing.

5.1 Fertility vs. life expectancy

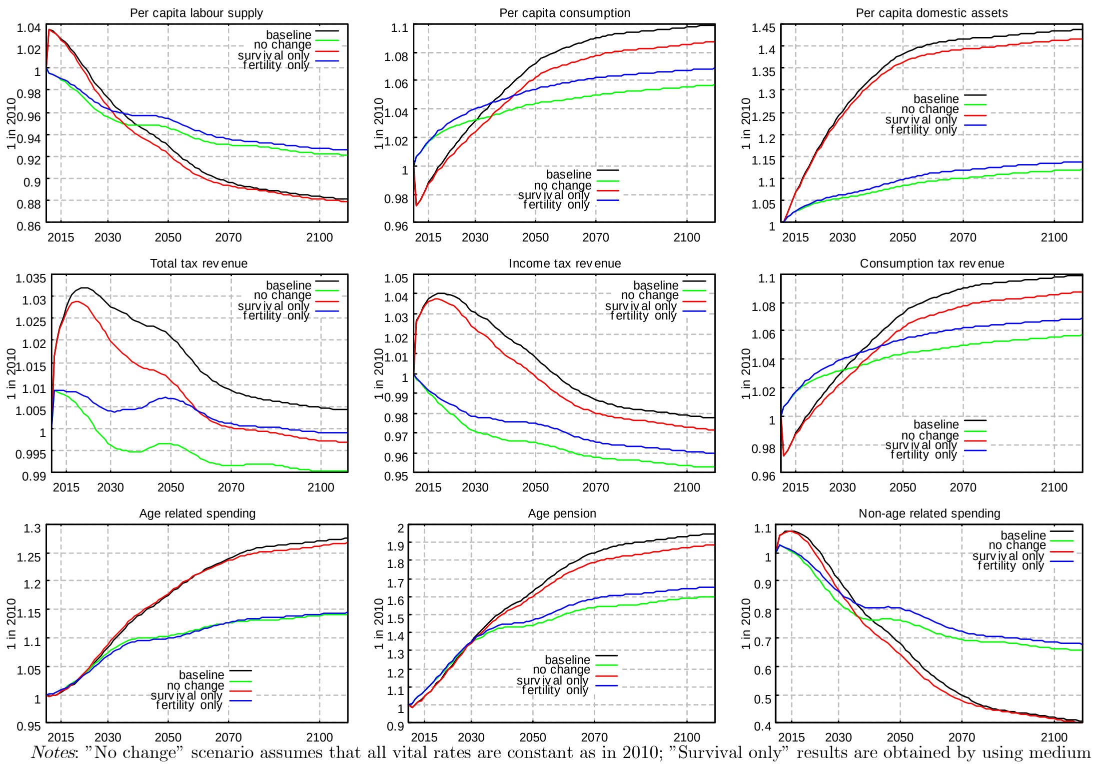
The simulation of the baseline demographic transition path assumes medium values for the demographic factors, with decreasing fertility rates and increasing survival rates (i.e., increasing life expectancy). To isolate the quantitative role of each demographic factor behind the fiscal effects, we conduct the following decomposition exercise. We start from the benchmark economy in 2010 and then simulate our model with three hypothetical demographic transition paths: (*i*) a no change path where fertility and survival rates remain constant at their 2010 levels – "no change"; (*ii*) a fertility driven path where fertility rates decline as in the baseline projection, while the age-specific survival rates are kept constant at the 2010 levels – "fertility only"; and (*iii*) life expectancy driven path where the survival rates increase as in the baseline projection, while fertility rates are

[29] Note that we find the total tax revenues to increase from 25 percent of GDP in 2010 to over 28 percent of GDP in 2100, mitigating the fiscal gap.

kept constant at the 2010 level – “survival only”.[30]

The simulation results are reported in Figure 5. To ease our comparison, we also include the results for the “baseline” demographic transition (fertility and life expectancy driven) path. Thus, Figure 5 shows four time profiles, with the black curve for the “baseline” path, the green curve for the “no change” path, the red curve for the “survival only” path and the blue curve for the “fertility only” path. The striking aspect is that broadly the “baseline” and “survival only” results track each other, while the effects of the “no change” and “fertility only” paths are close to each other. We discuss these results in detail below.

Figure 5: Macroeconomic and fiscal effects of separating the survival and fertility changes



Notes: "No change" scenario assumes that all vital rates are constant as in 2010; "Survival only" results are obtained by using medium increases in survival rates only, while the medium decreases in the total fertility only are assumed under the "fertility only" case.

Starting with the effects of the “no change” scenario (green curve), Figure 5 shows transitional decreases in per capita labour supply and increases in per capita assets and consumption, even though future fertility and longevity are unchanged. These transitional macroeconomic effects are driven by declining fertility and improving longevity in the past. The past changes in fertility and survival rates generate a declining proportion of the working age population and a higher old-age dependency ratio in future years, causing higher old-age related public expenditures and requiring cuts in other (non-age related)

[30] Similarly to the baseline demographic scenario, the demographic model in Section 2 is fitted with either declining fertility rates (and constant survival) or increasing survival rates (and constant fertility) to derive cohort shares for the two demographic scenarios during each transition path.

expenditures to maintain the budget balance.[31] Note that the differences in the results of the "no change" and "baseline" demographic paths give an estimate of the total effects of demographic shift driven by lower fertility rates and higher life expectancy.

To quantify the effect of the decreasing fertility rate, we compare two scenarios: the "fertility only" scenario (blue curve) vs. the "no change" scenario (green curve). Figure 5 shows that the decreases in the total fertility rate only generate relatively small changes in macroeconomic and fiscal variables, with the effects being very similar to the "no change" scenario. This is because both projections assume constant survival rates and so the transitional effects on household behaviour are limited only to changes in bequests (for both the "no change" and "fertility only" scenarios) and family benefits (only for the "fertility only" scenario). The differences in the results of the two projection scenarios show somewhat positive effects on per capita labour supply, consumption, domestic assets, taxation revenues and budget-neutralising other expenditures of the "fertility only" scenario. This is due to higher proportions of middle aged, working cohorts and old, retired cohorts with large asset holdings in the fertility-driven path scenario with the declining total fertility rate.[32]

Next, we isolate the role of higher survival rates, i.e., life expectancy. To do so, we compare the "survival only" scenario to the "no change" and "baseline" scenarios. On one hand, we find that the transition path results for the "survival only" scenario are close to those for the "baseline" scenario. This indicates that the projected increase in life expectancy is the main driver behind the baseline results reported in Section 4. On the other hand, the behavioural effects and the implications for the cohort shares in the population arising from future longevity improvements are shown to generate large differences in macroeconomic and fiscal results in comparison with the "no change" scenario. In the short and medium runs, households work longer hours and reduce consumption expenditures, resulting in higher average labour supply and lower consumption per capita. These changes lead to significantly larger assets that increase gradually over the entire transition path. In the long run, the smaller share of the working age population and the increases in the old-age dependency ratio relative to the "no change" scenario result in relatively lower average labour supply and higher per capita consumption. The increased old-age dependency ratio also drives up the age related expenditures, as the comparison of the red and green curves in Figure 5 shows. As a consequence, the budget-equilibrating reduc-

[31] The results for this scenario indicate that the structure of the population in 2010 is not stationary and that it takes some time to reach a stable population structure in the future, even though the demographic and economic parameters of the model are kept constant.

[32] The effects of the two demographic scenarios are not largely different due to small transitional decreases in the total fertility rate from 1.8 to 1.7 babies per woman by 2018 that are assumed under the "fertility only" scenario.

tion in other government expenditures under the "survival only" scenario is significantly greater in the long run, compared to the "no change" scenario.

In summary, our quantitative analysis leads to the conclusion that projected increases in survival rates and life expectancy, rather than the decline in fertility rates, are the main driving forces behind the increased fiscal costs during the demographic transition.

5.2 Fertility increase

We extend our analysis to consider the role of fertility in solving the fiscal challenge. It is well documented in the literature that the macroeconomic and fiscal effects of fertility change are inconclusive. For example, Hondroyiannis and Papapetrou (2005) find a positive and statistically significant relationship between higher fertility and output per capita in several European countries, while the simulation results of Guest and McDonald (2002) and Guest (2006) show higher future living standards as a result of a decrease in fertility in Australia.

To quantify the role of increasing fertility, we use the high MoDEM 2.0 assumption for the total fertility rate to construct a "high fertility" scenario. Specifically, our "high fertility" scenario assumes increases in the total fertility rate to 1.9 babies per woman by 2018, while keeping survival rates and immigration rates as in the baseline model. We simulate our economic model using this "high fertility" demographic transition path, compute percentage changes from the baseline transition and report the results in Table 6.

It should be pointed out that any increase in the total fertility rate, holding all other demographic assumptions constant, leads to a larger future population. Consequently, the effects of higher fertility on aggregate macroeconomic variables are positive, driven by increased population growth (not displayed here). The implications for the per capita or average variables are, however, determined by the changes in the shares of age cohorts in the population. In the case of the simulated fertility increase, the proportion of middle-age and older cohorts in the future population decreases, leading to reductions in per capita labour supply, assets and consumption compared to the baseline demographic transition with declining fertility. In particular, Table 6 shows relative decreases in per capita labour supply and domestic assets in 2050 by 2.04 percent and 3.83 percent, respectively.

Table 6: Macroeconomic and fiscal effects of high fertility
(Percentage changes in selected per capita variables from baseline results)

Variable	2015	2030	2050	2100
Labour supply	-0.44	-2.22	-2.04	-0.61
Domestic assets	-0.41	-2.02	-3.83	-4.34
Output (GDP)	-0.41	-2.15	-2.15	-0.78
Tax revenues	-0.41	-2.17	-2.61	-2.02
- Income taxes	-0.42	-2.09	-2.47	-1.58
- Consumption taxes	-0.37	-2.09	-2.66	-3.09
Age related spending	0.10	1.08	0.31	-1.96
- Aged care	-0.40	-2.15	-4.68	-10.19
- Age pension	-0.41	-2.21	-4.80	-8.53
- Family benefits	0.60	2.63	9.14	10.06
Other expenditures [a]	-1.44	-10.71	-13.72	-2.42

Notes: [a] These represent non-age related expenditures assumed to balance the budget.

The results for changes in selected government expenditures presented in Table 6 have the expected sign. Increased fertility reduces (increases) old-age (youth) related public expenditures. In the short and medium terms, total age related expenditures are higher, but they are lower in the long run due to reduced spending on the elderly, compared to the baseline case. The relative decrease in the age pension expenditure is shown to be 4.80 percent in 2050. Given the smaller shares of working middle-age and older cohorts, the increased fertility scenario generates lower tax revenues collected by the government from taxes on labour earnings, asset incomes and private consumption. Our simulation results for the budget-equilibrating policy instrument indicate that relative increases in the expenditures addressed to young households and decreases in average tax revenues dominate relative reductions in the old-age related expenditures, resulting in larger cuts in other expenditures to meet the balanced budget requirement.

5.3 Immigration increase

There is a conventional wisdom among many policy makers that higher immigration would mitigate the negative economic effects of population ageing on the government budget. However, the study by Fehr *et al.* (2004) shows that even a significant increase in skilled immigration would do little to alter future capital shortages, tax hikes and wage falls in the US. In this subsection, we study whether, and if so to what extent, a high immigration policy would be a solution for the fiscal challenge arising from an ageing population in Australia.

To do so, we first use the high MoDEM 2.0 assumptions for net immigration to construct a "high immigration" scenario that assumes 237,000 net immigrants (i.e., an increase of 60,000 immigrants from the baseline assumption). We then simulate our model using this “high immigration” demographic projection. The economic results of this simulation are reported in Table 7 as percentage changes in the selected per capita variables from the baseline results presented in Section 4.

The results for the higher net immigration scenario in our framework are driven solely by the extent to which the assumed immigration increase affects the future age structure of Australia’s population. As already mentioned, our model does not distinguish between native and immigrant households in terms of their behaviour, with immigrants assumed to behave exactly the same as native households of the same age. This is a standard assumption in this type of model (see, for example, Fehr and Habermann, 2006).

Similarly to increased fertility, higher immigration increases the population size, which has positive effects on aggregate variables, so we analyze the effects in terms of per capita variables. Table 7 shows higher per capita labour supply but lower domestic assets relative to the baseline scenario with the medium (lower) number of net immigrants. The concentration of immigrants is particularly high in the 20 to 35 year age group and so the increase in immigration raises the proportion of that age group in the population. The increase in working age population then has positive effects on per capita labour supply. However, the proportion of older cohorts in the total population decreases in the high immigration scenario, resulting in relatively lower assets per capita.

Table 7: Macroeconomic and fiscal effects of high net immigration
(Percentage changes in selected per capita variables from baseline results)

Variable	2015	2030	2050	2100
Labour supply	0.35	1.02	1.58	0.73
Domestic assets	-0.62	-1.58	-1.05	-0.30
Output (GDP)	0.09	0.78	1.37	0.65
Tax revenues	-0.20	0.10	0.48	0.26
- Income taxes	0.15	0.57	0.92	0.49
- Consumption taxes	-0.13	-0.52	-0.48	-0.16
Age related spending	-0.37	-1.07	-2.01	-0.82
- Aged care	-1.21	-4.12	-6.13	-2.58
- Age pension	-1.16	-3.86	-4.95	-1.57
- Family benefits	0.54	1.90	2.01	0.77
Other expenditures [a]	0.17	3.19	9.96	7.51

Notes: [a] These represent non-age related expenditures assumed to balance the budget.

The increased number of immigrants to Australia concentrated in younger age groups is shown to mitigate the effects of population ageing on the budgetary position, but only to a small extent. In Table 7, we report relatively smaller expenditures addressed to older Australians (e.g., aged care and age pension), causing total age related government spending to decline. The tax revenue also increases due to a larger income tax base. The increase in other (non-age related) expenditures, which represents a lower fiscal burden, is about 10 percent in 2050 relative to the baseline demographic transition. However, it should be emphasised that the annual increase of 60,000 in the number of net immigrants assumed under the high immigration scenario still requires a significant reduction in the assumed budget-equilibrating policy instrument (i.e., other government expenditures) by about 25 percent in 2050, compared to 2010. Furthermore, the Australian immigrants, who are concentrated in the young 20-35 age group when they arrive, also become old and eventually start receiving old-age related government expenditures.

6 Sensitivity analysis

This section is devoted to a sensitivity analysis of the results reported in Section 4 to alternative demographic projections and to alternative assumptions of the model. First, we consider two alternative demographic projections: low and high ageing scenarios. Second, the modifications of the economic model include (*i*) using adjustments in the consumption tax rate to balance the government budget rather than the level of government consumption, and (*ii*) allowing for an endogenous rate of interest. Finally, in the appendix, we also present the results of the model simulation where households are not allowed to adjust their lifecycle behaviour to demographic shift to shed light on the role that behavioural responses by households play in the model simulation results.

6.1 Two alternative demographic projections

To determine the impact of demographic shift assumptions on the model simulation outcomes, we now compare the baseline results with the economic results generated by the low and high ageing scenarios. The low (high) ageing scenario assumes (*i*) high (low) fertility and net immigration rates and (*ii*) low (high) survival rates, and generates a lower (higher) old-age dependency ratio. The specific assumptions behind the two alternative demographic scenarios are provided in Section 3. We start with comparing some of the behavioural life-cycle effects and then proceed to a comparison of the macroeconomic and fiscal effects.

6.1.1 Behavioural life-cycle effects

Table 8 reports the behavioural life-cycle effects of the two alternative ageing scenarios as percentage changes in the selected household variables for selected age cohorts relative to the baseline life-cycle results in 2015 and 2050. The results are presented for household labour supply, consumption, total assets and pension payments of young, middle-age, old and very old cohorts (i.e., those aged 30, 50, 65 and 80 years in 2015 and 2050).[33] For instance, the value of 9.51 for labour supply at age 65 under the high ageing scenario denotes a 9.51 percent increase in labour supply of a 65 year old in 2015 compared to the baseline labour supply of the same cohort in the same year.

Table 8: Behavioural life-cycle effects of alternative ageing scenarios
(Percentage changes in selected variables from baseline results in 2015 and 2050)

Variable	Age	Year 2015		Year 2050	
		Low ageing	High ageing	Low ageing	High ageing
Labour supply	30	-0.54	1.15	-0.67	1.39
	50	-1.00	2.15	-0.57	1.25
	65	-4.39	9.51	-0.38	1.93
Consumption	30	0.49	-1.05	0.49	-1.05
	50	0.78	-1.67	0.38	-0.86
	65	1.27	-2.74	0.11	-0.51
	80	1.83	-4.36	-1.27	1.40
Total assets	30	-4.41	8.56	-7.53	12.79
	50	-0.92	1.90	-2.89	5.65
	65	-1.22	2.57	-3.85	7.37
	80	-1.71	3.93	-7.84	15.49
Age pension	65	4.97	-10.60	6.49	-13.32
	80	0.32	-0.74	2.57	-5.06

The results in Table 8 are driven to a large extent by changes in survival rates and partly by changes in family benefits that are received by working households. Under the high (low) ageing scenario, survival rates increase (decrease) and family benefit payments decrease (increase) in comparison with the baseline demographic projections. As a result, households work more and consume less in the high ageing scenario with increased longevity and smaller family benefits. Consequently, households accumulate greater assets (especially in the long run), which lead to the means testing of increased incomes and lower age pension payments. Specifically, the total assets of the 65 year old in 2050 increase by 7.37 percent and her or his pension payments decline by 13.32 percent relative to the baseline scenario in 2050, as shown in Table 8.

6.1.2 Macroeconomic and fiscal effects

The macroeconomic and fiscal effects of the two alternative ageing scenarios displayed in Table 9 are partly determined by the life-cycle implications discussed above. The percent-

[33] The results for labour supply are not reported for 80 year olds as they are retired and thus supply no labour. The age pension payments for those aged younger than 65 are zero as these payments are only paid from age 65.

age changes in per capita labour supply are initially positive in the high ageing scenario as households respond to increased longevity by working longer hours. The declining share of the working age population causes per capita labour supply to decrease at a faster rate and by 2050 it is about 1.92 percent smaller compared to the baseline transition. On the contrary, per capita consumption initially declines (due to lower consumption at the household level), but is higher in the medium and long terms (due to increased shares of middle aged and older cohorts with higher consumption expenditures). Domestic total assets per capita grow significantly under the high ageing scenario. Note, however, that all macroeconomic aggregates are substantially smaller especially in the long run under the high ageing scenario, which is due to smaller population growth.[34]

Table 9: Macroeconomic and fiscal effects of alternative demographic transitions
(Percentage changes in the selected per capita variables relative to baseline results)

Variable	Low ageing scenario				High ageing scenario			
	2015	2030	2050	2100	2015	2030	2050	2100
Labour supply	-1.14	-1.48	0.06	1.07	2.23	1.43	-1.92	-4.06
Domestic assets	-2.20	-7.71	-10.14	-10.14	3.51	12.68	16.62	15.93
Output (GDP)	-1.07	-1.66	-0.25	0.84	1.85	1.62	-1.57	-3.78
Tax revenues	-1.14	-2.71	-2.57	-2.09	1.70	3.28	2.52	1.48
- Income taxes	-1.59	-2.94	-2.57	-1.85	2.98	4.23	2.75	1.14
- Consumption taxes	0.41	-2.39	-3.53	-3.96	-1.43	2.25	4.37	5.12
Age related spending	-0.22	-0.51	-3.44	-5.22	0.22	1.80	8.09	11.85
- Aged care	-2.57	-10.91	-19.97	-23.36	4.32	20.95	43.33	52.55
- Age pension	-0.79	-6.44	-12.14	-13.33	0.11	8.47	19.06	21.58
- Family benefits	1.23	5.11	12.52	12.82	-1.48	-6.63	-15.70	-16.34
Other expenditures [a]	-3.03	-8.50	0.74	18.82	4.72	7.16	-18.66	-67.66

Notes: [a] These represent non-age related expenditures that are assumed to balance the budget.

Table 9 shows that the sign for the age related fiscal expenditures is as expected. The high (low) age scenario generates larger (smaller) age related expenditures compared to the baseline demographic transition. For example, the relative increase in government spending on the age pension under the high ageing scenario is 19.06 percent in 2050. The tax revenue collected by the government is also higher under the high ageing scenario because of higher income and consumption tax receipts. In the short and medium run, the increased tax revenue dominates, which requires smaller reductions in non-age related government expenditures, as shown by positive effects on other expenditures in Table 9. In the long run, the reduction in the assumed budget-balancing instrument is greater because of increasingly higher public spending on health care, aged care and age pensions. In particular, we find a decrease of 18.66 percent in other expenditures under the high ageing scenario in 2050, compared to the baseline demographic transition.

[34] Recall that the low ageing scenario with increased fertility and net immigration is also a high population scenario.

6.2 Consumption tax adjustments

In this modification of the economic model, the other (non-age related) government expenditures are fixed in per capita terms and the government budget is balanced through changes in the consumption tax rate. While the changes in the non-age related government expenditures assumed in the two previous sections have had no effect on household behaviour, any adjustment to the consumption tax rate will impact consumption and labour supply decisions of households and alter their asset accumulations. The results for the two alterations of the model are displayed in Table 10 as percentage changes in the selected per capita variables relative to the baseline results.

Table 10: Sensitivity to adjustments in the consumption tax rate
(Percentage changes in selected variables relative to baseline results)

Variable	2015	2030	2050	2100
Labour supply	0.38	0.57	1.14	2.80
Wage rate	-0.07	0.00	0.00	-0.01
Capital stock	0.22	0.58	1.14	2.78
Domestic assets	0.78	4.05	5.24	3.08
Output (GDP)	0.29	0.57	1.12	2.78
Consumption	0.29	-0.69	-2.03	-4.20
Income taxes	0.64	1.82	2.82	4.06
Pension expenditure	-0.07	-1.03	-1.91	-2.13
Consumption tax rate [a]	-9.80	6.61	28.02	53.22

Notes: [a] This tax rate is assumed to balance the government budget.

Table 10 shows that the increase in the consumption tax rate is 28 percent by 2050 and 53.22 percent by 2100 in order to offset significantly larger old-age related expenditures.[35] This means that the effective rate of the consumption tax, which is about 14.6 percent in 2010 would increase to almost 19 percent in 2050 and to over 22 percent in 2100.[36] The increases in the consumption tax rate generate lower per capita net consumption in the medium and long terms relative to the baseline simulation in Section 4. On the other hand, per capita labour supply increases, compared to the baseline simulation. This is because households not only reduce consumption but also their leisure as a result of higher consumption taxes. The resulting higher labour supply and lower net consumption over the life-cycle translate to larger asset accumulations and higher domestic assets per

[35] Note that the fiscal situation in the short run actually improves due to increased overall taxation revenues, which allows for a reduction in the budget-equilibrating consumption tax rate in the short run.

[36] As discussed in the calibration section, we set the consumption tax rate to the statutory GST rate of 10 percent and then compute the adjustment factor to generate the consumption tax revenue set at 7.5 percent of GDP. The adjustment factor is about 1.46 because the consumption tax revenue includes not only the GST revenue but also the excise revenue. Therefore, the effective consumption tax rate is higher than the GST rate, amounting to around 14.6 percent in 2010.

capita relative to the baseline simulation.[37]

6.3 Endogenous domestic interest rate

We have so far assumed that the domestic interest rate was equal to the exogenously given world interest rate, which is a standard feature of an small open economy model. We now relax this assumption and consider an open economy where the domestic interest rate depends on not only the world interest rate but also the level of net foreign debt. In particular, we set the domestic interest rate to

$$r_t = \bar{r} + \gamma \left(FD_t / Y_t - FD_{2010} / Y_{2010} \right),$$

where $\bar{r}$ is the exogenous world interest rate, FD_t/Y_t is the ratio of net foreign debt to output and the parameter $\gamma > 0$ gives responsiveness to the changes in FD_t/Y_t. Under this specification, the domestic interest rate will rise if the ratio of net foreign debt to output increases. This assumption of an endogenous domestic interest rate implies that the capital labour ratio and the total wage rate faced by firms will now change in the long run as well as during the transition. Hence, long run changes in the capital stock, labour supply and output will differ under this model specification.

Following Guest (2006), we set $\gamma = 0.02$ and simulate our model with the baseline demographic transition path. The results for the selected per capita variables and for the changes in the domestic interest rate are reported in Table 11.

Table 11: Sensitivity to endogenous rate of interest
(Percentage changes in selected variables relative to baseline results)

Variable	2015	2030	2050	2100
Labour supply	-1.01	0.29	2.17	2.80
Wage rate	1.72	6.10	9.69	11.89
Capital stock	2.81	14.40	25.50	31.99
Domestic assets	-1.21	-6.05	-10.21	-11.58
Output (GDP)	0.19	5.78	11.48	14.53
Consumption	0.99	1.04	0.21	-0.92
Income taxes	0.16	5.72	11.40	14.19
Pension expenditure	0.50	4.04	7.00	8.46
Other expenditure [a]	-3.14	2.01	10.58	18.86
Interest rate	-3.90	-14.28	-19.90	-24.89

Notes: [a] These represent non-age related expenditures assumed to balance the budget.

[37] We do not report the effects on age related government expenditures other than the age pension. These effects are driven by the changes in the future cohort shares only, which are assumed to be the same as in Section 4.

The domestic interest rate is shown to decline by 19.9 percent from 5 percent in 2010 to 4 percent in 2050. This means a lower cost of capital, which has positive effects on investment demand and the capital stock. The capital stock increases by around 25 percent in 2050 relative to the baseline simulation with the exogenous interest rate. As a result, there are further increases in the market wage rate, which is also supportive for per capita labour supply. However, the increases in domestic assets per capita are not as large as under the baseline simulation due to the decreasing interest rate. Particularly, the domestic total assets decrease by 10.21 percent in 2050 relative to the baseline simulation.

The effects on government expenditures that are driven largely by the demographic change are similar to those reported in Section 4. However, the cuts in the non-age related expenditure required to balance the budget are smaller compared to the baseline simulation because of improved revenues from personal income and corporation tax revenues. Table 10 shows that the assumed budget-equilibrating instrument is over 10 percent higher than the baseline other expenditure in 2050.

6.4 Summary of sensitivity outcomes

The sensitivity of the baseline results have been examined with respect to (*i*) alternative demographic transitions (i.e., low and high ageing scenarios), (*ii*) an alternative budget-equilibrating policy (i.e., the consumption tax rate) and (*iii*) an alternative market structure (i.e., imperfect capital mobility with endogenous interest rate). The results of the two alternative demographic transition paths are shown to be highly significant at both the household and macroeconomic levels.

Under the high ageing scenario, households work more initially and accumulate larger assets, adjusting their behaviour to improved life expectancies. At the aggregate level, we show that the relative increase in age-related public expenditures and the required cuts in the budget-equilibrating other government expenditures, which represent the fiscal costs of ageing, are greater due to higher future shares of the elderly in the population. The second alteration of the baseline simulation with the consumption tax adjustments to balance the government budget provides an additional feedback/indirect effect on household behaviour. Relative to the baseline results, we find that the budget-equilibrating increases in the consumption tax rate reduce per capita consumption, but have somewhat positive effects on most other macro variables, including per capita labour supply and domestic assets. Finally, the imperfect capital mobility simulation with the endogenous domestic interest rate generates significant increases in the capital labour ratio and higher wages. Similar effects of the population ageing are often derived from closed economy models (e.g., Miles 1999).

7 Concluding remarks

Understanding the consequences of demographic transition in the context of Australian economy will give an insight for policy implications, not only for Australia but also for other ageing economies. In this paper, we have presented a quantitative analysis of the effects of projected future demographic changes in Australia, using a dynamic general equilibrium OLG model incorporating the main aspects of Australia's fiscal and retirement income policy settings. Our model specification pays special attention to the fiscal implications of the demographic shift, with a focus on the disaggregation of age-related government expenditure and on the tax base, and upon the individual roles played by the fertility, longevity and immigration aspects of Australia's demographic transition.

On the basis of our simulations, we find that the projected ageing of the population leads to decreases in the labor market activities of around 7 percent by 2050. This subsequently results in a contraction in production, with a decrease in GDP per capita of 6.2 percent by 2050. Fewer investment opportunities in the domestic economy lead to increased capital outflows. Moreover, we find important implications for the Australian government's budgetary situation. The demographic transition causes significant changes in the tax base, shifting from labor income to capital/asset income and private consumption. On the expenditure side, the higher proportion of older cohorts in the population causes substantial increases in old-age related spending of around 5.5 percent of GDP by 2050, with substantial variations between health care, age care and pensions. Significant adjustments in other government expenditures and/or taxes will be required to finance the larger old-age related benefits in the future.

Our paper has contributed to the understanding of the roles played by the several factors underlying demographic shift by decomposing their effects. Our analysis has revealed the increase in survival probabilities, rather than the decline in fertility rates, as the main driver behind the increased fiscal costs associated with population ageing. We also find that the transitional decreases in per capita labour supply, the increases in old-age related expenditures and the fiscal burden, expressed as reductions in other public expenditures, are partly driven by past changes in these demographic factors. Furthermore, increased fertility is found to further reduce GDP per capita and to increase the fiscal pressure. Importantly, the simulation results for higher net immigration rates are shown to be somewhat positive for GDP per capita and for the fiscal indicators. These effects are, however, small for quite a large increase in the number of net immigrants, which leads us to conclude that an increase in permanent immigration alone is not an effective solution to the challenges arising from population ageing.

The focus of this paper has been on the implications of the current and projected demographic transition in Australia. Thus, the analyses undertaken in this paper do not account for any non-demographic factors, including structural fiscal reforms that are to be implemented in near future. However, it is straightforward to extend our framework to quantify the effects of fiscal reforms to respond to the fiscal costs of population ageing. We leave this important issue for future research.

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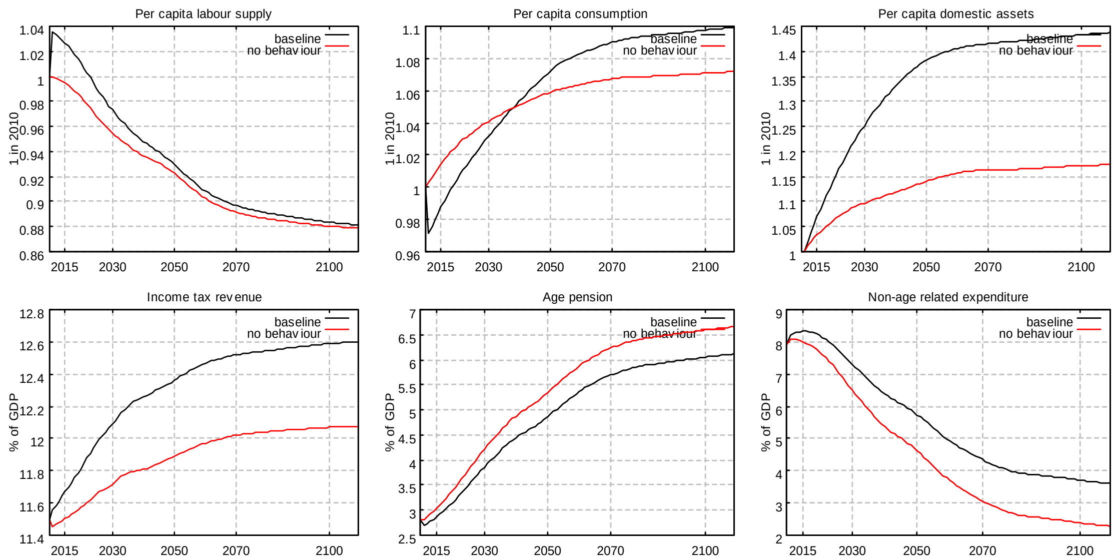
Appendix A - Abstracting from behavioural responses to ageing

The behavioural responses of households to the baseline demographic transition (e.g., increased total assets at the household level) that we have shown in Section 4 are absent in the simulation undertaken here. This means that for example, per capita labour supply is now calculated as the product of average labour supply in 2010 and the future cohort shares in the total population. The same holds for other per capita variables such as domestic total assets and consumption. Note that we allow the profit maximising behaviour in the production sector that uses per capita labour supply to compute other production variables, including average output (GDP), capital stock, investment, the wage rate and the price of capital. The results below, comparing simulation results with and without household behavioural responses, indicate that behavioural responses by households play an important role in determining the overall impacts of population ageing and policy upon the economy.

Figure A1: Macroeconomic and fiscal effects of abstracting from behavioural changes



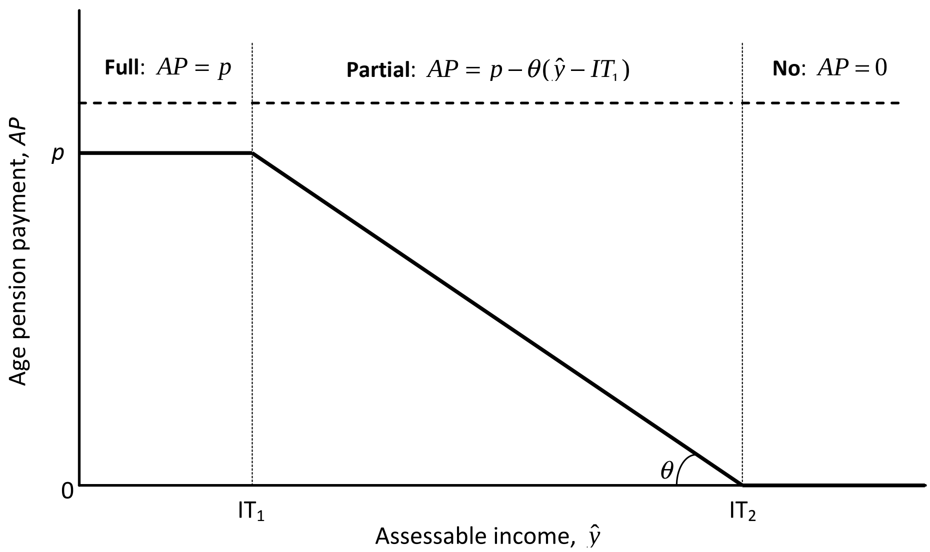
Notes: Non-age related expenditure is assumed to balances the government budget.

Figure $A1$ shows that abstracting from behavioural household responses generates greater decreases in per capita labour supply. The increases in domestic total assets per capita are due only to the projected changes in the future cohort shares.[38] Hence, domestic assets are significantly lower compared to the baseline simulation with behavioural household responses. In contrast, per capita consumption increases initially as households do not reduce their spending in response to increased life expectancy. The fiscal effects on the non-age related expenditure (labeled as other expenditure) indicate that a further decrease of 18.74 percent in this expenditure relative to the baseline simulation is required to maintain a balanced government budget in year 2050. This relative decrease in the assumed budget-equilibrating policy instrument is due largely to relative decreases in the income tax revenues and increases in the age pension expenditures.

Appendix B - Means-tested pension and progressive income tax functions

Means-tested pension. Figure A2 depicts the association between the age pension payment, AP, and assessable income, $\widehat{y}$. The figure indicates that eligible pensioners (i.e., those aged 65 years and over) are paid the maximum pension, p, provided that their assessable income is not above the (lower bound) income threshold, IT_1. If the assessable income exceeds this threshold, then the maximum pension is reduced at the income taper rate, θ, for every additional dollar of assessable income earned, $\widehat{y} - IT_1$. If the assessable income exceeds the upper bound threshold, IT_2, then there is no age pension paid.

Figure A2: Association between the age pension and assessable income

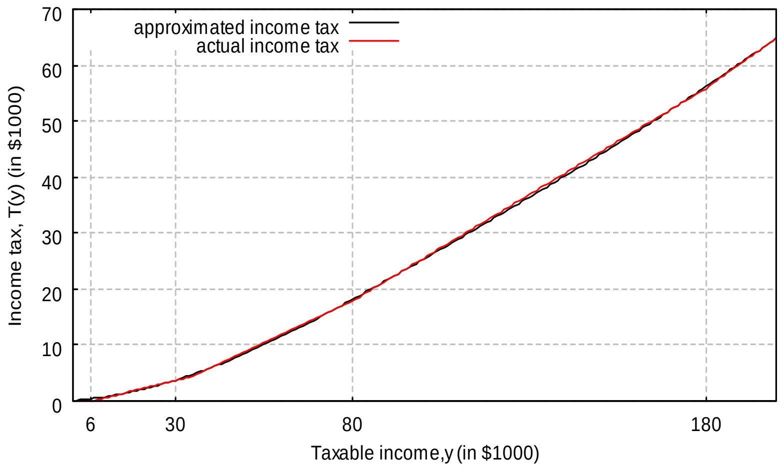


[38] At the household level, total assets are unchanged in this simulation.

Progressive income tax. In 2009-10, the Australian personal income tax schedule featured the following five tax brackets: \$0 to \$6,000 with a zero marginal tax rate, \$6,001 to \$30,000 with a marginal tax rate of 15 percent, \$30,001 to \$80,000 with a marginal tax rate of 30 percent, \$80,001 to \$180,000 with a marginal tax rate of 38 percent and above \$180,000 with the top marginal tax rate of 45 percent.

We use a differentiable approximation function of the 2009-10 Australian progressive personal income tax schedule. Figure A3 presents the income tax function used in the model, which is a close approximation of the actual progressive income tax schedule in 2009-10.[39]

Figure A3: Approximated and actual income taxation in 2009-10



[39]The approximation income tax function and the estimation procedure are available from the authors.