ARC Centre of Excellence in Population Ageing Research

Working Paper 2023/06

The Economy-wide Effects of Mandating Private Retirement Incomes

George Kudrna

This paper can be downloaded without charge from the ARC Centre of Excellence in Population Ageing Research Working Paper Series available at www.cepar.edu.au

The Economy-wide Effects of Mandating Private Retirement Incomes*

George Kudrna†

April 2023

Abstract

This paper investigates the economy-wide effects of mandating private pensions. Drawing on Australia's Superannuation Guarantee (SG) legislation, which mandates contributions to private retirement (superannuation) accounts, our objective is to quantify the long-term effects of the SG mandate on households' economic decisions, welfare, and macroeconomic and fiscal indicators. We begin with the partial equilibrium (PE) life-cycle analysis that considers private (liquid) and superannuation (illiquid) assets, highlighting the interactions of the SG mandate with income taxation, public pensions and bequest redistribution. We then develop a general equilibrium (GE) model that includes overlapping generations of heterogenous households, labor income and survival risks, and both types of household assets. The model is calibrated using Australian data and incorporates a detailed representation of government policy, including mandatory superannuation. The simulation results indicate that higher SG rates lead to significantly greater household wealth, output and consumption per capita, and household welfare across the skill distribution in the long run. These positive effects are due to (combination of) increased tax subsidies, more binding means testing reducing public pensions, redistribution of increased accidental bequests and also GE effects on factor prices (with higher gross wage rates).

Keywords: Private Pension, Social Security, Income Taxation, Labor Supply, Life-Cycle, General Equilibrium

JEL Classification: J32, H55, H31, J22, D15, C68

---

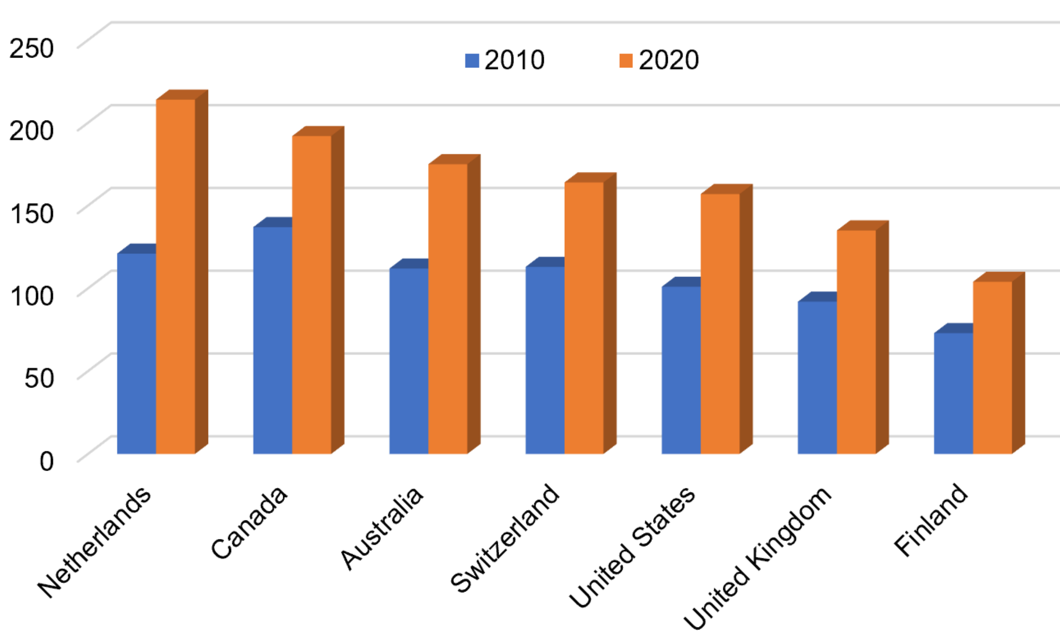
*Early versions of this paper were presented at annual 29^{th} Colloquium on Pensions and Retirement Research at UNSW Sydney, economic seminars at University of Wurzburg and Australian Treasury, and at Econometric Society Australasia Meeting (ESAM 2022). I thank participants of these conferences for their feedback. I also thank Hans Fehr, John Piggott, Alan Woodland and Chung Tran for their suggestions on earlier drafts of the paper. Financial support by the Australian Research Council via its grant to CEPAR is gratefully acknowledged.

†CEPAR, UNSW Business School, UNSW Sydney, and Centre for Applied Macroeconomic Analysis (CAMA), e-mail: g.kudrna@unsw.edu.au.

1 Introduction

Population ageing is placing an increasing burden on the funding of age pensions and social security around the world. In response, many governments, particularly in developed countries, have reformed their pension systems – cutting spending on public pensions and increasing their reliance on private pension pillars (OECD 2019, 2021; Willis Towers Watson 2021). As indicated in Figure 1, private pension assets in developed countries (those with the largest private pension funds globally) have increased significantly over the last decade.

Figure 1: Private pension assets as a percentage of GDP



Source: Global Pension Assets Study by Willis Towers Watson (2021).

Australia presents an interesting example – having an established superannuation system that features mandatory contributions, preserved superannuation assets (for financing retirement consumption) with tax-favored arrangements. Superannuation (private pension) assets in Australia have more than doubled over the last decade (to about 175% of GDP in 2020 (Willis Towers Watson, 2021)), and according to Chomik et al. (2018), various projections report substantial future increases, tripling by the middle of this century. The increases have been driven by the Superannuation Guarantee (SG) legislation, which mandates employer contributions to privately-managed superannuation funds. The SG rate has increased from 3% of gross wages in 1992 (when the mandate was introduced) to 10% of gross wages in 2018-19, and it is set to increase to a legislated rate of 12% by 2025-26. The mandatory scheme covers about 95% of Australia's employment. And since the system's objective is to provide individuals with retirement income, superannuation assets are illiquid during the accumulation stage, i.e., preserved on individual accounts until the preservation age (currently 65, without having to retire). The superannuation system is tax-favored, with concessional flat tax rates on mandatory (and other employer) contributions and fund investment earnings. The contributions and fund investment earnings are taxed separately by superannuation funds, while other private incomes are aggregated in the income tax base, which is subject to the progressive income tax schedule. The superannuation system also interacts with the Australian age pension, as superannuation assets at older ages are subject to the age pension means testing. Those with higher superannuation balances substitute away from public pensions, with around 25% of older Australians fully self-funding their older age expenditures.[1]

This paper examines the economy-wide effects of the SG mandate, quantifying its long-term impacts on household economic decisions over the life cycle, household welfare, and macroeconomic and fiscal aggregates (e.g., GDP and consumption per capita, average labor supply and household wealth, and government revenues and expenditures). We explore a range of policy counterfactuals with different SG rates, including the 12% SG rate (legislated for the future) and a (hypothetical) zero SG rate (no SG mandate). We also analyze different channels through which the SG mandate impacts the economy and household welfare in the long run.

To begin with, we employ a simple partial equilibrium (PE) life-cycle model that takes into account two types of household assets – private (liquid) assets and superannuation (illiquid) assets. The latter type is due to the SG mandate, which requires a percentage of gross wages to be made onto illiquid accounts (preserved for funding retirement consumption). We consider several cases (or variants) of the PE model and examines the effects of different SG rates on household economic behavior and welfare. This PE analysis highlights important interactions of the SG mandate with the progressive income taxation, public pensions and bequest redistribution (through which it impacts household welfare).

We then introduce a general equilibrium (GE) model that builds on previous work (for example) by Kitao (2014) and Hosseini and Shourideh (2019). Similarly, our model features overlapping generations of heterogeneous households with labor income and survival risks, and endogenous labor supply and retirement decisions. However, it also distinguishes between the liquid and illiquid household assets (ordinary private assets and superannuation assets preserved until older age), which are both subject to bequest redistribution. The benchmark model is calibrated to Australian data (pre-COVID-19), fitted to recent demographic, household survey and macroeconomic data, and it accounts for a detailed representation of the country's government policy, including its progressive income tax schedule, means-tested age pension, and mandatory superannuation.[2] The model is used to examine the macroeconomic and distributional effects of different SG rates. We assess the long-term implications for various aspects of the economy,

[1] For details on the superannuation policy rules and other aspects of the Australian tax and pension systems, see Appendix A.

[2] We note that our model can be extended to incorporate the tax and public pension policies that are common in other countries, such as the US, where (for example) the tax schedule is less progressive and social security pensions are linked to employment through a PAYG system. In our sensitivity analysis, we account for the role of the SG mandate under these features (which are approximated and examined within an Australian-calibrated model) and provide additional details in Appendix D.

including the labor market, capital accumulation, savings, and the final goods market, as well as the impact on households' economic behavior over the life cycle. Notably, we examine the welfare effects on different cohorts and skill types of households.

Based on the GE model simulations of alternative SG rates, we find that higher rates of the SG mandate generate larger household wealth, output or real GDP, consumption per capita and household welfare on average and across skill types (despite more working-age households facing liquidity constraints with near-zero liquid assets). Specifically, the counterfactual economy with the legislated 12% SG rate (compared to the 7% rate in the benchmark economy) generates significant long-term increases in total household wealth (by 13.42%), output or real GDP (by 6.15%), consumption (by 4.24%) and average welfare (by 0.85%). Conversely, the economy without the SG mandate ($SG = 0$) would experience a 20.7% decrease in average household wealth and a 2.47% decrease in average welfare compared to the benchmark economy.

Our results demonstrate that the positive long-run outcomes of higher SG rates are driven by (a combination of) various channels through which the SG mandate impacts household behavior and the broader economy. These channels include interactions with progressive income taxation (through increased superannuation tax concessions), public age pensions (via means testing of increased private retirement assets), and the redistribution of accidental bequests, as also highlighted under the PE analysis. Additionally, general equilibrium adjustments in factor prices, such as increased gross wage rates (under higher SG rates), further contribute to these outcomes. Collectively, these channels generate positive macroeconomic and welfare effects of higher SG rates in the long run.

Existing literature We contribute to various strands of literature. The first is a large body of research that uses large-scale overlapping generations (OLG) models (GE models with life-cycle behavior) to study social security and old-age pension reforms. Papers such as Kitao (2014), McGrattan and Prescott (2017), Hosseini and Shourideh (2019) for the US, Kitao (2015), Braun and Joines (2015) for Japan, and Kudrna et al. (2022) for Australia have studied policies of partial or full privatization of social security pensions, assuming voluntary savings with liquid assets available for funding consumption at any year. Our contribution to this literature is to account for both liquid private assets and illiquid superannuation assets, with the focus on the role of a private pension mandate, which indirectly reduces older people's reliance on public pensions through means testing.

The second strand of literature focuses on funded private pensions and, using OLG models, examines the introduction of voluntary or mandatory retirement savings accounts with a preferential tax treatment. We build on existing research by Imrohoroglu et al. (1998), Gomes et al. (2009), Nishiyama (2011), Ho (2017), and Lin et al. (2021) for the US, Fehr et al. (2008), Fehr and Kindermann (2010) for Germany, and Kitao (2015) for Japan. Our study fills a gap in the literature by analyzing the economic effects of private pension mandates, drawing on the established superannuation system in Australia. We examine the long-term effects in a framework that captures interactions of funded pensions with progressive income taxation and means-tested age pensions.

Our paper is also connected to studies on the economic effects of Australia's superannuation. We extend the early OLG analysis of mandatory superannuation carried out by Kudrna and Woodland (2013, 2018) and Creedy and Guest (2008) by accounting for the stochastic labor productivity, bequest motive, and greater government policy details, including progressive income taxation, means-tested age pension, and mandatory superannuation. Incorporating stochastic labor productivity and intended bequests means that the model now also captures precautionary and bequest motives for savings, which interact with the superannuation mandate.[3]

Additionally, there is a growing body of empirical literature studying tax-favored superannuation in Australia. For example, studies by Connolly and Kohler (2004) and Connolly (2007), using time series or household survey data, show positive impacts of compulsory superannuation on total assets and household savings. Longmuir (2021) provides an empirical analysis of household wealth between 2002 and 2018 in Australia, reporting that household retirement wealth has increased significantly, partly due to considerable gains in superannuation accounts, driven by mandatory contributions. Chan et al. (2022), using Australian tax register data, show significant income and labor supply responses to tax-favoured superannuation contributions. Our OLG model accounts for saving and labor supply responses to mandatory superannuation, as well as broader interactions with other government policy, and general equilibrium effects (that are shown to be important for the long-term economic effects of the SG mandate).

The remainder of the paper is organized as follows. Section 2 presents and discusses life-cycle and welfare effects of the superannuation mandate, using partial equilibrium life-cycle modeling to depict the channels through which the private pension mandate impacts household welfare. Section 3 provides a detailed description of the general equilibrium OLG model. Section 4 describes our calibration of the benchmark OLG economy to Australian macro-level and micro-level data. In Section 5, we present and discuss the long-term effects of the superannuation mandate via changing mandatory SG rates, featuring results for household life-cycle variables as well as macroeconomic and welfare effects. Section 6 considers several robustness checks by altering various model assumptions such as alternative market structure and household preferences, and alternative tax and public pension policy rules. The final section provides key conclusions, and points to future research.[4]

[3]Note that Creedy and Guest (2008) and Kudrna and Woodland (2018) focus on superannuation taxation, while Kudrna and Woodland (2013) examine the 2010 superannuation reform that included 3 p.p. increase in the SG rate to 12% of gross wages. None of these papers have studied the channels through which the SG mandate impacts welfare and the economy.

[4]Supplementary materials are provided in the Appendix, presenting more detailed information about Australia's tax and pension systems; additional results for the PE analysis; more details about the calibration of the GE model; and additional results for the sensitivity analysis, using several modifications of the GE model.

2 The partial equilibrium life-cycle analysis

In this section, we employ partial equilibrium (PE) life-cycle modelling to illustrate the economic channels through which mandatory superannuation impacts household behavior and welfare. This (simple consumption-saving) model will consider both liquid (ordinary private) and illiquid (superannuation) assets, with the latter being the result of mandatory superannuation guarantee (SG) contributions that accumulate during working years.

We begin with a simple life-cycle model, which assumes a single household with liquid ordinary private assets and illiquid superannuation assets, and there are no additional policies in place beyond the SG mandate. In this **case 1.**, we assume that there are no taxes on income or superannuation, and consequently, the rates of return for both liquid and illiquid assets are identical.

We will then extend our analysis to a heterogenous household life-cycle model, which considers two types of households with low and high earnings. In this **case 2.**, we introduce progressive income taxation and tax concessions to superannuation in this model.

In **case 3.**, we will add a public pension, which is assumed to be either universal or means-tested. The aim here is to show how mandatory private pensions interact with public pensions.

In the final **case 4.** of this section, we consider a partial equilibrium household model that accounts for accidental bequests and their redistribution within the household sector.[5]

We will describe the PE life-cycle model in more detail below and then analyze the role of the SG mandate under all four cases.

Model setup Our model is based on the simple partial equilibrium life-cycle model used by Hansen and Imrohoroglu (2008) to illustrate how (asset) annuitization affects the shape of life-cycle consumption. We have expanded this model to incorporate both liquid and illiquid (superannuation) assets holdings, while also assuming zero asset annuitization.[6] It should be noted that our model has additional extensions compared to the partial equilibrium model proposed by Hansen and Imrohoroglu (2008), including a stochastic income process, two types of workers, progressive income taxation, and public pensions (which we introduce sequentially under the four cases).

To begin, we consider a single household economy with deterministic labor income. In each period, one agent is born and can live a maximum of J periods. Labor supply is inelastic, and the lifetime endowment pattern, y_j, is given by

[5] Note that in this section, each case adds additional feature(s) to the model version in the previous case, while in the sensitivity analysis applied to the GE model (Section 6), we remove each feature separately (keeping other features of the GE model and so other SG impact channels in operation).

[6] Under the assumption of zero asset annuitization, annuities and their effects on the rate of return are not considered. In case 4., when individuals pass away, their total assets (consisting of both liquid and illiquid assets) are assumed to be fully redistributed as accidental bequests to surviving households.

$$y_j = \begin{cases} 1 & \text{for } j < j_R \\ 0 & \text{for } j \geq j_R \end{cases},$$

where j_R denotes the mandatory retirement age. Hence, individuals receive one unit of labor income in each period until they retire.[7]

A newborn in this economy decides on optimal path of consumption, c_j, by solving the following utility maximization problem:

$$\max \sum_{j=1}^{J} \beta^{j-1} \left(\prod_{z=1}^{j} \psi_z \right) \left\{ \frac{(c_j)^{1-\sigma}}{1-\sigma} \right\},$$

subject to

$$a_{j+1} = Ra_j + (1-\tau^p)y_j + b_j + sp_j + ap_j - t_j - c_j,$$

$$s_{j+1} = Rs_j + \tau^p y_j - st_j - sp_j,$$

$$a_j \geq 0,$$

where the parameters in lifetime utility include β : subjective discount factor ($\beta = \frac{1}{1+\delta}$, where δ is the rate of time impatience), ψ_z : survival probabilities and σ : the coefficient of relative risk aversion ($\frac{1}{\sigma}$ gives the intertemporal elasticity of substitution).

The lifetime utility function is maximized subject to household (per-period) budget constraint, with liquid savings a_{j+1} equal to the sum of interest income, Ra_j (where gross returns $R = (1+r)$ include the interest rate r), labor earnings net of mandatory contributions to private pensions, $(1-\tau^p)y_j$, accidental bequests, b_j, private pension drawdowns, sp_j (for $j \geq j_R$), public pension, ap_j (for $j \geq j_R$), less income taxation, t_j, and consumption expenditure, c_j.[8]

In addition to the budget constraint, for any positive SG rate $\tau^p > 0$, there is also illiquid superannuation asset accumulation (and decumulation for $j \geq j_R$), where s_{j+1} equal to the sum of fund earnings denoted by Rs_j (with the same gross return as that from liquid assets), mandatory contributions $\tau^p y_j$, less superannuation taxes st_j and superannuation withdrawals sp_j.[9]

We also impose borrowing constraint, $a_j \geq 0$, to prevent households from borrowing against

[7] In case of the stochastic model, we introduce a stochastic AR1 component to labor income, with the mean income equal to one during the working years (as in the deterministic framework). However, in the stochastic model, there is a distribution of labor incomes around the mean.

[8] Details on (bequest redistribution) b_j – only applicable for case 4. are given in that subsection. Similarly, we provide more details on the income tax function t_j (and superannuation taxes) and the public pension ap_j in the relevant subsection below.

[9] We make the same assumption about the drawdowns as in the full GE model, i.e. $sp_j = \zeta_j(1+r)s_j$, with the same drawdown fraction ζ_j (which is with age increasing).

their illiquid superannuation assets.

As for the parameterization of this PE model, we assume $J = 16$ (16 age groups – representing 20-24, ..., 95-99) and similar parameter values as in Hansen and Imrohoroglu (2008). Specifically, we set $\beta = 0.96$ (implying $\delta = 4\%$ p.a.), ψ_z is derived using survival rates average from males and females (using ABS 2019a), $\sigma = 2$, $y_{1 \leq j < j_R} = 1$ (in a single household deterministic framework) and $r = 4\%$ p.a.[10] In each case below, we vary the mandatory SG rate $\tau^p = \{0,\ 0.03,\ 0.07,\ 0.12)$.

2.1 Single household and no tax policy (case 1.)

Under case 1., all public policy parameters (other than τ^p) and bequest redistribution are set to zero – that is, $b_j = ap_j = t_j = st_j = 0$. In this simple life-cycle model, there are two assets: private and superannuation assets denoted by a_j and s_j. Both assets generate the same rate of return given by r.[11] However, s_j are illiquid and hence, it cannot be used to finance consumption before retirement. It is expected that, in this framework, the representative agent would experience a welfare loss for any $\tau^p > 0$, with the welfare loss increasing under higher τ^p.

We consider several alternatives to this simple framework, assuming either deterministic labor income (as in Hansen and Imrohoroglu (2008)) or stochastic labor income (with the same AR1 process and parameterization as in the large-scale GE model described in the next section). Since most analyses in this section feature stochastic labor income (with a precautionary saving motive), we present the life-cycle results in more detail for this stochastic model.[12]

[10] Note that in the case when the interest rate r equals the discount rate δ (assuming log consumption preferences and deterministic income), the resulting consumption profile would be flat under perfect annuitization (as shown by Hansen and Imrohoroglu, 2008). As said, we assume zero annuitization – and first we account only for single- and then two-household type consumption-saving behaviour over the life-cycle (in cases 1.-3.), setting accidental bequest transfers to zero. In case 4., bequests are set to equal to total assets of those who do not survive to age $j+1$, and we make different assumptions about the ages when these transfers are received.

[11] Note that in this simple framework, the two asset accumulation equations in the model setup become:

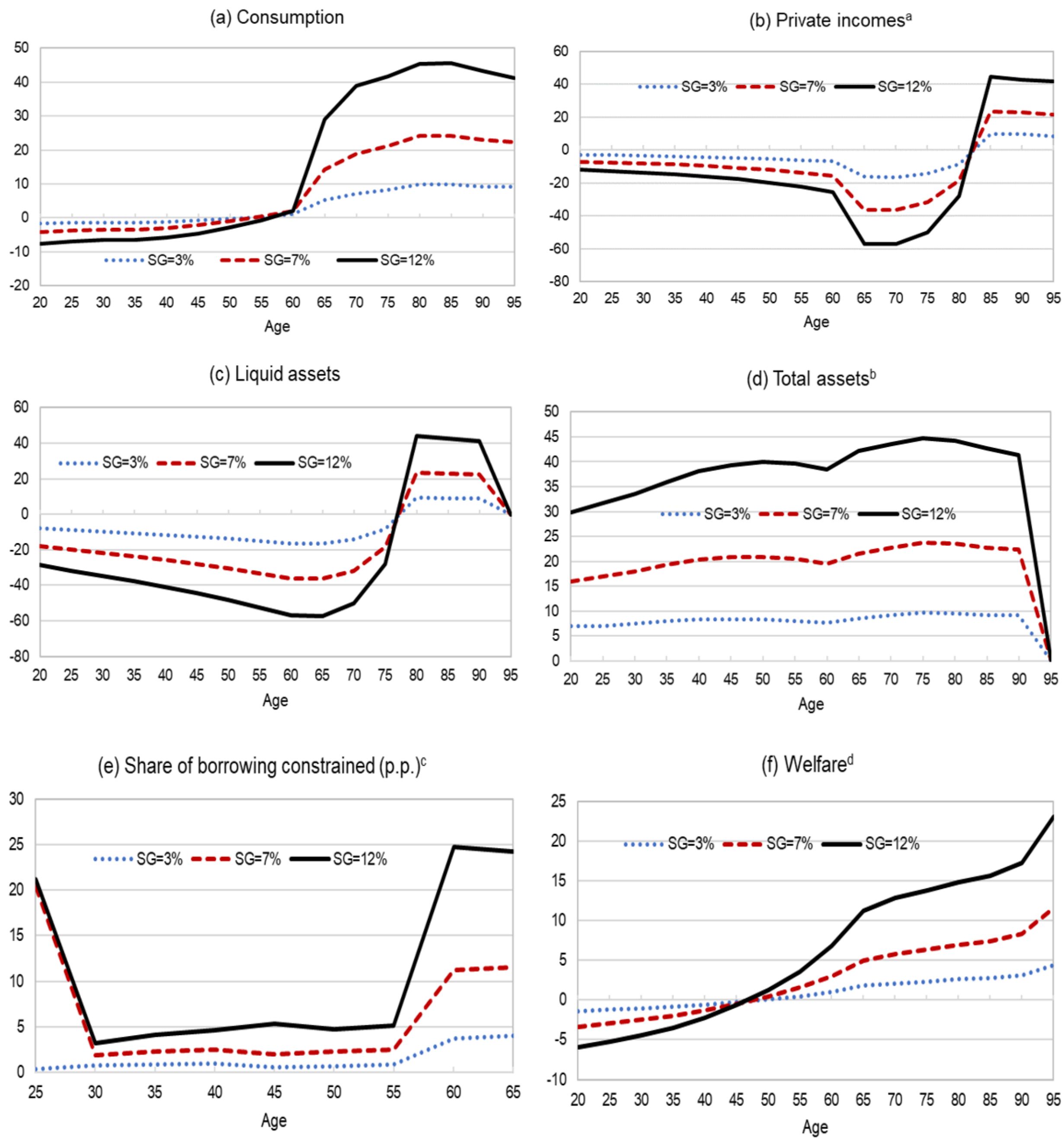
$$a_{j+1} = Ra_j + (1 - \tau^p)y_j + sp_j - c_j,$$

and

$$s_{j+1} = Rs_j + \tau^p y_j - sp_j.$$

[12] We also consider alternative values for preference parameter values – higher β (implying lower rate of time impatience) or higher σ (implying lower intertemporal elasticity of substitution).

Figure 2: Life-cycle effects of increasing mandatory SG rate (case 1.)*



Notes: *% change ralative to SG=0 (if not stated otherwise) and assuming stochastic labor income; [a]Excluding superannuation fund earnings; [b]Including both liquid and illiquid (superannuation) assets; [c]Percentage point (p.p.) change in the share of liquidity constrained agents (hand to mouth) (only ages with positive differences shown); [d]Measured as discounted lifetime utility at the given age, with that for newborn given at age 20.

Figure 2 shows the life-cycle effects of increasing SG rate (to 3%, 7% and 12% of labor income y) (assuming stochastic y), with the results reported as percentage change relative to $SG = 0$ (zero private pension mandate). As indicated, increasing SG contributions to illiquid superannuation accounts shifts household consumption from working years (when it is lower than under $SG = 0$) to retirement years when superannuation savings are being paid out, and hence, consumption is significantly higher.

As shown in Figure 2b, private (non-superannuation) incomes are lower (except for very old age when we assume a full superannuation payout), and this is due to lower liquid assets (see Figure 2c), i.e., superannuation offsets.[13] As higher SG rates lead to higher superannuation assets (which more than offset lower liquid assets), the total assets of households increase significantly. However, as shown in Figure 2e, the share of households that are liquidity constrained (defined in this paper as those with $a_j = 0$) increases under higher SG rates. It should be noted that in this model, households that are liquidity constrained are defined as wealthy hand-to-mouth, using the terminology introduced by Kaplan et al. (2014), as they all have some illiquid superannuation assets for any $SG > 0$.

Figure 1f depicts the welfare effects – measured as Hicksian equivalent variation (HEV) (or % change in discounted lifetime utilities, comparing higher SG rates relative to $SG = 0$) at the given age.[14] Since we are primarily interested in the long-term effects, the welfare change for the newborn, depicted in Figure 1f at age 20, is the most significant measure. As expected in this simple framework, higher SG rates result in negative welfare change for the newborn, as the lower consumption effect (when young) outweighs the higher retirement consumption effect. Therefore, in this simple economy, the representative agent would prefer $SG = 0$.

In Table 1, we present the welfare effects for the newborn under several variants of this simple life-cycle model. In each case, the welfare sign is negative. Hence, the main conclusion – that positive SG rates are not optimal – holds under each of the variants of this simple case.

Comparing the modifications, the deterministic income framework reduces the welfare losses from higher SG rates, compared to the stochastic income assumption discussed above. Clearly, with stochastic incomes, agents have preference for precautionary savings (in liquid asset accounts), which is negatively impacted by positive SG rates. Interestingly, higher β (agents are more patient and save more over the life-cycle) lowers the welfare losses, while higher σ (agents are more risk-averse) increases the welfare losses (for each $SG > 0$).

[13] Note that we keep the same assumption for superannuation withdrawals as in the GE model. If we assumed (full) lump-sum superannuation payout at age 65, then the private income and liquid assets would increase after that age relative to $SG = 0$.

[14] Specifically, we calculate HEV as:

$$\%\Delta = [\left(\frac{U}{U^*}\right)^{1/(1-\sigma)} - 1] * 100,$$

where U is the utility level under higher SG rates and U^* is the utility level under $SG = 0$. Figure 1f then depicts $\%\Delta_j$, with U_j and U_j^* discounted life-cycle utilities at the given age.

Note that in all the welfare tables of this section, $\%\Delta$ relates to HEV for the newborn, calculated using discounted life-cycle utilities U and U^* for the newborn at age 20.

Table 1: Welfare effects of higher SG for newborns under alternative specifications (case 1.)*

SG rate increased to	Deterministic labor income	Stochastic labor income	Stochastic labor income	
			+ Higher beta	+ Higher sigma
SG=3%	-1.11	-1.38	-1.08	-1.59
SG=7%	-2.67	-3.32	-2.54	-3.81
SG=12%	-4.83	-5.97	-4.47	-6.77

Note: *We report HEV for newborns (in % of initial resources relative to SG=0).

2.2 Household heterogeneity and tax policy (case 2.)

We now extend the simple case 1. (with stochastic income) to include progressive income taxation and concessional superannuation taxes. We also introduce household heterogeneity with three different cases (of household types with different incomes). First, there is no difference in incomes or zero income gap (i.e., as above, there is only one household type, but now with private income and superannuation taxed differently). Second, there are two types of households – low and high income types with an income gap of 50% (where (mean) $y = 1$ for the low-income type and $y = 1.5$ for high-income type). Third, the income gap between low- and high-income types is 100%, with (mean) $y = 2$ for the high-income type.

As for modeling income and superannuation taxation in case 2., we aim to maintain consistency with the full GE model, and therefore make similar assumptions. Specifically, income taxation applies to the total income tax base, denoted as $t(\tilde{y}_j)$, which includes labor income (net of mandatory contributions made at the rate τ^p) and investment income (generated by liquid assets a_j):

$$t_j = t(\tilde{y}_j) = t((1 - \tau^p)y_j + ra_j),$$

and it is taxed under the progressive tax schedule, given in Appendix A.[15]

In contrast, the superannuation taxes, st_j, equal to

$$st_j = \tau^s \tau^p y_j + \tau^r r s_j, \quad \text{iff} \quad j < j_R,$$

where τ^s and τ^r are concessional flat tax rates on contributions and superannuation fund earnings, respectively (only in the accumulation stage).[16]

[15] Note that we rescale the income thresholds at this model-generated average income $\overline{y}$ in each case. In the first case, $\overline{y} = 1$, and in the cases with a 50% and 100% income gap, $\overline{y} = 1.25$ and $\overline{y} = 1.5$, respectively, assuming equal shares of the population belong to low- and high-income types.

[16] As mentioned, this paper focuses on the Australian superannuation system and its taxation, which follows a *ttE* regime with concessional flat tax rates (t) on contributions and superannuation fund earnings. Our analysis aims to go beyond comparing different taxation regimes and instead addresses the broader question of how mandating illiquid private pensions (with tax concessions) impacts household welfare. It is important to note that the qualitative results of our analysis, comparing case 2. with case 1., would hold as long as private

Table 2 shows the effects of higher SG rates on the welfare of newborns, taking into account progressive income and concessional superannuation taxation, and considering three scenarios of household heterogeneity. In the first scenario (zero income gap), there is no income heterogeneity and so there is no distinction in the welfare effects for low- and high-income households, which is comparable to case 1. in Table 1. The second and third columns of Table 2 demonstrate the welfare effects for the two situations where there is an income gap of 50% and 100% between low- and high-income types, respectively. As indicated (first column of Table 2), the welfare effects of higher SG rates are also negative under case 2. (i.e., the representative agent would prefer $SG = 0\%$). Nevertheless, the welfare losses are significantly smaller, compared to the basic case 1. the framework with no superannuation tax concessions. This suggests that mandating superannuation with tax concessions can offer some advantages to households.

Table 2 highlights the significance of (inborn) income heterogeneity on the welfare effects. Importantly, the last column (with a 100% income gap) demonstrates that for the high-income type, changing the sign of welfare effects is observed. Specifically, higher SG rates lead to worsened welfare losses for the low-income type, while they greatly improve the welfare effects for the high-income type. As shown, under the 100% income gap framework, high incomes would gain in welfare and prefer the SG 7% rate (with the highest welfare gain).

Table 2: Welfare effects of higher SG for newborns (case 2.)*

Income type	SG rate increased to	Income gap[a]		
		0%	50%	100%
Average	SG=3%	-0.50	-0.36	-0.30
	SG=7%	-1.31	-1.05	-0.88
	SG=12%	-2.54	-2.23	-1.96
Low income	SG=3%		-0.58	-0.63
	SG=7%		-1.59	-1.64
	SG=12%		-3.10	-3.16
High income	SG=3%		-0.04	0.28
	SG=7%		-0.28	0.49
	SG=12%		-0.99	0.23

Notes: *HEV for newborns reported (in % of initial resources relative to SG=0); [a]We assume 0%, 50% or 100% income gap between low and higher income (e.g., under 50% gap, y=1.5 (mean) for high income).

Compared to case 1., the household welfare improves due to the concessional superannuation tax treatment. Additionally, the interaction between the progressive income tax schedule and the flat and concessional superannuation taxes disproportionately benefits the high-income type.

pensions, compared to personal income taxation, are concessionally taxed or tax-favored (using the terminology common in the US where the EET or TEE regimes typically applies to private pension taxation with either benefits or contributions subject to progressive federal income tax (T).

As the gap in earnings widens, higher incomes receive larger tax breaks, leading to further improvements in their welfare effects. However, for the low-income type, losses further increase under the higher income gap scenario, as shown by the comparison of the last two columns of Table 2. This is because their income declines relative to the average, resulting in lower tax concessions.[17] This is further documented in Appendix B that presents figures for selected household variables over the life cycle and by income types (e.g., consumption profiles).

2.3 Incorporating public pensions (case 3.)

In developed countries, public pensions are typically the primary source of income for older adults. In this subsection, we examine how they interact with mandatory private pensions. Specifically, we extend the model in case 2., which assumes stochastic labor income and a (mean) income gap of 100%, to incorporate a public pension. The public pension can be either $3i$. universal (not dependent on private resources at older age) or $3ii$. means tested (with benefits targeted to those with limited private financial resources). The age pension benefit, ap_j, (that is included in the budget constraint of the model setup) can be expressed as

$$ap_j = \begin{cases} \overline{p} & \text{for } j \geq j_R \quad \text{if universal} \\ \overline{p} - ID(\widehat{y}_j) & \text{for } j \geq j_R \quad \text{if means tested} \end{cases},$$

where $\overline{p}$ is a flat maximum pension rate (set at a modest level – ≈ one third of average income $\overline{y}$). In the universal case, $\overline{p}$ is paid to all agents of age $j \geq j_R$. In the means tested case, an income test is employed where $\overline{p}$ is reduced due to an income deduction ID that depends on private assessable income $\widehat{y}_j = r(a_j + s_j)$.[18]

In this sub-section, we also account for public pension financing by introducing a balanced government budget, that can be expressed as:

$$T^y + T^s + \tau^c C = G + AP,$$

where T^y is the tax revenue from personal income taxation, T^s is the tax revenue from superannuation taxes, $\tau^c C$ gives the consumption tax revenue due to the new tax rate τ^c on consumption (assumed to balance the government budget under higher SG rates).[19] The expenditure side includes government consumption G (calculated under $SG = 0$ case to generate a balanced budget (assuming $\tau^c = 0$)) and aggregate pension expenditure AP. For the higher SG rate counterfactuals ($SG > 0$), we keep G constant and adjust τ^c to balance the government

[17] In case 2., there is no government budget constraint balanced – hence, increasing SG rates (generating higher tax concessions and so lower income tax revenues) do not impact household behavior (as opposed to case 3., where we take into account a balanced government budget).

[18] More details on the modelling and parameterization of pension means testing are provided in the next and calibration sections related to the full GE model. Here, we use the same assumptions.

[19] In the household private budget constraint (in the model setup), the consumption expenditure becomes $(1 + \tau^c)c_j$.

budget constraint.[20]

Table 3 presents the welfare implications for the newborn (average and different income types) under this case 3., incorporating either universal or means tested age pension. Several observations can be drawn from this table. First, all the values are negative, and compared to the second result column in Table 2, they are more negative, implying large losses from higher SG rates when incorporating public pensions. There are two effects behind these greater losses: (a) public pensions offset private savings for retirement and make households more liquidity constrained (with zero financial assets); and (b) higher consumption tax rate effect (which balances the budget with increased tax concessions due to higher SG rates).[21] Note that $\tau^c = 2.7\%$ is required under $SG = 12\%$, assuming universal public pension case $3i$. (with consumption tax financing of the private pension as well as higher superannuation tax concessions).

Second, the last column of Table 3 shows that the means tested pension program is associated with smaller welfare losses due to higher SG rates compared to the universal case. This is due to both a smaller pension offset effect and a smaller consumption tax rate financing effect. Under the means tested case, most retirees receive a smaller public pension benefit as a result of means testing large assets in retirement (assuming higher SG rates), which lowers the overall pension expenditure. In contrast to the universal case, the effects here on τ^c are negligible and even fall slightly under $SG = 12\%$ case.

Third, under the means tested case, the welfare effects improve more for the high-income type compared to the low-income type. For the high-income type, the public pension offset effect is smaller (as they face more significant reductions in their ap_j due to means testing), which seems to dominate the consumption tax effect, a reduction in τ^c under the means tested case, which benefits the low-income type more.

[20] The same approach is used in the full GE model, drawing on the Australian policy rules. In most other countries, public pensions are financed via PAYG payroll tax, which is imposed on labor supply, and the benefits are linked to former earnings (e.g., the US). Recent papers by Kudrna et al. (2022) and Fehr et al. (2021) provide a comparison of the two types of public pension systems (Australia vs. US). Here, our focus is on the private pension mandate, and therefore we only account for the interactions with "non-contributory" public pensions that are financed from general tax revenues.

[21] For additional results for case 3., see Appendix B with selected life-cycle figures also for this case.

Table 3: Welfare effects of higher SG for newborns (case 3.)*

Income type	SG rate increased to	Public pension[a]	
		Universal[b]	Means tested[c]
Average	SG=3%	-1.68	-0.98
	SG=7%	-3.93	-2.35
	SG=12%	-6.87	-4.30
Low income	SG=3%	-2.01	-1.29
	SG=7%	-4.66	-3.04
	SG=12%	-7.95	-5.35
High income	SG=3%	-1.11	-0.46
	SG=7%	-2.67	-1.16
	SG=12%	-4.99	-2.46

Notes: *HEV for newborns reported (in % of initial resources relative to SG=0); [a]We assume case 3. with 50% income gap (mean) and add public pension with tax financing; [b]Universal pension benefit (modest at about 1/3 of avrage earnings); [c]Means tested (conditional on private incomes at older age with same maximum benefit as in b.

2.4 Partial equilibrium with bequest redistribution (case 4.)

In this section's final analysis, we extend the model in case 3*ii*. (which includes the means tested age pension) to account accidental bequest redistribution. Specifically, in case 4., we assume that total assets (including both liquid assets a_j and illiquid superannuation assets s_j) of households who do not survive to $j+1$, with probability of $(1-\psi_{j+1})$, are redistributed to surviving households, within each income type and within specific age ranges between j_L and j_U, as accidental bequests:

$$b_{j_L \leq j \leq j_U} = \frac{\sum_j (1-\psi_{j+1})\left[(1+r)(a_{j+1}+s_{j+1})\right] N_j}{\sum_{j_L \leq j \leq j_U} N_j},$$

where N_j gives the size of cohort at age j.[22,23] This bequest specification implies that individuals of the same income type who are eligible to receive bequests will receive the same amount at each age. This ensures that the cohort-weighted bequest redistributions are equal to the cohort-weighted total assets of those who do not survive to $j+1$.

[22] A similar assumption is made by Hansen and Imrohoroglu (2008) in their case of zero asset annuitization. They also assume a positive population growth rate, which is incorporated into our model through N_j. Note that we use the same population structure in this section as we do in the full GE model.

[23] This specification of accidental bequests applies to a model with deterministic incomes. For a stochastic model, to derive aggregate (or average cohort weighted) values we use integrals over the household state vector – for bequest specification, see one of the equilibrium conditions of the full GE model.

In Table 4, we present the welfare effects of higher SG rates on newborns, assuming two different bequest redistributions: $4i$. to those aged 45-64, and $4ii$. to those aged 20-64 (within each income type).

Table 4: Welfare effects of higher SG for newborns with bequests (case 4.)*

Income type	SG rate increased to	Bequest redistribution[a]	
		45-64[b]	20-64[c]
Average	SG=3%	-0.12	0.29
	SG=7%	-0.25	0.88
	SG=12%	-0.60	1.79
Low income	SG=3%	-0.39	0.05
	SG=7%	-0.89	0.27
	SG=12%	-1.63	0.70
High income	SG=3%	0.35	0.73
	SG=7%	0.86	1.96
	SG=12%	1.22	3.72

Notes: *HEV for newborns reported (in % of initial resources relative to SG=0); [a]We assume case 4. with means tested public pension and tax financing, and bequest redistribution (transfers to younger cohorts - within each income type); [b]Ages 45-64 (to middle-age cohorts when most bequests are received); [c]Ages 20-64 (also including younger cohorts).

Comparing the results in Table 4 with the last column of Table 3 reveals that incorporating bequest redistributions enhances the welfare effects of higher SG rates, especially for the high-income type. As a result of higher SG rates, total assets increase, leading to greater accidental bequests that younger generations are assumed to receive, allowing them to consume more. Since we assume bequest redistributions within income types, higher-income individuals receive larger bequests, resulting in greater benefits under higher SG rates compared to the low-income type. Additionally, the assumed ages when bequests are received also affect the welfare effects of mandating superannuation. As shown in the last column of Table 4, under case $4ii$ (redistributing bequests to younger working-age cohorts 20-64), higher SG rates generate welfare gains for newborns of both low-income and high-income types. However, it is worth noting that case $4i$ (bequest redistribution to 45-64) is more realistic, reflecting the ages when most bequests are received (see Wood et al. (2019) for Australian data work on bequest redistributions).

To summarize, this section has analyzed the behavioral and welfare effects of the SG mandate within the PE life-cycle framework. We emphasized the significant interactions of the SG mandate with household heterogeneity and income taxation (via superannuation tax concessions), public pensions, and bequest redistribution to the working-age population, and their impacts on household welfare. In the next section, we will introduce the GE model for long-term analysis of the SG mandate.

3 The general equilibrium model

In this section, we present a general equilibrium overlapping generations (OLG) model with endogenous labor supply and retirement and where households face labor income and lifespan uncertainty. The model consists of a household sector with overlapping generations of heterogenous households, profit-maximizing firms, and a government sector with detailed policy settings. We begin by providing a brief overview of the model's key features and highlighting its importance for analyzing tax and pension policies. Then, we describe the model's demographic structure and the distributional measure of households, followed by an algebraic description of each sector. Finally, we define the steady-state equilibrium of the model.

3.1 Key features of the model

We develop a stochastic OLG model that captures the economic behavior of individuals over the life cycle, while providing macroeconomic and fiscal implications by aggregating across individuals and sectors. This type of macroeconomic model has been extensively used to study taxation, social security, and private pensions in developed countries, as indicated in the existing literature. Our model includes the following features:

- Expected lifecycle utility maximization with endogenous labor supply, retirement, consumption, and saving (in both liquid and illiquid superannuation assets);
- Multiple generations aged from 20 to 99 years, with each generation represented by three heterogeneous skilled types of households (distinguished by educational attainment or skill type);
- Labor income risk, with stochastic labor productivity differentiated by skill type and estimated from the Household, Income and Labor Dynamics in Australia (HILDA) surveys (see Summerfield et al. (2019) for details about HILDA);
- Both intended and accidental bequests, with intended bequests modelled as a luxury good (De Nardi (2004)) and bequest redistribution within the household sector;
- Detailed representation of tax and retirement income policies in Australia, including mandatory superannuation, means-tested age pension and progressive income taxation;
- Dynamic general equilibrium model structure capturing the interactions between the household sector, the production sector and government policy.

These features enable us to examine the economy-wide effects of funded private pensions, including: (*i*) impacts on labor supply, saving, and retirement decisions of households over their life cycle; (*ii*) distributional welfare effects for different skilled types of households; and (*iii*) the macroeconomic effects on labor, capital, and goods markets, as well as the fiscal implications for the government budget. Our analysis focuses on the long-run implications of mandatory superannuation, examining alternative mandatory SG rates.

3.2 Demographics and distributional measure of households

The model economy is populated by overlapping generations of heterogeneous households with age from 1 to J. The model also distinguishes between the pension access age j_R and the retirement (from workforce) age $j_{\overline{R}}$ (with $j_{\overline{R}} > j_R$). By endogenous retirement, we mean that we do *not* force households to retire when reaching the pension access age.[24] When entering the model at $j = 1$, each household is assigned a permanent skill type $i \in \mathcal{I} = \{1, ., I\}$ according to the probability distribution ϖ_i. The model assumes a stationary demographic structure, with a constant population growth rate n and lifespan uncertainty given by survival probabilities ψ_j – conditional probabilities of surviving from age $j-1$ to age j with $\psi_1 = 1$ and $\psi_{J+1} = 0$.

The individual state vector is defined as:

$$z = (j, i, a_j, s_j, \eta_j) \in \mathcal{Z} = \mathcal{J} \times I \times \mathcal{A} \times \mathcal{S} \times \mathcal{E}$$

where $a_j \in \mathcal{A} = [0, \infty]$ denotes liquid ordinary assets held at the beginning of age $j \in \mathcal{J} = \{1, .., J\}$. These assets are set to zero at $j = 1$ and restricted throughout the whole life cycle to be non-negative, i.e., $a_j \geq 0$. During $j < j_{\overline{R}}$, households receive labor productivity shocks $\eta_j \in \mathcal{E}$ and during $j < j_R$, they also accumulate superannuation assets $s_j \in \mathcal{S} = [0, \infty]$, which is preserved in the superannuation fund for $j < j_R$. The productivity shocks follow a skill-specific finite-state Markov process. Therefore, households know their current productivity levels at the beginning of each j, but have to take expectations about next period productivities.

Consequently, the initial distributional measure of households at age $j = 1$ depends on the initial distribution skills and productivity shocks. Let $X(z_j)$ be the corresponding cumulated measure to $\phi(z_j)$, so that

$$\int_{\mathcal{I} \times \mathcal{E}} \mathrm{d}X(z_1) = 1 \qquad \text{with} \quad z_1 = (1, i, 0, 0, \eta_1) \tag{1}$$

must hold, since we normalized the cohort size of newborns to equal one. Let $\mathbf{1}_{k=x}$ be an indicator function that returns 1 if $k = x$ and 0 if $k \neq x$. Then, the law of motion for the measure of households at age j follows

$$\phi(z_{j+1}) = \frac{\psi_{j+1}}{1+n} \int_{\mathcal{Z}} \mathbf{1}_{a_{j+1}=a_{j+1}(z)} \times \mathbf{1}_{s_{j+1}=s_{j+1}(z)} \times \pi(\eta_{j+1}|\eta_j) \mathrm{d}X(z_j), \tag{2}$$

where $\pi(\cdot)$ denotes the transition probabilities for labor productivity of workers from one period to the next.

Note that in the model description provided below, the state index z is omitted, and agents

[24] Note that this type of retirement modeling has been used e.g. by Kitao (2014).

are only distinguished according to their age j.

3.3 Household sector

Preferences Households have preferences over streams of consumption c_j and leisure l_j as well as from leaving bequests upon death. The expected discounted lifetime utility function is given by

$$E\left[\sum_{j=1}^{J}\beta^{j-1}\left(\prod_{o=1}^{j}\psi_o\right)\left\{u(c_j,l_j)+\beta(1-\psi_{j+1,i})\mathcal{B}(\bar{b}_{j+1})\right\}\right], \tag{3}$$

where the annual utility takes the standard Cobb-Douglas functional form of

$$u(c,l)=\frac{\left(\left(\frac{c}{\mu}\right)^{\nu}l^{1-\nu}\right)^{1-\sigma}}{1-\sigma},$$

and the bequest function is given by

$$\mathcal{B}(\bar{b})=q_1\left[1+\frac{\bar{b}}{q_2}\right]^{1-\sigma_b}.$$

The utility function parameters include the subjective discount factor, β, the Cobb-Douglas consumption share parameter denoted by ν, the coefficient of relative risk aversion σ and the consumption equivalence parameter μ (which is age-specific and based on studies by Kaas et al. (2021) and Nishyiama and Smetters (2005)).[25] Note that future $u(c,l)$ is also discounted by survival rates, ψ_j. The bequest motive is specified following De Nardi (2004), where the term q_1 reflects the parent's concern about leaving bequests, q_2 measures the extent to which a bequest is a luxury good, and σ_b governs the relative risk aversion for the bequest. Agents derive utility from bequests that are equal to total assets (consisting of liquid (ordinary private) and illiquid (superannuation) assets, i.e. $\bar{b}_{j+1}=a_{j+1}+s_{j+1}$)) left by those agents who do not survive to $j+1$.

Labor productivity, supply and earnings In the model, agents start working at age $j=1$ and in each period $j<j_{\overline{R}}$, they receive an endowment of productive efficiency supplied to the labor market at the wage rate w. Labor productivity is assumed to be a function of a deterministic age–profile of earnings (per hour worked) e_j and a transitory component η_j. The latter evolves stochastically over time and is assumed to follow an AR(1) autoregressive structure:

$$\eta_j=\rho\eta_{j-1}+\epsilon_j \quad \text{with} \quad \epsilon_j\sim N\left(0,\sigma_\epsilon^2\right) \quad \text{and } \eta_0=0, \tag{4}$$

[25] In the sensitivity analysis, we consider alternative preference structures as in Conesa et al. (2009). Note that they also assumed the Cobb-Douglas preferences (non-separable in consumption and leisure) in the main analysis but abstracted from bequest motives. We also consider a separable annual utility function as one of the robustness checks.

where ρ is the persistence parameter and ϵ_j is the innovation of the process. The idiosyncratic innovation term ϵ_j is normally distributed with mean zero and variance, σ_ϵ^2. Note that labor productivity is also skill specific.

Labor supply is endogenous both at the intensive and extensive margins, given by $ls_j = 1 - l_j$, with the time endowment normalized to one.[26] Given the market wage rate, labor productivity and hours worked, households' gross labor income le_j then can be derived as follows:

$$le_j = \begin{cases} w \cdot e_j \cdot \exp\left[\eta_j\right] ls_j, & \text{if } j < j_{\overline{R}} \\ 0, & \text{if } j \geq j_{\overline{R}} \end{cases}.$$

Household budget constraint In addition to labor earnings, households aged $j < j_R$ receive government social transfer payments st_j and (skill-specific) bequests b_j.[27] Those aged $j < j_R$ also make mandatory superannuation contributions sc_j from their gross (pre-tax) earnings, le_j.[28] Older households aged $j \geq j_R$ can continue working (iff aged $j < j_{\overline{R}}$), they no longer pay contributions and receive withdrawals from their private pension fund sp_j, and they may receive (means-tested) age pension income ap_j. All households are subject to a consumption tax with the flat rate τ^c and progressive income taxation $T(\cdot)$, while superannuation taxes only apply to those $j < j_R$ and are concessional compared to $T(\cdot)$.[29]

The households' periodic budget constraint (with liquid assets at the beginning of $j+1$ denoted by a_{j+1}) can then be expressed as

$$\begin{aligned} a_{j+1} = (1+r)a_j + (le_j - sc_j) + b_j + st_j \\ + ap_j + sp_j - T(\cdot) - (1+\tau^c)c_j, \end{aligned} \tag{5}$$

with the right-hand side including the asset income ra_j, labor earnings net of superannuation contributions $le_j - sc_j$, bequest receipts b_j, social transfers st_j (for those $j < j_R$), public and private pensions ap_j and sp_j (for those $j \geq j_R$) minus the progressive income tax (function) $T(\cdot)$ and consumption expenditure $(1+\tau^c)c_j$.

[26] Assuming 15 non-sleeping hours per day and therefore 105 hours of the time endowment per week, one could simply derive weekly hours worked.

[27] Bequests are assumed to be received by households aged 45 to 64 (when most households receive inheritances in Australia, see e.g. Wood et al. 2019), and we assume constant amounts (within each skill type), as defined below (when describing the steady state equilibrium).

[28] We assume that mandatory superannuation contributions are made directly by households in our model, rather than by the representative producer or their employers as under the SG legislation). However, the effects of the policy changes investigated by this model (with profit-maximizing producers) would be identical, irrespective of who pays the contributions. Further note that in Australia, there is empirical evidence, showing that the incidence of mandatory superannuation is born largely by workers (e.g., see Breuning and Sobeck 2020).

[29] The tax and pension policy settings are discussed further in the subsection below on the government sector.

Borrowing constraint As in the PE model in Section 2, we also assume that every household is subject to the borrowing constraint, with non-negative liquid asset restriction:

$$a_j \geq 0,$$

which is to prevent working age households from borrowing against their illiquid superannuation assets.

We calculate the share of those individuals for whom this constraint binds ($a_j = 0$), which gives the share of so-called hand-to-mouth households (see Kaplan et al. (2014)).

3.4 Production sector

The production sector is characterized by a representative producer, representing a large number of perfectly competitive, profit-maximizing firms. The representative firm demands capital K and effective labor L on perfectly competitive factor markets to produce a single output good according to the Cobb-Douglas production technology:

$$Y = \kappa K^{\alpha} L^{1-\alpha}, \tag{6}$$

where α denotes the capital share in production and κ is the productivity constant. Capital is rented from households at a riskless rate and depreciates at the depreciation rate δ. Firms pay corporate taxes $T_k = \tau^k[Y - wL - \delta K]$, where the corporate tax rate τ^k is applied to the output net of the labor cost and capital depreciation. Factor prices are determined competitively by marginal productivity conditions:[30]

$$w = (1-\alpha)\left(\frac{K}{L}\right)^{\alpha}, \tag{7}$$

$$r = (1-\tau^k)\left[\alpha\left(\frac{L}{K}\right)^{1-\alpha} - \delta\right]. \tag{8}$$

3.5 Government sector

The government is responsible for collecting revenues from taxes on household income, consumption and superannuation as well as corporate income, 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 two publicly stipulated pillars of Australia's retirement income policy – the means-tested public age pension and the mandatory private superannuation scheme. The modeling of fiscal and pension policies is described in more detail below, starting with the

[30]Note that in the sensitivity analysis section, we also consider a small open economy (SOE) framework, where the domestic interest rate is exogenous and set to the world interest rate ($r = r^w$). Assuming SOE, a policy change would have no GE impact on the factor prices – neither domestic interest rate nor wage rate, unless r^w or any production parameter is changed.

modeling of mandatory superannuation (which is the main focus of this paper).[31]

Mandatory superannuation Australia's major employment-related pension pillar is represented by mandatory, privately managed retirement savings accounts, which are based on defined contributions and regulated by the government under the legislation known as the Superannuation Guarantee (SG).

The model assumes that mandatory SG contributions sc_j are made by households aged $j < j_R$, up to a legislated cap (see below). The contributions, net of the contribution tax sct_j, are added to the stock of superannuation assets s_j, which earns investment income at the after-tax interest rate, $(1-\tau^r)\, r$. Superannuation assets are assumed to be preserved in the fund (and so they are illiquid) until households reach the access age j_R. For those aged $j \geq j_R$, we assume the (age-specific) draw-down fraction of the superannuation balance denoted by ζ_j, which determines their withdrawals from the fund $sp_j = \zeta_j(1+r)s_j$ that are included in the household budget constraint (5). The superannuation asset accumulation and decumulation (with superannuation assets at the beginning of $j+1$ denoted by s_{j+1}) can be expressed as follows:

$$s_{j+1} = \begin{cases} (1+(1-\tau^r)\, r)s_j + sc_j - sct_j, & \text{if } \; j < j_R \\ (1-\zeta_j)(1+r)s_j, & \text{if } \; j \geq j_R \end{cases}, \tag{9}$$

where r is the interest rate and τ^r denotes the fund earnings tax rate. The mandatory superannuation contributions sc_j are made at the SG rate τ^p from labor earnings, but they are capped at $\overline{sc}$ (reflecting the policy rule of the cap on concessional contributions), i.e., $sc_j = \min\left[\tau^p le_j; \overline{sc}\right]$. The superannuation contribution tax sct_j is due to the concessional tax rate τ^s imposed on mandatory contributions sc_j and paid by those with earnings above the tax-free threshold $y_{\min}$ (which reflects the policy of superannuation co-contributions that effectively removes the contribution tax for low-income individuals, $sct_j = 0$), i.e., $sct_j = \tau^s sc_j$, iif $le_j > y_{\min}$.[32]

Public age 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 ap_j is paid to households of the access age ($j \geq j_R$) provided that they satisfy the means test. In the model, we only consider the income test, but we calibrate its parameters to closely approximate the distribution of the pension-age eligible population with respect to their age pension payments (with more details provided in the next section on the model calibration).

The income test works as follows. The legislated maximum age pension benefit $\overline{p}$ is paid to age-eligible households provided that their assessable income $\widehat{y}_j$ is not greater than the given

[31] More details on Australia's tax and pension systems are provided in Appendix A.

[32] Note that all superannuation taxes are only imposed in the accumulation phase and we allow for some progressivity in the taxation of superannuation contributions, sct_j (approximating the Australian superannuation tax rules).

pension income threshold $\widehat{y}_{\min}$. If $\widehat{y} > \widehat{y}_{\min}$, ap_j gets reduced at the taper rate θ (for every dollar of $\widehat{y} > \widehat{y}_{\min}$ until $ap = 0$). The age pension benefit then can be expressed as

$$ap_j = \begin{cases} 0, & \text{for } j < j_R \\ \max\left\{\min\left\{\overline{p}, \overline{p} - \theta\left(\widehat{y}_j - \widehat{y}_{\min}\right)\right\}, 0\right\}, & \text{for } \ j \geq j_R \end{cases}, \tag{10}$$

where the assessable income $\widehat{y}_j = y_j + 0.5le_j$ includes the deemed income and half of labor earnings (which reflects the policy rule of preferential means testing of employment income). The deemed income y_j is derived from the total assets – sum of private ordinary and superannuation assets $ta_j = a_j + s_j$, as $y_j = 0.04(ta_j - \min[ta_j; a_{min}]) + 0.025 \min[ta_j; a_{min}]$, with the deeming rates of return of 4% and 2.5% p.a. applied above and below the asset (for deeming) threshold a_{min}.[33,34]

The total expenditure of the public pension program is given by $P_A = \sum_{j \geq j_R}^{J} \int_{\mathcal{X}} ap(z) \mathrm{d}X(z)$.

Social transfers The government also runs a social transfer program that pays social transfers st_j to households aged $j < j_R$.[35] The total social transfer expenditure (excluding the age pension) is given by $ST = \sum_{j=1}^{j_R-1} \int_{\mathcal{X}} st(z) \mathrm{d}X(z)$.

Taxes To finance its spending programs, the government collects taxes from various sources, including households and firms. Households are taxed on their income, consumption, and superannuation, while firms are taxed on their taxable corporate income. The model incorporates a progressive income taxation system and flat tax rates on other revenue sources.

Households' taxable income $\tilde{y}_j$ is taxed under the 2017-18 progressive income tax schedule $T(\tilde{y}_j)$. The taxable income comprises gross labor earnings, net of mandatory superannuation contributions $le_j - sc_j$, returns on liquid ordinary private assets ra_j and the age pension ap_j, i.e.,

$$\tilde{y}_j = (le_j - sc_j) + ra_j + ap_j. \tag{11}$$

The government's total tax revenue, TR, is composed of revenues from various taxation sources, including the household progressive income tax, T^Y, consumption tax, T^C, (concessional) superannuation taxes, T^S, as well as corporate tax paid by firms, T^K. The government's

[33] As in Kudrna et al. (2022), we do not model housing directly, but in order to closely target actual income tax revenues and age pension expenditures, we calculate the age-specific fraction of owner-occupied housing on total net worth from ABS (2019e). It is further assumed that the interest income generated by that fraction of assets is exempt from personal income taxation and the age pension means test.

[34] Further note that under the counterfactuals examined in Section 6, these deeming rates follow the changes in the reported endogenous interest rate exactly. This reflects the current rules for the income test and deeming rates. However, as mentioned, in Australia there are two tests – an income and an asset test – and with declining interest rates, it is the asset test that now binds for most age pensioners. In the sensitivity check, we model this by assuming that the pension deeming rates are kept constant (as in the benchmark).

[35] Drawing on the Australian social security programs for the unemployed, families with children and those with disability, the age profiles of the sum of these benefits are estimated for the three skill types, using the HILDA survey data. Further details are provided in the calibration section.

tax receipts can be expressed as

$$
\begin{aligned}
T^Y &= \int_{\mathcal{Z}} T(\tilde{y}(z))\mathrm{d}X(z), \\
T^C &= \tau^c \int_{\mathcal{Z}} c(z)\mathrm{d}X(z), \\
T^S &= \textstyle\sum_{j=1}^{j_R-1} \displaystyle\int_{\mathcal{X}} [sct(z) + \tau^r rs(z)]\mathrm{d}X(z), \\
T^K &= \tau^k[Y - wL - \delta K].
\end{aligned}
\tag{12}
$$

Budget balance The government collects taxes from both households and firms (with total tax revenue TR), in order to finance various expenditures such as general government expenditure G, transfer payments $P_A + ST$, and interest payments on its debt. In the steady state, the government budget constraint becomes

$$TR = G + P_A + ST + (r - n)B_G, \tag{13}$$

where B_G denotes net government debt.

In the benchmark steady state equilibrium, we specify the debt-to-output ratio b_y and let public consumption G balance the government budget. We also use five adjustment parameters (f_{ap}, f_{st}, f_i, f_c, f_k) calculated to match observed ratios of the given expenditure or tax revenue to output. These adjustment parameters alter the effective (tax or transfer) rates, with f_{ap}, f_{st}, f_i and f_c being included in the households' optimisation problem and f_k in the firms' marginal productivity of capital condition.[36]

Under each counterfactual policy experiment examined in Section 5, B_G and G and all the adjustment parameters (f_{ap}, f_{st}, f_i, f_c, f_k) are kept at their benchmark levels and we adjust the consumption tax rate τ^c to balance the government budget in (13).

3.6 Equilibrium

Given the government fiscal and pension policy, a stationary recursive equilibrium is a set of value functions $\{V(z_j)\}_{j=1}^J$, household decision rules $\{c_j(z_j), l_j(z_j), a_{j+1}(z_j), s_{j+1}(z_j)\}_{j=1}^J$, distribution of bequests $\{b(z_j)\}_{j=1}^J$, and time-invariant measure of households $\{\phi(z_j)\}_{j=1}^J$ such that the following conditions are satisfied:

1. households make optimal consumption/saving and leisure/labor decisions by maximizing

[36] For example, $\tau^c = \overline{\tau}^c f_c$ in the household budget constraint (5) and consumption tax revenue (12) is the effective consumption tax rate, a product of the statutory rate and the consumption tax adjustment parameter targeting the observed consumption tax revenue to GDP ratio. Similarly, the age pension benefit ap_j needs to be scaled by f_{ap}, which is calibrated to match the observed pension expenditure to GDP ratio.

(3) subject to the household budget constraint (5), the borrowing constraint $a_j \geq 0$, time constraint $l_j \leq 1$ and the non-negativity constraint on consumption and leisure;

2. the domestic interest and wage rates are determined according to (7) and (8);

3. the aggregation holds

$$L = \int_{\mathcal{Z}} e_j \cdot \exp[\eta_j]\, ls_j \mathrm{d}X(z_j),$$
$$C = \int_{\mathcal{Z}} c(z_j)\mathrm{d}X(z_j),$$
$$A = \int_{\mathcal{Z}} a(z_j)\mathrm{d}X(z_j),$$
$$S = \int_{\mathcal{Z}} s(z_j)\mathrm{d}X(z_j);$$

4. let $\mathbf{1}_{k=x}$ be an indicator function that returns 1 if $k = x$ and 0 if $k \neq x$. Then the law of motion for the measure of households at age j follows

$$\phi(z_{j+1}) = \frac{\psi_{j+1}}{1+n} \int_{\mathcal{Z}} \mathbf{1}_{a_{j+1}=a_{j+1}(z)} \times \mathbf{1}_{s_{j+1}=s_{j+1}(z)} \times \pi(\eta_{j+1}|\eta_j)\mathrm{d}X(z_j);$$

5. bequests satisfy[37]

$$\int_{\mathcal{Z}} b(z_j)dX(z_j) = \int_{\mathcal{Z}} (1-\psi_{j+1})\big[(1+r)(a_{j+1}(z_j) + s_{j+1}(z_j))\big]\mathrm{d}X(z_j);$$

6. the government budget (13) (with given B_G/Y) is balanced by choosing G (only in the benchmark equilibrium);

7. the capital market clears

$$K = A + S - B_G; \tag{14}$$

8. the goods market clears[38]

$$Y = C + (n+\delta)K + G. \tag{15}$$

[37] Bequest payments b are assumed to be made within each skill type and received by those aged 45 to 64 (as a constant amount at each age).

[38] Note that in the SOE framework with the exogenous domestic interest rate, the capital stock K is determined from (8) and the capital market clears with net foreign debt set to $B_F = A + S - (K + B_G)$. The (steady state) goods market clearance then becomes $Y = C + (n+\delta)K + G + (n-r)B_F$. As mentioned, in the sensitivity analysis section, one of the robustness checks examines the effects of alternative SG rates (focusing on the 12% SG rate legislated for the future) under this SOE market structure with constant factor prices.

4 Calibration

The benchmark economy of our stochastic OLG model is assumed to be in a stationary steady state equilibrium. We calibrate this benchmark steady state equilibrium to Australia, utilizing macro-level and fiscal policy data averaged over 5 years ending in June 2018, as well as micro-level data from the HILDA surveys conducted between 2001 and 2018 (for more information on the HILDA surveys, see Summerfield et al. (2019)).

In this section, we first discuss our parameter choices for the benchmark model, starting with demographic, household and production parameters presented in Table 5. We then provide a discussion of the values of government policy parameters reported in that subsection. Finally, we examine the benchmark solution and compare it to macroeconomic and fiscal data.

Table 5: Key parameter values of benchmark model

Definition	Value	Source
Demographics		
Survival probabilities	See the text	ABS (2019a)
Population growth rate (p.a.)	1.6% p.a.	Calibrated[a]
Skill distribution	[0.19, 0.50, 0.31]	HILDA18
Household preferences		
Intertemporal elasticity of subs.	0.5	Kudrna et al. (2021)
Ordinary consumption share	[0.36, 0.37, 0.38]	Calibrated[b]
Time discount factor	0.972	Calibrated[c]
Bequest motive parameters	See the text	Cho and Sane (2013)
Labor productivity		
Deterministic age-wage function	See the text	HILDA18
AR(1) correlation	0.95	Freestone (2018)
Transitory variance	0.017	Freestone (2018)
Production sector		
Capital share	0.4	Calibrated[d]
Capital depreciation rate (p.a.)	7%	Calibrated[e]
Production constant	1.6	Calibrated[f]

Notes: [a]To target old-age dependency ratio; [b]to target average hours worked (also by skill type); [c]to target capital output ratio (K/Y); [d]to target interest rate; [e]to target investment rate (I/K); [f]to target wage rate that is normalized to one.

4.1 Demographic structure

The model's time period spans 5 years, and agents begin life at age 20 (represented by model age $j = 1$) and can live up to the age of 99 years ($J = 16$), corresponding to age group 20-24 through 95-99. We assume that households become eligible for age and superannuation pensions at age 65 (representing age group 65-69) ($j_R = 10$) and that they are forced to retire at age 85 (representing age group 85-89) ($j_{\overline{R}} = 14$).

The model assumes a stationary demographic structure with survival probabilities ψ_j and a population growth rate n that jointly determine the sizes of different age cohorts. The age-specific survival probabilities are derived from the 2016-18 Australian life tables (ABS 2019a) as averages for male and female survival probabilities from age 20 to 100 and adjusted for the 5-year age groups. We calibrate the population growth rate n to approximate the old-age dependency ratio of 0.26 in 2018 (ABS 2019b).[39] As shown in Table 5, $n = 1.6\%$ closely matches the population growth rate in 2018. The model also replicates the life expectancy targets derived from ABS (2019a), with the model-generated life expectancy at age 20 and 65 being 62.3 and 20.2 years, respectively.

4.2 Household preferences

We adopt Cobb-Douglass non-separable preferences (in consumption and leisure), which are standard in the related social security literature. Following Kudrna et al. (2022), we set the risk aversion parameter $\sigma = 2$. The value of the discount factor $\beta = 0.972$ is calibrated such that the model's capital to output ratio matches the macro target of 3.3 (as other macro targets, averaged over the 5 years ending in June 2018 (ABS 2019c)).

The consumption share parameter in the periodic utility ν_i is skill-specific. We set the value for the middle-skill type to $\nu_{i=2} = 0.37$, so that the model approximates average work hours of 0.32 (of the time endowment normalised to one) (ABS 2019d). For low-skill and high-skill types, the value is reduced to 0.36 and is increased to 0.38, respectively. This is to better match their labor supply, which is smaller for low-skill and higher for high-skill than average hours worked, particularly at older ages (based on HILDA1-18 waves). To incorporate consumption equivalence into the periodic utility, we follow Kaas et al. (2021) and Nishiyama and Smetters (2005). We derive the parameter values over the life cycle using the OECD-modified equivalence scale and ABS (2019e) data, setting $\mu_j = (1, 1.4, 1.9, 1.75, 1.65, 1.56)$ for broader age groups (20-24, 25-34, 35-44, 45-54, 55-64, 65+).

The bequest function parameterization follows De Nardi (2004) and Cho and Sane (2013), with the parameters set to $q_1 = -9$, $q_2 = 11.6$ and $\sigma_b = 1.5$.[40]

4.3 Skills and labor productivity

The model assumes that individuals belong to one of three skill types, based on their highest level of education completed. Specifically, households are classified as low-skilled if they have

[39] The old-age dependency ratio is defined here as the ratio of the population aged 65 and over to the population aged 20 to 64.

[40] In the sensitivity analysis, we consider alternative preference structures as in Conesa et al. (2009), with increased σ and no bequest motive. We also consider an alternative periodic utility function that is separable in consumption and leisure as one of the robustness checks.

less than 12 years of schooling, middle-skilled if they have 12 years of schooling or more but have not completed a bachelor's degree, and high-skilled if they have completed a bachelor's degree or higher. The initial probability distribution for the three skill types is derived from HILDA18 data, using employed individuals (both male and female) aged 20 to 64 years, for the 18 survey waves released between 2001 and 2018. The probabilities are set to reflect the distribution of low-, middle-, and high-skilled households in the population, with values of ϖ_i = (0.193, 0.502, 0.305) for the low-, middle-, and high-skilled types, respectively.

The three skill types have different labor productivities, which are determined by a deterministic age-profile and a transitory component following an AR(1) process. The deterministic age-profile $e_{j,i}$ is skill-specific and estimated from HILDA18 data. It is based on a quadratic wage equation that includes both age and age-squared terms. The age-profiles for the three skilled types are shown in Figure C.1 in Appendix C, normalized by the labor productivity of low-skilled workers at age 20, $e_{1,1}$. As data on labor supply for individuals aged 65 and older is limited in the HILDA surveys, we assume that labor productivity declines linearly after age 65, reaching zero at age 85 ($j_{\overline{R}} = 14$), consistent with Kudrna et al. (2022).

To capture the stochastic nature of labor productivity, we follow Conesa et al. (2009) and Fehr et al. (2013). Specifically, we assume that the transitory component of labor productivity follows an AR(1) process, with the autocorrelation and variance parameters in (4) derived from Freestone (2018).

4.4 Production sector

The production function in (6) takes the Cobb-Douglas functional form, which is commonly used in related literature (e.g., see Hosseini and Shourideh 2019). We calibrate the capital share parameter $\alpha = 0.4$ and the depreciation rate of the capital stock $\delta = 0.07$ p.a. to approximate the investment rate ($I/K = 0.077$) and the gross investment to output ratio ($I/Y = 0.25$). The wage rate, w, is normalized to one by calibrating the value of the productivity constant $\varrho = 1.46$. We use the Australian national account data as 5-year averages ending in 2018 (ABS 2019c) for this purpose. The domestic interest rate is $r = 4.3\%$ p.a., which is similar to the values used in Australian-based OLG models by Kudrna et al. (2019, 2022) or in the US-based model by Hosseini and Shourideh (2019).

4.5 Government sector

This section provides details on the policy rules and parameters of the Australian tax and pension systems. The parameter values are reported in Table 6. We follow the same policy order as in the model section, starting with the parameterization of the mandatory superannuation system.

Table 6: Calibration of government policy in benchmark model

Definition	Value	Source
Superannuation		
Mandatory SG rate	7%	Calibrated[a]
Contribution tax rate	15%	Data
Fund earnings tax rate (effective)	7%	Data
Public pension		
Maximum pension	0.34y	Data
Means test disregard	0.16y	Calibrated[b]
Taper rate	0.9	Calibrated[c]
Social transfers		
Age- and skill-specific transfers	See the text	HILDA18
Taxes		
Personal income tax	See the text	Data
Statutory corporate tax rate	30%	Data
Statutory cons. tax rate (GST)	10%	Data
Fiscal adjustment parameters (scalars)[d]		
Public age pension	0.8	Calibrated
Social transfers	0.9	Calibrated
Personal income tax	0.9	Calibrated
Corporate tax	0.75	Calibrated
Consumption tax	1.05	Calibrated

Notes: [a]To target superannuation assets to GDP ratio; [b]to target the share of full age pensioners; [c]to target the share of self-funded seniors; [d]these scalars are calculated to target the given government expenditure or tax revenue to GDP ratio.

Mandatory superannuation We focus on the mandatory Superannuation Guarantee scheme that was legislated in 1992. It requires employers to make contributions on behalf of their employees, with the SG rate initially set at 3% of gross wages in 1992. This rate increased to 10% in 2018-19 and is set to reach 12% by 2025. For our benchmark model, we assume that mandatory contributions made by working households aged below 65 will be at the SG rate of $\tau^p = 7\%$. This rate approximates superannuation assets of 150% of GDP for 2018, which we have taken from Chomik et al. (2018).[41] The mandatory contributions are made up to a contribution cap of $\overline{sc} = 0.3\overline{y}$.

The superannuation taxes on mandatory contributions and fund earnings are made during the superannuation assets accumulation ($j < j_R$), with the tax rates set to $\tau^s = 15\%$ and $\tau^r = 7\%$, respectively.[42] We also assume that low income individuals with earnings below

[41]Note that under more recent estimates by Willis Towers Watson (2021), Australia's superannuation assets are already at 175% of GDP.

[42]Note that τ^r is the effective fund's earnings tax, with the value set as in Kudrna and Woodland (2013, 2018).

the income tax free threshold ($y_{min} = 0.3\overline{y}$) do not pay any contribution tax, which reflects a government policy of super co-contributions introduced in 2012.

The superannuation assets are illiquid and cannot be accessed prior to the superannuation access age $j_R = 10$ (representing age group 65-69). Individuals aged $j \geq j_R$ are paid their accumulated superannuation savings at the assumed age-specific fractions ζ_j of their superannuation balance, with $\zeta_j = (0.25, 0.35, 0.5, 1)$ for age groups (65-69, 70-74, 75-79, 80+). Based on the current legislation (since 2007), these drawdowns are tax-free.

Public pension Households become eligible for the public pension ap_j at the same eligibility age as for superannuation payouts, $j_R = 10$ (representing the age group 65-69). The pension benefit is means-tested and subject to the calibrated income test in the model. The income test includes the maximum pension benefit $\bar{p}$ (which applies to single pensioners $\bar{p} = 0.34\overline{y}$), the income threshold (or disregard) $\widehat{y}_{\min}$ (up to which $\bar{p}$ is payable) and the taper θ (at which $\bar{p}$ reduces for every dollar of the assessable income above the threshold $\widehat{y} > \widehat{y}_{\min}$). The assessable income $\widehat{y}$ consists of the deemed income $\widehat{y}$ (derived from financial assets) and half of labor earnings (for working households).[43] As for the deemed income, there are two deeming rates of 4% p.a. and 2.5% p.a. above and below the asset (for deeming) threshold $a_{min} = 0.7\overline{y}$ (applicable to single pensioners). For the deeming rates and the relevant asset threshold, we use pension policy data from 2016 (when the pension access age was 65). The income disregard and the taper are calibrated to approximate the share of those on full (maximum) pension and those on no pension (i.e., self-funded seniors), respectively, with $\widehat{y}_{\min} = 0.16\overline{y}$ and $\theta = 0.9$ in our benchmark model (which closely match the distribution by age pension payments as shown in Table 7).[44] Finally, we scale the pension benefits ap_j (and so the maximum pension $\bar{p}$) by the adjustment factor $f_{ap} = 0.80$, so that the model matches the observed pension expenditure to output ratio $P_A/Y = 0.029$.[45,46]

Social transfers The model includes social transfer payments that the government pays to households aged $j < j_R$, aimed at those with lower incomes. These payments aim to capture transfer payments to the unemployed, families with children and the disabled (such as Newstart Allowance, various family benefits and the Disability Support Pension). We derived the transfer age-profile for each skill type from HILDA18 and scale these transfer profiles in the model to match the observed ratio of social transfer expenditure to output, $ST/Y = 0.054$.[47]

[43] In terms of preferential means testing of labor earnings, we follow Kudrna et al. (2022). Alternatively, we could incorporate the maximum earnings that are to be exempted from the income test, as in Kudrna (2016).

[44] By calibrating these parameters, we effectively combine the actual income and asset test into one - the means test in (10).

[45] Scaling down the pension benefit reflects our use of the maximum pension rate for single pensioners, which is higher than the maximum pension for each of the pensioner couple.

[46] Note that all the calibration fiscal targets (including the one for the pension expenditure here) are 5-year averages ending in June 2018, derived from budget papers over the period (Australian Government, 2018).

[47] The age-profiles for these transfers to working age households are plotted by skill type and can be found in Appendix C.

Taxes The model includes four sources of total tax revenue: personal income taxes, superannuation taxes, corporate taxes and consumption taxes. The personal income tax base (11) comprises labor earnings (net of mandatory contributions), asset income and the public age pension, and it is subject to progressive taxation. We use the Australian 2017-18 personal income tax schedule with five tax brackets and marginal tax rates.[48] We scale the income tax payable by $f_i = 0.90$ to match $T^Y/Y = 0.114$.[49]

Other tax revenues in the model come from superannuation, corporate (or firms' taxable income) and consumption taxes. As previously discussed, the tax rates on superannuation contributions and fund earnings are set to $\tau^s = 0.15$ and $\tau^r = 0.07$ (i.e., effective tax rate on superannuation fund earnings during the accumulation stage). The corporation and consumption tax rates shown in Table 6 are effective rates, which are the products of their statutory rates ($\overline{\overline{\tau}}^k = 0.3$ and $\overline{\overline{\tau}}^c = 0.1$) and the respective adjustment factors. Similar to household income taxation, we calculate adjustment factors ($f_k = 0.75$ and $f_c = 1.05$) for these taxes to match the ratios of the given revenue to output ($T^K/Y = 0.046$ and $T^C/Y = 0.062$). In the benchmark economy, we set the government net debt to the observed ratio to output $b_y = 0.2$ and determine government consumption to balance the government budget specified in (13) of Section 3.

4.6 Benchmark solution and comparison with data

The benchmark solution is obtained by numerically solving the model for the initial steady state equilibrium, with the specified parameters and government policy settings. The computation method follows the Gauss-Seidel procedure outlined by Auerbach and Kotlikoff (1987), which for stochastic OLG models is explained in great detail by Fehr and Kindermann (2018).

The numerical solution process begins with guesses for aggregate variables, bequest distribution, and exogenous policy parameters. Then, the factor prices and individual decision rules and value functions are computed. The latter involves the discretization of the state space. Next, we obtain the distribution of households and aggregate assets and government consumption (or the consumption tax rate under policy counterfactuals examined in the next section) that balances government budgets (and the five policy adjustment parameters, targeting the ratios of the given tax revenue or government expenditure to output). This information allows us to update the initial guesses, and the procedure is repeated until the initial guesses and the resulting values for capital, labor, bequests, and endogenous taxes have sufficiently converged.

In this subsection, we first present and discuss the life-cycle solutions generated by the model for the main household variables. These implications drive the macroeconomic and fiscal solutions, which we discuss next. We also provide a detailed comparison of the model-generated and actual macroeconomic and budgetary implications, including the distributions of the retired

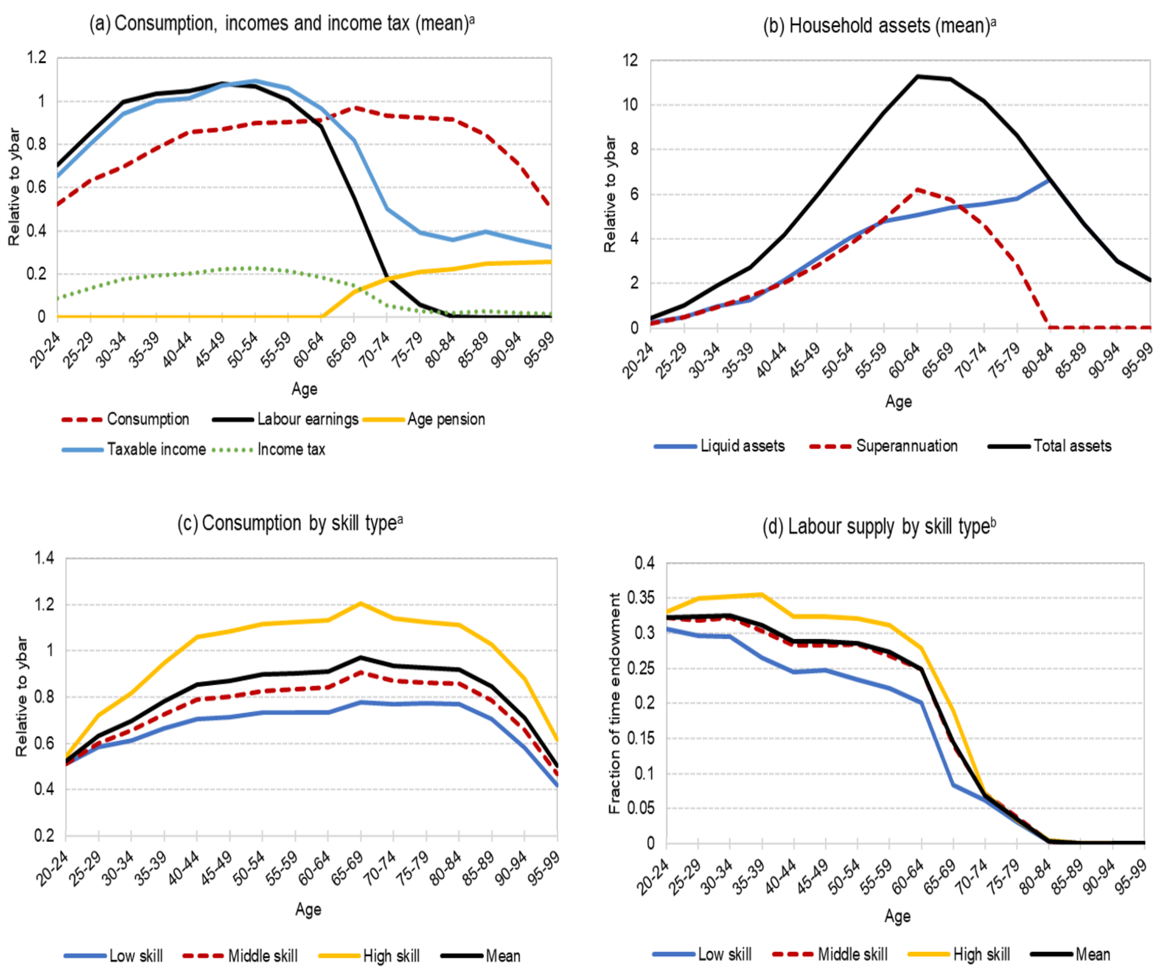
[48] For details, see Appendix A.

[49] One could think of this scalar as the proportion of total income that is not taxable (e.g., due to various tax deductions or exemptions).

population in relation to their public pension receipts.

Life cycle solutions The main life-cycle solutions are plotted in Figure 3. These include 3(a) consumption, incomes and income taxes, 3(b) household assets (mean), 3(c) consumption by skill type, and 3(d) labor supply by skill type. Apart from labor supply, which is presented as the fraction of normalized time endowment (with assumed 105 non-sleeping hours per week or 5,460 hours p.a.), all other variables are expressed as the fraction of economy-wide average labor earnings (approximately A\$64,000 derived from ABS (2019f) for 2018).

Figure 3: Benchmark solutions for consumption, incomes, assets and labour supply over life cycle



Notes: [a]Relative to benchmark economy-wide average earnings (ybar=A\$64,000 p.a.); [b]Fraction of annual time endowment (=5,460 hours).

As shown in Figure 3, consumption, earnings, incomes, taxes, total assets and labor supply have standard hump-shapes, driven by stochastic labor productivities, (with age-declining) survival productivities and also, importantly, by government policy. It is worth noting that during younger ages, the individual taxable income is typically below the labor earnings, due to the deduction of concessional mandatory contributions into private superannuation accounts.

On average, households at older ages pay very low income taxes and their public pension benefits increase with age due to means testing, which is less binding at very old ages.

The household assets shown in Figure 3(b) represent the holdings at the end of each age group. As discussed, it is assumed that the superannuation assets are preserved and remain illiquid in the fund until the access age j_R. For households aged 65-69 and above, a certain fraction of their private pension balance is drawn as a payout into liquid private assets, as per our assumption. This assumption can have a significant impact on the asset composition of those aged $j \geq j_R$ (but only small impact the level of total assets in retirement).

In Figures 3(c) and 3(d), we show distributional differences in consumption and labor supply (hours worked) profiles amongst different skill types. In our model, consumption peaks at an older age of 65, coinciding with the availability of illiquid superannuation assets and public pensions. This peak is consistent with many simulation studies that account for social security, such as Hansen and Imrohoroglu (2008). However, our model predicts a higher consumption peak compared to estimates for nondurable consumption in the US, such as those presented by Fernández-Villaverde and Krueger (2007). The decline in labor supply at older ages is attributed to both declining productivity and the impact of pension policies, including the availability of public age pensions and superannuation savings for those aged $j \geq j_R$. The observed gap in hours worked between high- and low-skill types is partly due to our assumption of a higher preference parameter for leisure among low-skill types. We report additional life-cycle and distributional results in Appendix C, including age-profiles of total assets, the share of liquidity constrained households, and income tax rates.

Macroeconomic and fiscal solutions The macroeconomic and fiscal solutions of the benchmark model with a comparison to Australian data are reported in Table 7, with most selected variables expressed as a percentage of GDP. As seem, our benchmark model matches Australian macroeconomic and budgetary data well. As pointed out, in the benchmark model we assume no net export (and net foreign assets), allowing us to examine the closed economy effects with general equilibrium adjustments in factor prices such as wage and interest rates. To approximate the observed superannuation assets to GDP ratio, we use the 7% SG rate.

As demonstrated in Table 7, our model exactly matches many of the fiscal targets, such as government expenditures and tax revenues, by utilizing the discussed fiscal adjustment parameters. We target the revenue from overall consumption taxation (including the GST), and the target for pension expenditure includes both age and service pensions (which are subject to the same means testing rules). We closely approximate the progressive income tax schedule (given in Appendix A) by assuming linear increases in the marginal tax rates around each income threshold (instead of actual jumps to a higher marginal tax rate in the next tax bracket). The (cohort weighted) average marginal income tax rate in the benchmark economy is about 26%, which is significantly higher than concessional flat tax rates on superannuation contributions and fund interest earnings.

Table 7: Benchmark macroeconomic and fiscal solutions and targets*

Variable	Model	Target[a]
Expenditures on GDP		
Consumption	74.2	75.2
Private consumption	59.2	56.9
Government consumption	15.1	18.3
Gross investment	25.8	25.3
Net export	0.0	-0.6
Capital markets		
Capital stock	332.8	329.5
Government (net) debt	20.0	20.0
Household wealth	352.8	
Superannuation assets	160.4	150[b]
Interest rate p.a. (%)	4.3	
Share of liquidity constrained (%)	29.4	30[c]
Government policy[d]		
Income tax revenue	11.4	11.4
Marginal income tax rate (%)	26.4	
Superannuation tax revenue	0.9	0.6
Corporate tax revenue	4.6	4.6
Consumption tax revenue	6.2	6.2
Effective cons. tax rate (%)	10.5	
Public pension benefits	2.9	2.9
Social welfare benefits[e]	4.5	4.5
Interest on gov. net debt	0.9	
Mandatory SG rate (%)[f]	7.0	
Distribution of those aged 65+ (%)[g]		
No age pension	22.9	25.0
Full age pension	44.4	43.5
Part age pension	32.8	31.5

Notes: *% of GDP, if not stated otherwise; [a]targets derived from ABS (2019c) as 5-year average ending in June 2018; [b]taken from Chomik et al. (2018); [c]to apporximate share of hand-to-mouth population, for the US see Kaplan et al. (2014) and for Australia see La Cava and Wang (2021); [d]targets derived from Australian Government (2018) as 5-year average ending in June 2018; [e]paid to those aged younger than 65 (including unemployment, disability and family benefits); [f]to approximate current superannuation asset to GDP ratio; [g]based on DSS (2016) for June 2016.

The model also closely approximates the average share of liquidity constrained households, which are those with liquid assets sufficiently close to zero. For the relevant data work on this topic, see Kaplan et al. (2014) for the US and La Cava and Wang (2021) for Australia.

As discussed, we calibrate the pension means test, in order to approximate the distribution of households aged 65 years and over in relation to age pension payments. We base our data comparison on DSS (2016) data reported in Table 7. For the calibration targets of this distribution, we first use the ABS (2019b) population data and DSS (2016) demographic data for 2016 to derive the proportion of self-funded seniors. This proportion is about 30% of the age-eligible population, but we target 25% since not all age-eligible population would satisfy the minimum residency eligibility for the age pension. We then derive the proportions of those on full and part pension based on DSS data. As shown, in 2016, around 44% and just over 32% of those aged $j \geq j_R$ were receiving full age pension and part age pension, respectively. The benchmark model matches these observations very closely.[50]

5 Quantitative analysis

In this section, we examine the long-run economic effects of alternative mandatory SG contribution rates, using the GE model described and calibrated earlier. Specifically, we investigate the following counterfactual scenarios with varying SG rates set at $\tau^p = 0\%$, 3%, 12% or 15% of gross wages and compare the benchmark model with $SG = 7\%$. We consider two sets of counterfactual scenarios relative to the benchmark model, one with lower SG rates and one with higher SG rates. Hence, we consider two sets of counterfactuals with lower and higher SG rates. As previously noted, the $SG = 12\%$ counterfactual has already been legislated, with the increased rate set to take effect after 2024. All other counterfactual scenarios (e.g., no mandate setting $SG = 0\%$) are hypothetical in the Australian context.

For each policy counterfactual, the government budget is balanced by adjusting the effective consumption tax rate, while keeping government consumption, government debt, and all fiscal adjustment parameters or scalars at their benchmark levels. As previously mentioned, the model accounts for general equilibrium (GE) effects via changes in factor prices and also allows for redistributions of bequests (left by those who pass away), which generate feedback or indirect effects on household life cycle behavior. In the following subsections, we first examine the key life-cycle implications, which capture both direct and indirect effects of alternative rates of the SG mandate in our model, before moving on to aggregate effects of the SG mandate (on the economy, government budget and welfare of newborns).

5.1 Behavioral life-cycle effects

The life-cycle implications of the SG rate alternatives (as demonstrated in this subsection by setting the mandatory SG rate to 0% or the legislated future 12%) are plotted in Figure 4 for (a) household consumption, (b) labor supply (hours worked as a fraction of time endowment), (c) income tax base (i.e., taxable income (11) defined in Section 3), (d) marginal income tax

[50] Note that the Australian public pension program is significantly more progressive than the US Social Security old age program, which, among developed countries' pay-as-you-go (PAYG) pension systems, is considered to have a rather progressive public pension benefit formula (see Fehr et al., 2021). Currently, in Australia, around 25% of older Australians do not receive any public pension. This group of affluent elderly relies entirely on their own resources in old age.

rate (%), (e) share of liquidity-constrained households (% of those with liquid assets sufficiently close to zero), and (f) total household assets (including both liquid assets and illiquid superannuation). All variables are expressed as the mean values across the three skill types, with monetary variables (e.g., consumption) expressed relative to the economy-wide average labor earnings ($\overline{y} \approx$A\$64,000 p.a.). Note that we used the same (benchmark) value of $\overline{y}$ in Figure 4 to enable comparison across the SG rate alternatives.[51]

Consider first the future economy with the legislated 12% SG rate, depicted by the blue dotted lines in Figure 4. The results show an increase in life-cycle consumption, particularly at older ages, and a significant increase in total assets over the life-cycle, compared to the benchmark economy with a 7% SG rate (black line) (see Figure 4(a)).

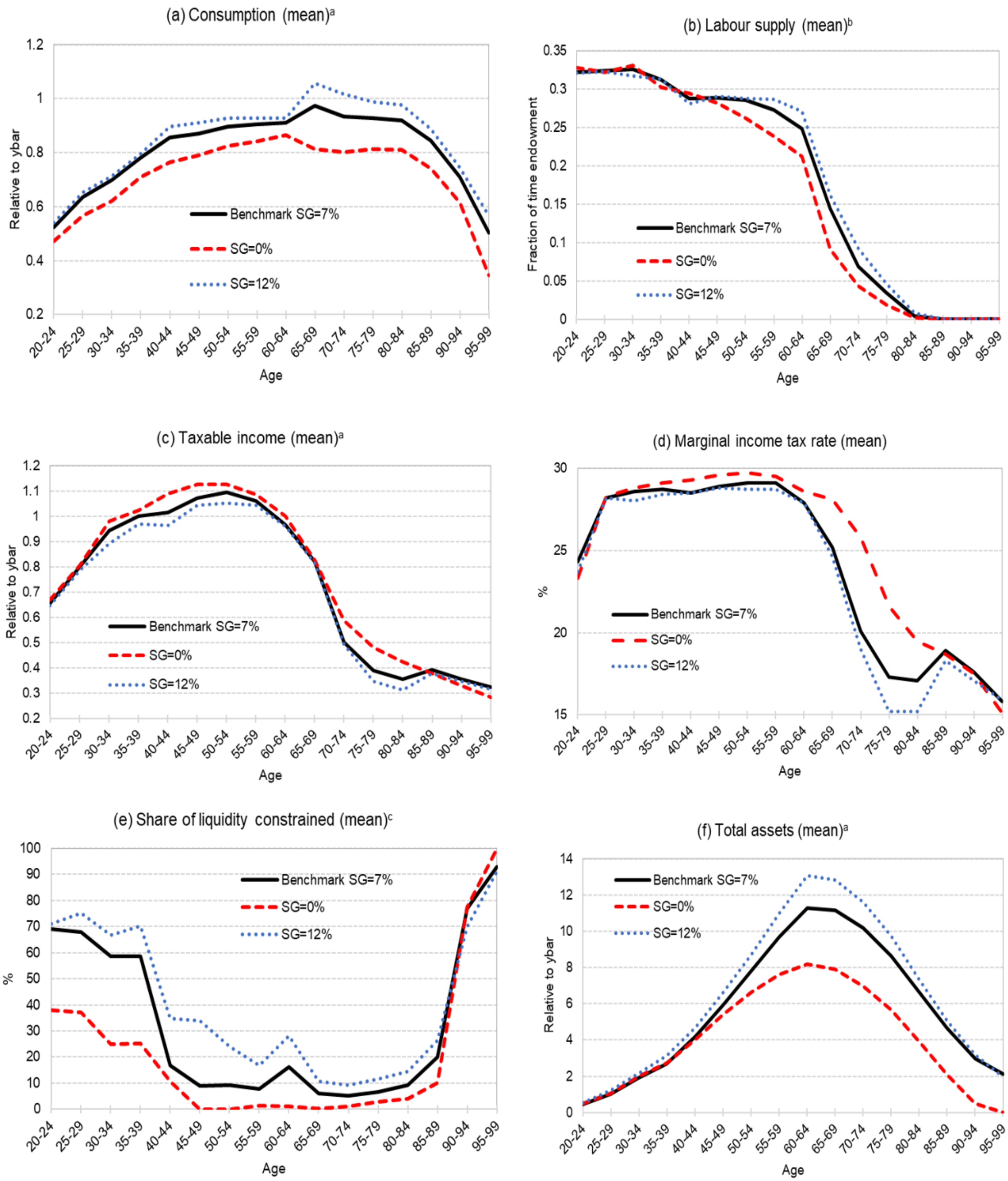
Interestingly, higher consumption at younger ages is due to more households accumulating lower liquid savings and being liquidity constrained at younger ages (as shown in Figure 4(e)). The SG mandate also has an impact on labor supply (see Figure 4(b)), which is higher under higher SG rates, particularly at mature and older ages prior to eligibility for superannuation payouts. This is due to reduced distortions from the lower income tax base subject to progressive income taxation (see Figure 4(c)) and the marginal income tax rate over the life-cycle (in Figure 4(d)), as well as general equilibrium (GE) effects with an increasing market wage rate discussed in more detail in the next subsection.[52] Importantly, as shown in Figure 4(f), the impact of higher SG mandates on total household assets is significantly positive, with increases in illiquid assets dominating lower liquid assets as a result of the higher mandate. This finding suggests that a higher SG rate provides greater retirement savings for households, which could lead to higher welfare in retirement. Additionally, the increase in total assets could also have positive implications for intergenerational transfers, as higher bequests may be passed down to future generations.

In contrast, in a hypothetical economy with a 0% SG rate (no superannuation mandate), households would have lower consumption levels, and average household wealth would be significantly reduced (and they would face higher marginal tax rates and pay higher income taxes) over their entire life cycle, particularly in old age, as shown by the red dashed lines in Figure 4. This counterfactual economy largely resembles the Australian economy before the introduction of the SG legislation in the 1980s when average earnings and household wealth, in real terms, were significantly lower than the current economy.

[51] As discussed in the next subsection, the SG rate alternatives have significant long-term macroeconomic impacts that also alter the average economy-wide labor earnings to some extent. For example, the results show higher average earnings in the economy with the 12% SG rate (compared to the benchmark $\overline{y}$).

[52] Note that the effects of a higher SG mandate on labor supply are not straightforward and can vary depending on the model used. In a small open economy (SOE) framework that abstracts from general equilibrium effects (as shown in the sensitivity analysis section), household labor supply tends to fall at middle and older working ages and on average. Kudrna and Woodland (2013) discuss that there are both substitution and income (or wealth) effects due to a higher SG mandate. In the model used in this paper, which accounts for general equilibrium effects, the substitution effect of higher wage rates dominates the wealth effects of higher overall wealth and bequests, resulting in increased labor supply, particularly at mature and older ages. However, in the SOE model, the wealth effect dominates the substitution effect, resulting in lower labor supply on average, and particularly at older ages.

Figure 4: Behavioral life-cycle effects of different SG rates in long run



Notes: [a]Relative to benchmark economy-wide average earnings (ybar=A$64,000 p.a.); [b]Fraction of annual time endowment (=5,460 hours); [c]Share of liquidity constrained household (wealthy hand to mouth as most working age households have some illiquid assets (for any positive SG rate).

As mentioned earlier, the life cycle outcomes are a result of direct behavioral impacts of different SG mandates (higher rates leading to larger household wealth and consumption in old age) as well as indirect effects from adjustments within the household sector (such as bequest redistributions), the government sector (via budget-equilibrating policy instruments – e.g. the consumption tax rate), and GE effects on the economy-wide (gross) wage rate and domestic interest rate (which will be discussed below).

5.2 Macroeconomic, welfare and fiscal effects

In this subsection, we present and discuss the macroeconomic, fiscal and welfare implications of policy counterfactuals with the SG rate reduced to 0% and 3%, and increased to 12% and 15% of gross wages, in comparison to the benchmark model with $SG = 7\%$ of gross wages.

The long run results for labor, goods and capital markets as well as the welfare of newborns (both on average and by skill type) are reported in Table 8, while the fiscal effects of alternative SG rates on the government budget are presented in Table 9. For most variables displayed, the results are indexed to the benchmark solutions, which are shown in the middle column of each table (indexed to 100). Moving away from the middle column provides indexed (and so %) changes for lower and higher SG rates relative to the benchmark. For example, in Table 8, long-run output is shown to be 6.15% higher under $SG = 12\%$ compared to $SG = 7\%$. Note that the long-run welfare effects in Table 8 are also indexed to the benchmark model, using the same HEV measure as in Section 2. Here, we simply calculate % changes in the expected lifetime utility relative to the benchmark model. Table 9 also provides the distribution of the age-eligible population for public means-tested age pension (in the model, those aged 65+), indicating the percentage of those on no, full, and part age pension under the benchmark model and each SG rate alternative.

Table 8: Macroeconomic and welfare effects of alternative SG rates in long run*

Variable	Alternative SG=0%	Alternative SG=3%	Benchmark SG=7%	Alternative SG=12%	Alternative SG=15%
Labor market					
Effective labour	96.04	98.19	100.00	101.05	101.93
Market wage rate	91.90	95.60	100.00	105.00	108.10
Average labor earnings	88.31	93.95	100.00	106.05	110.23
Taxable income (tax base)	104.13	102.29	100.00	96.94	95.93
Goods market					
Output (GDP)	88.31	93.87	100.00	106.15	110.22
Private consumption	89.77	94.90	100.00	104.24	106.98
Gross investment	77.96	87.85	100.00	114.06	123.57
Capital market					
Capital stock	78.01	87.83	100.00	114.09	123.58
Household wealth	79.23	88.55	100.00	113.42	123.49
Liquid assets	145.23	124.28	100.00	73.84	62.96
Superannuation assets	0.00	45.66	100.00	160.94	196.14
Share of liquidity constrained (%)	13.11	22.15	29.40	40.29	46.55
Annual interest rate (%)	5.34	4.85	4.31	3.76	3.44
Welfare impacts[a]					
Average welfare	97.53	98.85	100.00	100.85	101.28
Low-skill	98.20	99.20	100.00	100.60	100.92
High-skill	97.02	98.61	100.00	101.03	101.56

Notes: *Indexed to benchmark with SG=7% (=100), if not stated otherwise, with % change derived as alternative-benchmark; [a]Comparing lifetime utility levels for newborns under each alternative relative to benchmark.

Table 9: Fiscal effects of alternative SG rates in long run*

Variable	Alternative SG=0%	Alternative SG=3%	Benchmark SG=7%	Alternative SG=12%	Alternative SG=15%
Total tax revenue (from)	103.76	101.96	100.00	97.88	96.57
Progressive income taxes	105.30	102.98	100.00	95.70	94.54
Superannuation taxes	0.00	42.55	100.00	168.09	208.51
Consumption taxes	119.76	110.03	100.00	91.49	84.19
Average income tax rate (%)	13.55	13.25	12.94	12.59	12.48
Marginal income tax rate (%)	27.19	26.77	26.35	25.88	25.65
Consumption tax rate[a] (%)	13.99	12.17	10.48	9.19	8.25
Age pension expenditure	122.08	91.49	100.00	87.01	79.87
Distribution of those aged 65+ (%)					
- No age pension	7.05	15.35	22.86	30.51	34.39
- Full age pension	51.08	47.66	44.36	39.71	36.05
- Part age pension	41.87	36.99	32.77	29.78	29.55

Notes: *Indexed to benchmark with SG=7%, if not stated otherwise; [a]Effective consumption tax rate assumed to balance government budget.

Macroeconomic effects Table 8 shows the qualitatively opposite macroeconomic effects for increased SG rates (moving right from the benchmark column) compared to lower SG rates (moving left from the benchmark column).

Let's first consider the higher SG rate alternatives. The GE effects on factor prices are a result of capital deepening or a higher capital-labor ratio, which causes the market wage rate to increase while the domestic interest rate decreases.[53] The higher market wage rate, which has a substitution effect that dominates the wealth effect of larger household wealth, causes effective labor supply (or hours worked in efficiency unit) to increase, leading to higher (economy-wide) average labor earnings. However, as more income is subject to concessional superannuation taxation, the personal income tax base falls. The second GE effect allows for lower domestic interest rates in the long run, increasing investment demand, which in turn leads to a larger capital stock. These two inputs to production (capital and labor) generate higher output or real GDP under higher SG rate counterfactuals.

Table 8 indicates that households accumulate larger total assets under higher SG rates, as increased superannuation assets more than offset reduced liquid private assets. Moreover, households consume more, particularly at older ages, under these alternatives (as shown in Figure 4). For instance, in the economy with $SG = 12\%$, total household wealth increases by 13.42% (due to increased superannuation assets), and consumption increases by 4.24% in the long run compared to the benchmark with $SG = 7\%$. The share of liquidity-constrained households is also higher at 40.29% under $SG = 12\%$, compared to 29.4% under $SG = 7\%$ (due to an increased superannuation offset).

Contrary to the higher SG rate alternatives, the hypothetical $SG = 0\%$ counterfactual leads to a decline in total wealth, consumption and labor earnings per capita in the long run, despite a lower share of liquidity-constrained households in the economy. Specifically, total wealth, consumption and labor earnings per capita are shown to decline by 20.77%, 10.23% and 11.69% respectively, relative to the benchmark model with $SG = 7\%$.

[53] It is worth noting that mandatory superannuation (and particularly the legislated increase in the mandatory SG rate) has been frequently criticized for reducing take-home wages or limiting their growth. In Table 8, we report the long-run effects on the market (gross) wage rate, which increases under higher SG rate alternatives. We could also show the effects on the wage rate net of the mandatory SG rate (relative to $w - \tau^p = 0.93$ in the benchmark model), which are negative under higher SG rates. In fact, in the SOE model (abstracting from GE effects), any increase in the SG rate would be fully offset by a corresponding reduction in the take-home wage rate. However, in the present general equilibrium (closed economy) framework, we show that this negative effect of a higher SG rate on the take-home wage rate is mitigated in the long run.

Note that mandatory superannuation (and specifically the legislated increase in the mandatory SG rate) has been frequently criticized due to a reduction in take-home wages (or growth in take-home wages). In Table 8, we report the effects on the market (gross) wage rate which increases under higher SG rate alternatives. We could show the effects on the wage rate net of the mandatory SG rate (i.e., relative to $w - \tau^p = 0.93$ in the benchmark model) – which are negative under higher SG rates. In fact, in the SOE model (abstracting from GE effects), any increase in the SG rate would be fully offset by a corresponding reduction in the take-home wage rate. In the present general equilibrium (closed economy) framework, we show that this negative effect (of a higher SG rate) on the take-home wage rate is mitigated in the long run.

Fiscal effects The fiscal effects in Table 9, also indexed to the benchmark column in the middle of the table, indicate that higher SG rates reduce the size of the government budget in terms of total tax revenue, while lower SG rates increase it. It should be noted that under each SG rate counterfactual, government consumption and net debt (as well as social transfers) are kept constant, while the government budget is balanced by adjusting the consumption tax rate. Therefore, the reduction in total tax revenue is due to lower pension expenditures, which fall by 13% under $SG = 12\%$ compared to $SG = 7\%$. This is because of the age pension means testing (discussed below).[54]

As expected, higher SG rates reduce government revenues from progressive income taxes, while increasing revenues from (concessional) superannuation taxes. The lower income tax base in Table 8 leads to a decline in both (cohort-weighted average) marginal and average income tax rates under higher SG rates, reducing the progressivity of income taxation. We estimate the tax expenditure due to mandatory superannuation by calculating the total income tax revenue (including superannuation tax revenue) under each counterfactual and comparing it to the benchmark. This tax expenditure increases by about 0.6% of the benchmark GDP under $SG = 12\%$ (not shown in Table 9).

However, despite the increased superannuation tax expenditure, the (budget-equilibrating) consumption tax rate is adjusted down under higher SG rates. For example, under $SG = 12\%$, the consumption tax rate is reduced to 9.19% (from 10.48% in the benchmark). As indicated above, this reduction is due to changes in interest payments on government debt and public pension expenditure, both of which are lowered under higher SG rate counterfactuals.[55]

Table 9 also shows that changes to the SG mandate have an impact on public age pensions due to means testing. Higher (lower) SG rates result in larger (smaller) assets at older ages, causing pension expenditures to decline (increase) in the long run. For example, in an economy with no superannuation mandate, the public pension expenditure would increase by over 22% due to the reduced proportion of self-funded seniors (receiving no age pension) at 7.05% of the age-eligible population (compared to 22.86% in the benchmark). In contrast, in an economy with a future 12% SG rate, the public pension expenditure declines by 13%, with the proportion of self-funded seniors increasing to 30.51%. Therefore, the SG mandate not only impacts the progressivity of the income taxation (reducing it) but also impacts the progressivity of the public pension program (increasing it).

Welfare effects The average welfare effects, across all skill types, as well as for low- and high-skill types, are reported in Table 8. To calculate these effects, we simply determine the value of the lifetime utility function in (3) under each counterfactual and express the resulting

[54] In fact, the lower interest rates under higher SG rate alternatives also impact interest payments on government debt, which further contributes to the lower total tax revenue requirement.

[55] However, as shown in the next section, assuming SOE market structure (with constant factor prices), a higher SG rate would require a higher consumption tax rate to balance the government budget in the long run.

welfare effects as a percentage change relative to the benchmark value (indexed to 100).[56]

The lower section of Table 8 shows that increasing (reducing) the superannuation mandate leads to an improvement (deterioration) in average welfare in the long term, with the high-skill type experiencing larger welfare gains (losses) than the low-skill type. Eliminating mandatory superannuation (with $SG = 0\%$) would result in a long-term reduction of the average welfare by 2.47%, with high-skill households experiencing a welfare loss of approximately 3%, while low-skill households would experience a loss of 1.2%, relative to the benchmark economy with $SG = 7\%$.

In the economy with a future 12% SG rate, future-born households would experience an average welfare gain of 0.85%, as well as gains across the skill distribution, with low-skill households (high school dropouts) gaining 0.6%, and high-skill households (college graduates) gaining 1.03%, as indicated in Table 8. The last column of the table demonstrates that raising the SG rate to 15% of gross wages would result in an additional improvement in long-term welfare, with an average increase of 1.28%.[57]

Summary In this main result section, we have examined the long-term, economy-wide effects of the superannuation mandate, which requires working individuals to contribute to their retirement accounts, thus funding their income at older ages. We have demonstrated that the counterfactual economy without any mandate ($SG = 0\%$) would be much worse than the benchmark economy, with households being, on average, over 20% poorer in terms of their net wealth. Our model strongly supports the superannuation mandate (and higher SG rates), indicating that the economy with an increased SG rate of 12% will experience significantly higher average household wealth, labor supply, capital stock, output, consumption, and household welfare.

Next, we present sensitivity results, using modifications of this GE model, to explain and quantify the channels that contribute to the positive effects of the SG mandate.

[56] As indicated above, one could think of these percentage changes in the value functions as equivalent variations measuring the proportional percentage increase/decrease in consumption and leisure for each household needed in the benchmark model to produce the realized lifetime utility under each counterfactual.

[57] In fact, the optimal SG rate in the long term is much higher under the benchmark preferences as well as alternative preferences, as demonstrated in Appendix D. However, the effectiveness of the SG mandate should not be evaluated solely based on its long-term impact on the welfare of future generations, which is the focus of this paper. Although higher mandatory SG rates benefit future generations in the long run, they are likely to lead to short-term welfare losses for current elderly households. These households, while not directly affected by the increased mandate, would experience indirect effects through lower interest rates (with reduced returns on their asset holdings) and higher consumption taxes in the short term (due to financing increased tax expenditure resulting from higher tax-favored superannuation). Since the welfare losses of these elderly households must be compensated, very high SG rates are unlikely to be optimal over the transition path. We leave this optimal SG rate analysis over the transition path for future research.

6 Sensitivity analysis

This section provides the sensitivity analysis of the long-run results (previously reported for the $SG = 12\%$ counterfactual) for various modifications of the model, including both its economic features and the policy side of the model. The objective here, as in Section 2, is to identify and quantify the primary factors that contribute to the positive effects of increasing the SG rate to 12%.[58]

We consider the following modifications of the model: (i) market structure (a small open economy (SOE) with constant factor prices, which highlights the importance of general equilibrium (GE) effects in the benchmark model); (ii) superannuation tax concessions (eliminating all superannuation tax concessions by setting concessional tax rates to zero but with both contributions and fund investment earnings included in the income tax base); (iii) public age pension (a zero taper rate, implying a universal pension benefit to all age-eligible households); (iv) bequest redistribution changes (no redistribution, with all bequests fully taxed away, and government consumption balancing the government budget, which has no impact on household behavior); (v) the sum of all $(i) - (iv)$ modifications.[59]

It should be noted that only simulation (i) uses the same benchmark model as in the previous section. The other sensitivity checks require a new benchmark economy for each case. Our approach is to only recalibrate the productivity constant (normalizing to the benchmark wage rate = 1) and adjust government consumption (using the same tax schedule as in the benchmark model used in the previous section and given in Appendix A). While the utility levels across these modified benchmarks are not exactly the same as in the benchmark model calibrated in Section 4, they are similar enough to allow us to compare the long-term effects of the increased SG rate to 12% (from 7%) under these model modifications, relative to the results reported in Section 5.

Table 10 provides a comparison of the long-run macroeconomic and welfare effects of the increased mandatory contribution rate to 12% under the different model modifications (compared to the baseline results in Section 5 for the 12% SG rate (increased from 7%), which are reported in the first column of Table 10). We provide a brief discussion of the results for each model modification below.

[58] Note that in Section 2, we introduced the channels through which the SG mandate impacts household welfare sequentially – e.g. case 2 included household heterogeneity in labor income and the interaction of income tax and superannuation taxations, but not the age pension and bequest redistribution. In this section, we use the benchmark GE model and examine one modification at a time, changing one channel (e.g., removing superannuation tax concessions) while keeping all other channels in operation.

[59] In Appendix D, we present additional simulation results for various scenarios, including (a) a progressive income tax cut that affects superannuation tax concessions, (b) an alternative budget-equilibrating policy instrument that adjusts government consumption, (c) changes in household heterogeneity with respect to low- and high-skill types, including variations in labor productivity risk and gaps, and (d) alternative household preferences based on Conesa et al. (2009). For scenario (d), we also discuss the results for optimal SG mandate rates.

Table 10: Long-term effects of 12% SG rate under alternative model specifications*

Variable	Baseline[a]	(i) (SOE)[i]	(ii) (T^S)[ii]	(iii) (ap)[iii]	(iv) (bequest)[iv]	(v) (sum)[v]
Effective labour	1.05	-2.22	0.67	0.63	1.89	-0.96
Wage rate	5.00	0.00	6.00	5.10	5.20	0.00
Output (GDP)	6.15	-2.22	6.77	5.69	7.16	-0.98
Private consumption	4.24	3.03	4.50	3.65	3.26	-1.70
Capital stock	14.09	-2.22	16.35	13.63	15.44	-0.99
Household wealth	13.42	29.79	15.76	12.93	14.60	34.55
Liquid private assets	-26.16	-3.42	-31.40	-25.83	-25.71	-2.90
Superannuation assets	60.94	69.67	57.84	60.53	61.88	68.82
Liquidity constr. (p.p.)[b]	10.89	2.72	16.57	11.41	15.73	4.24
Interest rate (p.p.)	-0.55	0.00	-0.66	-0.56	-0.58	0.00
Marginal tax rate (p.p.)	-0.47	-0.90	0.78	-0.28	-0.33	0.14
Pension expenditure	-12.99	-11.69	-14.09	0.00	-13.33	0.00
Cons. tax rate (p.p.)[c]	-1.29	0.51	-3.47	-0.54	0.00	0.00
Welfare effects						
- Average	0.85	0.39	0.84	0.68	0.30	-1.84
- Low skill	0.60	0.34	0.80	0.43	0.06	-1.52
- High skill	1.03	0.45	0.87	0.84	0.50	-2.00

Notes: *% (or percentage point p.p.) changes relative to benchmark equilibrium with SG=7%; [a]Baseline results for the increased 12% SG rate in main Section 5; [b]Share of liquidity constrained household with p.p. change; [c]Assumed to balance the govt. budget (except for iv and v); [i]Small open economy market structure abstracting from general equilibrium effects on factor prices; [ii]Removal of superannuation tax concessions; [iii]Setting age pension taper rate to zero (universal pension to all age-eligible households); [iv]Bequest fully taxed and government consumption balancing govt budget; [v]Sum of modifications (i)-(iv).

(i) SOE market structure In this modification of the model, the analysis is conducted in a small open economy framework, which abstracts from general equilibrium (GE) effects on factor prices that were derived from the closed economy (CE) model used in Section 5. In this SOE economy, an exogenous interest rate (and wage rate) is assumed, with foreign assets and net export balancing the capital and goods markets. Comparing the results in columns 2 and 1 of Table 10, we observe that households accumulate larger household wealth but have lower consumption and labor supply relative to the baseline effects for the 12% SG rate. However, it is important to note that the CE market structure provides the upper bound for output, consumption and welfare results, while the SOE model provides the upper bound for household wealth effects (since the interest rate is constant and so would not decline in the counterfactual economy with higher SG rates).

Interestingly, the higher SG rate case causes average labor supply to fall in the SOE model because the wealth effect of larger household wealth dominates the substitution effect due only to concessional taxation of the SG mandate (as the market wage rate is constant in the SOE case).

Regarding welfare effects, in the SOE framework, the average welfare increases by 0.39%, which is lower than the 0.85% increase in the baseline effect under the CE framework. This difference is because the increased (gross) wage rate under the CE framework with the 12% SG rate, which also results in a consumption tax cut (down by 1.29 p.p.), while under the SOE framework, the consumption tax rate would need to increase to balance the government budget (up by 0.51 p.p.). These changes in the consumption tax rate affect the welfare effects differently. However, both frameworks show that the increased SG rate has a positive effect on average welfare, albeit at different magnitudes.

In summary, accounting for the GE effects of a higher SG mandate contributes to higher output, consumption and household welfare in the long run.

(ii) Superannuation tax concessions There are a number of options to account for the superannuation tax concession channel. In this (policy) modification, we assume that there are no superannuation tax concessions – by setting $\tau^s = \tau^r = 0$, but now both superannuation contributions and fund earnings included in the income tax base and fully taxable under $T(\tilde{y}_j)$.[60] In this case (as with all other modifications that will follow) we recalibrate the benchmark solution (with the 7% SG rate).

In the economy with no superannuation tax concessions (benchmark economy with $SG =$ 7%), there are more illiquid superannuation assets, resulting in lower liquid private assets. This is because there is no taxation of superannuation accumulated in illiquid accounts, while both SG contributions and fund investment earnings are now subject to progressive income taxation. Interestingly, the welfare and macroeconomic effects are similar to those in the main section with concessional superannuation tax arrangements. Specifically, the average welfare effects are similar to the baseline results, but as shown, they improve for the low-skill type and worsen for the high-skill type compared to the baseline results.

As mentioned earlier, there are other channels at play besides superannuation tax subsidies, such as the GE effects and pension means testing and bequest channels. Since superannuation contributions and withdrawals are mandated, an increased SG rate (with no taxes paid by superannuation funds) leads to a larger increase in superannuation assets and a larger offset in liquid assets (in absolute terms compared to the baseline results). Since superannuation contributions and fund earnings (like other personal income) are now taxed under the progressive tax schedule, the higher SG mandate leads to significantly larger revenues from progressive income taxes (note the increase in the marginal tax rate in Table 10) and a lower age pension expenditure (due to means testing of larger retirement assets). This allows for a greater cut in consumption tax, which has a positive impact on welfare, especially the low-skill type. The GE effects and bequest redistributions are also more pronounced under this modification with no

[60] In Appendix D, we also examine the 12% SG mandate in the economy with 30% income tax cut, which also reduces tax subsidies to superannuation.

superannuation tax concessions.

In summary, lowering superannuation tax concessions has only a marginal impact on the welfare effects of the increased SG rate, as other channels, such as the GE effects, are in operation with opposing effects on long-run welfare.

(iii) Age pension means test We will now examine the impact of removing the means testing of the age pension by setting the taper rate to $\theta = 0$. This modification results in a universal pension benefit ($\overline{p}$) paid to all elderly individuals aged $j \geq j_R$ at the same maximum rate as in the benchmark model. This change eliminates the interaction between mandatory superannuation and the public age pension – as is the case in many other developed countries with social security pension systems that are not means-tested and provide benefits independent of asset holdings and other private resources at older ages.

As shown in column *iii* of Table 10, due to the increased SG rate, the pension expenditure does not change, and hence the budget-equilibrating consumption tax cut is smaller (under the closed economy model with the GE effects in operation). While this modification removes some saving disincentives (as the pension benefit is no longer means tested or conditional on private retirement resources), it also implies higher pension benefits for many older people (compared to the baseline results with means-tested pensions). Similar to case 3. in Section 2, here (using the GE model) the welfare gains from an increased SG rate are lower (on average at 0.68%, compared to 0.85% for the baseline).

(iv) Bequest redistribution In this modification, we assume that bequests are fully taxed by the government and households no longer receive them. Therefore, bequests become a revenue component of the government budget, but we also assume that government consumption G is adjusted to balance the budget (instead of adjusting the consumption tax rate). This assumption applies to both the benchmark and the counterfactual economy with the increased 12% SG rate. The increase in SG rates results in higher bequest tax revenues, which do not affect household behavior and welfare (as they are not receiving any bequests).[61]

As observed in this counterfactual economy where bequests are fully taxed, effective labor, household assets, and output are larger than the baseline results, but the welfare gains are smaller (on average and by skill type). This is because the transfers of bequests to younger generations generated a pure income effect on labor supply, leading to a larger increase in average labor under this modification. However, the welfare effects across the skill distribution are relatively smaller due to reduced consumption when households are young and middle-aged, as bequests are now assumed to be fully taxed, and there is no consumption tax cut (with G balancing the budget).

[61] In Appendix D, we also present the results for budget-equilibrating adjustments in government consumption only (with the same bequest redistribution as in the benchmark model).

(v) Combined modification and summary In the final experiment of this section, we combine the four modifications$(i) - (iv)$ above into (v), and examine the long-term effects of the increased 12% rate on the economy. As shown in the last column of Table 10, under this combined model modification, the increased SG rate generates lower effective labor, output, and consumption per capita compared to the baseline results. With the removal of various channels depicted above, the increased SG mandate generates negative effects on household long-run welfare (similar to case 1. in Section 2).

In this sensitivity analysis section, we have examined the long-run economy-wide effects of increasing the SG rate to 12% (from 7%) under several modifications of the model (described in Section 3 and calibrated in Section 4). We have shown that the baseline effects of the higher SG mandate (discussed in Section 5) are impacted by interactions with the tax schedule and superannuation tax concessions, interactions with public pensions, bequest redistributions (similarly to the PE analysis in Section 2), but also the GE effects with adjustments in factor prices. None of these model modifications (alone) alters the sign of the welfare effect from the (legislated future) increased SG rate. However, under the combined modification in (v) (eliminating all the channels), the higher SG mandate would generate a welfare loss, which is shown to be larger for the high-skill type of households.[62]

7 Conclusions

This paper has analyzed the long-run economy-wide effects of the superannuation mandate – the mandatory contribution rate that individuals must contribute to their retirement accounts for the purpose of funding their retirement incomes. Using a stochastic OLG model with liquid ordinary private and illiquid private pension assets, we have shown that alternative mandatory rates generate different behavioral life cycle, macroeconomic and welfare effects in the long run. Our findings demonstrate that higher mandatory rates lead to significantly larger household total wealth, output and consumption per capita, and household welfare in the long run, whereas lower rates generate the opposite effect.

Specifically, our analysis suggests that the future economy with the legislated 12% SG rate would see significantly larger output, private consumption, and total household assets compared to the current benchmark economy. Average household wealth would increase by over 13% in the long run, and more elderly individuals would be fully self-funded, thereby reducing the reliance on means-tested public age pensions. Conversely, in an economy without a superannuation mandate, average household wealth and consumption per capita would reduce by over 20% and 10%, respectively.

Furthermore, our analysis indicates that the welfare of future generations would be significantly higher in an economy with the 12% SG rate, with gains across the skill distribution.

[62] Similar conclusions can be drawn from additional sensitivity analyses presented in Appendix D, which investigate modifications related to a less progressive income taxation, greater (inborn) income heterogeneity, and different household preferences.

Both low- and high-skill households would experience an increase in welfare, although the welfare gains of the superannuation mandate would be larger for high-skill households. Overall, our analysis highlights the crucial role of the superannuation mandate in improving long-term economic outcomes, particularly in terms of household welfare and consumption in retirement.

Importantly, we have identified and studied economic and policy channels through which a higher SG mandate impacts household welfare and the economy. These include the interactions with progressive income taxation (via superannuation tax concessions), public age pension (via means testing) and bequest redistributions (accidental bequest transfers to working age population) as well as general equilibrium effects on factor prices (long run adjustments in the labor market wage and domestic interest rates). Collectively, these channels generate positive macroeconomic and welfare effects of higher SG rates in the long run.

In this paper, we contribute to the existing literature on public pension privatizations and retirement financing (e.g., McGrattan and Prescott (2017), Hosseini and Shourideh (2019)) and private pensions (e.g., Nishiyama (2011), Ho (2017)), by analyzing the long-term effects of the private pension mandate. Our focus is on the economic impacts of alternative mandatory contribution rates of gross wages accumulated on illiquid superannuation accounts, which are preserved for retirement consumption. As indicated, our analysis takes into account the interaction of the private pension mandate with the public age pension, where higher mandatory contribution rates lead to lower public pensions due to means testing, thereby partially privatizing public pensions.

While previous literature on private pensions has focused on their taxation and liquidity features (e.g., penalties on early withdrawals) or specific reforms (including early Australian studies by Creedy and Guest (2008) and Kudrna and Woodland (2013, 2018)), we contribute to the literature by examining the economy-wide effects of the superannuation mandate. Specifically, we analyze the impact of the mandate on household economic decisions over the life cycle, welfare, and macroeconomic and fiscal aggregates. Our study fills an important gap in the literature on private pensions.

It is important to note that any modelling analysis, such as the one employed in this paper, is subject to qualifications and limitations. Firstly, we assume that households do not have the choice to contribute more than the mandate (up to the cap) into their retirement accounts and we also mandate superannuation withdrawals. It would be interesting to explore the extent to which allowing for voluntary superannuation contributions and withdrawals (within a rational agent framework) could alter the long-term effects of the increased mandate in this paper.

Secondly, we have used an OLG model with rational agents. A potential avenue for future research would be to study the economic effects of the increased mandatory contribution rate in an OLG model populated by agents that do not behave rationally and instead have self-control preferences, as used, for example, by Kumru and Thanopoulos (2011) in their analysis of US social security. In such a model, with some or all myopic households, the welfare effects of the superannuation mandate may further improve, as the mandate would help to correct for myopic behavior.

Thirdly, we have abstracted from the transition path effects of the private pension mandate on household welfare and the economy, focusing solely on its long-term impacts. As discussed earlier, higher mandatory SG rates, which are shown to benefit future generations' welfare in the long run, are likely to lead to short-term welfare losses for current elderly households. Although these households are not directly affected by the increased mandate, they would experience indirect effects through lower interest rates and higher budget-equilibrating tax rates in the short term. A future research direction could involve conducting a transition path analysis of the SG mandate, accounting for aging transition, to better understand both its short-term and long-term welfare and economic impacts.

8 References

Australian Bureau of Statistics (ABS) (2019a), Life Tables, States, Territories and Australia, 2016-2018. Cat. no. 3302.0.55.001.

ABS (2019b), National, State and Territory Population, Cat. no. 3101.0.

ABS (2019c), Australian System of National Accounts, Cat. no. 5204.0.

ABS (2019d), Labor Force, Australia. Cat. no. 6202.0.

ABS (2019e), Household Income and Wealth, Australia, Cat. no. 6523.0.

ABS (2019f), Average Weekly Earnings, Australia, Cat. no. 6302.0.

Australian Government (2018), Budget Paper No. 1: Budget Strategy and Outlook. Commonwealth of Australia, Canberra.

Auerbach, A. and L. Kotlikoff (1987), *Dynamic fiscal policy*, Cambridge.

Beshears, J., J. Choi, D. Laibson and B. Madrian (2009), "The importance of default options for retirement saving outcomes: Evidence from the United States", in: J. Brown, J. Liebman and D. Wise (eds.), *Social Security Policy in a Changing Environment*, University of Chicago Press.

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

Breuning, R. and K. Sobeck (2020), The Economic Incidence of Superannuation, Crawford School of Public Policy, Canberra.

Chan, M., T. Morris, C. Polidano and H. Vu (2022), "Income and saving responses to tax incentives for private retirement savings", *Journal of Public Economics* 206.

Cho, S. and R. Sane (2013), "Means tested age pensions and homeownership: Is there a link?", *Macroeconomic Dynamics* 17(6), 1281-1310.

Chomik, R., S. Graham, S. Yan, H. Bateman and J. Piggott (2018), Retirement income in Australia: Part III – Private resources, CEPAR research brief, November 2018.

Chomik, R. and J. Piggott (2018), "Tax Expenditures on Pensions: Concepts, Concerns, and Misconceptions", in: R. Holzmann and J. Piggott (eds.), *The Taxation of Pensions*, Cambridge: MIT Press.

Conesa, J., S. Kitao and D. Kruger (2009), "Taxing capital? Not a bad idea after all!", *American Economic Review* 99, 25-48.

Connolly, E. (2007), "The effect of the Australian Superannuation Guarantee on household saving behaviour", Reverse Bank of Australia Research Discussion Paper, Sydney.

Connolly, E. and M. Kohler (2004), "The Impact of Superannuation on Household Saving", Research Discussion Paper 2004-01, Reserve Bank of Australia, Sydney.

Creedy, J. and R. Guest (2008), "Changes in Taxation of Private Pensions: Macroeconomic and Welfare Effects", *Journal of Policy Modelling* 30, 693-712.

De Nardi, M. (2004), "Wealth Inequality and Intergenerational Links", *Review of Economics Studies* 71, 743-768.

Fehr, H., C. Habermann and F. Kindermann (2008), "Tax-Favored Retirement Accounts: Are They Efficient in Increasing Savings and Economic Growth?", *FinanzArchiv: Public Finance Analysis* 64, 171-198.

Fehr, H., M. Hofmann and G. Kudrna (2021), "Pensions, Income Taxes and Homeownership: A Cross-country Analysis", CEPAR Working Paper 2021/23.

Fehr, H., M. Kallweit and F. Kindermann (2013), "Should pensions be progressive?", *European Economic Review* 63, 94-116.

Fehr, H. and F. Kindermann (2010), "Pension funding and individual accounts in economies with life-cyclers and myopes", *CESifo Economic Studies* 56, 404-443.

Fehr, H. and F. Kindermann (2018), *Introduction to Computational Economics Using Fortran*, Oxford University Press.

Fernández-Villaverde, J. and D. Krueger (2007), "Consumption over the life cycle: Some facts from consumer expenditure survey data", *Review of Economics and Statistics* 89 (3), 552-565.

Freestone, O. (2018), "The Drivers of Life-Cycle Wage Inequality in Australia", *Economic Record* 94, 424-444.

Gomes, F., A. Michaelides and V. Polkovnichenko (2009), "Optimal savings with taxable and tax-deferred accounts", *Review of Economic Dynamics*, 718-735.

Ho, A. (2017), "Tax-deferred saving accounts: Heterogeneity and policy reforms", *European Economic Review* 97, 26-41.

Hansen, G. and S. Imrohoroglu (2008), "Consumption over the life cycle: The role of annuities", *Review of Economic Dynamics* 11, 566-583.

Hosseini, R. and A. Shourideh (2019), "Retirement financing: An optimal reform approach", *Econometrica* 84(4), 1205-1265.

Imrohoroglu, A., S. Imrohoroglu and D. Joines (1998), "The effect of tax-favored retirement accounts on capital accumulation", *American Economic Review* 88(4), 749-768.

Kaas, L., G. Kocharkov, E. Preugschat and N. Siassi (2021), "Low homeownership in Germany: A quantitative exploration", *Journal of the European Economic Association* 19(1), 128-164.

Kaplan G., G. Violante and J. Weidner (2014), "The Wealthy Hand-to-Mouth", *Brookings Papers on Economic Activity*, Spring, 77-138.

Kitao, S. (2014), "Sustainable social security: Four options", *Review of Economic Dynamics* 17(4), 756-779.

Kitao, S. (2015), "Pension reform and individual retirement accounts in Japan", *Journal of the Japanese and International Economics* 38, 111-126.

Kudrna, G. (2016), "Economy-wide effects of means-tested pensions: The case of Australia", *Journal of the Economics of Ageing* 7, 17-29.

Kudrna, G., and A. Woodland (2013), "Macroeconomic and Welfare Effects of the 2010 Changes to Mandatory Superannuation", *Economic Record* 89, 445-468.

Kudrna, G. and A. Woodland (2018), "Progressive tax changes to superannuation in a life-cycle framework", in: R. Holzmann and J. Piggott (eds.), *The Taxation of Pensions*, Cambridge: MIT Press.

Kudrna, G., C. Tran, and A. Woodland (2019), "Facing demographic challenges: Pension cuts or tax hikes?", *Macroeconomic Dynamics* 23(2), 625-673.

Kudrna, G., C. Tran, and A. Woodland (2022), "Sustainable and Equitable Pensions with Means Testing in Aging Economies", *European Economic Review* 141, 103947.

Kumru, C. and A. Thanopoulos (2011), "Social Security Reform with Self-control Preferences", *Journal of Public Economics* 95(7), 886-889.

La Cava, G. and L. Wang (2021), "The Rise in Household Liquidity", Reverse Bank of Australia Research Discussion Paper 2021-10, Sydney.

Lin, H-C, A. Tanaka and P-S Wu (2021), "Shifting from pay-as-you-go to individual retirement accounts: A path to a sustainable pension system", *Journal of Macroeconomics* 69, 103329.

Longmuir, M. (2021), Fair crack of the whip? The distribution of augmented wealth in Australia from 2002 to 2018, Melbourne Institute Working Paper No. 04/21.

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

Nishiyama, S. (2011), "The budgetary and welfare effects of tax-deferred retirement saving accounts", *Journal of Public Economics* 95(11), 1561-1578.

Nishyiama, S and K. Smetters (2005), "Consumption Taxes and Economic Efficiency with Idiosyncratic Wage Shocks", *Journal of Political Economy* 113(5), 1088-1115.

OECD (2019), Pensions at a Glance 2019: OECD and G20 Indicators, OECD Publishing, Paris.

OECD (2021), Pension Markets in Focus 2021, OECD Publishing, Paris.

Summerfield, M., Bright, S., Hahn, M., La, N., Macalalad, N., Watson, N., Wilkins, R. and Wooden, M. (2019). HILDA User Manual – Release 18. Melbourne Institute: Applied Economic and Social Research, University of Melbourne.

Willis Towers Watson (2021), Global Pension Assets Study 2021.

Wood, D., K. Griffiths and O. Emslie (2019), Generation Gap: Ensuring a Fair Go for Younger Australians, Grattan Institute.

9 Appendix

In this appendix, we provide more details about A. Australia's tax and pension systems, B. results for partial equilibrium (PE) model analysis, C. calibration of the GE model and D. results for the sensitivity analysis, using the general equilibrium (GE) model.

A. Australia's tax and pension system

Australia's tax and transfer system In Australia, the largest share of government revenue comes from taxing household income, with the tax base including labor earnings and public pensions, as well as capital income. However, most government transfers are means-tested and targeted towards those in need. The tax and transfer system is highly progressive, not only due to the income tax schedule (provided below), but also due to the progressivity of government transfer payments. Corporate taxation is comparatively high, with a statutory rate of 30% for large companies. In contrast, indirect consumption taxes are low in Australia compared to many European countries, with an effective consumption tax rate of about 10% (including all indirect taxes) and only a 7% effective GST rate.

Below, we provide more details about the progressive income tax schedule in Australia. It has five tax brackets, including the first tax-free brackets, four positive marginal tax rates, imposed on the tax base $\widetilde{y}$, which includes labor earnings (net of mandatory superannuation contributions), capital income and public pension. The schedule used in the paper is based on the 2017-18 financial year, with the total income tax $T(\widetilde{y})$ in (5) expressed as:

$$T(\widetilde{y}) = \begin{cases} 0 & \text{if} \quad \widetilde{y} \leq 0.28\overline{y} \\ 0.19\,(\widetilde{y} - 0.28\overline{y}) & \text{if} \quad 0.28\overline{y} < \widetilde{y} \leq 0.58\overline{y} \\ 0.056\overline{y} + 0.325\,(\widetilde{y} - 0.58\overline{y}) & \text{if} \quad 0.58\overline{y} < \widetilde{y} \leq 1.4\overline{y} \\ 0.325\overline{y} + 0.37\,(\widetilde{y} - 1.4\overline{y}) & \text{if} \quad 1.4\overline{y} < \widetilde{y} \leq 2.8\overline{y} \\ 0.845\overline{y} + 0.45\,(\widetilde{y} - 2.8\overline{y}) & \text{if} \quad \widetilde{y} > 2.8\overline{y} \end{cases} .$$

where we index the income thresholds and taxes (paid at the thresholds) to the annual average earnings of $\overline{y} = \$64,000$ in 2018 (ABS 2019f) – e.g., the tax-free and top income thresholds in dollar terms are $\$18,200$ and $\$180,000$, respectively.[63]

Fehr et al. (2021) show that Australia collects a higher proportion of its revenue from income taxes compared to other developed countries such as the US and Germany. However, unlike many other countries, Australia does not collect a payroll tax to fund public pensions. Consequently, the overall taxation of labor in Australia is lower than in many other developed

[63] In our model, we have adjusted the tax schedule to account for the Medicare levy of 2%, which increases the marginal tax rate for all non-zero income levels. As a result, the top marginal tax rate (in the highest tax bracket) now stands at 47%.

To represent this tax schedule in our model, we use a linear approximation that increases the marginal tax rates in each tax bracket around its threshold. For instance, between the income levels of $0.25y$ and $0.28y$, the marginal tax rate increases linearly from 0% to 19%.

countries. To illustrate, if we were to include the payroll tax rate that finances PAYG pensions in Germany, the effective top marginal tax rate on labor, under its progressive personal income taxation system, would be well over 50%.

Australia's public pension While most developed countries rely on their PAYG social insurance systems, which provide the elderly with defined benefit pensions financed by payroll taxes on workers, Australia has a non-contributory and means-tested public age pension with a modest maximum pension benefit. As outlined in Kudrna et al. (2022), the age pension has the following distinct features: (*i*) pension benefits are means-tested and targeted towards the age-eligible population with limited private financial resources; (*ii*) pension coverage is not universal, as some affluent retirees do not receive any public pension; (*iii*) pension benefits are independent of an individual's contribution or working history; and (*iv*) the financing instrument for the pension is not restricted to the payroll tax revenue collected from the current working population. Note that the pension benefit is affluence-tested in Australia, with around 75% of eligible recipients receiving some payment, and only 45% of the age-eligible population receiving the maximum benefit, which is modest at around 30% of average earnings.

The means test for the age pension consists of two tests: an income test and an asset test. The outcome of each test determines the lower pension benefit that is applied (i.e., the binding test). Each test comprises three elements: (*i*) the maximum benefit (which depends on the household unit and homeownership status); (*ii*) the disregard (up to which the maximum benefit is paid); and (*iii*) the taper (at which the pension benefit is reduced if the private resource (income and asset) exceeds the disregard). The interactions between the income and asset tests are complex, and the taper can be non-linear with respect to assessable income and assets.

In our model, we approximate these complex interactions by employing the calibrated income test, which mainly captures retirement assets and incomes, and only partly considers earnings at older ages. As demonstrated in Section 4, our benchmark model closely aligns with the observed distribution of the age-eligible population for the age pension and the total pension expenditure, which is less than 3% of GDP. This expenditure is relatively low compared to other developed countries (see OECD 2019).

Australia's superannuation In Australia, the second pension pillar is based on a mandatory, privately-managed retirement savings system known as superannuation. This defined contribution system is regulated by the government and is represented by privately-managed retirement saving accounts. The legislation that governs the system is known as the Superannuation Guarantee (SG), which has been in place for over 30 years. The SG rate was initially set at $3-4\%$ (of gross wages) when the legislation was introduced in 1992. The rate is currently at 10% and is set to increase to 12% in the financial year of 2025-26 and beyond. Table $A.1$ provides a record of the SG rates since 1992. Initially, the SG rate differed depending on the size of the employer, and the increasing SG rate suggests that the mandatory superannuation system is still in a transition phase.

In our model, we calibrate the mandatory SG contribution rate to approximate the current size of the superannuation system. The benchmark SG rate is 7%, which approximates the average SG rate between 1992 and 2017.

Table A.1: Mandatory SG rate (% of gross wages)

Year/Period	Small employers	Large employers
1992	3	4
1993	3	5
1994	4	5
1995	5	6
1996-97	6	6
1998-99	7	7
2000-01	8	8
2002-13	9	9
2014	9.25	9.25
2015-21	9.5	9.5
2022	10	10
2023	10.5	10.5
2024	11	11
2025	11.5	11.5
2026+	12	12

Source: Australian Taxation Office (ATO)

Note that Australia's third pension pillar includes voluntary superannuation that receives smaller tax concessions and is also illiquid until reaching the preservation age. Australians often have only one superannuation account which collects all (mandatory and voluntary) contributions. In the model, we abstract from modeling voluntary contributions (of the household choice) since the focus on the superannuation mandate. On average, voluntary (after-tax) contributions are less important (and only relevant for higher skill types at mature ages). As indicated, the superannuation mandate (minimum employer contributions) is the main driving force behind significant increases in superannuation assets in Australia (in the past and projected over the next 40 years).[64]

It is important to note that superannuation assets are subject to the means test for the public age pension. This means that having higher private retirement assets will reduce the dependence on the public age pension and lower public pension expenditure. Unlike other private income, superannuation is not subject to progressive personal income taxation. Instead, taxes on superannuation contributions and fund earnings are highly concessional, featuring flat

[64] Also note that many employers pay higher rates of mandatory contributions to their employees' superannuation (e.g., academics at Australian universities are paid 17% of gross wages to superannuation).

rates at 15% on contributions and (effective) 7% on fund earnings. This is in contrast to the top marginal tax rate of 47%, including the Medicare levy. This concessional tax treatment generates the so-called superannuation tax expenditure – the income tax revenue forgone from taxing superannuation income at lower rates (see Chomik and Piggott (2018) for details on calculating such tax expenditures). Our model takes into account this expenditure, which increases with higher SG rates, as well as the means testing for the public pension at older age.

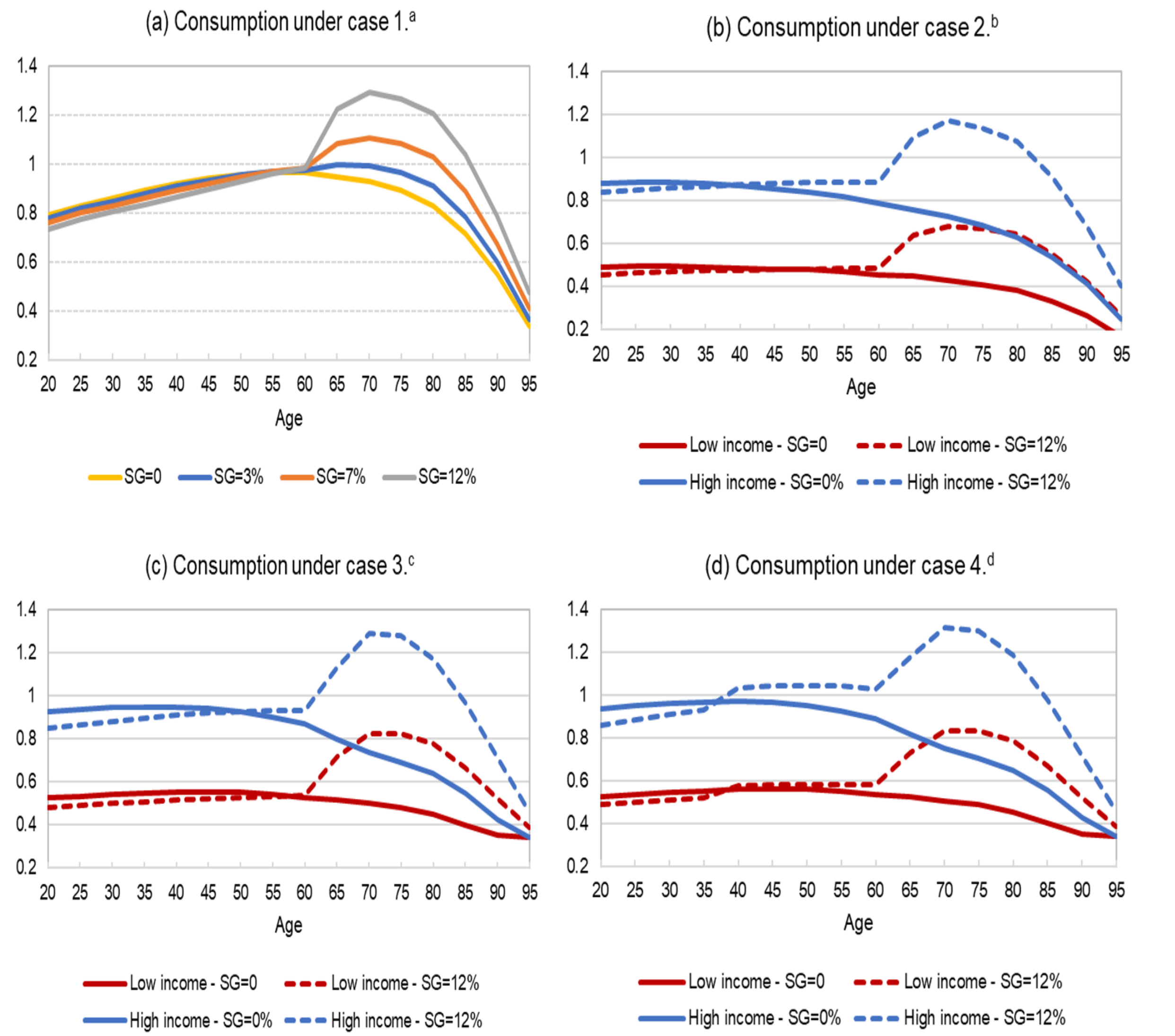
How does Australia's superannuation scheme compare to private pension systems in other developed countries? For example, in the US, the private pension system is well developed, based on individual retirement accounts (IRAs), with main (employment-related) 401k plans that are also tax-favored. Although the US government does not mandate contributions to these accounts, many employment schemes use behavioral economics and finance features to replicate the mandate, such as auto-enrollment and contribution rate escalations (see Beshears et al. 2009). In our model with rational agents, we provide strong support for mandating retirement savings, but we also show these positive effects would be mitigated under public policy settings with less progressive income taxation and public pensions that are independent of private retirement resources.

B. Additional results for PE analysis

In this appendix, we present additional results for the partial equilibrium (PE) life-cycle analysis of the superannuation mandate discussed in Section 2 of the main text.

In Figure $B.1$, we display the consumption profiles under different mandatory SG rates for the four examined cases (variations of the PE model). For case 1., where we assume stochastic labor income and only one household type, we plot the consumption profiles for all the examined SG rates. In the other cases, there are two types of workers with high and low incomes. We assume a 100% (mean) gap in the incomes of the low and high-income types, and for clarity, we only present the consumption profiles under $SG = 0\%$ and $SG = 12\%$. For case 3., we assume a means-tested public pension, and for case 4., we assume accidental bequest redistribution (transfers of aggregated total assets of all those that pass away) to surviving households aged 40-60 (within each skill type).

Figure B.1: Life-cycle effects on different SG rate on consumption under cases 1.-4.*

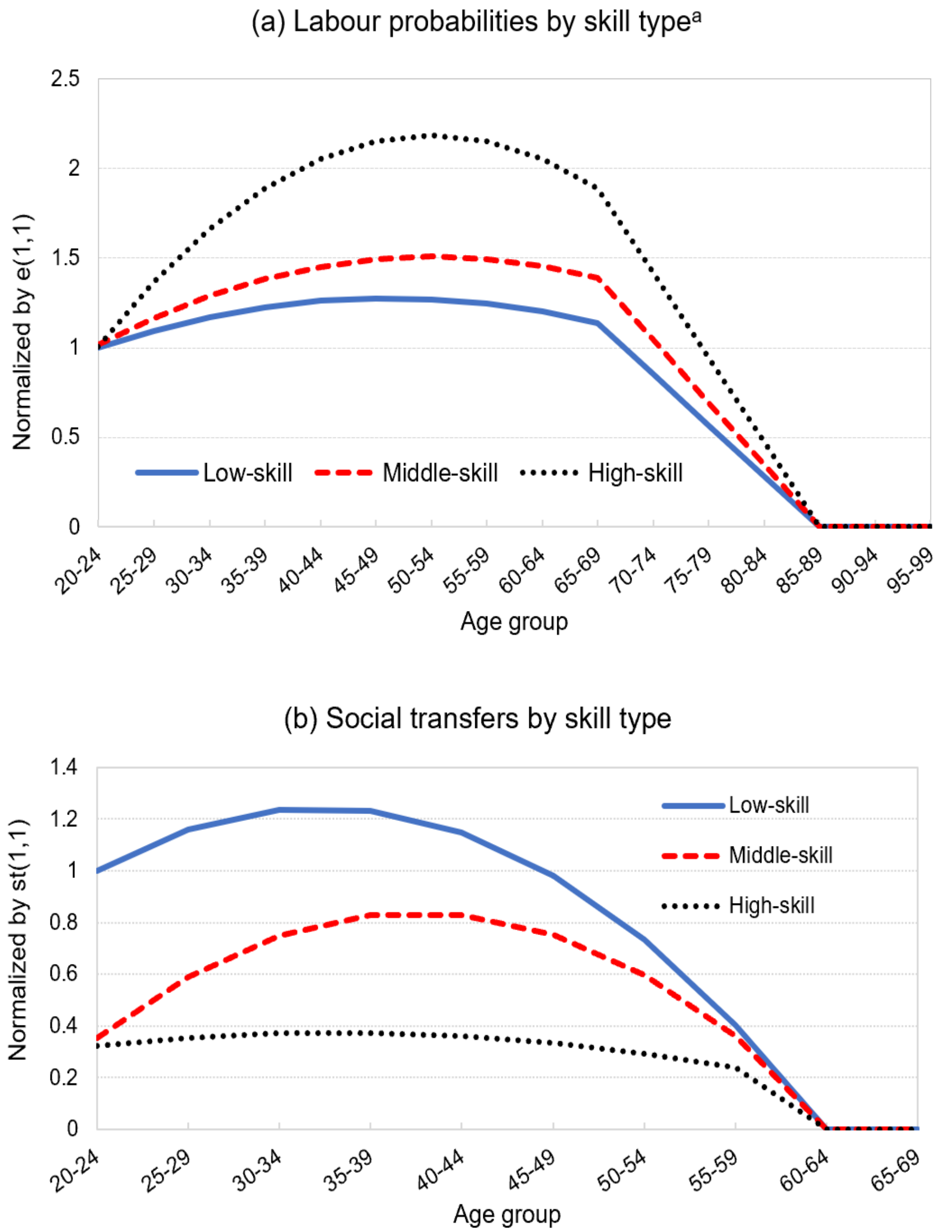


Notes: *Relative to average labor income; [a]Assuming stochastic labor income; [b]Assuming 100% income gap between low- and high-income types; [c]Assuming means-tested public pension; [d]Assuming bequest redistribution to those 40-60 (or 40-44 to 60-64 age groups).

C. Details on calibration and performance of the model

Labor productivity and social transfers Labor productivity and social transfers are estimated using HILDA18 (Survey waves 1-18). The age-profiles by educational type – low (high school (HS) dropouts), middle (HS graduates and those with vocational degrees) and high (college graduates with bachelor degree and above) types – for the deterministic component of labor productivity, $e_{j.i}$ and social transfers (to working age households) $st_{j.i}$ are presented in Figure $C.1$.

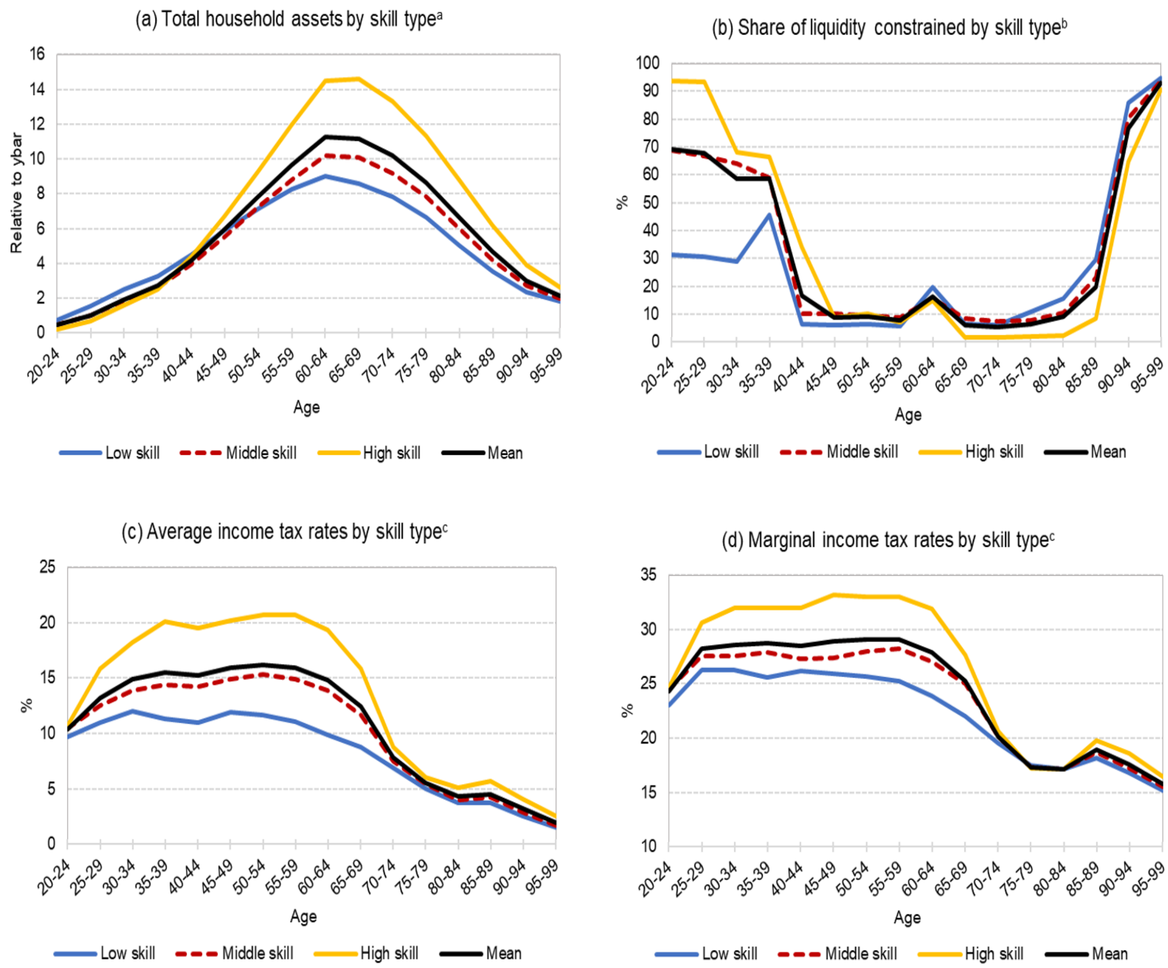
Figure C.1: Estimated labour productivity (mean) and social transfers*



Notes: *Estimated using HILDA-18 data, with low-skill types = HS dropouts, middle-skill types = HS graduates + those with vocational degrees, and high-skill types = college graduates with bachelor degree and above; [a]Deterministic component of labor productivity.

Additional life-cycle solutions of the benchmark model Figure C.2 plots the benchmark solutions for (a) total household assets, (b) liquidity constraint measure, (c) average income tax rates and (d) marginal income tax rates (over the life cycle and by skill type).

Figure C.2: Benchmark solutions for selected household variables over the life cycle



Notes: [a]Relative to benchmark average earnings (ybar=A\$64,000 p.a.); [b]Share of liquidity constrained households (wealthy hand-to-mouth with illiquid assets (due to the SG mandate); [c]Income tax rate in %.

As anticipated, these distributional outcomes reveal that high-skill types accumulate larger assets and face higher average and marginal income tax rates compared to low-skill types. The distributional gaps are the widest for older working ages between 55-64. As indicated in Figure $C.2(d)$, even low-skill types face higher marginal income tax rates than the (concessional) superannuation tax rates. However, since high-skill types face higher marginal income tax rates, they benefit more from the SG mandate than low-skill types. Interestingly, as shown in Figure $C.2(b)$, the share of liquidity-constrained households (wealthy hand-to-mouth) is higher among high-skill households at younger working ages. This is because they consume more (and save less in liquid assets) in anticipation of future earnings and superannuation assets, which are both larger for high-skill households compared to low-skill types.

D. Additional results for sensitivity analysis

In this appendix, we present additional results for the sensitivity analysis under (other) modifications of the GE model, assuming (a) less progressive income taxation; (b) an alternative budget-equilibrating policy instrument; (c) more household income heterogeneity (changing parameterization of the variance or deterministic component of labor productivity for low- and high-skill household types); and (d) alternative household preferences. In Table D.1, we present the long-term effects of the increased 12% SG rate under modifications (a) – (c), which we briefly describe below. Following that, we discuss the results for modifications under (d) with alternative household preferences (of rational agents), drawing on Conesa et al. (2009).

Table D.1: Long-term effects of 12% SG rate under different model specifications*

Variable	Baseline[a]	(a) (T(y))[i]	(b) (G)[ii]	(c) (LeRisk)[iii]	(c) (LeGap)[iv]
Effective labour	1.05	0.88	1.08	1.32	1.23
Wage rate	5.00	4.30	5.00	4.90	5.00
Output (GDP)	6.15	5.21	6.15	6.27	6.45
Private consumption	4.24	3.32	3.03	4.50	4.61
Capital stock	14.09	11.96	14.05	13.98	14.62
Household wealth	13.42	11.42	13.26	13.15	14.31
Liquid private assets	-26.16	-25.49	-26.42	-25.35	-24.86
Superannuation assets	60.94	62.21	60.89	61.49	61.27
Liquidity constr. (p.p.)	10.89	8.15	8.19	9.19	8.98
Interest rate (p.p.)	-0.55	-0.47	-0.56	-0.54	-0.56
Marginal tax rate (p.p.)	-0.47	-0.35	-0.44	-0.39	-0.57
Pension expenditure	-12.99	-12.03	-12.99	-12.82	-11.49
Cons. tax rate (p.p.)[b]	-1.29	-1.16	0.00	-1.38	-1.41
Welfare effects					
- Average	0.85	0.62	0.45	0.85	0.81
- Low skill	0.60	0.44	0.22	0.69	0.29
- High skill	1.03	0.78	0.63	0.96	1.19

Notes: *% (or percentage point p.p.) changes relative to benchmark (of each modification); [a]Baseline results for increased 12% SG rate in Section 5; [b]Balancing govt budget (except for (b)), [i]Scaling the tax schedule down by 30% (i.e., proportional 30% tax cut); [ii]Government consumption balancing govt budget; [iii]Lowering (increasing) variance of labor productivity of low skill (high skill); [iv]Lowering (increasing) deterministic labor productivity of low skill (high skill).

(a) Less progressive income tax schedule Under this modification, we assume a less progressive income tax schedule by implementing a 30% tax cut – scaling the progressive income tax schedule by $0.73 \cdot f_i$.[65] As shown in the (a) column of Table D.1, in the economy with lower progressive income taxes, the benefits of an increased SG rate in terms of welfare effects are lower, since the superannuation tax concession channel has been reduced. However, households still gain on average (0.61%) in welfare, as other channels, such as higher bequest redistribution and positive GE effects, are in operation. As expected, high-skill households experience a greater

[65] Recall that in the benchmark model, we calculate the income tax scalar ($f_i = 0.9$) to match the government progressive income tax revenue (of 11.4% of GDP). This scalar is further scaled down by 30% under the new benchmark with $SG = 7\%$ and the counterfactual with $SG = 12\%$.

drop in their welfare gain (compared to the baseline result) under this tax policy modification of the model. Hence, the less progressive income tax schedule (which implies lower superannuation tax concessions) reduces the welfare gains from the increased SG rate.

(b) Alternative budget-equilibrating policy instrument Here, we consider an alternative budget-balancing policy instrument: government consumption G (which has no impact on household behavior in our model). Under this modification, the consumption tax rate is kept at the benchmark level (so the change in τ^c in Table $D.1$ is zero).

As seen in the (b) column of Table $D.1$, the macroeconomic effects are very similar to the baseline, but the welfare effects are smaller, with average welfare effects at 0.45% (compared to 0.85% for the baseline), as higher G (not shown in the table) is assumed to have no effect on household welfare. Similarly to (a), the choice of a budget-equilibrating tax policy under (b) is shown to impact the results of the higher SG rate quantitatively, but not qualitatively.[66]

(c) Changes to inborn heterogeneity in labor productivity In this model modification, we incorporate two changes in labor productivity for low- and high-skill types. First, we reduce (increase) the variance of labor productivity for the low-skill (high-skill) type, denoted as LeRisk. Second, we reduce (increase) the deterministic labor productivity for the low-skill (high-skill) type, denoted as LeGap.

The last two columns of Table 10 show that the long-term macroeconomic variables and average welfare results are very similar to the baseline results. This is not surprising because in both modifications, we account for offsetting effects for low- and high-skill types, while keeping the labor productivity for the middle-skill type (which represents nearly 50% of the population) the same as in the benchmark model. However, there are different distributional welfare effects under the two modifications. Under (i) LeRisk, the low-skill (high-skill) type benefits more (less) from the SG rate increase due to a lower (higher) labor income risk. Similar implications were shown in Section 2 for case 1., where we compared the effects of a higher SG mandate in a stochastic versus a deterministic life-cycle model. In contrast, under (ii) LeGap, the low-skill (high-skill) type benefits less (more) from the SG rate increase compared to the baseline results. We observe the same channel (widening the income gap with changes to relative superannuation tax concessions through their interactions with the progressive income tax schedule) as in Section 2, but here in the GE model, other channels also come into operation, which impact household welfare and the economy. As a result, the effect on the low-skill type's welfare is still positive under (ii) LeGap.

[66] Recall that the positive welfare effects due to the budget-equilibrating adjustments (cuts) in the consumption tax rate are conditional on the active GE effect channel. As shown in the sensitivity analysis section, under the SOE model abstracting from the GE effects, the consumption tax rate was actually increased as a result of the higher SG mandate (and higher superannuation tax concessions).

(d) Alternative household preferences We present additional sensitivity checks of the long-run results to alternative household preferences. We follow Conesa et al. (2009) in removing the bequest motive and assuming non-separable preferences in consumption and leisure, as well as separable preferences. For each modification, we fully recalibrate the model for the new initial steady state to match all the targets of the benchmark model described in Section 3. It is worth noting that this is different from the sensitivity checks in Section 5, where we did not fully recalibrate the new benchmarks (i.e., the discount factor remained unchanged), whereas in the model without the bequest motive and with alternative preferences, the discount factor is recalibrated to match the benchmark K/Y. Below, we first provide the notation for these alternative preferences and then discuss the long-run results.

In line with Conesa et al. (2009), we assume that households have preferences over streams of consumption c_j and leisure l_j, where the expected discounted lifetime utility function is expressed as follows:

$$E\left[\sum_{j=1}^{J}\beta^{j-1}\left(\prod_{o=1}^{j}\psi_{o,i}\right)u(c_j,l_j)\right],$$

where the annual utility is either $u(i)$ non-separable of Cobb-Douglas functional form[67]

$$u(c,l)=\frac{\left(c^{\nu}l^{1-\nu}\right)^{1-\sigma}}{1-\sigma},$$

or $u(ii)$ separable in consumption and leisure and given by

$$u(c,l)=\frac{c^{1-\sigma_1}}{1-\sigma_1}+\chi\frac{l^{1-\sigma_2}}{1-\sigma_2}.$$

As in Conesa et al. (2009), in the first case $u(i)$, σ is set to 4 and ν to 0.37 (that is the same for each skill type and targets average hours), both determining the coefficient of relative risk aversion in consumption as $\sigma\nu+1-\nu$. In the second case $u(ii)$, we set $\sigma_1=2$, $\sigma_2=3$ and $\chi=2.5$ (to match average hours). For each modification, the subjective discount factor, β, is recalibrated to match the benchmark K/Y. Under these alternative preferences, we also abstract from the consumption equivalence parameter (denoted μ in (3) of the model section).

As indicated in each of the alternative preference cases above, we fully recalibrate the initial steady-state solution and then study the effects of the increased future 12% SG rate in these alternative preference frameworks. The long-run effects of the increased SG rate (i.e., change from 7% SG rate to 12% SG rate) are shown in Table $D.2$, which also includes the baseline results for comparison (discussed in the main quantitative section of the paper). Note that since household preferences differ across the three initial steady states, the welfare effects can only be compared qualitatively across the alternatives. However, since we recalibrate the benchmark

[67] The same function is used in the main text, but here we abstract from bequest motive and consumption equivalance – exactly following Conesa et al. (2009).

model (with $SG = 7\%$) for this part (d), the macroeconomic results of the SG rate increase can be compared both qualitatively and quantitatively.

Table D.2: Long run effects of SG rate increase - alternative utility assumptions*

Variable	SG=12%		
	Baseline	u(i)	u(ii)
Effective labour	1.05	1.00	0.39
Wage rate	5.00	5.50	5.00
Output (GDP)	6.15	6.58	5.49
Private consumption	4.24	4.27	3.26
Capital stock	14.09	15.96	14.04
Household wealth	13.42	15.19	13.52
Liquid private assets	-26.16	-21.23	-22.71
Superannuation assets	60.94	60.74	61.64
Liquidity constr. (p.p.)	10.89	6.22	6.52
Interest rate (p.p.)	-0.55	-0.63	-0.57
Marginal tax rate (p.p.)	-0.47	-0.47	-0.48
Pension expenditure	-12.99	-12.50	-13.10
Cons. tax rate (p.p.)[a]	-1.29	-1.44	-0.95
Welfare effects			
- Average	0.85	0.87	1.05
- Low skill	0.60	0.65	0.80
- High skill	1.03	1.02	1.15

Notes: *% (or percentage point p.p.) changes relative to benchmark equilibrium under each model, with baseline results as in Section 5 and u(i) and u(ii) denoting the effects under two alternative household preferences; [a]Balancing the government budget.

The main finding observed from Table $D.2$ is that qualitatively, the effects of the SG rate increase are similar across the three models with alternative preferences. Quantitatively, the effects are also largely similar, with the exception of the long-run impact on effective labor, which is lower under $u(ii)$. Additionally, there are some quantitative differences under $u(ii)$, such as a smaller increase in aggregate consumption but higher and more equal welfare effects.

We have also examined the long-run effects of higher SG rates (above 20%) under the three utility specifications. The findings indicate that the magnitude of the results becomes larger but with the same direction, except for effective labor supply under $u(ii)$ which declines for higher rates of the SG mandate, indicating a dominating wealth effect on hours worked. Note that the SG rate that generates optimal average welfare change in the long run is high, ranging from 25% to 30% (and somewhat lower for small open economy (SOE) simulations but still over 20%). However, it should be noted that our focus is on the long-run steady state effects of the SG mandate, studying the channels or mechanisms through which it impacts household welfare, government's budgetary position, and the economy. To investigate the optimality of the SG rate, one would need to consider the transition path (between the steady states). Higher SG rates are expected to generate welfare losses to the current elderly, who would not be directly impacted by the mandate change but are expected to face increased taxes to pay for superannuation tax concessions and lower rates of return on their retirement assets. Since these households would need to be compensated, high SG rates that are optimal in the long run are unlikely to be optimal over the transition path. As indicated in the conclusion section of the main text, we defer the transition path analysis to future research.