Sustainable and Equitable Pensions with Means Testing in Aging Economies

By

George Kudrna
Chung Tran
Alan Woodland

ANU Working Papers in Economics and Econometrics
#666

December 2018 JEL: H2, H55, J1, C68

ISBN: 0 86831 666 0

Sustainable and Equitable Pensions with Means Testing in Aging Economies*

George Kudrna† Chung Tran‡ Alan Woodland§

December 2018

Abstract

A means-tested pension system has a distinct feature that tailors the level of pension benefits according to individual economic status. In the context of population aging with widening gaps in life expectancies, this feature generates an automatic adjustment mechanism that (*i*) mitigates the pressing fiscal cost of an old-age public pension program (fiscal stabilization device) and (*ii*) redistributes pension benefits to those in need with shorter life expectancies (redistributive device). To evaluate this automatic adjustment mechanism, we employ an overlapping generations model with population aging. Our results indicate that this novel mechanism plays an important role in containing the adverse effects of population aging on the fiscal costs and progressivity of a pension system. More pronounced aging scenarios further strengthen the role of this mechanism. A well-designed means test rule can create a sufficiently strong automatic mechanism to keep public pensions sustainable and equitable. Importantly, it is feasible to devise a pension reform that better adapts a means-tested pension system to more pronounced demographic trends, but does not lower the welfare of current and future individuals of all ages and income.

Keywords: Population Aging, Sustainability, Social Security, Means Testing, Redistribution, Automatic Stabilizer, Overlapping Generations, Dynamic General Equilibrium.

JEL Classification: H2, H55, J1, C68

*We would like to thank participants of the Econometric Society Australasian Meeting 2018, 9^{th} Annual APRU Research Conference on Population Aging and of seminars at the Australian National University, University of New South Wales and University of Lausanne for comments and feedback. This research was supported by the Australian Research Council through its grant to the ARC Centre of Excellence in Population Ageing Research (CEPAR).

†CEPAR, University of New South Wales, e-mail: g.kudrna@unsw.edu.au.

‡Research School of Economics, Australian National University, e-mail: chung.tran@anu.edu.au.

§School of Economics, University of New South Wales, e-mail: a.woodland@unsw.edu.au.

1 Introduction

Population aging poses unprecedented challenges for pension systems in many countries. A central issue with pension systems is a failure to adapt to long-run demographic trends, including declining fertility, increasing life expectancy and disparity in life expectancies.[1] Many features of a traditional social security pension system such as contribution rates, defined benefits and retirement ages were set in the earlier stages of demographic transition and now are not consistent with extending retirements and rapidly growing older populations. In response to the rising fiscal costs associated with population aging, many governments have reformed their pension systems to keep them fiscally affordable. The common measures include delaying the age-pension access age, extending the contribution period, lowering indexation, adjusting the pension benefit formulae and introducing some longevity adjustment factors.

The main source of aging-related fiscal problems in such defined-benefit pension systems (e.g., pay-as-you-go social security in the US) is their static design with no automatic adjustment to demographic trends. However, there exists a variety of other pension systems across advanced economies. For instance, Australia, Denmark and the UK have pension systems in which (some) public pension benefits are means tested. Australia is a notable example where the age pension system has the following distinct features: (*i*) the benefits are dependent on economic status (income and/or assets); (*ii*) the benefits are independent of individuals' earnings and contribution history; and (*iii*) the system is not universal, with around 30% of the age-eligible population (i.e., affluent elderly) not receiving any age pension.[2] Hence, the Australian age pension is means-tested, non-contributory, and funded from general tax revenues.

In this paper, we study the means testing of public pensions as a response mechanism to population aging. We argue that inclusion of means testing in benefit payments creates a novel mechanism that automatically adapts public pension systems to changing demographic trends. In the context of population aging, such a dynamic design allows governments to keep financing costs of a public pension program in check (fiscal stabilization) while directing pension benefits to those seniors most in need (redistribution). This automatic adjustment mechanism provided by means testing has not previously been analyzed in the literature. The main purpose of this paper is to better understand to what extent this built-in mechanism can contain the adverse effects of population aging on the fiscal costs and progressivity of a pension system.

To do so, we begin by formulating a simple two-period model to theoretically explore how means testing provides an automatic adjustment mechanism that responds to population aging. In our model, individuals are heterogeneous in their earning ability and mortality. In particular, we assume those with higher earning ability have lower mortality. This assumption is motivated by the empirical research that documents a negative correlation between income and mortality (e.g., see Waldron (2007) and Cristia (2009)). We find that the presence of means

[1] Life expectancy differences by socio-economic status are documented, for example, by Von Gaudecker and Scholz (2008) for Germany, Clarke and Leigh (2011) for Australia, Villegas and Haberman (2014) for England, Cristia (2009) and Chetty et al. (2016) for the US and OECD (2016) for selected OECD countries.

[2] A more detailed description of Australia's public pension system is provided in the appendix.

testing introduces interaction between private savings and public pension benefits. In an aging environment, this feature generates an automatic mechanism that partly shifts the funding of retirement income provision from the public to the private sector (fiscal stabilization device) and that redistributes public pension income toward lower-income, shorter-lived individuals (redistributive device).

More specifically, the presence of means testing establishes a link between the individual-specific economic status and the level of public retirement income support. This feature creates a built-in adjustment mechanism that automatically adjusts the level of individual-specific pension benefits and the total fiscal costs according to changes in demographic factors, thus creating a fiscal stabilization device. The logic is as follows. Forward-looking agents optimally alter their consumption, savings and labor supply over the life cycle in response to anticipated changes in fertility and survival rates. The anticipated increases in longevity will thereby induce individuals to save and work more and to participate longer in the labor force, so that they can support themselves through a longer retirement period. Other things equal, such increases in savings and labor supply will reduce the level of pension benefits paid by the government because of the means testing based on current incomes and/or asset levels. Indeed, this built-in device will automatically adjust the balance of retirement income support between a public pension system and private retirement savings. The role of this automatic fiscal stabilization device embedded in the means tested pension system becomes more pronounced under population aging because it can limit the fiscal costs of aging demographics, while allowing individuals to adjust their labor supply and savings for retirement years ahead.

In addition, means testing introduces another mechanism that automatically adjusts the progressivity of pension benefits, mitigating distributional consequences of increased disparity in life expectancies across income groups, i.e., a redistributive device. Generally speaking, higher skilled agents who command higher earnings typically have lower mortality rates and, hence, greater life expectancy. Population aging through greater life expectancy correlated with skill levels is thus likely to increase the proportion of seniors in higher skilled categories and hence, via the means testing of age pensions, likely to reduce the proportion of seniors receiving the full age pension and reduce the pension benefits for those receiving part pension payments. Accordingly, this positive correlation between longevity and income provides an important channel for means testing to facilitate the sustainability of the age pension system and to redistribute income from richer to poorer agents.

With this theoretical guide based on a simple two-period model, we next quantify the role of this adjustment mechanism in a full dynamic general equilibrium model. We formulate a multi-period, overlapping generations (OLG) model with population aging. This class of macroeconomic models was pioneered by Auerbach and Kotlikoff (1987) and used by many researchers worldwide to analyze the economic effects of population ageing (see, for example, Fehr (2000); Nishiyama (2004); Krueger and Ludwig (2007); Kitao (2014)). In our model, individuals of each cohort are heterogeneous in their earning ability and mortality. In addition, our model includes the salient features of Australia's means-tested pension system. We discipline the benchmark model to match key patterns of the life-cycle behavior of Australian households as well as essential macroeconomic aspects of the Australian economy.

In our quantitative analysis, we consider several population aging scenarios projected for Australia in the next 50 years, approximating demographic changes projected for many other developed countries. We conduct a series of partial and general equilibrium analyses and demonstrate that the automatic adjustment mechanism provided by means testing is quantitatively important in containing the adverse effects of population aging on both the fiscal costs and progressivity of a pension system. Our quantitative results can be summarized as follows.

First, the fiscal costs of age pension programs will increase significantly due to population aging, especially in the economy with a universal pay-as-you-go pension system. A means-tested pension system with a built-in automatic fiscal stabilization device can contain the increased fiscal costs. The strength of this automatic adjustment mechanism depends on the value of the taper rate (at which means-tested pension benefits are withdrawn). Higher values of the taper rate strengthen this fiscal stabilization mechanism. There is a range of progressive means testing rules with relatively high taper rates that would keep the pension system fiscally sustainable in the long run.

Second, the gap in life expectancies between low- and high-income groups is expected to widen, which will weaken the redistribution role of traditional social security pension systems. The means-tested pension system, through its automatic redistributive device, can mitigate such adverse effects on income distribution and the overall progressivity of public pension payments. Our quantitative results indicate that means-tested systems with higher taper rates automatically direct public pension benefits toward lower-skilled, less-affluent and shorter-lived groups of households and maintain the progressivity of public pension income.

Third, the automatic adjustment mechanism embedded in means-tested pension systems becomes more effective under more pronounced population aging scenarios. That is, the role of the automatic adjustment mechanism is further strengthened in a fast aging economy. More pronounced demographic trends require more progressive means testing rules.

Finally, pension reforms are necessary to better adapt a means-tested pension system to demographic challenges. However, it is challenging to do it in a welfare-improving way for all current and future individuals of all ages. Our analysis indicates that it is possible to devise a pension reform that does not lower the welfare of any individual in any birth cohort relative to the continuation of status quo, while enhancing the role of automatic stabilization device and making a means-tested pension system more sustainable and equitable.

Hence, our findings indicate that a careful design of means-tested pensions can provide a sufficiently strong automatic adjustment mechanism that effectively addresses both sustainability and equity concerns caused by population aging. Accordingly, our results have potentially important implications for reforming pay-as-you-go social security systems in the US and many other Organisation for Economic Co-operation and Development (OECD) countries.

Related literature. Our paper is related to recent research analyzing the economic effects of means testing in the context of public transfer programs, using OLG models. Braun et al. (2017) explore the insurance role of means testing associated with social insurance programs such as Medicaid and Supplemental Security Income for retirees in the US. They show that the welfare gains from these programs are large, even though the current scale of means-tested social insurance programs in the US is small. Kitao (2014) studies the option of introducing the means test into the US social security system, in order to control the pressing fiscal costs of population aging in the US. Her paper considers one special form of the means test, causing the pension benefits to fall one-to-one with income above a test threshold level (i.e., effectively setting the taper rate to one). None of these previous studies explores the automatic adjustment mechanism embedded in a means-tested pension system under population aging, which is the focus of our paper.

Our study contributes to the recent literature on the effects of means-tested pension systems in general equilibrium life-cycle models. This literature has predominantly relied on the OLG models with stationary demographic structures, thus abstracting from population aging (e.g., see Sefton et al. (2008); Kudrna and Woodland (2011), Tran and Woodland (2014); Fehr and Uhde (2014); Kudrna (2016)). We extend that literature by introducing population aging and examining how means-tested pension systems perform under a wide range of demographic scenarios, including plausible future demographic structures with declining population growth, increasing overall longevity and widening mortality gaps between high- and low-skilled groups of individuals.

Our paper is also connected to a large body of literature that quantifies the fiscal costs of population aging in advanced economies and studies the implications of pension and tax policy reforms designed for the mitigation of these fiscal costs. Various reforms have been proposed to reduce the cost of the social security programs or raise revenue to fund them (e.g., see Kotlikoff et al. (2007), Krueger and Ludwig (2007), Kitao (2014), Nishiyama (2015) and McGrattan and Prescott (2017) for the US; Braun and Joines (2015), Kitao (2015) and Imrohoroglu et al. (2016) for Japan; and Kudrna et al. (2018) for Australia). McGrattan and Prescott (2017) in particular consider several reform proposals to switch from a pay-as-you-go (PAYG) social security system that relies on high payroll taxes to a fully-funded, saving-for-retirement system in the US. They show that it is possible to devise a transition path from the current US system to a funded system that increases the welfare of both current and future generations. Differently, we do not consider any particular reform of tax increases and old-age benefits cuts. Rather, we focus on the new mechanism that automatically adapts means-tested pension systems to demographic trends. We show that it is possible to devise an automatic adjustment mechanism that is capable of containing the fiscal costs in an aging economy.

Hosseini and Shourideh (2018) study Pareto optimal policy reforms aimed at overhauling retirement financing as part of a comprehensive fiscal policy in the US. They use a heterogeneous-agent, overlapping-generations model that matches the aggregate and distributional features of the US economy. They consider the Pareto optimal policy reform in which the consumption tax is used to finance additional fiscal costs of population aging. Our paper shares similar modeling features, including heterogeneity in earning ability and mortality, but has a different focus. We study a design of a means-tested pension system that is fundamentally different from a defined-benefit pension system as in the US. We show that the proper designs of means-tested pension payments enable a built-in adjustment mechanism that automatically adapts a pension system to population aging.

It is well documented that life expectancy increases more for those at the top of the income distribution in the US (e.g., see Cristia (2009) and Chetty et al. (2016)). The effect of the widening gap in life expectancy between low and high income groups on the US social security system has received attention recently (Waldron (2007) and Auerbach et al. (2017)). Specifically, Auerbach et al. (2017) find that the growing disparity in life expectancy significantly reduces the progressivity of the US defined-benefit social security system. Our study approaches this issue from a different perspective. We show that a different design of a pension system with the presence of mean testing can mitigate the adverse effects of widening life expectancy gap on the progressivity of a pension system. Indeed, it is possible to devise an automatic redistributive mechanism that automatically directs pension benefits to less-affluent and shorter-lived retirees in an aging economy.

The rest of the paper is organized as follows. In the next section, we formulate a simple two-period model to demonstrate the dual role of means testing – as a fiscal stabilization device and as a redistributive device. Section 3 describes the dynamic general equilibrium OLG model. Section 4 reports on the calibration of the model to the Australian economy and the properties of the calibrated benchmark model. Section 5 presents the quantitative analysis of the automatic adjustment mechanism embedded in a means-tested pension system under different aging scenarios. Section 6 is devoted to a sensitivity analysis of the model results to several modifications. Section 7 offers some concluding remarks. The Appendix reports our additional results.[3]

2 A simple two-period model

This section constructs a two-period model to highlight how the presence of means testing in a public pension program automatically (i) mitigates the fiscal costs due to aging and (ii) redistributes public pensions toward low-skilled, shorter-lived retirees.

2.1 Environment

We consider a simple partial equilibrium economy that consists of agents living for two periods: young in period 1 and old in period 2. Agents are endowed with 1 unit of time, work in period

[3]The Appendix is also available online at https://bit.ly/2rNJaIU.

1 and retire in period 2. Agents are different in terms of work ability, which determines labor income w_1^i received at the beginning of period 1, and the survival probability π^i to period 2.

Household utility maximization. Each agent decides on consumption and saving in period 1 and consumption in period 2 to maximize expected utility, taking the government pension policy as given. The agent's optimization problem is

$$\max_{c_1^i,\, c_2^i,\, s^i} \left\{ u\left(c_1^i\right) + \beta \pi^i u\left(c_2^i\right) : c_1^i + s^i = \left(1 - \tau^{ss}\right) w_1^i \text{ and } c_2^i = \left(1 + r\right) s^i + P^i \right\}, \tag{1}$$

where β is the time discount factor, c_1^i is consumption when young, s^i denotes saving, c_2^i is consumption when old, r stands for the market rate of return on saving, τ^{ss} is the social security tax rate and P^i is the means-tested pension benefit.

The government runs a means-tested pension system. A general function for the means-tested pension payment is given by

$$P^i = \begin{cases} P^{\max} - \theta r s^i & \text{if } r s^i < \overline{y}_2, \\ 0 & \text{if } r s^i \geq \overline{y}_2, \end{cases} \tag{2}$$

where $P^{\max}$ is the maximum pension benefit, θ is the taper rate, $\overline{y}_2$ is the income test threshold and rs^i is the individual testable (or assessable) income earned from saving s^i.

To aid the exposition, we consider a case in which individuals have log preferences $u\left(c\right) = \log c$ and $\beta = 1$ and in which the optimal solution yields $rs^i < \overline{y}_2$. This implies that $P^i = P^{\max} - \theta r s^i$ and the household budget constraint in period 2, $c_2^i = \left[1 + (1 - \theta) r\right] s^i + P^{\max}$. In this case, the lifetime budget constraint is defined by $c_1^i + \frac{c_2^i}{R} = \left(1 - \tau^{ss}\right) w_1^i + \frac{P^{\max}}{R}$, where $R = 1 + \left(1 - \theta\right) r$ the gross rate of return after the income test. Using these simplifications and defining $M^i = \left(1 - \tau^{ss}\right) w_1^i + \frac{P^{\max}}{R}$ to be the lifetime income, the optimal consumption and saving plans of each i-type agent are derived from the first-order optimality conditions as

$$\begin{aligned} c_1^i &= \frac{1}{1 + \pi^i} M^i, \\ c_2^i &= \frac{\pi^i R}{\left(1 + \pi^i\right)} M^i, \\ s^i &= \frac{\pi^i}{\left(1 + \pi^i\right)} \left(1 - \tau^{ss}\right) w_1^i - \frac{1}{1 + \pi^i} \frac{P^{\max}}{R}. \end{aligned} \tag{3}$$

Means testing and incentive to save. The presence of means testing affects incentives to save for retirement. Taking the first derivatives of the optimal saving function derived above with respect to the maximum pension benefit and taper rate yields $\frac{\partial s^i}{\partial P^{\max}} = -\frac{1}{1+\pi^i} \frac{1}{R} < 0$ and $\frac{\partial s^i}{\partial \theta} = \frac{1}{1+\pi^i} \frac{r P^{\max}}{R^2} > 0$, respectively. The former derivative implies that an increased maximum pension benefit reduces savings for retirement, which is a classic result from the social security literature. The latter derivative indicates that a higher taper rate induces agents to save more for retirement. The intuition is that tightening the means test lowers the pension benefit received in period 2, i.e., $\frac{\partial P^i}{\partial \theta} = -rs^i$, which then requires more private saving to fund retirement consumption.

2.2 Automatic adjustment mechanism

Fiscal stabilization device. Survival rates have direct effects on means-tested pension benefits. As agents expect to live longer, they optimally increase their savings for retirement as shown by

$$\frac{\partial s^i}{\partial \pi^i} = \frac{1}{(1+\pi^i)^2} M^i > 0.$$

Such a behavioral response lowers pension benefits, $\frac{\partial P^i}{\partial s^i} = -\theta r < 0$, due to the means testing of increased income earned from savings. As a result, the pension benefits received when retired are lower for those agents who have higher survival rates, $\frac{\partial P^i}{\partial \pi^i} = \frac{\partial P^i}{\partial s^i} \frac{\partial s^i}{\partial \pi^i} < 0$. Precisely, the effect of a change in the survival rate on the means-tested pension benefit is given by

$$\frac{\partial P^i}{\partial \pi^i} = \frac{-\theta r}{(1+\pi^i)^2} M^i < 0.$$

Proposition 1 *An increase in life expectancy induces more individual savings for retirement and subsequently reduces pension benefits in a means-tested pension system.*

In the economy where the government shuts down the means testing aspect by setting $\theta = 0$ and runs a universal pension system, i.e., a PAYG system, this automatic adjustment device is removed, that is, $\frac{\partial P^i}{\partial \pi^i} = 0$. In other words, the universal pension benefits are pre-defined and not influenced directly by changes in life expectancy. However, in the economy where the government runs a means-tested pension system considered above, the combination of the forward-looking behavioral response and the means test generates a mechanism that automatically reduces the public pension benefit according to increases in life expectancy. Subsequently, this allows governments to contain the overall fiscal cost of the public pension system in an aging economy.

Notice that this fiscal stabilization device exists only in a means-tested pension system when the taper rate is positive, i.e., $\theta > 0$. The responsiveness of this channel depends on the value of θ. The higher the value of θ, the more responsive is this fiscal stabilization device, that is, $\frac{\partial}{\partial \theta}\left(\frac{\partial P^i}{\partial \theta \partial \pi^i}\right) < 0$.

Redistributive device. It is evident from empirical data that there is a positive correlation between incomes and survival rates (e.g., see Chetty et al. (2016)). Higher income or skilled individuals tend to live longer. In this setting, we argue that the means testing of the age pension also represents a device that directs public benefits to less affluent retirees with shorter life expectancies.

To illustrate this mechanism, consider a case with two types of agents: type 1 agents have low income $\left(w_1^L\right)$ with a low survival rate (π^L), while type 2 agents have high income $(w_1^H \geq w_1^L)$

with a high survival rate ($\pi^H \geq \pi^L$). Let $a = \frac{w_1^H}{w_1^L} \geqslant 1$ measure income inequality between low- and high-income types. The government runs a means-tested pension system with the individual-specific pension benefit given by $P^i = P^{\max} - \theta r s^i$. Combining this expression with the optimal savings function gives

$$P^i = P^{\max}\left(1 + \frac{1}{1+\pi^i}\frac{\theta r}{R}\right) - \theta r \frac{\pi^i}{(1+\pi^i)}\left(1-\tau^{ss}\right) w_1^i, \tag{4}$$

with $i = L$ and H.

The two types of agents receive different pension benefits because of the assumed income and survival differences between them. The pension difference or gap between low- and high-income types of agents defined by $\Delta P = P^L - P^H$ may be expressed as

$$\Delta P = \frac{\theta r}{(1+\pi^L)(1+\pi^H)}\left[\begin{array}{c} \frac{P^{\max}\left(\pi^H - \pi^L\right)}{R} + \\ \left(a\pi^H\left(1+\pi^L\right) - \pi^L\left(1+\pi^H\right)\right)\left(1-\tau^{ss}\right) w_1^L \end{array}\right]. \tag{5}$$

When the pension gap is positive, $\Delta P > 0$, the low-income type receives a higher pension payment than the high-income type. When the pension gap is zero, $\Delta P = 0$, there is no difference in the pension payment. When the pension gap is negative, $\Delta P > 0$, the high-income type receives a higher pension benefit. Thus, the pension gap is an indicator of whether a pension system is progressive or regressive. The pension system is progressive when it directs more benefits to the low-income group. In the economy where the government removes the means testing aspect by setting $\theta = 0$ and runs a universal pension system, the redistributive device is removed since $P^L = P^H$. That is, the universal pension system is regressive and does not target the low-income agents.

If $w_1^H > w_1^L$ and $\pi^H > \pi^L$ in an economy where $\theta > 0$, it can be shown from (5) that the pension gap is positive, $\Delta P > 0$, meaning that the low-income type receives a higher pension payment than the high-income type. This implies that the low-income type receives a higher pension benefit in the means-tested pension system. Moreover, the larger the income gap, the higher the pension benefit paid to the low-income type relative to the high-income type ($\frac{\partial \Delta P}{\partial a} > 0$). Similarly, the larger the difference in the survival rates ($\pi^H - \pi^L$), the higher will be the pension benefit the low-income type relative to the high-income type ($P^L - P^H$). In other words, the larger the life expectancy gap, the more progressive the means-tested pension system will be, directing more public pension income to low-income groups of individuals.[4]

These results are summarized in the following proposition.

Proposition 2 *The means-tested pension system is progressive as the low-income agents with shorter life expectancy receive relatively higher pension benefits.*

[4]Notice that *total* pension payments, $\overline{P^i} = P^i \pi^i$, for the two income types of agents also depend on their survival rates. Assuming $\pi^H > \pi^L$, the universal pension system with $\theta = 0$ pays lower total benefits to low-income agents, $\overline{P^L} < \overline{P^H}$, simply because they are expected to receive a universal pension for a shorter period. In a means-tested pension system $\theta > 0$, the ratio pension payments, $\frac{\overline{P^L}}{\overline{P^H}}$, increases for higher values of θ.

2.3 A numerical example

We now consider a numerical example. As above, the economy consists of two types of agents with the maximum life-cycle of 2 periods, the same preferences but different income endowments and survival rates. The mass of young agents is the same for each type.

Specifically, the agents' preferences are of a Constant Relative Risk Aversion (CRRA) form, $u(c) = \frac{c^{1-\sigma}}{1-\sigma}$, with $\sigma = 2$. The income endowments in period 1 are normalized such that they set to 1 for the low-income type ($w_1^L = 1$) and 1.3 for the high-income type ($w_1^H = 1.3$). The periodic survival rates for both agents are initially set to $\pi^L = \pi^H = 0.7$, but are changed later when allowing for aging. The annual interest rate is set to $r = 0.03$. The time discount factor is set to $\beta = 0.971$. The maximum pension payment, $P^{\max}$, is indexed to average income, $\overline{y} = \frac{w_1^L + w_1^H}{2}$, by specifying $P^{\max} = \Psi\overline{y}$, where the gross replacement rate Ψ is set to 0.3. The payroll tax rate τ^{ss} is used as a financing instrument and is endogenously determined to balance the government budget.

We mimic population aging by assuming different survival scenarios and examine a range of taper rates θ in order to explore how different pension designs affect the fiscal costs and redistribution of public pensions.

The fiscal and redistributive effects for alternative taper rates under different demographic assumptions for survival probabilities are reported in Table 1. Precisely, the results are provided for the pension expenditure (to demonstrate the fiscal-stabilization role of a means-tested program) and for the share of pension expenditure paid to the low-income type (to demonstrate the redistributive role of a means-tested program).

Table 1: Fiscal and redistributive effects for alternative taper and survival scenarios

Variable/	Survival probability scenario			
Taper rate scenario	$\pi^L = 0.7$ $\pi^H = 0.7$	$\pi^L = 0.8$ $\pi^H = 0.8$	$\pi^L = 0.75$ $\pi^H = 0.85$	$\pi^L = 0.7$ $\pi^H = 0.9$
Pension expenditure (level)				
$\theta = 0$	0.483	0.552	0.552	0.552
$\theta = 0.25$	0.416	0.471	0.469	0.467
$\theta = 0.5$	0.341	0.377	0.372	0.367
$\theta = 0.75$	0.262	0.270	0.260	0.249
$\theta = 1$	0.198	0.162	0.138	0.136
Share of pension paid to low-income group (%)				
$\theta = 0$	50.0	50.0	46.9	43.8
$\theta = 0.25$	52.0	52.1	49.4	46.6
$\theta = 0.5$	55.4	55.8	53.9	52.0
$\theta = 0.75$	62.0	63.9	64.2	64.7
$\theta = 1$	74.2	85.8	100.0	100.0

Several lessons can be drawn from the results summarized in Table 1. First, comparing the rows for the pension expenditure results for each column (survival rates) reveals that a means-tested program with a higher taper rate results in significantly lower spending on public pensions than the fiscal expenditure needed to fund the universal system ($\theta = 0$). For instance, when the survival rates are both equal to 0.7 the expenditure falls from 0.48 to 0.198 as the taper rate increases from $\theta = 0$ to $\theta = 1$.

Second, comparing the columns for the pension expenditure for each row (taper rate) indicates how alternative public pension designs perform when population aging with increased survival probabilities is considered. For instance, the universal system with $\theta = 0$ requires a higher pension expenditure of 0.55 under the scenario with increased survival probabilities to $\pi^L = \pi^H = 0.8$ (i.e., a 14% increase in the pension expenditure relative to the scenario with $\pi^L = \pi^H = 0.7$). Tightening the pension taper is then shown to mitigate the increased pension costs. In fact, the strict means-tested program with $\theta = 1$ generates a relative decline in the pension expenditure between the higher and lower survival scenarios, as shown by comparing the second and first column of Table 1. This numerical result confirms the theoretical result stated in Proposition 1.

Third, tightening the means test redistributes pension payments to low-income groups of individuals. The results show that under the strict means-tested program with $\theta = 1$, the low-income type receives 74.2% of the overall pension expenditure, compared to 50% under the universal system with $\theta = 0$, which pays the same (flat-rate) pension benefit to both types of agents. This numerical finding is consistent with the theoretical result stated in Proposition 2.

Fourth, accounting for survival gaps between high- and low-income groups has also important implications for the redistribution of public pension income. Means-tested systems with higher taper rates redistribute more pension income to the low-income, shorter-lived type, whereas the redistribution in the opposite direction is shown for the universal system. Under the fourth demographic scenario with $\pi^L = 0.7$ and $\pi^H = 0.9$, the share of public pension income received by the low-income type is 100% in the means-tested system with $\theta = 1$, compared to only 43.8% in the universal system. Thus, the presence of means testing increases the progressivity of a pension system when different income groups age differently (Proposition 2).

In summary, this numerical exercise highlights that the automatic adjustment mechanism embedded in means-tested pension systems reduces the overall pension costs and directs public pension payments to those most in need (i.e., lower-income, shorter-lived groups of individuals). This mechanism is further strengthened when life expectancies are extended, especially for high-income earners.

3 A full dynamic model

In this section, we formulate a dynamic general equilibrium model, which consists of overlapping generations of heterogeneous households, a perfectly competitive, profit-maximizing production sector, a government sector incorporating essential tax and pension policy settings, and a foreign sector with perfect international capital mobility. The simulation model is essentially a small open economy version of an OLG model similar to the one in Auerbach and Kotlikoff (1987) with extensions to model observed demographic transitions, including differences in longevity and life-cycle profiles of mortality by socio-economic status. The detailed description of our model is provided below.

3.1 Demographics

The model economy is populated by overlapping generations of heterogeneous agents (households) whose ages are denoted by $j \in [1, ..., J]$ and whose skill types are denoted by $i \in \left[1, ..., \widehat{I}\right]$. Each period a continuum of agents of age $j = 1$ are born. Agents face an age- and skill-dependent survival probability, $\pi^i_{j,t}$ (with $\pi^i_{j=1,t} = 1$), and live at most J periods. The total population grows at an exogenous growth rate, n_t.

At each point in time, there are J overlapping generations. Letting $N_{j,t}$ denote the size of a cohort of age j in time t, the total population is a sum of all cohorts alive in period t as $P_t = \sum_{j=1}^{J} N_{j,t}$. The share of the j-age cohort at any point in time t is given by $\mu_{j,t} = \frac{N_{j,t}}{P_t}$. When the demographic pattern is stationary (with both n and π^j_j being time-invariant), the population share of the j-age cohort of skill type i is constant in every time period and can be derived recursively as $\mu^i_j = \mu^i_{j-1}\pi^j_j / (1 + n)$. The share of i-type agents who do not survive to age j is $\widetilde{\mu}^i_j = \mu^i_{j-1}(1 - \pi^i_j) / (1 + n)$. Given the conditional survival probability, π^i_j, the life expectancy can be calculated as $\sum_{j=1}^{J} \left(1 - \pi^i_{j+1}\right) \prod_{z=1}^{j} \pi^i_z \cdot j$.

3.2 Endowments, preferences and technology

Endowments. Each generation (or age cohort) consists of five skill (or income) types $i \in \left[1, ..., \widehat{I}\right]$ that are represented by the lowest, second, third, fourth and highest quintiles. These skill groups are distinguished by their exogenously given labor productivity profiles and social welfare payments. Note that the skill type is pre-determined and unchanged over the life span and time. We denote the intra-generational skill shares by ω_i.

In every period of life, households of age j and skill type i are endowed with one unit of labor time that has earning ability (efficiency unit) given by e^i_j. The efficiency unit, e^i_j, is skill- and age-dependent. According to this specification, agents have working abilities that vary by age and change over the life cycle. The quantity of an agent's effective labor services is $h^i_j = (1 - l^i_j)e^i_j$, where $(1 - l^i_j)$ is labor supply of i-type household at age j and leisure time for i-type household at age j is constrained by $0 \leq l^i_j \leq 1$.

Preferences. All agents have identical preferences over streams of consumption $c^i_j \geq 0$ and leisure l^i_j. Utility is additively separable over age and agents discount future periods with the constant subjective discount factor, β, and the unconditional survival probability, $\prod_{z=1}^{j} \pi^i_z$. The expected lifetime utility function for a i-type agent who begins her economic life at time t

and chooses consumption, c, and leisure, l, at each age j then reads as

$$E\left[\sum_{j=1}^{J}\beta^{j-1}\left(\prod_{z=1}^{j}\pi_z^i\right)u(c_{t+j-1}^i,l_{t+j-1}^i)\right] \quad \text{with} \quad u(c,l)=\frac{\left[c^{\rho}l^{1-\rho}\right]^{1-\sigma}}{1-\sigma}, \tag{6}$$

where ρ is the weight of consumption in periodic utility and the agent's risk aversion parameter, σ, determines the intertemporal elasticity of substitution. We assume that periodic utility, $u(c,l)$, is non-separable in consumption and leisure and of a Cobb-Douglas functional form so that the elasticity of substitution between consumption and leisure is always one.

Technology. The production sector is assumed to contain a large number of perfectly competitive firms that produce a single all-purpose output good that can be consumed, invested in production capital or traded internationally. The production technology is described by a Cobb-Douglas production function

$$Y_t = F(K_t, L_t) = AK_t^{\alpha}L_t^{1-\alpha},$$

where K_t is the capital stock, L_t is the labor input, A is the productivity constant, α denotes the capital share parameter and all variables are in per capita terms. Capital depreciates over time at the depreciation rate δ so that the capital stock (in per capita terms) evolves as

$$(1+n)K_{t+1} = I_t + (1-\delta)\,K_t,$$

where I_t is the gross investment.

3.3 Government policy

The government is responsible for collecting revenues from taxing household income and consumption and corporate profits in order to pay for its general consumption and transfer payments. It is also responsible for regulating the pension system. We incorporate the main features of the Australian pension system. This system features a modest means-tested public pension and a mandatory private superannuation scheme (Australia's term for private defined-contribution pension scheme). We model these two publicly-stipulated pillars of Australia's retirement income policy. The modeling of fiscal and pension policies is described in more detail below.

Public pension. The publicly-managed "safety net" pillar of the Australian pension system is represented by a non-contributory, means-tested age pension financed through general taxation revenues.

The age pension, $p_{j,t}^i$, is paid to households of skill type i and age pension age ($j \geq J_p$) if they satisfy the following income test.[5] Let $p^{\max}$ denote the maximum age pension paid by the

[5] The actual means test of the age pension also includes the asset test and it is the binding test (the income

government to pensioners provided that their assessable income does not exceed the income threshold, y_1. The maximum pension, $p^{\max}$, is then reduced at the pension taper (withdrawal) rate, θ, for every dollar of assessable income above y_1. Algebraically, the age pension benefit only for those $j \geq J_p$ households can be written as

$$p^i_{j,t} = \begin{cases} p^{\max} & \text{if } \widehat{y}_{j,t} \leq y_1 \\ p^{\max} - \theta\left(\widehat{y}_{j,t} - y_1\right) & \text{if } y_1 < \widehat{y}_{j,t} \leq y_2 \\ 0 & \text{if } \widehat{y}_{j,t} > y_2 \end{cases}, \qquad \text{for } j \geq J_p, \tag{7}$$

where the assessable income, $\widehat{y}^i_{j,t}$, consists of interest income, $r_t A^i_{j-1,t-1}$, and half of labor earnings, $0.5 \times w_t h^i_{j,t}$ (reflecting recent policy changes to encourage labor supply at older ages). The parameters y_1 and y_2 denote the lower and upper bound thresholds for the assessable income.

The total expenditure of the public pension program to the government is given by $P_t = \sum_{i=1}^{\widehat{I}} \omega_i \sum_{j=J_p}^{J} p^i_{j,t}\, \mu^i_j$, where ω_i and μ^i_j denote intra- and inter-generational skill shares.[6]

Private pension. The second pension pillar is represented by mandatory, privately-managed retirement saving accounts, which are based on defined contributions made by employers and are regulated by the government. This private pension program, known as the Superannuation Guarantee, requires employers to contribute a given percentage of gross wages into the employee's superannuation fund.

Accordingly, the model assumes that mandatory contributions are made by firms on behalf of working households at the contribution rate, ν, from their gross labor earnings, $w_t h^i_{j,t}$. The contributions net of the contribution tax, $\tau^s \nu$, are added to the stock of superannuation assets, $\widehat{s}^i_{j,t}$, which earns investment income at the after-tax interest rate, $(1-\tau^r)\, r_t$. The superannuation asset accumulation equation can be expressed as

$$\widehat{s}^i_{j,t} = \left[1 + (1-\tau^r)\, r_t\right] \widehat{s}^i_{j-1,t-1} + (1-\tau^s)\, \nu w_t h^i_{j,t}, \quad j \leq J_s,\ \widehat{s}^i_{1,t} = 0, \tag{8}$$

where r_t is the market interest rate, τ^r and τ^s denote the earnings and contribution tax rates paid by the superannuation fund. The superannuation assets must be kept in the fund until households reach age $j = J_s$ when the accumulation ceases, and households are assumed to receive their accumulated balances as lump sum payouts. It is further assumed that working households $j \geq J_s$ are paid mandatory contributions directly into their private asset accounts. Therefore, superannuation payouts denoted by $s^i_{j,t}$ in the per-period budget constraint (13) (defined later in this section) may be expressed as

$$s^i_{j,t} = \begin{cases} 0 & j < J_s \\ \widehat{s}^i_{J_s,t} & j = J_s \\ (1-\tau^s)\, \nu \cdot w_t h^i_{j,t} & j > J_s. \end{cases} \tag{9}$$

test or the asset test resulting in a lower pension benefit) that is used to determine the pension payment. The model considers only the income test as it is the binding test for most age pensioners.

[6] Note that all aggregate variables are defined in per-capita terms.

Social transfer. The government also runs a social transfer program that pays social transfer benefits, st_j^i, to households aged $j < J_p$ (prior to reaching the eligibility age for the age pension). These benefits are targeted to lower income households and determined exogenously, with further details provided in the calibration section. The total social transfer payment, ST_t, is given by

$$ST_t = \sum_{i=1}^{\widehat{I}} \omega_i \sum_{j=1}^{J_p-1} st_j^i \ \mu_j^i.$$

Taxes. The government collects taxes to finance its spending programs. The total tax revenue, T_t, consists of revenues from five different taxes: household progressive income tax, T_t^Y, consumption tax, T_t^C, superannuation tax paid by the superannuation fund, T_t^S, as well as corporate tax paid by firms, T_t^F. The per capita tax receipts in period t are given by

$$\begin{aligned} T_t^Y &= \sum_{i=1}^{\widehat{I}} \omega_i \sum_{j=1}^{J} \tau(y_{j,t}^i) \ \mu_j^i \\ T_t^C &= \sum_{i=1}^{\widehat{I}} \omega_i \sum_{j=1}^{J} \tau^c \ c_{j,t}^i \ \mu_j^i \\ T_t^S &= \sum_{i=1}^{\widehat{I}} \omega_i \sum_{j=1}^{J_s} \left[\tau^s \nu \cdot w_t h_{j,t}^i + \tau^r r_t \cdot \widehat{s}_{j-1,t-1}^i\right] \ \mu_j^i \\ T_t^F &= \tau^f \varrho_t, \end{aligned} \tag{10}$$

where $\tau(y_{j,t}^i)$ is the income tax payment paid by individual households, τ^c represents the consumption tax rate, τ^f is the corporate tax rate imposed on the firm's profit, ϱ_t, and where ω_i and μ_j^i denote intra- and inter-generational shares. The total tax revenue is then given by $T_t = T_t^Y + T_t^C + T_t^S + T_t^F$.

Budget balance. The government activities include an issue of new debt, $\Delta D_{t+1} = D_{t+1} - D_t$, and tax revenues, T_t, that finance general government consumption expenditure, G_t, interest payments on current public debt, $r_t D_t$, and transfer payments to households, comprising pensions and social transfers, $TR_t = P_t + ST_t$. In each period, the government budget constraint is balanced, so that

$$\Delta D_{t+1} + T_t = G_t + r_t D_t + TR_t. \tag{11}$$

Note that in our setting, the issue of new government debt (or the change in net government debt) in period t is equal to the budget deficit in that period.

3.4 Market structure

For the benchmark simulations, we employ a small open economy framework, which is most appropriate for the Australian economy. Specifically, in our small open economy model, the domestic capital market is fully integrated with the world capital market. Capital freely moves across borders so that the domestic interest rate, r_t, is exogenously set by the world interest rate, r^w.[7] In this framework, the wage rate is determined by the world interest rate and the

[7] The exogenous interest rate assumption is relaxed in Section 6, which examines how sensitive the results are to the imperfect capital mobility assumption with an endogenous interest rate.

production technology. Provided that neither of these change, the wage rate remains constant. Finally, it is assumed that there is no difference between domestically and internationally produced consumption goods.

Letting A_t^F stand for the (per capita) net foreign assets at the beginning of t, the international budget constraint can be specified as

$$(1+n)A_{t+1}^F - A_t^F = r_t A_t^F + X_t, \tag{12}$$

where the left side of (12) represents per capita capital flows and the right side is the current account comprising the per capita net trade balance denoted by X_t, and the per capita interest receipts (payments) from foreign assets (debt), $r_t A_t^F$.

3.5 Equilibrium

Households. Households are assumed to make optimal consumption/saving and leisure/labor supply choices by solving a utility maximization problem with the objective function (6) subject to the per-period budget constraints that can be written as

$$\begin{aligned} a_{j,t}^i &= (1+r_t)a_{j-1,t-1}^i + w_t h_{j,t}^i + p_{a,t}^i + s_{j,t}^i \\ &\quad + st_j^i + b_{j,t}^i - (1+\tau^c)c_{j,t}^i - \tau(y_{j,t}^i). \end{aligned} \tag{13}$$

In (13), $a_{j,t}^i$ denotes the stock of ordinary private assets held at the end of age j and time t. This equals the assets at the beginning of the period, plus the sum of interest income, $r_t a_{j-1,t-1}^i$, gross labor earnings, $w_t h_{j,t}^i$, public age pension payments, $p_{j,t}^i$, private superannuation payouts, $s_{j,t}^i$, social welfare payments, st_j^i, and bequest receipts, $b_{j,t}^i$, minus the sum of consumption expenditure, $(1+\tau^c)c_{j,t}^i$, (including the consumption tax rate, τ^c) and the progressive income tax denoted by $\tau(y_{j,t}^i)$. The progressive income tax is a function of the taxable income, $y_{j,t}^i$, which comprises labor earnings, interest income and the age pension.

The gross labor earnings are equal to the product of effective labor supply, $h_{j,t}^i = e_j^i(1-l_{j,t}^i)$, and the market wage rate, w_t. Recall that e_j^i is the age- and skill-specific earnings ability variable. The labor supply is required to be non-negative, $1 - l_{j,t}^i \geq 0$, which implies that leisure, $l_{j,t}^i$, cannot exceed the available time endowment (normalized to one). When $l_{j,t}^i = 1$, the household does not work. However, the retirement from workforce is not irreversible, meaning that households can re-enter the workforce.

Following Gokhale et al. (2001), we abstract from intended bequests, with all inter-generational transfers being accidental. Accidental bequests, $b_{j,t}^i$, are calculated by aggregating the assets of deceased agents within each skill type i and equally redistributing them to all surviving i-type agents aged $J_{b_1} \leq j < J_{b_2}$. The model is a pure life cycle model in the sense that households are assumed to be born with no wealth and exhaust all wealth if they survive to the maximum age J (i.e., $a_{1,t}^i = a_{J,t+J}^i = 0$). We also impose borrowing constraints (i.e., $a_{j,t}^i \geq 0$) to prevent younger households from borrowing against their superannuation (private pension) payouts, as such borrowing is prohibited by legislation.

Firms. The perfectly competitive firms demand capital, K_t, labor, L_t, and gross investment, I_t, to maximize the present value of all future profits subject to the (per capita) capital accumulation equation as in

$$\begin{aligned} \max_{\{K_t,\ L_t,\ I_t\}} \quad & \sum_{t=0}^{\infty} D_t \left[\left(1-\tau^f\right) \varrho_t \right] \\ \text{s.t.} \quad & (1+n)K_{t+1} = I_t + (1-\delta) K_t, \end{aligned} \tag{14}$$

where $\varrho_t = F(K_t, L_t) - (1+\nu)w_t L_t - \delta K_t$ is the firm's profit comprising the sale of output net of total labor costs and capital depreciation, $D_t = (1+n)^t/(1+r_t)^t$ is the discount rate adjusted by population growth, and τ^f stands for the corporation tax rate. Notice that total labor costs also include the private pension contributions made by firms at the mandatory rate ν on gross labor earnings.

Equilibrium. Given government policy settings for the taxation and pension systems, the demographic structure and the world interest rate, a competitive equilibrium is such that

(a) households make optimal consumption and leisure decisions by maximizing their lifetime utility (6) subject to their budget constraint (13);

(b) competitive firms choose labor and capital inputs to solve their profit maximization problem in (14);

(c) the government budget constraint (11) is satisfied;

(d) the current account is balanced and net foreign assets, A_t^F, freely adjust so that $r_t = r^w$, where r^w is the exogenously given world interest rate;

(e) the labor, capital and goods markets clear

$$\begin{aligned} L_t &= \textstyle\sum_{i=1}^{\widehat{I}} \omega_i \sum_{j=1}^{J} h_{j,t}^i \ \mu_j^i, \\ q_t K_t &= \textstyle\sum_{i=1}^{\widehat{I}} \omega_i \sum_{j=1}^{J} (a_{j-1,t-1}^i + \widehat{s}_{j-1,t-1}^i)\mu_j^i + A_t^F - D_t, \\ Y_t &= \textstyle\sum_{i=1}^{\widehat{I}} \omega_i \sum_{j=1}^{J} c_{j,t}^i \ \mu_j^i + I_t + G_t + X_t; \end{aligned} \tag{15}$$

(f) the bequest transfers are equal to the sum of the assets left by the deceased agents within each skill type, $b_t^i = \sum_j \left(1-\pi_j^i\right) (a_{j,t}^i + \widehat{s}_{j,t}^i)\mu_j^i$.[8]

[8] We assume that accidental bequests are equally redistributed to surviving households of the same income type aged $J_{b_1} \leq j < J_{b_2}$, where J_{b_1} and J_{b_2} are set to actual ages of 45 and 65, thus reflecting inter-generational transfers from older parents (with higher mortality rates) to their adult children. The redistribution within the same skill type means that the bequests received by higher income households are significantly larger than those received by lower income types.

4 Calibration

The benchmark model economy is assumed to be in an initial steady state equilibrium, which is calibrated to the Australian economy in 2013-14, targeting key macroeconomic and fiscal aggregates as well as approximating the life-cycle behavior of Australian households observed from survey data in that financial year. In this section, we report on the calibration procedure, present the resulting parameters for the benchmark model and then compare the benchmark steady state solution generated by the model with Australian data. The values and sources of the main parameters in this benchmark economy are provided in Table 2.

Table 2: Values of main model parameters

Description	Value	Source
Demographics		
Population growth rate (annual) n	0.016	Data
Intra-generational skill shares ω	All 0.2	Data[a]
Conditional survival probabilities (annual) π	ABS (2015)	Data[b]
Preferences		
Risk aversion parameter σ	2	Literature[c]
Weight of consumption in periodic utility ρ	0.372	Calibrated
Subjective discount factor (annual) β	0.982	Calibrated
Technology		
Production constant A	1.749	Calibrated
Capital share α	0.408	Calibrated
Depreciation rate δ	0.085	Calibrated

Notes: [a]Households are disaggregated into income quintiles based on ABS (2012). [b]ABS life tables are used to get survival probabilities for the third quintile, with the profiles of survival probabilities for other skill types adjusted based on life expectancy gaps obtained by Clarke and Leigh (2011). [c]The value of σ is in the range of values used by others (e.g., Imrohoroglu and Kitao, 2009).

4.1 Demographics

Following Tran and Woodland (2014), one model period corresponds to five years.[9] Households become economically active at age 20 ($j = 1$) and face a random survival up to the maximum age of 100 years (equal to the maximum model period $J = 16$). Hence, the model consists of 16 overlapping generations (or cohorts) of five skill types of households ($\widehat{I} = 5$) in each period.

The demographic parameters include the age- and skill-specific survival rates, π_j^i, and the annual population growth rate, n. We use the 2012-14 ABS life tables (Australian Bureau of Statistics (ABS) (2015)) to derive the age-specific survival rates for the third type, π_j^3 (as

[9]Note that all rates (e.g., discount factor, interest and population growth rates) reported below as per year are in the model converted to periodic rates.

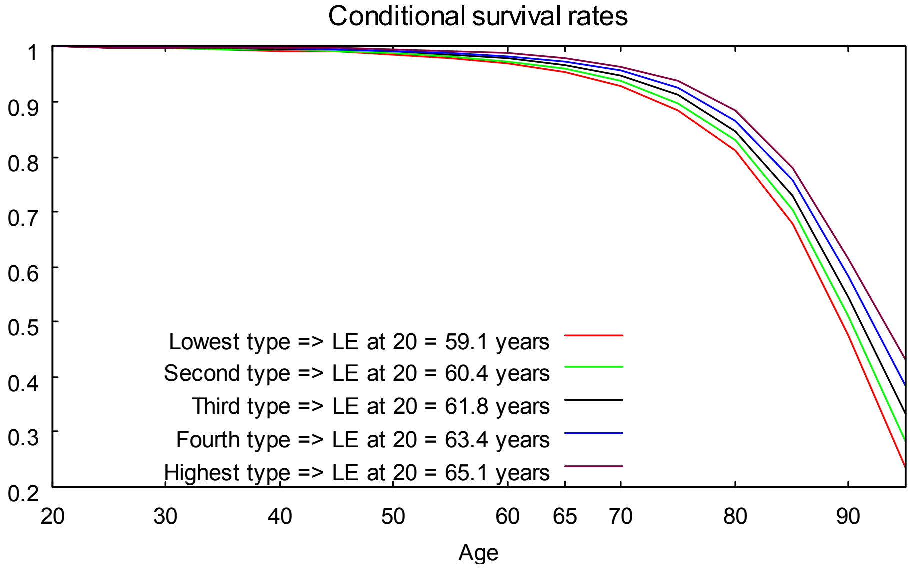

Figure 1: Conditional survival rates and implied life expectancies

the average age-specific survival probabilities for males and females). We then adjust these survival probabilities for lower and higher skill types to approximately generate estimated life expectancy gaps by levels of income in Australia obtained by Clarke and Leigh (2011). They show that the life expectancy gap between the highest and lowest income quintile is about six years for both men and women. We assume that the life expectancy gap between the fourth and second skill types of households is about three years in the model and adjust their survival curves accordingly. Figure 1 plots the survival curves (i.e., periodic age- and skill-specific conditional probability of survival) used in the benchmark model and reports the corresponding life expectancy for each skill type of households at age 20.

In the benchmark model, we set periodic n to 0.0826, which corresponds to the 1.6% annual growth rate of Australia's total population for 2013-14. Given the chosen values for n and π_j^i, the benchmark model generates an old-age dependency ratio of 0.25, which is similar to the actual dependency ratio (i.e., the ratio of the population aged 65 and older to the working-age population aged 20 to 64) in 2014. The intra-generational skill shares, ω_i, are equal to 0.2 for each skill group of households in the model, based on the quintiles used by ABS (2012).

4.2 Endowments, preferences and technology

Endowments. The model includes five skill types of households in each cohort, and they differ by their exogenously given earnings ability (and social welfare benefits that are discussed in the subsection dealing with the calibration of pension and fiscal policy). The earnings ability (or labor productivity) profiles are constructed by employing the estimated lifetime wage function taken from Reilly et al. (2005) and the income distribution shift parameters derived from ABS (2012). In particular, the earnings ability profile for the third quintile in the model is taken from Reilly et al. (2005).[10] The earnings ability profiles for lower and higher income quintiles are shifted down and up, using the shift parameter whose values are derived from ABS (2012), to approximately replicate the private income distribution in Australia.[11] Given that Reilly et al. (2005) considered only workers aged 15-65, the earnings ability after age 65 is assumed to decline at a constant rate, reaching zero at age 90 for each income class.

Preferences. The periodic utility in consumption and leisure is of the Cobb-Douglas functional form, which is standard in related literature. Following İmrohoroğlu and Kitao (2009), the risk aversion parameter, σ, is set to 2. The (annual) value of the subjective discount factor, $\beta = 0.982$, in the lifetime utility (6) is calibrated to match the capital to output ratio of 3.1 in 2013-14 (ABS, 2017a). The value of the parameter that gives the weight of consumption in the periodic utility, $\rho = 0.372$, is calibrated to match average work hours of 0.33 (out of the time endowment normalized to one in the model).

Technology. The Cobb-Douglas functional form is also assumed for our production function. The values of most production parameters, including the capital share and depreciation rate parameters, are calibrated to replicate calibration targets such as the investment rate of 0.09 (ABS, 2017a). The wage rate, w, is normalized to one by calibrating the value of the productivity constant, A.

4.3 Government policy

The calibration of government policy involves the use of the statutory rates for the age pension, mandatory superannuation and taxation in 2013-14 and the observed ratios of government expenditures and tax revenues to Gross Domestic Product (GDP) in 2013-14. Specifically, we calculate the effective rates for pension payments and government taxes so that the benchmark model replicates the exact composition of the government budget in 2013-14. We further assume that the government has zero public debt and balances its budget by adjusting its general consumption, G.

Table 3 reports on the calibration of pension and fiscal policies in the initial steady state. The statutory pension and tax rates reported in column 1 are actual rates set by the Australian government for 2013-14. The composition of the government budget in column 2 (with transfers and tax revenues % of GDP) is computed from data reported by Australian Government (2015). As mentioned above, the effective pension and tax rates in column 3 are calibrated to match the corresponding shares in GDP in the benchmark steady state. Technically, the effective rates are the product of the statutory rates and the computed adjustment factors. The details of our

[10] The earnings ability profile for the third quintile takes the form: $e_a = \exp(\alpha_0 + \alpha_1 X + \alpha_2 X^2)$, where parameters α_0, α_1 and α_2 are taken from Reilly et al. (2005) as average estimates for males and females with 12 education years, X represents years of potential experience ($a - 5-$education years).

[11] It is also assumed that the two lower income types have 10 years of schooling and the two higher income types 15 years of schooling, resulting in labor productivity profiles that differ not only by the level but also by the shape (i.e., being relatively flat for lower income types compared to higher income types).

Table 3: Calibration of pension and fiscal policy in baseline model

Variable	Statutory rate (Data) (2013-14)	% of GDP (Data) (2013-14)[a]	Effective rate (Calibrated) (2013-14)
Public pension	-	2.93	[b]
- Access age (years)	65	-	-
- Maximum pension p.a. ($)	21504	-	Down by 11.9%
- Income free threshold p.a. ($)	4056	-	-
- Taper/withdrawal rate	0.5	-	-
Private pension (superannuation)			
- Access (tax-free) age (years)	60	-	-
- Contribution rate (%)	9.5	-	-
- Contribution tax rate (%)	15	0.7	9.1
Social welfare transfers	-	4.59	Calibrated
Personal income tax[c]	-	10.9	Down by 20.2%
Consumption tax rate (%)	10	6.4	11.5
Corporate tax rate (%)	30	4.6	25.5

Notes: [a]The calibration targets for government expenditures and tax revenues (as % of GDP) in 2013-14 based on Australian Government (2015). [b]To match public pension expenditures (at 2.93% of GDP) in 2013-14, the maximum pension benefit is adjusted. [c]The income tax function is estimated, using the 2013-14 income tax schedule.

calibration strategy for the two-publicly stipulated pillars of Australia's pension system, social transfers and the tax system are discussed below.

Public pension. The age pension parameters include the pension access age, $J_p = 65$, the maximum pension benefit $p^{\max} = \$21,504$ per year, the income test lower threshold (for receiving the maximum benefit), $y_1 = \$4,056$ per year and the taper rate, $\theta = 0.5$. These values are those applicable to single pensioners from September 2013 to June 2014. Government total spending on the age (and service) pension was 2.93% of GDP in 2013-14. Hence, the effective age pension payments are adjusted for each skill type of households to match this pension expenditure. Specifically, the maximum pension benefit is adjusted down by 11.9% in the benchmark steady state, in order to account for the application of the statutory pension parameters to single pensioners.[12]

Private pension. The mandatory superannuation contribution rate is 9.5% of gross earnings, which is the effective rate in the model. However, the effective tax rates on superannuation contributions and earnings in the model are lower than the statutory ones in data. We scaled

[12]Note that the age pension policy rules in Australia distinguish between higher pension rates for single pensioners and lower pension rates for couple pensioners (each). As the majority of pensioners at early pension ages receive lower pension rates for couples, the maximum single-rate pension used in the model needs to be scaled down so that the benchmark model matches the observed ratio of the overall pension expenditure to GDP.

down that statutory rate in order to match the ratio of superannuation tax revenue to GDP in the initial steady state. This is because Australia's private pension system has yet to achieve full maturity, whereas it is fully mature in the model with mandatory contributions at 9.5% of gross earnings made over the entire working life. The superannuation access age is set to $J_s = 60$ (i.e., the current tax-free age from which no exit tax is paid on superannuation benefits).

Social welfare. The government is also assumed to pay social welfare benefits to eligible households of the lowest to fourth skill types aged $j < 65$ at a constant (skill-specific) rate. In the calibration of the benchmark steady state, we compute the skill-specific social welfare payments denoted by st_j^i in (13) to replicate the share of social welfare in gross total income for each skill type (income quintile) derived from the ABS (2012) data. The total social welfare benefit is determined so that the benchmark model matches the government expenditure on social welfare, which includes transfer payments (other than the age pension) such as family benefits, disability support pension and unemployment benefit.

Taxes. The income tax rates are nonlinear and progressive. We use a differentiable income tax function that is estimated to approximate the 2013-14 progressive income tax schedule. Although the estimated income tax function is a close approximation of the actual income tax schedule, it was scaled down for the model to match the exact share of income tax revenue in GDP in 2013-14. The reason is that the model does not account for any tax deductions or tax offsets available to lower income earners.

The consumption and corporation tax rates are linear with the statutory rates at 10% and 30%, respectively. In the benchmark model calibration, we adjust these statutory rates to match the actual ratios of the given tax revenue to GDP in 2013-14. The effective corporate tax rate is smaller in our calibration, reflecting the fact that many firms use various other deductions to lower their tax rate. The effective consumption tax rate equals 11.5% in the benchmark steady state, which is higher than the statutory Goods and Services Tax (GST) rate of 10%. This is because we target the total consumption tax revenue that includes not only the GST revenue but also receipts from other indirect taxes.

4.4 Market structure

In our small open economy model, the domestic interest rate is exogenous and given by the world interest rate. The annual world interest rate is set to 4%. We also use the equilibrium condition for the capital market to target the net foreign assets to capital ratio of -0.18 in the benchmark steady state. This reflects the net foreign ownership of 18% of Australia's capital stock in 2013-14 (ABS, 2017a).

4.5 Benchmark solution and comparison with data

The benchmark solution is obtained by numerically solving the model for the initial steady state equilibrium, with the parameters and the government policy settings specified above. We use

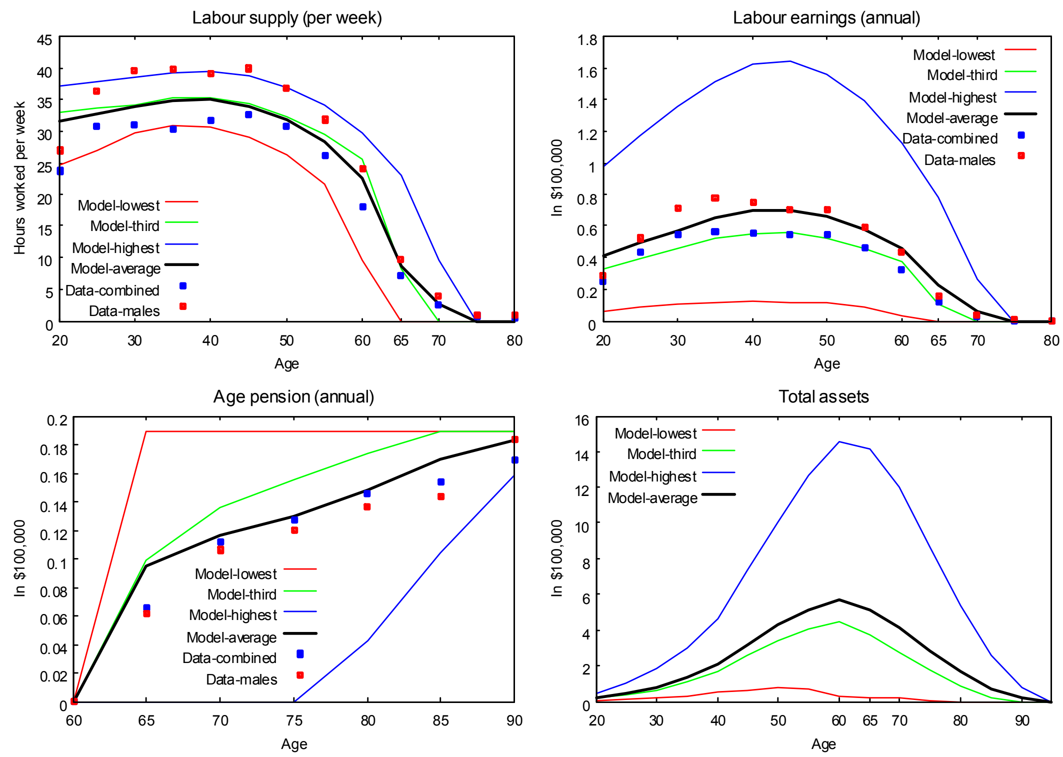

Figure 2: Life-cycle profiles and data comparison

the GAMS software and the Gauss-Seidel iterative method to solve for the benchmark steady state equilibrium (as well as transition paths for all the examined changes to the means test of the age pension reported in the next section). The algorithm involves choosing initial guesses for some variables and then updating them by iterating between the production, household and government sectors until convergence (see Kudrna and Woodland (2011) for more details). The main model-generated results at both the household life-cycle and aggregate levels are presented and discussed below.

Life-cycle household profiles. The benchmark solutions for selected life-cycle household profiles are depicted by Figure 2. The age-profiles of labor supply and earnings exhibit the standard hump-shape, rising at early ages and then declining. The shapes of these profiles reflect the assumed hump-shaped productivity profiles, the increasing mortality risk and the effects of retirement income policy, particularly the age pension. As shown, the pension payments differ across the selected skill types (the lowest, third and highest quintiles) due to the means testing. While the lowest quintile receives the maximum benefit from age 65 onwards (with assessable income below the income disregard, y_1), the third quintile receives part pension at age 65 and the highest quintile households do not receive any pension until age 75. The average pension payments increase with age as older households run down their assets, with declining interest (or assets) income assessed under the income test.

Figure 2 also presents the average profiles for labor supply, labor earnings and pension payments (for males and both males and females, labeled as "combined") derived from the Household, Income and Labour Dynamics in Australia (HILDA) survey (Wooden et al. (2002)). A comparison of the data plots with the model-generated average profiles reveals similar shapes and levels for all three variables. Notice, however, that the average labor supply and average labour earnings of individuals are overestimated by the benchmark solution (black curves) at most ages compared to the "data-combined" HILDA data (blue dots). The model also somewhat overestimates the average pension payments at older ages. This is because all households are required to completely exhaust their savings, if they survive until the assumed maximum age. Hence, even the top skill type (income quintile) eventually qualifies for the maximum pension.[13]

Macroeconomic and income data. The comparison of selected macroeconomic variables and net income indicators generated by the benchmark solution with the Australian data in 2013-14 (derived from ABS, 2017a) is presented in Table 4.

Table 4: Comparison of benchmark solution with Australian macro and income data

Variable	Benchmark model	Australia 2013-14
Expenditures on GDP (% of GDP)		
Private consumption	55.50	54.61
Investment	27.90	27.60
Government consumption	15.08	17.95
Trade balance	1.51	-0.29
Calibration targets		
Capital-output ratio	3.10	3.10
Investment-capital ratio	0.09	0.09
Foreign assets-capital ratio	-0.18	-0.18
Average hours worked	0.33	0.33
Net income shares (%)		
Lowest quintile	6.1	7.5
Second quintile	11.5	12.3
Third quintile	17.9	16.9
Fourth quintile	24.3	22.4
Highest quintile	40.2	40.8
Gini coefficient (in net income)	0.36	0.33

Notes: The Australian macro data taken from ABS (2017a) and the Australian net (disposable) income data based on ABS (2017b).

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 benchmark model (which has been mostly negative in Australia over the last decade) is due to the targeted negative foreign assets position.[14] Given the use of the effective rates for government expenditures and

[13] There are only limited observations for individuals aged over 90 years in the HILDA survey. Therefore, in Figure 2, we only present age payments up to the age of 90. Note that in the model, households in each skill group that survive past this age qualify for the maximum pension.

[14] In a steady state, the foreign budget constraint in (12) becomes $(n-r)A^F = X$, where the trade balance

tax revenues, the model-generated government indicators displayed in Table 4 match exactly the composition of the government budget in 2013-14.

Table 4 also reports net income shares for each skill type and the Gini coefficient in net income (i.e., aggregated population-weighted disposable income consisting of all gross income sources minus the income tax). The benchmark model-generated income indicators are shown to be very similar to the data derived from ABS (2017b).

5 Quantitative analysis

In this section, we apply the calibrated model to study the quantitative importance of the automatic adjustment device embedded in means-tested pension systems under population aging. We start with a series of partial equilibrium analyses where we keep prices unchanged. We then extend our analysis to a general equilibrium framework where we account for dynamic general equilibrium adjustments, including income tax rate adjustments required to fund the pension costs and balance the government budget under alternative pension settings. This separation of partial and general equilibrium effects facilitates understanding of the results, as discussed further below.

Our analysis is undertaken under two main aging scenarios: (*i*) "no aging" scenario with the population growth rate and survival probabilities kept unchanged at the levels specified in the benchmark model; and (*ii*) "aging" scenario with demographic structures assumed to follow the population projections by United Nations (2015) and ABS (2013) and, in particular, their medium projections for year 2060.[15] The "no aging" scenario generates an old-age dependency ratio of about 0.25, while the future "aging" scenario implies a much higher aged dependency ratio of 0.45.

5.1 Partial equilibrium analysis

We learnt from the two-period model applied in Section 2 that the inclusion of means testing introduced a novel automatic adjustment mechanism. In this subsection, we quantify the role of this mechanism in a partial equilibrium framework in which we abstract from any dynamic general equilibrium adjustments.

(or next export), X, is positive if the net foreign assets, A^F, is negative and $r > n$. The Australian System of National Accounts (ABS, 2017a) shows that (*i*) Australia is a net borrower from the world capital market, having accumulated large net foreign debt, and (*ii*) Australia's trade balance has been mostly negative over the last decade. Since our benchmark economy cannot accommodate both facts, we assume that Australia is a net borrower with 18% of total national assets being foreign-owned, which then implies positive trade balance in the benchmark steady state.

[15] We use population projections by United Nations (2015) and ABS (2013) and, in particular, their medium projections for year 2060. In numbers, the population growth rate is projected to decline to 0.5% per year (from 1.6% in 2013-14) and the improved average survival probabilities for 2060 imply the average life expectancy at age 20 of 65.7 years. We also assume that life-expectancy gaps (at age 20) increase to 8 years between the highest and lowest skilled types and to 4 years between the fourth and second skilled types, drawing on empirical findings of widening life-expectancy differentials by socio-economic status (e.g., see Villegas and Haberman (2014)).

Table 5: Macro and fiscal effects of alternative taper rates in partial equilibrium

Demographic	Taper rate				
scenario/Variable	0	0.25	0.5	0.75	1
No aging (indexed to "no aging" scenario with taper rate = 0.5 (=100))					
- Labor supply	99.6	99.3	100.0	100.2	100.7
- Domestic assets	100.5	98.6	100.0	99.5	101.1
- Consumption	101.8	100.3	100.0	99.8	99.9
- Pension expenditure	167.3	122.4	100.0	91.9	84.1
Aging (indexed to "no aging" scenario with taper rate = 0.5 (=100))					
- Labor supply	87.4	87.5	87.9	88.2	89.0
- Domestic asset	141.5	138.3	139.2	139.0	145.5
- Consumption	106.5	104.1	103.3	103.0	103.5
- Pension expenditure	264.9	184.8	150.2	137.3	122.4
Aging (indexed to "aging" scenario with taper rate = 0.5 (=100))					
- Labor supply	99.4	99.5	100.0	100.3	101.2
- Domestic asset	101.6	99.3	100.0	99.8	104.5
- Consumption	103.2	100.8	100.0	99.7	100.3
- Pension expenditure	176.3	123.0	100.0	91.4	81.5

Notes: The results abstract from any general equilibrium effects (e.g., tax adjustments financing pension expenditure under different taper rates). All variables are in per capita terms.

Automatic adjustment mechanism. In order to isolate the automatic adjustment mechanism we examine different pension settings with the taper rate, θ, taking the values of 0, 0.25, 0.5, 0.75 and 1. We concentrate on the implications for the size of pension payments and the equity of these pension policy alternatives.

Table 5 reports the economic effects of alternative taper rates under the “no aging” and “aging” scenarios. To ease comparison, the results for each per capita variable are indexed to (*i*) the “no aging” scenario with the benchmark taper rate of $\theta = 0.5$ (= 100) and in the bottom set of the results (*ii*) the “aging” scenario with the benchmark taper rate of $\theta = 0.5$ (= 100).

We begin with the effects of increasing the extent of means testing (increasing the taper rate θ from 0 to 1). The overall pension expenditure (that gives the size of the pension system) is significantly smaller under a means-tested system than under the universal system with $\theta = 0$ (comparing columns in the first block for the case of “no aging” and in the third block for the “aging scenario”). This is predominantly because of the pension cuts but also due to increased behavior incentives in means-tested pension systems. First, means-tested pension systems lower pension payments to those with larger private financial resources and even exclude some from receiving any public pension. Second, per capita labor supply and domestic assets are somewhat higher in a means-tested system, indicating that positive behavioral effects (due to reduced pension benefits) dominate negative behavioral effects of high effective marginal tax rates faced by some retirees. This implies a higher income tax base under a means-tested system. Third, in this partial equilibrium framework, the overall impact on per capita consumption is somewhat negative in a means-tested system because of lower pension payments.

The effects of population aging can be assessed comparing the two demographic scenarios for the given taper rate (i.e., comparing the columns of the first two sets of the results in Table 5). Assuming the benchmark taper rate of $\theta = 0.5$, the outcomes under the aging scenario show: (*i*) reduced per capita labor supply by 12.1% (driven by a relatively smaller proportion of the working-age population); (*ii*) increased domestic assets by 39.2% (due to a higher proportion of the elderly population with large asset holdings and stronger life-cycle incentives to save resulting from the life expectancy improvement); and (*iii*) significantly larger pension expenditure up by 50.2% (because of a much larger size of the age-eligible elderly population for the age pension).

Fiscal stabilization device. In order to tease out the net effects of the automatic adjustment mechanism provided by means testing, we compare the differences between aging and no-aging cases with the results indexed to each scenario with the benchmark taper rate of $\theta = 0.5$. The comparison (of the first and third sets of outcomes) reveals that means-tested pension systems under the aging scenario perform better in terms of controlling the fiscal cost with larger reductions in the pension expenditure, compared to the no aging scenario. For example, under "no aging" the index for pension expenditure falls from 167.3 to 84.1 as the taper rate increases from 0 to 1, whereas it falls from 176.3 to 81.5 under the "aging" scenario. The quantitative results confirm the logic described by our theoretical analysis. As population ages, the automatic adjustment device is activated. Forward looking households rationally work and save more to respond to increased longevity. Consequently, the effect of means testing is to further reduce pension benefits received by households as well as total pension expenditure. This automatic fiscal stabilization device makes means-tested pension systems more robust in adapting to aging trends. Moreover, means testing public pensions has a positive fiscal impact on the overall tax revenue relative to the universal system. This is due to the further expansion of consumption and income tax bases, making the overall fiscal system more sustainable in the long run.

Redistributive device. The distributional effects of alternative taper rates in the two different aging scenarios are reported in Table 6, which shows the implications for the age pension shares received by different skill groups of households.

The first point to note from Table 6 is that, under the universal system with $\theta = 0$, the shares of the public pension income received by higher skilled households are greater than those by lower skilled types, even though such a system pays an equal pension to every pensioner. Disparity in life expectancy across skill groups makes the universal pension system a regressive redistribution system. This unintended consequence happens because higher skilled individuals live longer and thus receive larger overall public pension income in such system.

Second, as shown by comparing the columns within each block, tightening the pension means test redistributes (or directs) public pension income toward less-skilled and less-affluent pensioners. In contrast to the universal system, a means-tested system with a non-zero taper

Table 6: Redistributive effects of alternative taper rates on age pension shares by skill type in partial equilibrium

Demographic scenario/	Taper rate				
Skilled type	0	0.25	0.5	0.75	1
No aging					
- Lowest type	17.80	24.33	29.78	32.39	35.41
- Second type	18.78	24.37	29.08	31.71	34.55
- Third type	19.91	22.31	23.46	23.81	20.15
- Fourth type	21.14	19.25	13.77	9.70	7.66
- Highest type	22.38	9.73	3.90	2.38	2.23
Aging					
- Lowest type	17.29	24.79	30.49	33.35	37.41
- Second type	18.53	24.72	29.71	32.22	37.10
- Third type	19.87	22.69	23.40	23.74	17.06
- Fourth type	21.33	19.16	12.92	8.16	6.66
- Highest type	22.98	8.65	3.48	2.53	1.77
Difference (Aging-No aging)					
- Lower types (a)	-0.75	0.80	1.34	1.47	4.55
- Higher types (b)	0.79	-1.18	-1.28	-1.40	-1.46

Notes: The results abstract from any general equilibrium impacts (e.g., tax adjustments financing pension expenditure under different taper rates. Results presented as age pension shares in %).

rate is shown to increase shares of the age pension paid to low-skilled, short-lived types of households and to reduce the shares paid to high-skilled, long-lived households. For instance, under the means-tested system with $\theta = 1$, the age pension shares paid to the lowest and highest skilled types are shown to be 35.4% and only 2.2%, respectively. Thus, means testing works as a redistributive device that automatically accounts for differences in life expectancy in pension payments. Low-income households with shorter life expectancy receive relatively more in pension payments, which makes means-tested pension systems progressive.

The progressivity of means-tested pension systems is further improved under the aging scenario, especially when disparity in life expectancy is further widened. Table 6 shows that under the aging scenario the means-tested system with $\theta = 1$ generates the age pension shares of 37.4% and 1.77% for the lowest and highest skilled groups, respectively. The intuition for this result is pointed out in Proposition 2. In the aging scenario, the life expectancy of higher-skilled individuals is assumed to improve more relative to the life expectancy improvement experienced by lower-skilled individuals. Consequently, higher-skilled individuals save and work more also due to this widening of life expectancy gaps between high- and low-skilled groups of individuals. The means testing of increased private financial resources accumulated particularly by high-skilled households results in further reductions in their public pension payments. This is also depicted by the differences in the results between aging and no aging scenarios for the age pension shares by lower and higher skilled types in the third block of Table 6. In the aging environment, tightening the pension means test better targets pension income toward lower-skilled, shorter-lived households, while making the pension system universal further worsens the equity of public pension income, redistributing it toward higher-skilled, longer-lived households.

In summary, the partial equilibrium results confirm the analytical results described in Propositions 1 and 2. That is, the presence of means testing generates an automatic adjustment mechanism acting as a fiscal stabilization device and a redistributive device. This automatic adjustment mechanism keeps means-tested pension systems fiscally sustainable (with lower pension spending and higher tax revenues relative to the universal system) and also equitable (with public pensions targeted toward those pensioners in need). The automatic adjustment mechanism is more pronounced in an aging environment.

5.2 General equilibrium analysis

We now proceed to the general equilibrium analysis and report the effects of public pension systems with alternative taper rates and aging scenarios, using the full general equilibrium model described and calibrated in Sections 3 and 4. The results presented below take into account both the direct and indirect (or general equilibrium) effects of alternative pension systems, including tax adjustments required to balance the government budget.[16] We assume that the government budget is balanced through adjustments in the taxation of household income. Specifically, the budget is balanced by proportionally raising or lowering the progressive income taxation function (thus proportionally raising or lowering average and marginal income tax rates).

Means testing and incentives to save and work. Figure 3 depicts the average life-cycle profiles of labor supply and total assets, assuming the universal system with $\theta = 0$ and the strict means-tested system with $\theta = 1$ and accounting for general equilibrium adjustments.

The results are qualitatively similar to those obtained from the partial equilibrium framework. However, the reductions (increases) in progressive income taxation under the means-tested (universal) system in this sub-section generate additional (dis-)incentives for working-age households to work and save, causing much stronger labor supply and saving adjustments. Similarly, accounting for population aging with greater life expectancies makes the differences in the results for life-cycle labor supply and total assets between the two pension systems even larger. In the means-tested system, households rationally responding to greater life expectancies by working and saving more, on average, see their pensions automatically reduced because of more binding means tests. This provides additional incentives to self-finance their retirement by private means.

The life-cycle effects presented by Figure 3 suggest that the means-tested system will further outperform the universal system at least in relation to fiscal sustainability. We present the long

[16] Note that in our small open economy model, factor prices (i.e., domestic interest and wage rates) are unchanged by altering public pension settings. Therefore, the general equilibrium effects are limited to budget-balancing tax adjustments and changes to accidental bequests. We modify this small open economy assumption in Section 6, where we examine the effects of alternative taper rates, assuming imperfect capital mobility with endogenous factor prices.

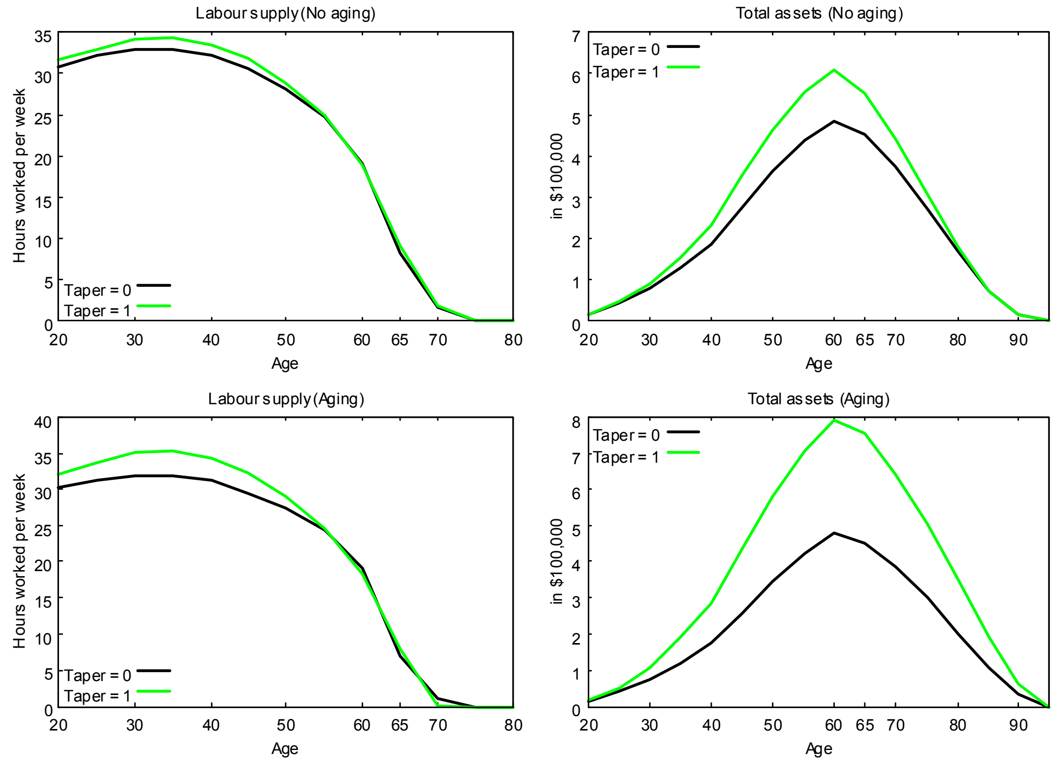

Figure 3: Life-cycle profiles under different taper (general equilibrium)

run steady state results for fiscal sustainability and equity below.

Fiscal sustainability. In the previous subsection dealing with the partial equilibrium analysis, we find the benefits of means-tested pensions in terms of reduced government spending and increased labor supply and assets. These benefits become more pronounced when general equilibrium effects (with adjustments in the income taxation) are taken into account, as indicated in Table 7. The table demonstrates that means-tested systems with higher taper rates improve both pension sustainability (in terms of reduced overall pension costs) and tax affordability (allowing for significant income tax cuts). For example, the means-tested system with $\theta = 1$ under the no aging scenario generates an income tax cut of 8.3% (relative the benchmark case with $\theta = 0.5$). This tax cut then has positive indirect (or feedback) effects on labor supply, assets and consumption that were not captured by the partial equilibrium analysis.

Table 7 also shows that in the aging environment, income tax cuts due to the means testing of public pensions are significantly higher than under the no aging scenario. Under the aging scenario, the means-tested system with $\theta = 1$ allows for an income tax cut of almost 20% (relative to the benchmark case with $\theta = 0.5$), while the universal system with $\theta = 0$ requires an income tax hike of 51.8% to restore the government budget balance. As mentioned, households respond to improved survival probabilities and longer expected lives by working and saving more. As a result, their private financial resources in retirement increase, with more binding means tests resulting in lower public pension payments. In addition, means-tested systems

Table 7: Macro and fiscal effects of alternative taper rates in general equilibrium

Demographic scenario/	Taper rate				
Variable	0	0.25	0.5	0.75	1
No aging (indexed to "no aging" scenario with taper rate = 0.5 (=100))					
- Labor supply	96.9	98.4	100.0	100.4	101.2
- Domestic assets	88.0	91.1	100.0	102.2	108.0
- Consumption	94.3	96.6	100.0	100.9	102.8
- Pension expenditure	167.3	125.0	100.0	91.3	82.4
- Tax rate[a]	122.5	111.4	100.0	96.6	91.7
Aging (indexed to "no aging" scenario with taper rate = 0.5 (=100))					
- Labor supply	81.7	85.4	87.9	88.5	89.1
- Domestic asset	103.3	113.7	139.2	151.8	171.2
- Consumption	87.6	94.4	103.3	106.8	112.0
- Pension expenditure	264.9	197.6	150.2	132.5	115.8
- Tax rate[a]	151.8	125.8	100.0	91.0	80.8
Aging (indexed to "aging" scenario with taper rate = 0.5 (=100))					
- Labor supply	93.0	97.1	100.0	100.6	101.3
- Domestic asset	74.2	81.7	100.0	109.0	123.0
- Consumption	84.8	91.4	100.0	103.4	108.5
- Pension expenditure	176.3	131.5	100.0	88.2	77.1
- Tax rate[a]	151.8	125.8	100.0	91.0	80.8

Notes: For "aging" scenario, the baseline simulation with benchmark taper rate = 0.5 assumes that government consumption (G) adjusts to balance the budget. This adjusted G is kept constant to assess effects of alternative taper rates with the budget being balanced via income tax rate adjustments. [a]Budget-balancing income tax rates.

allow for lower tax rates, generating additional incentives for households to work and save (see increased total assets reported in Table 7), and so further improving the long run fiscal sustainability due to increased overall tax base (relative to the universal system).

Redistribution. Table 8 presents the percentage shares of the overall pension expenditure for different skilled groups, assuming alternative taper rates and the two demographic scenarios in the general equilibrium framework.

Similarly to the partial equilibrium analysis, the vertical equity of public pension systems improves with higher taper rates, as demonstrated in Table 8 by increased (reduced) age pension shares for lower (higher) skilled groups of households. Accounting for the budget-equilibrating income tax changes in a means-tested system further improves redistribution of public pension income toward lower-skilled groups of pensioners. For instance, under the aging scenario, the means-tested system with $\theta = 1$ generates the pension share of 39.56% (1.49%) for the lowest (highest) skilled type, as reported in Table 8. This compares to the pension share of 37.41% (1.77%) for the lowest (highest) skilled type under the same taper rate and demographic scenarios presented in Table 6, which did not consider budget-equilibrating income tax adjustments. This is because lower progressive income taxes associated with a means-tested system provide additional work and saving incentives particularly to higher-skilled households (on high mar-

Table 8: Effects of alternative taper rates on age pension shares by skill in general equilibrium (Results presented as age pension shares in %)

Demographic scenario/	Taper rate				
Skilled type	0	0.25	0.5	0.75	1
No aging					
- Lowest type	17.80	23.83	29.78	32.61	36.13
- Second type	18.78	23.93	29.08	31.90	35.01
- Third type	19.91	22.20	23.46	23.78	19.71
- Fourth type	21.14	19.43	13.77	9.36	7.03
- Highest type	22.38	10.61	3.90	2.36	2.13
Aging					
- Lowest type	17.29	23.18	30.49	34.57	39.56
- Second type	18.53	23.42	29.71	33.08	38.99
- Third type	19.87	21.92	23.40	23.93	15.69
- Fourth type	21.33	19.76	12.92	6.34	4.27
- Highest type	22.98	11.72	3.48	2.08	1.49
Difference (Aging - No aging)					
- Lower types[a]	-0.75	-1.16	1.34	3.15	7.42
- Higher types[b]	0.79	1.44	-1.28	-3.29	-3.39

Notes: [a]Sum of pension shares of the two low skilled classes of agents. [b]Sum of pension shares of the two low skilled classes of agents.

ginal tax rates). As a result of their increased private financial resources, they face a more binding means test at older ages, resulting in lower pension payments.

General equilibrium effects. We have already established that accounting for general equilibrium strengthens the budget stabilization and redistribution properties of a means-tested pension program. Table 9 quantifies differences in the results obtained from general equilibrium vs. partial equilibrium simulations. The difference is largely due to the general equilibrium effects that the budget-equilibrating changes in the progressive income taxes generate. For example, the results for per capita domestic assets show the additional 18.5% increase in the means-tested system with $\theta = 1$ (compared $\theta = 0.5$) in general equilibrium with additional income tax cut of 19.2% than the partial equilibrium impacts on domestic assets with unchanged income tax rates depicted in Table 5.

The equity effects that are presented in Table 9 as differences in age pension shares (in %) between general equilibrium and partial equilibrium are as expected. The benchmark system with $\theta = 0.5$ is the same for both frameworks. Notice that removing the means test by setting $\theta = 0$ has no impact on the difference. This is because in the universal system, changes in income and assets affected by tax adjustments have no impact on flat-rate public pension payments. Tightening the pension means test with $\theta > 0.5$ is shown to further increase (decrease) the share of pension income received by lower (higher) skilled households when income taxes are adjusted to restore the budget balance.

Table 9: General equilibrium vs. partial equilibrium effects of alternative taper rates in aging scenario

Variable/	Taper rate				
Skilled type	0	0.25	0.5	0.75	1
Macro and Fiscal (% point differences in GE vs PE results)					
- Labour supply	-6.5	-2.4	0.0	0.3	0.1
- Domestic assets	-27.4	-17.6	0.0	9.2	18.5
- Consumption	-18.3	-9.4	0.0	3.7	8.2
- Pension expenditure	0.0	8.5	0.0	-3.2	-4.4
- Tax rate[a]	51.8	25.8	0.0	-9.0	-19.2
Equity (Difference in pension shares (%) between GE and PE)					
- Lowest type	0.00	-1.61	0.00	1.22	2.15
- Second type	0.00	-1.30	0.00	0.86	1.89
- Third type	0.00	-0.77	0.00	0.18	-1.37
- Fourth type	0.00	0.60	0.00	-1.81	-2.39
- Highest type	0.00	3.07	0.00	-0.45	-0.28

Notes: [a]Budget-balancing income tax rates.

Thus, our quantitative results indicate that the presence of means testing in public pension systems (*i*) induces households to work and save, (*ii*) contains the fiscal cost and (*iii*) improves vertical equity of public pension income. Indeed, the automatic adjustment mechanism is at work and plays a significant role in adapting public pensions to aging trends.

5.3 Transition dynamics

We now turn our analysis to investigate how the dynamic design of means-tested pensions activates the automatic adjustment mechanism along demographic transition. To do so, we consider experiments in which we replace the benchmark pension system (i.e., $\theta = 0.5$) with two alternative designs: (*i*) the universal program with $\theta = 0$ and (*ii*) the strict means-tested program with $\theta = 1$.

These two pension alternatives are examined under the two demographic scenarios: no aging and aging. Under the aging scenario, we assume that the survival probabilities are changed in year 2015 (using those in 2060) and we model a baby bust by reducing the growth rate of future-born generations to 0.5% (observed annual population growth rate in 2060). The resulting trends in the population age structure (i.e., the old-age dependency ratio) and the growth rate under the aging scenario are depicted in Figure 4. As shown, the mortality improvement (for older cohorts in particular) initially increase the old-age dependency ratio and the growth rate. In the succeeding years, the aged dependency ratio continues to increase but the population growth rate declines because of the assumed fall in the growth rate of new cohorts. In our framework, it takes about 75 years to reach a new stationary demographic structure with the

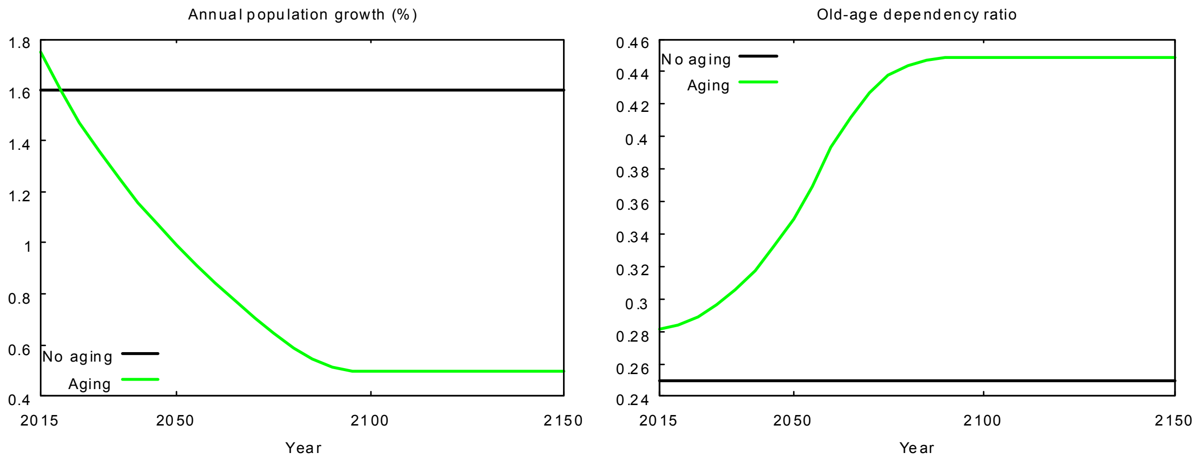

Figure 4: Demographic indicators over the transition path

old-age dependency ratio of 0.45 and the annual population growth rate of 0.5%.[17]

The results for the two pension policy alternatives are computed over the transition path spanning from 2015 to 2150. The outcomes for year 2150 represent the long run steady state effects and match those discussed in previous subsection dealing with the general equilibrium effects in the long run. We now present and discuss these results.

Fiscal sustainability. Figure 5 shows the transitional effects on the pension expenditure and the budget-balancing income tax adjustments of the alternative taper rate changed to zero or one in the first year of transition. The results presented in Figure 5 under the no aging and aging scenarios are displayed as percentage changes in the two fiscal variables relative to their values obtained from the simulations with the benchmark taper rate of $\theta = 0.5$.

Pension expenditure is shown to be significantly higher under the shift to the universal system with $\theta = 0$. In the non-aging scenario with the existing population age structure, the age pension is not a function of private means/resources and, hence, the pension expenditure is constant over the entire transition path. In the aging world with increased life expectancies and a much older population, the transitional effects of setting $\theta = 0$ varies, showing increasing expenditure over the transition path due to changing demographics. Initially, the increase in the pension expenditure is not as large as under the current “no-aging” case. This relative difference is due to lower pension spending in early years of the demographic transition with the benchmark taper rate $\theta = 0.5$ (as households responding to increased life expectancies by saving more privately). Given that early on the demographic structure is quite similar to that in the benchmark model (calibrated to 2014), the increase in the pension expenditure due to setting

[17] Note that the demographic changes in Figure 4 are more pronounced in the short and medium run than those observed from the actual ABS demographic projections made for 2012-2101. This is because of our assumption of improved survival probabilities in 2015. However, since we kept the survival rates and the growth rate of newborn cohorts constant (as in 2060), the actual ABS projections shows far more significant increases in the old-age dependency ratio and declines in the population growth rate by the end of this century.

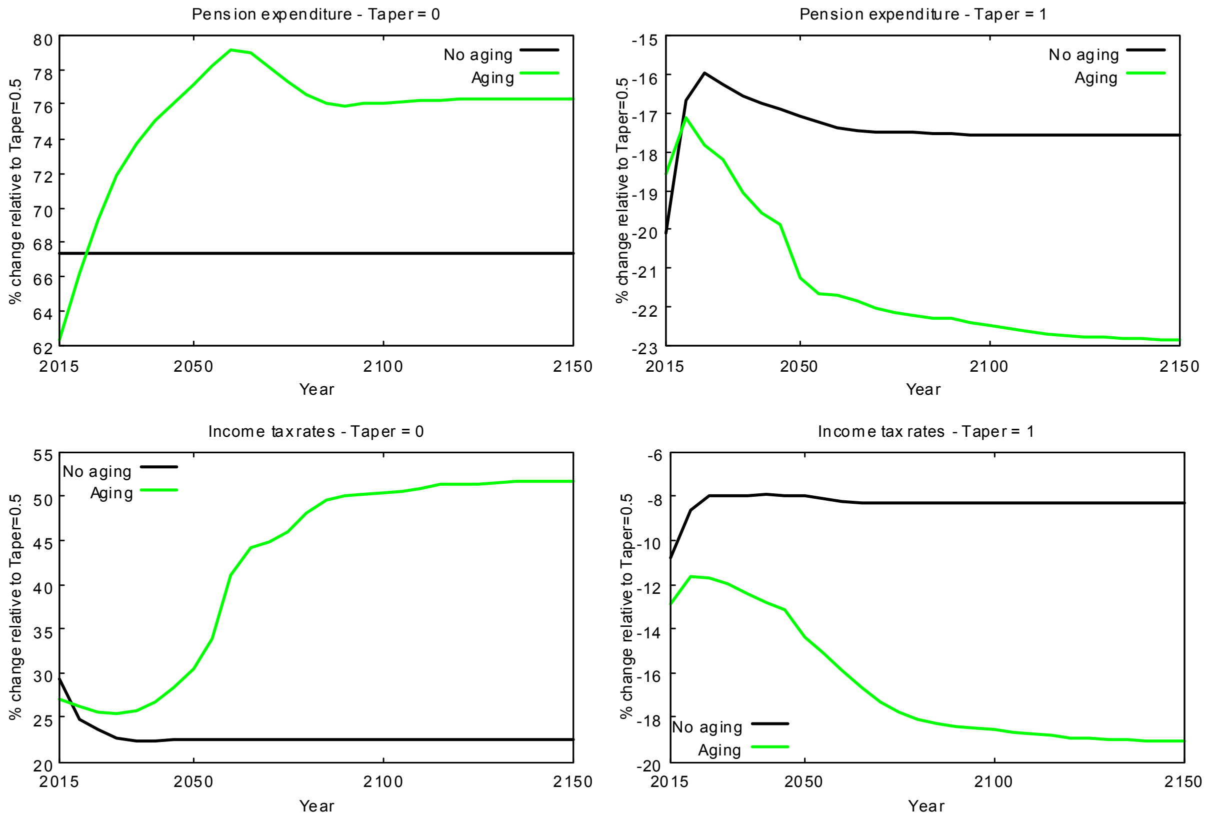

Figure 5: Fiscal impacts over the transition path

$\theta = 0$ is not as large as under the current demographic scenario. However, the costs associated with the shift to this universal system increase significantly during the aging transition. This is because the aging transition with the benchmark means-tested system (i.e., $\theta = 0.5$) limits higher spending on public pensions driven by behavioral responses to population aging (with people, on average, working and saving more, and so substituting away from means-tested pensions).

Tightening the pension means test by setting $\theta = 1$ effectively represents a pension cut, which in our framework amounts to around 20% of the current pension expenditure. Some older households face disincentives to work and save, making the immediate decline in overall pension expenditure less pronounced, but only in the short run. As the income tax rates required to balance the government budget are lowered, pension expenditure continues to further decline relative to the benchmark case with $\theta = 0.5$ during the transition, particularly when this policy is implemented under the aging transition.

To balance the government budget, income tax rates have to be increased to finance the universal system with $\theta = 0$, but they fall under the means-tested system with $\theta = 1$. The negative (positive) gap between the "aging" and "no-aging" impacts from setting the taper rate to $\theta = 1$ ($\theta = 0$) is shown to widen due to increased (reduced) work and saving incentives and the overall tax base when population aging is considered.

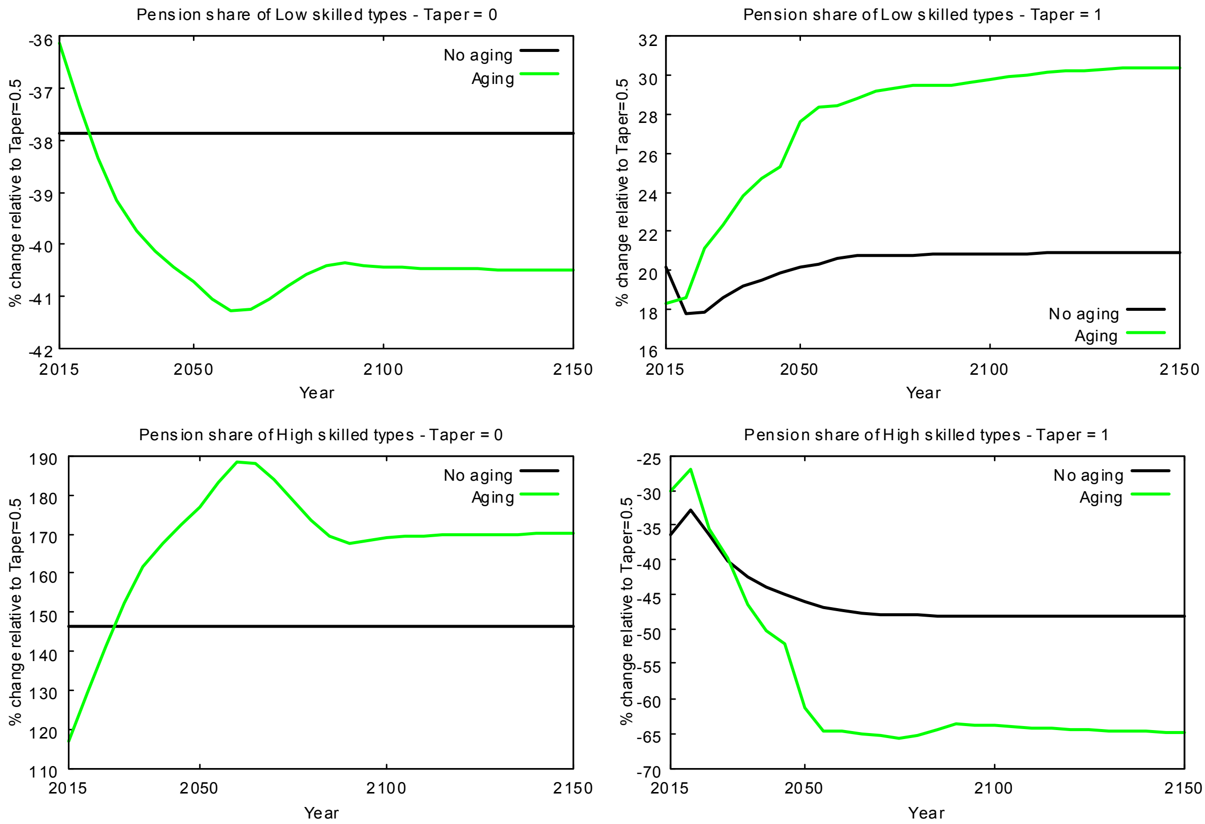

Figure 6: Equity impacts over the transition path

Redistribution. The equity effects of the two alternative pension systems are presented in Figure 6, which shows the pension shares of low skilled types (the sum of the bottom two quintiles) and of high skilled types (the sum of the top two quintiles). As above, we report the results as percentage changes from the no aging and aging scenarios with $\theta = 0.5$. Recall also that under the universal system, the pension is no longer dependent on private income and assets. This means that setting $\theta = 0$ has time-invariant impacts on pension shares, reducing the share for low skilled types by almost 38% and increasing the share for high skilled types by almost 150%. These undesirable distributional impacts of the means test removal worsen further during the aging transition, which again is caused by the pension payments under the aging scenario with the benchmark taper rate $\theta = 0.5$. Note that the labor supply and saving incentives from greater life expectancy are stronger for higher skilled types, leading to reductions in their public pension income. Thus, population aging further supports this undesired redistribution of "universal" pension income toward higher-skilled, longer-lived households.

In contrast, setting $\theta = 1$ makes the pension system more equitable, as shown by the redistribution of pension income towards low-skilled types (with their pension share up by about 20% on impact) and away from high-skilled types (with their pension share down by over 30% on impact). During the aging transition, high-skilled, longer-lived households increase their private retirement savings, further substituting away from public pension income. Hence, the means-tested system with $\theta = 1$ improves the equity of public pension income during the demographic transition and, in particular, in the long run, as shown in Figure 6 by increasing (reducing) the pension share for the low-skilled (high-skilled) households.

In the Appendix, we have also included the transitional effects on other variables, including aggregate labor supply, assets and the welfare of different generations and skilled groups. In brief, the transitional implications of setting $\theta = 1$ for labor supply and assets are also positive, but the labor supply increases in particular are higher in the short run than in the long run, and in the case of the aging scenario (given the behavioral responses to population aging with greater longevity). The welfare effects of tightening the means test are positive for younger and future born generations (benefiting from increased private savings and reduced income taxes) but negative for some older generations (experiencing pension cuts). Even though the pension payments are reduced for high-skilled households, they gain more welfare in the long run compared to low-skilled types, because of benefiting more from lower progressive income taxes.

6 Sensitivity analysis and extension

This section examines the sensitivity of long-run general equilibrium results reported in Section 5 to alternative demographic and modelling assumptions. We first consider different population aging scenarios and an alternative budget-balancing tax instrument. We then consider a model with imperfect capital mobility so that the domestic interest rate is endogenous. We also alter household preferences. Finally, we consider a Pareto-improving pension reform.

6.1 Different aging scenarios

Different aging scenarios are considered here in order to better understand dynamic interactions between underlying demographic factors and means-testing instruments. The motivation is that different public pension systems (i.e., universal vs. means-tested systems) will have potentially different macroeconomic and distributional impacts depending on the nature of the population aging process.

Accordingly, we account for a number of alternative aging scenarios constructed by reducing the population growth rate (due to declining fertility rates in the past), increasing longevity (as measured by improved survival rates) and abstracting from widening the life-expectancy gaps. For clarity, we will list all the consider demographic scenarios, including the no aging and aging cases covered above. The list includes:

(1) No aging with the existing population growth rate and survival probabilities, generating an old-age dependency ratio of 0.25;

(2) Aging (based on demographic projections for 2060) with separately

(2A) reduced population growth rate (0.5% per year) (due largely to lower fertility in the past), generating an old-age dependency ratio of 0.38;

(2B) increased survival probabilities (but unchanged life expectancy gaps as in the benchmark), generating an old-age dependency ratio of 0.28;

(3) Aging (based on demographic projections for 2060) with jointly

(3A) reduced growth rate and increased survival probabilities, but same life-expectancy gaps, generating an old-age dependency ratio of 0.45;

(3B) reduced growth rate, increased survival probabilities and increased life-expectancy gaps, also generating an old-age dependency ratio of 0.45.

The focus is on the performance of means-tested pension programs under three alternative aging scenarios (2A), (2B) and (3A) – given that the effects obtained under Scenarios (1) (no aging) and (3B) (aging) were already discussed in the previous section. The results reported below for the macroeconomic, equity and welfare implications of alternative taper rates under all five demographic scenarios are related to each scenario with the benchmark taper rate of $\theta = 0.5$.[18] The objective here is to compare how alternative pension systems (different taper rates) perform within each demographic scenario.

Fiscal sustainability. Table 10 reports the fiscal and macroeconomic effects of alternative taper rates relative to the benchmark taper rate of $\theta = 0.5$ within each demographic scenario. It indicates that under both aging Scenarios (2A) and (2B), tightening the pension means test by increasing the taper rate leads to more positive macroeconomic and fiscal outcomes than when Scenario (1) with no aging is assumed. However, it is the improvement in survival probabilities used in Scenario (2B) under which a means-tested system has largely positive implications on fiscal sustainability and the selected macroeconomic outcomes. This is because households respond to greater life expectancies by accumulating larger private financial resources for retirement, resulting in lower average pension payments and overall pension costs in the means-tested system. It needs to be pointed out that this aging scenario generates only a modest increase in the old-age dependency ratio to 0.28.[19]

In contrast, Scenario (2A) with a lower population growth rate (taken from the ABS (2013) medium population projection for 2060) alters the future age structure of the population significantly, increasing the old-age dependency ratio to 0.38 from the existing ratio of 0.25 in

[18] Note that similarly to aging Scenario (3B), the fiscal costs of population aging under each alternative aging scenario are assumed to be financed by reduced government consumption, and when the effects of alternative taper rates are calculated, we assume that the government budget is balanced through adjustments in the progressive income taxation.

[19] Note that in Scenario (2B), we use average survival probabilities for 2060 from the medium population projection by ABS (2013), which imply relatively modest improvements in the future life expectancies compared to other population projections made for Australia by, for example, Productivity Commission (2013). If we used higher future survival probabilities (or those assumed for year 2100), the means-tested system would have a more positive impact on long-run fiscal sustainability relative to the universal system.

Table 10: Macro and fiscal effects of alternative taper rates under different demographic scenarios (Results indexed to each scenario with benchmark taper of 0.5 (=100))

Taper scenario/ Variable	Demographic scenario				
	No aging (1)	Aging (2A)	Aging (2B)	Aging (3A)	Aging (3B)
Taper rate = 0					
- Labor supply	96.9	94.8	96.7	93.7	93.0
- Domestic asset	88.0	84.0	84.0	77.9	74.2
- Consumption	94.3	90.3	93.0	86.9	84.8
- Pension expenditure	167.3	164.1	176.3	172.6	176.3
- Tax rate[a]	122.5	135.7	127.5	146.2	151.8
Taper rate = 0.25					
- Labor supply	98.4	97.5	98.8	97.4	97.1
- Domestic assets	91.1	89.0	92.7	85.6	81.7
- Consumption	96.6	94.4	97.2	93.0	91.4
- Pension expenditure	125.0	125.2	125.5	129.0	131.5
- Tax rate[a]	111.4	117.7	110.3	122.0	125.8
Taper rate = 0.75					
- Labor supply	100.4	100.5	100.6	100.6	100.6
- Domestic assets	102.2	103.7	105.4	111.6	109.0
- Consumption	100.9	101.5	101.7	104.1	103.4
- Pension expenditure	91.3	91.0	89.8	87.9	88.2
- Tax rate[a]	96.6	94.7	94.7	89.7	91.0
Taper rate = 1					
- Labour supply	101.2	101.4	101.5	101.3	101.3
- Domestic asset	108.0	111.0	116.5	122.5	123.0
- Consumption	102.8	104.4	104.9	108.1	108.5
- Pension expenditure	82.4	82.0	78.8	77.9	77.1
- Tax rate[a]	91.7	87.7	87.2	81.1	80.8

Notes: For "aging" scenario, the baseline simulation with benchmark taper rate = 0.5 assumes that government consumption (G) adjusts to balance the budget. This adjusted G is kept constant to assess effects of alternative taper rates with the budget being balanced via income tax rate adjustments. [a]Budget-balancing income tax rates.

the benchmark model. This scenario generates substantial fiscal pressure (not shown), which is mitigated by tightening the pension means test. However, changing the population growth rate has no direct impact on household decisions about their labor supply and saving and, therefore, the effects of alternative taper rates are not as pronounced as under Scenario (2B) with mortality improvements.

Accounting for both lower population growth and greater life expectancies in Scenarios (3A) and (3B) is shown to further strengthen the case for means testing public pensions. The results in Table 10 indicate that the means-tested system with $\theta = 1$ performs the best in terms of improving the long run fiscal sustainability and tax affordability under aging Scenario (3B), which also captures increased life expectancy gaps.

Table 11: Effects of alternative taper rates on age pension shares under different aging scenarios (Results indexed to each scenario with benchmark taper of 0.5 (=100))

Taper scenario /Selected skilled type	Demographic scenario				
	No aging (1)	Aging (2A)	Aging (2B)	Aging (3A)	Aging (3B)
Taper rate = 0					
- Lowest type	59.76	60.94	56.72	57.92	56.71
- Third type	84.86	84.59	87.38	86.74	84.92
- Highest type	573.25	498.11	671.92	588.08	660.03
Taper rate = 0.25					
- Lowest type	80.03	79.89	79.67	77.54	76.02
- Third type	94.62	93.98	97.84	95.12	93.70
- Highest type	271.73	256.55	263.23	295.58	336.60
Taper rate = 0.75					
- Lowest type	109.51	109.94	111.34	113.74	113.39
- Third type	101.36	101.52	100.03	101.97	102.25
- Highest type	60.38	62.44	62.30	57.89	59.70
Taper rate = 1					
- Lowest type	121.32	121.92	126.97	128.37	129.77
- Third type	84.02	85.84	64.12	66.50	67.06
- Highest type	54.49	54.91	38.50	38.61	42.79

Notes: For "aging" scenario, the baseline simulation with benchmark taper rate = 0.5 assumes that government consumption (G) adjusts to balance the budget. This adjusted G is kept constant to assess effects of alternative taper rates with the budget being balanced via income tax rate adjustments. [a]Budget-balancing income tax rates.

Redistribution. The equity effects of alternative taper rates on the age pension shares for selected skilled groups are provided in Table 11. The results are indexed to the age pension shares derived under each examined demographic scenario with the benchmark taper rate of $\theta = 0.5$. For example, under aging Scenario (3B), the universal pension system with $\theta = 0$ reduces (increases) the age pension share of the lowest (highest) skilled type by 43.29% (550.03%) relative to the means-tested system with $\theta = 0.5$. In contrast, tightening the pension means test to $\theta = 1$ increases (reduces) the age pension share of the lowest (highest) skilled type by 29.77% (57.21%) relative to $\theta = 0.5$ under the same aging scenario.

One of the main benefits of means-tested pensions is that they are designed to direct public pension payments to those seniors most in need. Our findings demonstrate that this redistribution feature of means-tested pensions is automatically strengthened under more pronounced aging scenarios, particularly when accounting for longer expected lives with increasing life expectancy gaps under Scenario (3B). By contrast, the universal system with $\theta = 0$ results in a more inequitable redistribution of public pension income to higher-skilled, more-affluent and longer-lived groups of households.

Welfare effects. The welfare effects of alternative taper rate settings are assessed on the basis of standard equivalent variations. In Table 12, the welfare effects are presented as the percentage changes in initial wealth for each selected skilled type (and averaged across all five types) needed in the benchmark case with $\theta = 0.5$ to produce lifetime utility obtained under each alternative taper rate and within each demographic scenario.

Table 12 reveals that tightening the pension means test (with the taper rate increased to 0.75 and 1) has positive impacts on average welfare, while relaxing the pension means test (with the taper rate reduced to 0.25 and 0) lowers average welfare. These effects become more significant under more pronounced aging scenarios. For instance, assuming most probable future aging Scenario (3B), the means-tested system with $\theta = 1$ increases average welfare by 1.21% in initial resources (relative to $\theta = 0.5$), whereas the universal system with $\theta = 0$ produces an average welfare loss of 2.8% (relative to $\theta = 0.5$).

The distributional welfare results also reveal that tightening the means test increases the welfare of the highest-skill households more than the welfare of the lowest-skill households. The welfare gains experienced by high-skill households in means-tested systems are due to lower progressive income taxes, increased life-cycle saving and self-funding in retirement. Therefore, means-tested systems not only redistribute public pension income to low-skill households but also benefit high-skill households in terms of lower taxes needed to finance a cheaper public pension program.

Thus, the automatic adjustment mechanism embedded in means-tested pension systems becomes more effective under more aggressive population aging scenarios.

6.2 Tax financing instrument

In this and the following subsections, we discuss the robustness checks of the long run general equilibrium results reported in Section 5 to several model modifications. We start with the sensitivity of the results to the consumption tax financing instrument and the imperfect capital mobility framework. We then conclude by reporting on the sensitivity of the results to alternative specifications of household preferences.

Table 13 presents results for the alternative tax financing instrument and the imperfect capital mobility modifications. The results are presented as percentage point deviations of the

Table 12: Welfare effects of alternative taper rates under different demographic scenarios (Equivalent variation in % relative to each scenario with taper = 0.5)

Taper scenario/	Demographic scenario				
Selected skilled type	No aging (1)	Aging (2A)	Aging (2B)	Aging (3A)	Aging (3B)
Taper rate = 0					
- Lowest type	-0.57	-0.90	-0.72	-1.21	-1.35
- Third type	-0.52	-1.27	-0.68	-1.83	-2.21
- Highest type	-2.53	-4.50	-3.22	-6.03	-6.96
- Average	-0.89	-1.74	-1.14	-2.38	-2.80
Taper rate = 0.25					
- Lowest type	-0.29	-0.45	-0.27	-0.58	-0.67
- Third type	-0.28	-0.64	-0.07	-0.75	-0.99
- Highest type	-1.58	-2.52	-1.40	-3.19	-3.87
- Average	-0.51	-0.90	-0.37	-1.13	-1.43
Taper rate= 0.75					
- Lowest type	0.08	0.13	0.14	0.27	0.24
- Third type	-0.27	-0.21	-0.22	0.00	-0.08
- Highest type	0.52	0.85	0.82	1.63	1.30
- Average	0.06	0.17	0.20	0.58	0.48
Taper rate = 1					
- Lowest type	0.21	0.31	0.34	0.51	0.50
- Third type	-0.14	0.06	0.30	0.72	0.74
- Highest type	1.22	1.85	2.04	3.10	3.02
- Average	0.33	0.59	0.69	1.14	1.21

Notes: For "aging" scenario, the baseline simulation with benchmark taper rate = 0.5 assumes that government consumption (G) adjusts to balance the budget. This adjusted G is kept constant to assess effects of alternative taper rates with the budget being balanced via income tax rate adjustments.

effects of the examined taper rate changes (relative to the taper rate of 0.5) under the no aging case obtained from the given model modification and those obtained using the baseline model and reported in Section 5.

The baseline results for the taper rate changes carried out in Section 5 assumed adjustments in the income taxation to balance the government budget. Here instead, we assume that the consumption tax rate is adjusted to balance the government budget under alternative pension designs.

As shown in Table 13, increasing (lowering) the taper rate results in a cut (hike) in the consumption tax rate. Specifically, the means-tested system with $\theta = 1$ allows for a 10.15% consumption tax cut, while the universal system with $\theta = 0$ requires a 26.92% consumption tax hike (relative to $\theta = 0.5$ under no aging scenario).[20] The fiscal, macroeconomic and equity

[20] Under the aging scenario (3B), the pension system with $\theta = 1$ allows for a 10.15% consumption tax cut, while the universal system with $\theta = 0$ requires a 26.92% consumption tax hike (relative to $\theta = 0.5$). The differences in the macroeconomic, equity and welfare results with consumption and income tax adjustments

Table 13: Sensitivity to alternative model assumptions under no aging scenario (Percentage point deviation from baseline long run results)

Model modification/	Taper rate			
Variable	0	0.25	0.75	1
Consumption tax rate balancing the budget				
- Labour supply	2.34	0.96	-0.23	-0.51
- Domestic assets	12.29	7.26	-2.46	-6.67
- Consumption	4.89	2.39	-0.70	-1.75
- Pension expenditure	0.00	-2.57	0.83	1.86
- Tax rate[a]	26.92	13.07	-4.02	-10.15
- Pension share - low types[b]	0.00	1.58	-0.91	-2.12
- Pension share - high types[c]	0.00	-5.68	1.90	3.78
- Welfare - low types[d]	-0.33	-0.17	0.06	0.16
- Welfare - high types[e]	1.62	0.80	-0.24	-0.59
Imperfect capital mobility with endogenous interest rate				
- Labour supply	-0.50	-0.32	0.06	0.24
- Domestic assets	0.37	0.02	-0.09	-0.53
- Interest rate	1.51	1.28	-0.28	-1.06
- Consumption	-0.77	-0.58	0.10	0.34
- Pension expenditure	0.00	-0.21	0.13	0.52
- Tax rate[f]	1.86	1.31	-0.18	-0.56
- Pension share - low types[b]	0.00	0.08	-0.13	-0.42
- Pension share - high types[c]	0.00	-0.15	0.19	0.60
- Welfare - low types [d]	-0.11	-0.09	0.02	0.06
- Welfare - high types[e]	-0.26	-0.20	0.03	0.11

Notes: [a]Consumption tax changes are assumed to balance the government budget. [b]The sum of lowest and second skill types. [c]The sum of fourth and highest skill types. [d]The average of lowest and second skill types. [e]The average of fourth and highest skill types. [f]Income tax changes are assumed to balance the government budget.

implications of tightening the pension means test are not as favorable when the consumption tax rate is adjusted to balance the government budget. For instance, under the means-tested system with $\theta = 1$, Table 13 reports a relative decline of 6.67 percentage points in (larger) domestic assets (with respect to $\theta = 0.5$) when assuming budget-equilibrating consumption rather than income tax adjustments. This is because the progressive income taxation is more distortive for labor supply and saving decisions than the consumption taxation. Hence, the behavioral responses of (especially higher-skill) households to a consumption tax cut generated by increasing the taper rate are not as positive as their responses to an income tax hike.

In sum, this sensitivity check indicates that income taxes should be adjusted (reduced) in a means-tested system to maximize the budget-stabilization and redistribution properties of means-tested public pensions.

become more pronounced in an aging world. The comparison between the two tax adjustments under the aging scenario (3B) can be requested from the authors.

6.3 Imperfect capital mobility

In this subsection, we relax the assumption of perfect capital mobility across borders and assume that the domestic interest rate is partially endogenous. Specifically, the domestic interest rate is given by $r_t = \overline{r} + \gamma \left(A_t^F / Y_t - \overline{A}^F / \overline{Y} \right)$, where $\overline{r}$ is the exogenous world interest rate, A_t^F / Y_t is the ratio of net foreign assets to GDP and $\overline{A}^F / \overline{Y}$ is that ratio in the benchmark steady state. The parameter γ gives responsiveness of r_t to the changes in A_t^F / Y_t and is set to 0.02, as in Kudrna et al. (2018). This specification implies that the domestic interest rate r_t will increase if A_t^F / Y_t declines and (similarly to a closed economy) the capital labor ratio and the wage rate will no longer be constant in the long run.

Table 13 shows that increasing the taper rate leads to a lower domestic interest rate. The interest rate declines because of larger domestic assets that are partly invested abroad, thus reducing net foreign debt. The reduced rate of return has somewhat negative long run effects on per capita assets (relative to the baseline case with exogenous interest rate), as reported in Table 13 for the two increases in the taper rate to 0.75 and 1. However, the positive effects on per capita labor supply and consumption (and on the economy through increases in GDP per capita) are higher than those obtained previously with the fixed interest rate. These effects are due to increased wages.[21]

6.4 Household preferences

The period utility function used in the main results section is $u(c,l) = \frac{\left[c^{\rho} l^{1-\rho}\right]^{1-\sigma}}{1-\sigma}$. This utility function has been used in most general equilibrium studies of social security reforms. In our calibration, the parameter σ that determines the agent's risk aversion is set to 2. The Frisch elasticity of labor supply in this weakly separable specification of household preferences varies and affects incentives to work over the life-cycle.[22]

We now conduct the sensitivity analysis of our long run results to different specifications of household preferences. We first consider different values of the risk aversion parameter, setting it to the alternative values of 1 and 4. In addition, we examine the following two additively separable utility functions: $u(c,l) = \log c + \psi \frac{l^{1-v}}{1-v}$ and $u(c,l) = \frac{c^{1-\sigma}}{1-\sigma} - \chi \frac{(1-l)^{1+\frac{1}{\gamma}}}{1+\frac{1}{\gamma}}$.[23]

We re-calibrate the model with different parameter values and utility functions, and repeat the experiments for alternative means-testing policy settings. Specifically, in each of the four model modifications, the subjective discount factor β and the parameter ρ (alternatives 1 and 2) or ψ (alternative 3) or χ(alternative 4) are re-calibrated to match the capital to output ratio

[21] The lower interest rate drives up investment, leading to a larger capital stock. Consequently, the capital labor ratio increases, which has positive effects upon wages. Similar effects would occur in a closed economy framework.

[22] The Frisch elasticity is given by $\frac{l}{1-l} \frac{1-\rho(1-\sigma)}{\sigma}$. It varies over the life cycle as a function of leisure relative to labor supply.

[23] The former is commonly used in the real business cycle literature. In that specification, the labor supply elasticity, $\frac{1}{\nu} \frac{l}{1-l}$ also varies over the life-cycle. But the latter implies that the intertemporal elasticity of substitution in labor is constant over the life-cycle and given by γ.

and average hours worked, respectively. The parameterization of the two alternative utility functions is based on İmrohoroğlu and Kitao (2009), with the values set to $\upsilon = 2$, $\sigma = 2$ and $\gamma = 0.5$.

Table 14: Sensitivity to alternative specifications of household preferences (% change in pension expenditure and shares relative to the policy with taper of 0.5)

Model modification/	Taper rate			
Variable	0	0.25	0.75	1
Benchmark - weakly separable preferences with $\sigma = 2$				
- Pension expenditure	67.34	24.96	-8.68	-17.57
- Pension share - low[a]	-37.86	-18.86	9.59	20.85
- Pension share - high[b]	146.16	69.94	-33.74	-48.22
Alternative 1 - weakly separable preferences with $\sigma = 1$				
- Pension expenditure	56.95	18.45	-10.68	-17.61
- Pension share - low[a]	-33.80	-14.80	11.02	21.47
- Pension share - high[b]	100.36	41.82	-31.77	-39.82
Alternative 2 - weakly separable preferences with $\sigma = 4$				
- Pension expenditure	86.10	32.30	-12.91	-23.56
- Pension share - low[a]	-43.17	-22.75	13.78	30.43
- Pension share - high[b]	227.03	111.22	-50.91	-67.58
Alternative 3 - additively separable preferences with changing Frisch elasticity				
- Pension expenditure	98.93	40.03	-16.53	-23.06
- Pension share - low[a]	-43.59	-24.79	16.84	26.01
- Pension share - high[b]	213.36	114.46	-35.29	-50.19
Alternative 4 - additively separable preferences with constant Frisch elasticity				
- Pension expenditure	65.03	19.61	-11.32	-13.34
- Pension share - low[a]	-36.57	-15.56	12.37	17.51
- Pension share - high[b]	120.76	47.30	-21.62	-37.66

Notes: [a]The sum of lowest and second skill types; [b]The sum of fourth and highest skill types.

The results are provided in Table 14 for the pension expenditure and shares for low-skill and high-skill types obtained from the four alternative specifications of household preferences and the benchmark with the results reported in Section 5.

The effects indicate that the gains from means testing public pensions are greater in frameworks with higher risk aversion. Similar findings are obtained by İmrohoroğlu and Kitao (2009) for the long run economic benefits from privatizing social security. Overall, even though there are some quantitative differences in the fiscal and distributional implications, the examined alternative preference specifications and parameter values do not change the effects of means testing qualitatively, in the sense of having the same direction of change in reported long-run results of the main results section.

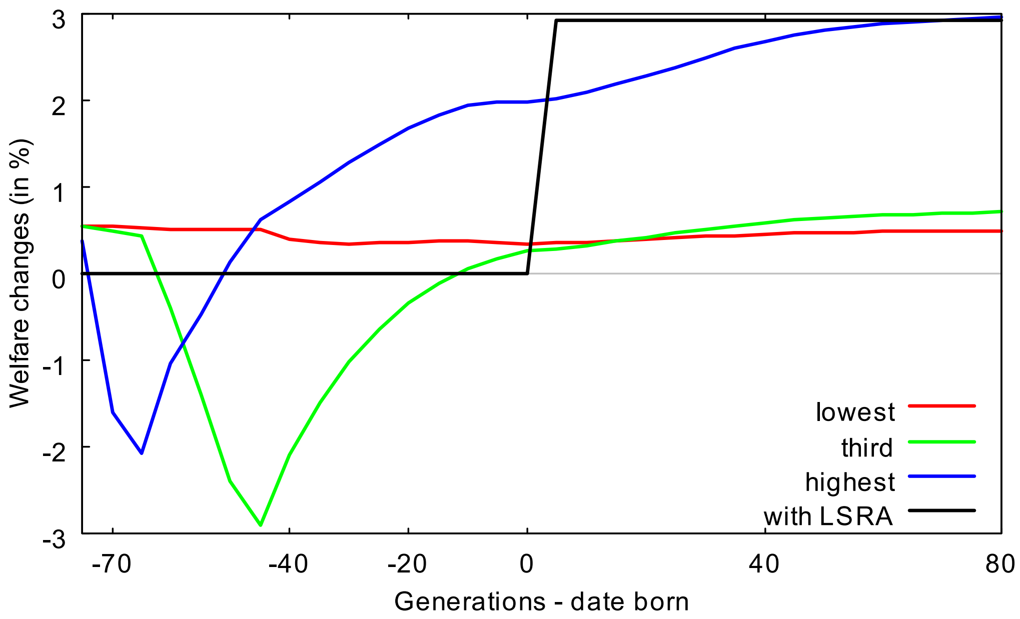

Figure 7: Welfare effects of increasing taper to one along aging transition

6.5 Pension reform

The previous discussion shows that there are designs of means testing that can devise a sufficiently strong automatic mechanism to keep public pensions sustainable and equitable under population aging. More aggressive demographic trend requires more progressive means testing rules to better adapt a means-tested pension system to pressing fiscal challenges.

In this section we investigate if it is feasible to devise a pension reform that does not lower the welfare of any individual in any birth cohort relative to the continuation of status quo, while making a means-tested pension system more sustainable and equitable. Specifically, we consider a pension reform in which the government increases the taper rate from the current rate of $\theta = 0.5$ to a more progressive rate of $\theta = 1$.

Along the aging transition to the new steady state there exists a hypothetical Lump Sum Redistribution Authority (LSRA) who runs a compensating tax and transfer system. As proposed by Auerbach and Kotlikoff (1987), the LSRA uses lump sum transfers/taxes in order to restore the utility of all currently alive agents to their pre-reform levels. On other hand, the LSRA makes (collects) an additional lump-sum transfers (taxes) to all future born generations such that the sum of all current and discounted future transfers/taxes equals zero. Such additional lump-sum transfers (taxes) raise (reduce) their utility by a uniform amount, indicating that the policy is potentially Pareto improving (worsening) in welfare.

Figure 7 presents the resulting aggregate efficiency impact (labelled "with LSRA") of tightening the means test (with $\theta = 1$) together with the inter-generational welfare implications for three selected skilled types during the aging transition. The welfare results show that while all future born generations gain in welfare, some current generations experience welfare losses.

However, the aggregate efficiency result is positive with all future generations gaining a welfare improvement of 2.9% after the redistribution scheme leaves all current generations as well off as with the benchmark taper.[24]

Thus, it is possible to devise a more progressive pension system that yields an aggregate efficiency gain and, hence, a potential Pareto improvement in welfare.

7 Conclusion

In this paper, we have studied the means testing of public pensions in an aging economy. We find that means-tested pension systems have two built-in automatic adjustment devices: a fiscal stabilization device and a redistributive device. Under population aging these two devices activate an adjustment mechanism that automatically adapts the pension system to changing demographic trends. As a result, this automatic adjustment mechanism contains the increasing fiscal costs and mitigates the adverse equity effects caused by population aging.

In order to quantify the fiscal and equity effects of this novel mechanism, we have developed a dynamic general equilibrium, life-cycle model with overlapping generations of heterogeneous households, profit-maximizing firms and government with detailed model-equivalent pension and tax policy settings. The benchmark model has been calibrated to Australia because it already has a means-tested pension system. We have considered a range of demographic scenarios, including several population aging scenarios projected for Australia in the next 50 years, approximating demographic changes projected for many other developed countries. We conduct a series of quantitative analyses and demonstrate that the automatic adjustment mechanism is quantitatively important in mitigating the adverse effects of population aging.

Our quantitative analysis implies the following three key findings. First, a means-tested pension system, through its automatic fiscal stabilization device, mitigates the large fiscal costs associated with population aging. The right levels of the taper rate (at which pensions are withdrawn based on private financial means/resources) maintain the fiscal sustainability of a pension system in an aging economy. Second, a mean-tested pension system, through its automatic redistributive device, mitigates the adverse effects on equity caused by differences in life expectancies by socio-economic status. The progressivity of public pension payments is maintained in a means-tested system as it directs public pension benefits toward lower-skilled, less-affluent and shorter-lived groups of households. Third, this automatic adjustment mechanism becomes more important under more pronounced population aging scenarios.

Overall, the inclusion of the means testing in a public pension system significantly improves both fiscal sustainability and equity in an aging economy. Our findings highlight the dual role of a means-tested pension program in providing fiscally sustainable and equitable pensions for an aging population. Not only do these results have direct policy relevance for national

[24] McGrattan and Prescott (2017) show that it is possible to devise a transition path from the current US system to a fully funded system that increases the welfare of both current and future generations.

governments' age pension program settings, but they also contribute to addressing the OECD's concern for the prevention of aging unequally (OECD, 2017).

References

Auerbach, A., K. Charles, C. Coile, W. Gale, D. Goldman, R. Lee, C. Lucas, P. Orszag, L. Sheiner, B. Tysinger, D. Weil, J. Wolfers, and R. Wong (2017). How the growing gap in life expectancy may affect retirement benefits and reforms. *NBER Working Paper No. 23329*.

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

Australian Bureau of Statistics (ABS) (2012). *Government Benefits, Taxes and Household Income.* Cat. No. 6537.0. Australian Government Publishing Service.

Australian Bureau of Statistics (ABS) (2013). *Population Projections, Australia, 2012 (base) to 2101.* Cat. No. 3222.0. Australian Government Publishing Service.

Australian Bureau of Statistics (ABS) (2015). *Life Tables – Australia 2012–2014.* Cat. No. 3302.0.55.001. Australian Government Publishing Service.

Australian Bureau of Statistics (ABS) (2017a). *Australian System of National Accounts 2016–17.* Cat. No. 5204.0. Australian Government Publishing Service.

Australian Bureau of Statistics (ABS) (2017b). *Household Income and Income Distribution 2016–17.* Cat. No. 6523.0. Australian Government Publishing Service.

Australian Government (2015). *Budget Paper No. 1: Budget Strategy and Outlook 2008-09.* Commonwealth of Australia, Canberra.

Braun, A., K. Kopecky, and T. Koreshkovai (2017). Old, sick, alone, and poor: A welfare analysis of old-age social insurance programmes. *Review of Economic Studies 84*, 580–612.

Braun, R. A. and D. H. Joines (2015). The implications of a graying Japan for government policy. *Journal of Economic Dynamics and Control 57*, 1–23.

Chetty, R., M. Stepner, S. Abraham, S. Lin, B. Scuderi, N. Turner, A. Bergeron, and D. Cutler (2016). The association between income and life expectancy in the United States, 2001 - 2014. *Journal of the American Medical Association 315*, 1750–1766.

Clarke, P. and A. Leigh (2011). Death, dollars and degrees: Socio-economic status and longevity in Australia. *Economic Papers: A journal of applied economics and policy 30*(3), 348–355.

Cristia, J. P. (2009). Rising mortality and life expectancy differentials by lifetime earnings in the United States. *Journal of Health Economics 28*(5), 984–995.

Fehr, H. (2000). Pension reform during the demographic transition. *Scandinavian Journal of Economics 102*, 419–443.

Fehr, H. and J. Uhde (2014). Means-testing and economic efficiency in pension design. *Economic Modelling 44*, 57–67.

Gokhale, J., L. Kotlikoff, J. Sefton, and M. Weale (2001). Simulating the transmission of wealth inequality via bequests. *Journal of Public Economics 79*(1), 93–128.

Gruber, J. and D. Wise (2000). Social security programs and retirement around the world. In *Research in Labor Economics*, pp. 1–40. Emerald Group Publishing Limited.

Hosseini, R. and A. Shourideh (2018). Retirement financing: An optimal reform approach. *Working Paper.*

İmrohoroğlu, S. and S. Kitao (2009). Labor supply elasticity and social security reform. *Journal of Public Economics 93*(7-8), 867–878.

Imrohoroglu, S., S. Kitao, and T. Yamada (2016). Achieving fiscal balance in Japan. *International Economic Review 57*, 117–154.

Kitao, S. (2014). Sustainable social security: Four options. *Review of Economic Dynamics 17*, 756–779.

Kitao, S. (2015). Fiscal cost of demographic transition in Japan. *Journal of Economic Dynamics and Control 54*, 37–58.

Kotlikoff, L., K. Smetters, and J. Walliser (2007). Mitigating America's demographic dilemma by pre-funding social security. *Journal of Monetary Economics 54*(2), 247–266.

Krueger, D. and A. Ludwig (2007). On the consequences of demographic change for rates of returns to capital, and the distribution of wealth and welfare. *Journal of Monetary Economics 54*(1), 49–87.

Kudrna, G. (2016). Economy-wide effects of means-tested pensions: The case of Australia. *Journal of the Economics of Ageing 7*, 1–49.

Kudrna, G., C. Tran, and A. Woodland (2018). Facing demographic challenges: Pension cuts or tax hikes? *Macroeconomic Dynamics*, 1–49.

Kudrna, G. and A. Woodland (2011). An inter-temporal general equilibrium analysis of the Australian age pension means test. *Journal of Macroeconomics 33*, 61–79.

McGrattan, E. R. and E. C. Prescott (2017). On financing retirement with an aging population. *Quantitative Economics 8*(1), 75–115.

Nishiyama, S. (2004). *Analyzing an Aging Population: A Dynamic General Equilibrium Approach.* Congressional Budget Office.

Nishiyama, S. (2015). Fiscal policy effects in a heterogeneous-agent overlapping-generations economy with an aging population. *Journal of Dynamic Economics and Control 61*, 114–132.

Organisation for Economic Cooperation and Development (OECD) (2016). Fragmentation of retirement markets due to differences in life expectancy. In *OECD Business and Finance Outlook 2016.* OECD Publishing, Paris.

Organisation for Economic Cooperation and Development (OECD) (2017). *Preventing ageing unequally.* OECD Publishing, Paris.

Productivity Commission (2013). An ageing Australia: Preparing for the future. *Research Paper, Canberra.*

Reilly, R., W. Milne, and S. Zhao (2005). *Quality-adjusted labour inputs.* Australian Bureau of Statistics.

Sefton, J., J. vandeVen, and M. Weale (2008). Means testing retirement benefits: Fostering equity or discouraging savings? *The Economic Journal 118*, 556–590.

Tran, C. and A. Woodland (2014). Trade-offs in means-tested pension design. *Journal of Economic Dynamics and Control 47*, 72–93.

United Nations (2015). *World Population Prospects: The 2015 Revision*. Population Division, Department of Economic and Social Affairs, United Nations, New York.

Villegas, A. M. and S. Haberman (2014). On the modeling and forecasting of socioeconomic mortality differentials: An application to deprivation and mortality in England. *North American Actuarial Journal 18*(1), 168–193.

Von Gaudecker, H. M. and R. Scholz (2008). Differential mortality by lifetime earnings in Germany. *Demographic Research 17*(4), 83–108.

Waldron, H. (2007). Trends in mortality differentials and life expectancy for male social security-covered workers by socioeconomic status. *Social Security Bulletin 67*, 1.

Wooden, M., S. Freidin, and N. Watson (2002). The household, income and labour dynamics in Australia (HILDA) survey: Wave 1. *Australian Economic Review 35*, 339–348.

Appendix

In this appendix, we provide more details about Australia's public pension system and additional results for the transitional impacts of public pension alternatives.

A. Australia's means-tested pension system

There is a variety of public pension systems across developed countries. Countries such as France, Germany and the US have pay-as-you-go (PAYG) pension systems in which pension coverage is practically universal, and the benefit level is mainly determined by individual contributions over working ages and only implicitly means tested by some redistributive factors.[25] On other hand, countries such as Australia, Denmark and the United Kingdom have public pension systems in which (some) pension benefits are explicitly means tested and independent of individual contributions.

The Australian age pension system. The Australian public pension system has the following distinct features: (i) pension benefits are dependent on economic status (assets and/or income) and targeted to the age-eligible population with limited private financial resources/means; (ii) pension coverage is not universal in that some affluent retirees are covered by this public pension system; (iii) pension benefits are independent of individuals' contribution/working history; and (iv) the tax financing instrument is not restricted to the payroll tax revenue collected from the current working population. Hence, the Australian age pension is means-tested, non-contributory, and funded from general tax revenues.

Figure A1 illustrates the income test formula for pension benefit payments in Australia. The figure depicts the relationship between the age pension, p, and assessable income, $\widehat{y}$, which was algebraically given by expression (7) in Section 3.[26] As indicated, the presence of means testing divides the age-eligible population into three distinct groups: (i) full-age pensioners with $\widehat{y} \leq y_1$ receiving the maximum benefit ($p = p^{\max}$), (ii) part-age pensioners with $y_1 < \widehat{y} \leq y_2$ receiving partial benefits ($0 < p < p^{\max}$) and (iii) self-funded retirees with $\widehat{y} > y_2$ receiving no public pension ($p = 0$). Means tests allow governments to better direct benefits to those seniors most in need and to control overall funding costs by providing flexibility to control the condition for receiving pension benefits and the benefit level.

[25] See Gruber and Wise (2000) for an overview of PAYG pension systems in advanced countries.

[26] Note that the actual means test of the Australian age pension also includes the asset test (with its own taper rate and thresholds) and it is the binding test that is used to determine the pension payment. In our model, we consider only the income test so that we can study the effects of making the pension system more means tested or more universal by altering only one public pension parameter – the income taper rate.

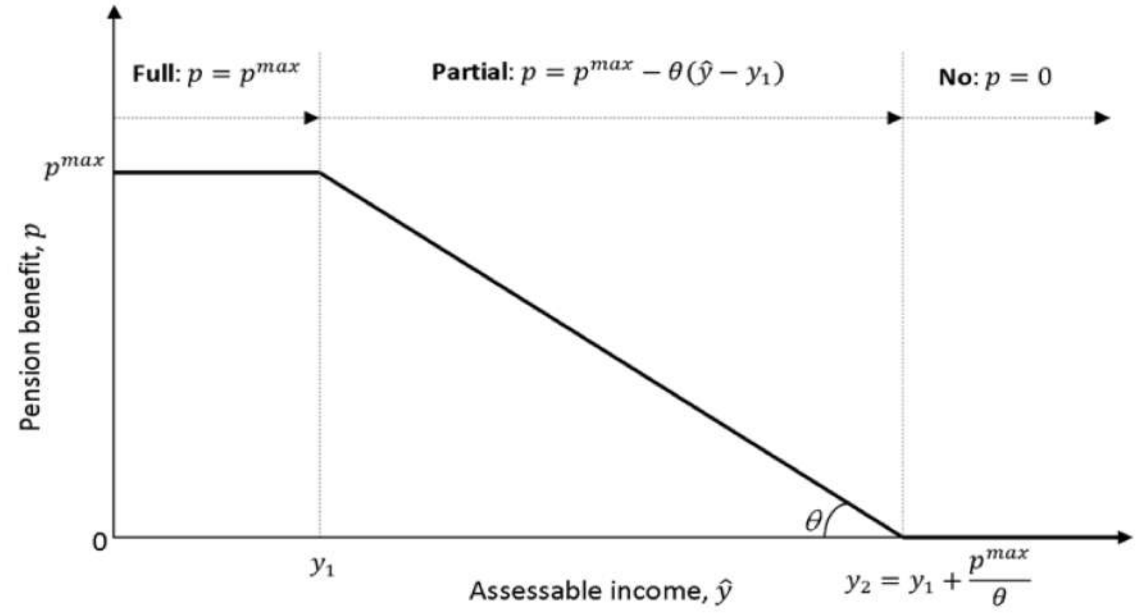

Figure A1: Graphical representation of the pension income test in Australia

Means-testing and pension benefits. In order to illustrate how the Australian means-tested pension system works, we document some stylized cross-sectional facts derived from the Australian household survey data in 2014. Specifically, we utilize the Household, Income and Labour Dynamics in Australia (HILDA) survey – wave 14. Indeed, the evidence shows that the means test directs pension payments to relatively less skilled and affluent households. This can be seen in Figures A2 and A3 that display the average pension benefits by wealth quintiles and by skills, respectively. The pension means test implies that those pensioners with lower private income and assets receive higher public pension benefits. Figures A2 shows that the top wealth quintile, in particular, receives significantly lower pension payments compared to the other wealth groups because of facing a more binding means test. The top left graph of Figure A2 also shows that there is a large group of people aged 60 years and over with no age pension payments (over 40%).[27] The other two peaks in the distribution of age pension benefits depict those on the full age pension that was around \$A17,000 per year for each of a pensioner couple and \$A20,000 per year for a single pensioner in 2014.

[27] Notice that in our sample, we also included the population aged 60-64 not eligible for any pension. Hence, the actual proportion of the age-eligible population for the age pension (that in 2014 was 65 years and over) is smaller, around 30%.

Figure A2: Age pension benefits by wealth quintile

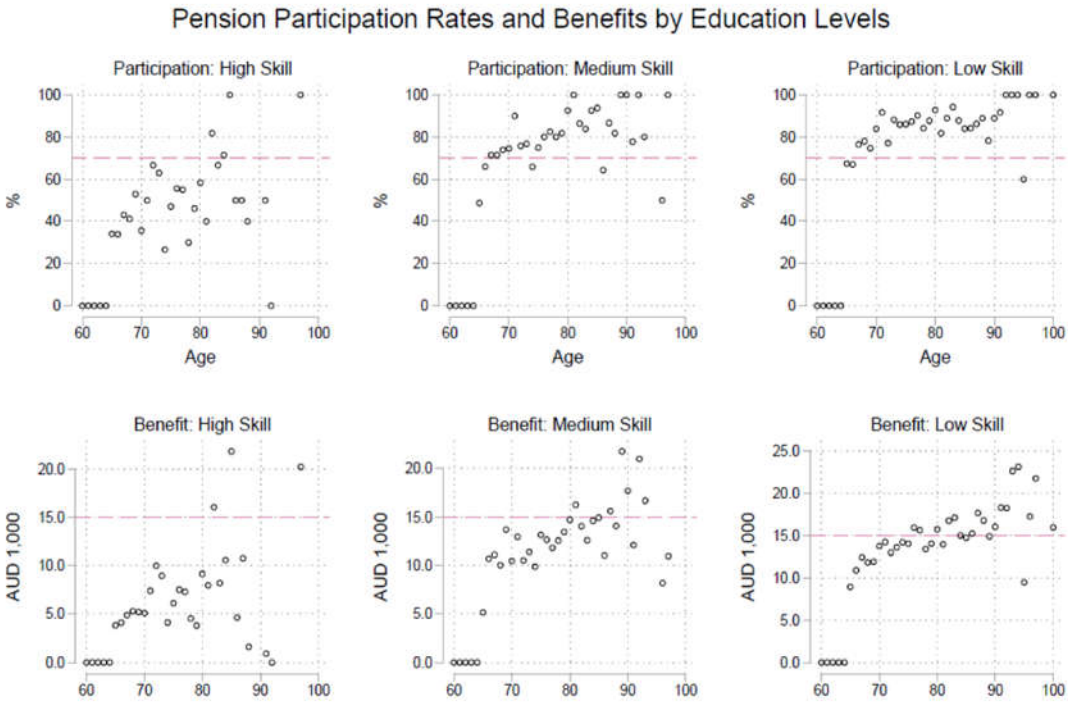

Figure A3: Pension participation rate and benefits by skill

Figure $A3$ displays the average pension benefit and the share of age-eligible population receiving at least some pension (i.e., pension participation) by skills, measured by educational attainment. We consider three skilled groups: those with less than 12 years of schooling (low-skill), those with 12 years of schooling and higher educational qualifications (medium-skill) and those with bachelor's degree and above (high-skill). As shown, both the pension participation rates and benefits are, on average, smaller for high-skill groups with larger private incomes and assets assessed under the pension means test compared to low-skill types. In addition, a much larger proportion of the high-skill population tends to be self-funded, relying only on private means in retirement.

B. Means testing and transitional effects

In this subsection of the appendix, we present more detailed and additional results for the transitional implications of replacing the existing means test either with the universal system (by setting the taper rate to zero, $\theta = 0$) or with the strict means-tested system (by setting the taper rate to one, $\theta = 1$). The transitional results for the two pension policy alternatives are examined under the "no aging" and "aging" scenarios.

The results in Table B1 also include the macroeconomic implications of changing the taper rate for per capita (effective) labor supply, domestic assets and consumption in the selected years of the no aging and aging transitions (in addition to the fiscal effects discussed in Section 5).

Table B1: Macroeconomic and fiscal effects of alternative taper rates under no aging and aging transition paths (% changes relative to each scenario with Taper = 0.5)

Transition scenario/	Taper rate = 0				Taper rate = 1			
Variable	2015	2030	2050	Long run	2015	2030	2050	Long run
No aging transition								
- Labor supply	-8.5	-3.8	-3.2	-3.1	4.1	1.6	1.2	1.2
- Domestic asset	0.0	-8.8	-11.7	-12.0	0.0	5.5	7.3	8.0
- Consumption	-5.6	-4.9	-5.5	-5.7	2.0	2.1	2.6	2.8
- Pension expenditure	67.3	67.3	67.3	67.3	-20.1	-16.3	-17.1	-17.6
- Tax rate[a]	29.3	22.7	22.5	22.5	-10.8	-7.9	-8.0	-8.3
Aging transition								
- Labor supply	-7.6	-4.1	-3.8	-7.1	5.5	2.8	2.1	1.3
- Domestic assets	0.0	-10.0	-14.4	-25.7	0.0	10.2	15.1	22.9
- Consumption	-4.7	-4.7	-6.9	-15.2	2.0	3.1	5.1	8.4
- Pension expenditure	62.3	71.8	77.1	76.3	-18.6	-18.2	-21.3	-22.9
- Tax rate[a]	27.0	25.4	30.5	51.8	-12.8	-11.9	-14.3	-19.1

Note: For "aging" scenario, the baseline simulation with benchmark taper rate = 0.5 assumes that government consumption (G) adjusts to balance the budget. This adjusted G is kept constant to assess effects of alternative taper rates with the budget being balanced via income tax rate adjustments. [a] Budget-balancing income tax rates.

Similar to the long run results, the transitional implications of setting $\theta = 1$ (a shift to the strict means-tested system) for labor supply, domestic assets and consumption are positive, while completely removing the means test and paying the universal pension to every pensioner have negative impacts on these macroeconomic variables. Interestingly, the labor supply increases are higher in the short run than in the long run. The positive macroeconomic implications of means testing public pensions are more pronounced in the case of the aging transition (because of the behavioral responses to population aging with greater longevity).

The distributional welfare effects on the current and future-born generations are reported in Figure $B1$. As in Section 5 of the paper, these effects measure percentage changes in consumption and leisure for heterogeneous households (differentiated by age and skill type) required to make them as well of as in the no-aging or aging scenario with the benchmark taper rate of $\theta = 0.5$. We show the effects on the selected skilled types and average welfare (averaged across all skill types of households).

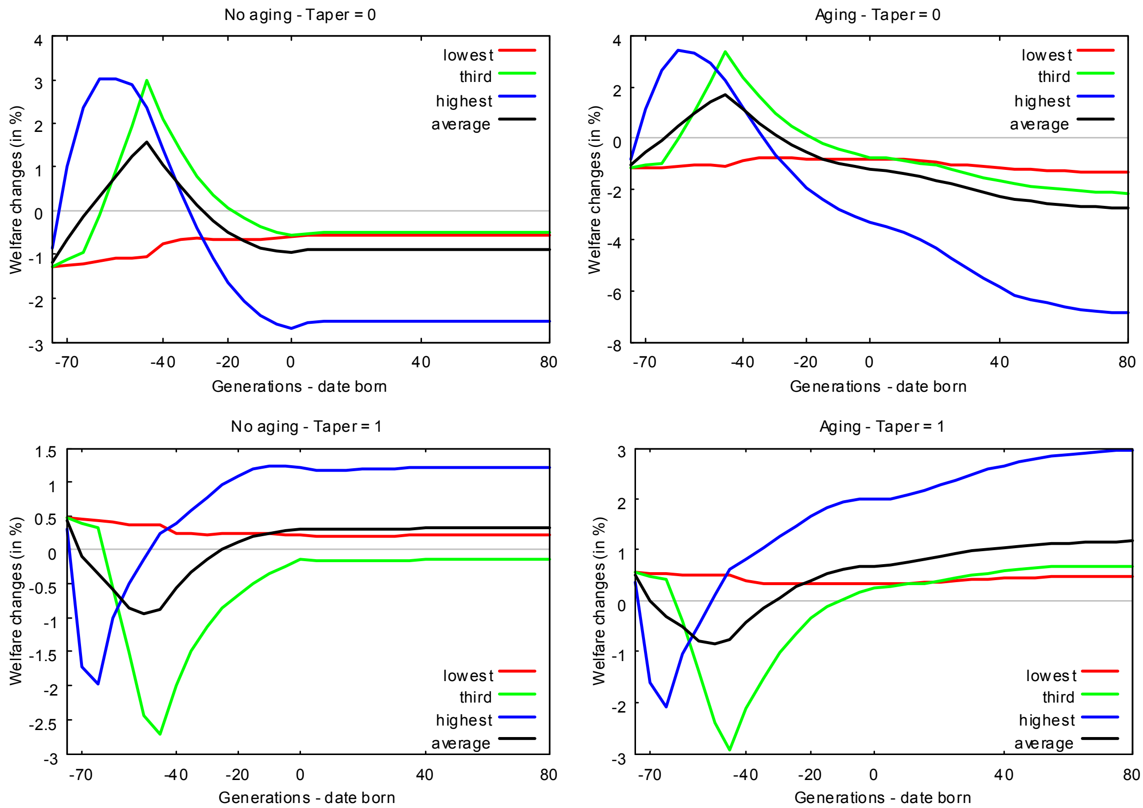

Figure B1: Welfare effects of policy changes during transition paths

Figure $B1$ indicates that the welfare effects of tightening the means test (by setting the taper rate to one) are positive for younger and future-born generations (benefiting from increased private savings and reduced income taxes) but negative for some older generations (experiencing pension cuts). And, even though the pension payments are cut for high-skill groups of households, they gain more in the long run welfare (compared to low-skill types), because of benefiting more from lower progressive income taxes.