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# On the Complementarity of Public and Private Pensions: Equity, Efficiency, and Optimal Design

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## CAMA Working Paper 34/2026
## May 2026



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## Abstract

This paper studies whether shifting retirement financing from public to mandatory private pensions can deliver Pareto improvements across generations when the implicit return on public pensions is persistently below the market return on capital. We develop a dynamic general equilibrium overlapping-generations model with heterogeneous households facing idiosyncratic earnings risk, endogenous labor supply and retirement, and a mixed public–private pension system. Calibrated to Australia – where strict means testing creates strong complementarity between public and private pensions – the model shows that higher private contributions raise aggregate wealth and future welfare but impose transitional welfare costs on current workers. The optimal contribution rate is around 14 percent of gross wages, yielding efficiency gains of 0.23 percent of lifetime consumption through reduced public pension eligibility and lower distortionary taxation. When combined with compensating transfers, the reform delivers a Pareto improvement across generations. In contrast, in systems with weaker or no means testing – such as pension designs comparable to those in the Netherlands and the United States – these gains diminish or turn negative, indicating that the linkage between private wealth and public pension entitlements is central to the scope for Pareto-improving reform.

**Keywords**

social security, private pension, income taxation, labor supply, efficiency, life-cycle, stochastic OLG model

**JEL Classification**

H55, J26, H24, H21, D15, C68

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**ISSN 2206-0332**

# On the Complementarity of Public and Private Pensions: Equity, Efficiency, and Optimal Design*

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**Abstract**

This paper studies whether shifting retirement financing from public to mandatory private pensions can deliver Pareto improvements across generations when the implicit return on public pensions is persistently below the market return on capital. We develop a dynamic general equilibrium overlapping-generations model with heterogeneous households facing idiosyncratic earnings risk, endogenous labor supply and retirement, and a mixed public–private pension system. Calibrated to Australia – where strict means testing creates strong complementarity between public and private pensions – the model shows that higher private contributions raise aggregate wealth and future welfare but impose transitional welfare costs on current workers. The optimal contribution rate is around 14 percent of gross wages, yielding efficiency gains of 0.23 percent of lifetime consumption through reduced public pension eligibility and lower distortionary taxation. When combined with compensating transfers, the reform delivers a Pareto improvement across generations. In contrast, in systems with weaker or no means testing – such as pension designs comparable to those in the Netherlands and the United States – these gains diminish or turn negative, indicating that the linkage between private wealth and public pension entitlements is central to the scope for Pareto-improving reform.

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*We thank Alan Woodland, Hans Fehr, Morten Ravn, Pierre-Carl Michaud and John Piggott for their comments and suggestions. Early versions of this paper were presented at the Econometric Society Australasia Meeting (ESAM 2023) and the 32nd Colloquium on Pensions and Retirement Research (2024). We thank the participants of these conferences for their feedback. We gratefully acknowledge financial support from the Centre of Excellence in Population Ageing Research (CEPAR).

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# 1 Introduction

Public pensions, typically organized as pay-as-you-go (PAYG) systems, provide essential protection against old-age income shortfalls and longevity risk by pooling contributions and redistributing resources across individuals and cohorts. Because benefits are financed from current workers rather than accumulated capital, the implicit rate of return depends on population and productivity growth (Samuelson (1958)). As population ($n$) and productivity ($g$) growth slow, the internal rate of return on PAYG pensions falls below the market return on capital ($r$), undermining long-run benefit adequacy and intergenerational fairness for younger cohorts. Population aging further pressures PAYG systems by requiring higher payroll taxes, which can discourage labor supply, lower disposable income, and crowd out private savings.

In response, many OECD countries have reformed their PAYG systems and placed greater emphasis on private pension arrangements in which contributions are invested in financial assets. Such private schemes allow participants to earn the market rate of return – persistently exceeding the implicit PAYG return ($r > g + n$; Aaron (1966))[1] – and enhance work incentives and strengthen the link between contributions and retirement resources. However, private pensions lack the redistribution and risk pooling inherent in PAYG systems. Benefits depend on market performance and individual longevity, exposing participants to investment and longevity risk unless complemented by collective mechanisms. Moreover, mandatory private saving may impose welfare losses on liquidity-constrained households by forcing contributions above their preferred saving levels, potentially creating distortions comparable to those in PAYG systems and widening disparities across individuals.

These contrasting strengths and limitations highlight the complementarity of public and private pensions when they insure different risks and perform distinct economic functions. The public pillar provides intergenerational redistribution and social insurance against longevity and earnings risks, while the funded pillar delivers higher returns and enforces saving discipline. When these risks and functions are imperfectly correlated, combining the pillars can improve both redistribution and efficiency. The optimal design of a mixed pension system therefore hinges on the nature and strength of this complementarity: the extent to which public and private pensions reinforce or offset each other in achieving redistribution and efficiency objectives.

This paper studies two related questions. First, can a government shift retirement financing from public pensions toward mandatory private saving in a way that generates Pareto improvements across generations – leaving no existing cohort worse off while improving outcomes for future generations? Second, what institutional features of the pension system determine whether such reforms are feasible, and what contribution rate for mandatory private saving maximizes aggregate efficiency?

[1] Nozaki (2017) quantifies the long-run internal rate of return on PAYG systems across 172 countries and shows that the median Long-Run Biological Interest Rate (LBIR) – the real-world analogue of Samuelson's biological interest rate – is only about 1% per year globally. The LBIR is particularly low in advanced economies and is estimated to be negative in many of them, implying that PAYG schemes in these countries can offer very low or even negative internal returns without additional financing or productivity gains.

To address these questions, we first develop a simple two-period model to illustrate the key economic mechanisms through which pension system design shapes the efficiency–equity trade-off and the scope for Pareto-improving reforms. We then document how different institutional settings generate varying degrees of complementarity between public and private pensions in mixed pension systems. The Australian system exhibits strong complementarity, where means-tested public pensions interact closely with mandatory private pensions. The Netherlands represents a system of moderate complementarity, combining a universal tax-financed public pension with quasi-mandatory occupational pensions. The United States, in contrast, illustrates weak complementarity, with a relatively generous PAYG Social Security system alongside largely voluntary private retirement savings. Finally, we quantify this mechanism using a dynamic general equilibrium, overlapping-generations (OLG) model with a mixed system of public pensions and mandatory private contributions to illiquid, tax-favored retirement accounts (i.e., private pensions).

Overall, our analysis highlights how the degree of complementarity between public and private pensions shapes the welfare and efficiency consequences of retirement-income reform. In systems with strong complementarity, higher mandatory private saving reduces reliance on public pensions and lowers the distortionary taxes required to finance them, thereby expanding the scope for Pareto-improving reforms. In contrast, systems with weaker complementarity generate substantially smaller efficiency gains from mandatory private pensions.

More specifically, our OLG model builds on Kitao (2014), Hosseini and Shourideh (2019), and Kudrna et al. (2022). The model features overlapping cohorts of heterogeneous households facing idiosyncratic labor productivity risk, endogenous labor supply and retirement decisions, a representative firm, and a detailed government sector. We extend this framework to incorporate illiquid private pension assets arising from mandatory contributions. The benchmark economy is calibrated to Australia using recent demographic, macroeconomic, fiscal, and household survey data. The model replicates key institutional features of the Australian system – including progressive income taxation, a means-tested public age pension, and mandatory private pensions – with the contribution rate chosen to match the observed ratio of private pension assets to GDP.

We conduct counterfactual experiments by varying the mandatory contribution rate to evaluate macroeconomic, distributional, intergenerational welfare, and aggregate efficiency effects of private pension reforms along the transition path and in the steady state. Aggregate efficiency effects are evaluated using a mechanism-design approach that applies welfare-neutralizing transfers to both current and future cohorts to achieve Pareto comparisons. Robustness checks include replacing the benchmark age pension system with Dutch- and US-style arrangements, and we also alter the financing structure of public pensions (income- versus consumption-based) and the market structure (small open economy (fixed factor prices) versus closed-economy (endogenous prices) environments).

Our counterfactual simulation results are summarized as follows. First, in the steady state, higher mandatory private pension contributions raise aggregate wealth and welfare. These gains are largest under means-tested public pensions, where stronger public–private complementarity lowers distortionary taxation and facilitates partial privatization of retirement provision. Second, along the transition, higher contributions impose short-run welfare losses on existing working-age cohorts due to lower disposable income and temporarily higher taxes. Over time, however, rising private wealth and declining public pension expenditures generate welfare gains for future generations, highlighting important intergenerational trade-offs. Third, using a mechanism-design framework with compensating transfers, we show that under means-tested pensions modest increases in mandatory contributions can generate aggregate efficiency gains and Pareto improvements across generations. Aggregate efficiency gains are hump-shaped in the mandatory contribution rate, with the efficiency-maximizing contribution rate around 14 percent of gross wages and associated gains of 0.23 percent of lifetime consumption. Fourth, cross-country comparisons indicate that stronger public–private complementarity – as in Australia – amplifies welfare and efficiency gains from mandatory saving, whereas systems with weaker complementarity, such as the Netherlands and the United States, exhibit substantially smaller or even negative efficiency effects. Finally, our sensitivity analysis shows that these welfare and efficiency effects are robust to alternative financing assumptions and market structures with endogenous factor prices.

**Related literature.** This paper contributes to three related strands of literature on pension design and reform.

First, a substantial body of research has examined the fiscal and welfare implications of social security and public pension reforms, using large-scale OLG models. Prominent studies include Kitao (2014), McGrattan and Prescott (2017), and Hosseini and Shourideh (2019) for the United States; Kitao (2015) and Braun and Joines (2015) for Japan; and Kudrna et al. (2022) for Australia. These studies have analyzed policies ranging from partial to full privatization of public pensions, exploring how such reforms influence consumption, labor supply, and intergenerational redistribution. However, this literature has largely focused on liquid private savings and has typically abstracted from illiquid private pension assets and their interactions with public pension means testing. Our study extends this literature by explicitly modeling illiquid, tax-favored private pensions and their interaction with means-tested public pensions.

Second, we relate to the literature on funded private pensions, which has investigated voluntary or mandatory retirement saving accounts with preferential tax treatment. Building on İmrohoroğlu et al. (1998), Gomes et al. (2009), Nishiyama (2011), Ho (2017), and Lin et al. (2021) for the United States, and Fehr and Kindermann (2010) for Germany, this line of research has focused on the macroeconomic and welfare consequences of introducing or expanding funded private pillars. A closely related contribution is Andersen et al. (2024), who analyze Denmark's transition toward funded pensions and show that mandatory saving can reduce wealth inequality by increasing asset holdings among low-income and liquidity-constrained households. In contrast, we emphasize the interaction between funded pension mandates and means-tested public pensions, focusing on general equilibrium effects, intergenerational welfare, and the scope for Pareto-improving pension reform. Central to our framework is the fiscal feedback from private retirement wealth to public pension expenditures, which amplifies efficiency gains and gives rise to an efficiency-maximizing mandatory contribution rate.

Finally, our paper is closely connected to studies of Australia's superannuation system – the country's mandatory private pension scheme – within dynamic general equilibrium frameworks. We build on the analyses of Creedy and Guest (2008), Kudrna and Woodland (2013), and Kudrna and Woodland (2018), who examined the macroeconomic and fiscal consequences of mandatory contributions and tax-favored arrangements. Our model extends this work by incorporating idiosyncratic labor productivity risk, endogenous retirement decisions, bequest motives, and a detailed fiscal structure featuring progressive income taxation and a means-tested public pension. This allows us to capture the complex interactions between mandatory private saving, redistribution, and intergenerational welfare in a stochastic general equilibrium setting.[2]

The remainder of the paper proceeds as follows. Section 2 presents the theoretical, institutional, and empirical background, including the simple two-period model, cross-country institutional comparisons, and stylized facts from Australian microdata. Section 3 presents the dynamic OLG framework, while Section 4 describes its calibration to Australian macro- and micro-level data and assesses model fit against selected empirical targets. Section 5 analyzes the macroeconomic, welfare, and efficiency effects of alternative pension policies, focusing on how changes in mandatory private contribution rates interact with means-tested public pensions under strong complementarity. Section 6 conducts robustness checks and evaluates how alternative public pension designs – featuring varying degrees of means testing and benefit generosity motivated by institutional contrasts across advanced economies – alter the macroeconomic, welfare, and efficiency effects of private pension mandate reforms. The final section concludes with key findings and policy implications.[3]

# 2 Theoretical, Institutional and Empirical Background

This section establishes the analytical, institutional, and empirical foundations for understanding why public and private pension pillars are socially desired, even when market returns exceed the implicit return of PAYG financing. We begin with a simple two-period framework to illustrate the core economic mechanism: the interaction between mandatory private saving and public pensions. We then describe the institutional features of pension systems in advanced economies. Finally, we present key stylized facts from Australian microdata that motivate the model's structure and inform its calibration.

[2]In addition, there is a growing body of empirical literature studying tax-favored superannuation in Australia. For example, Connolly (2007), using household survey data, shows positive impacts of compulsory superannuation on household savings. Longmuir (2023) provides an empirical analysis of household wealth between 2002 and 2018 in Australia, reporting that 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-favored superannuation contributions. Our model accounts for saving and labor supply responses to mandatory superannuation, as well as broader interactions with other government policy, and general equilibrium effects, shown to be important for the long-term economic effects of the private pension mandate.

[3]Supplementary materials provide additional institutional background, empirical evidence, details on the numerical solution, calibration, and extended quantitative results.

## 2.1 Economic intuition in a simple two-period model

We consider a simple partial-equilibrium overlapping-generations economy in which individuals live for two periods: young and old. Each period a cohort of size $N_t$ is born, with population growing at rate $n$ so that $N_{t+1} = (1+n)N_t$. Labor productivity grows at rate $g$, implying wage growth $w_{t+1} = (1+g)w_t$. Individuals supply one unit of labor inelastically when young, and retire when old. Survival into old age occurs with probability $\pi$.

When young (at time $t$), an individual earns wage income $w_t \equiv w$ and chooses consumption $c_1$ and savings $s$. When old (at time $t+1$), if alive, she consumes $c_2$, financed by accumulated savings and pension benefits. The market interest rate is $r$. A mandatory pension system collects contributions $\tau w$ when young and pays benefit $P$ in old age (conditional on survival).

Preferences are assumed to be logarithmic. The individual solves

$$\max_{c_1,c_2,s} \{\log c_1 + \beta\pi \log c_2\} \quad \text{s.t.} \quad c_1 + s = (1-\tau)w, \quad c_2 = (1+r)s + P, \tag{1}$$

with $c_1 \geq 0$, $c_2 \geq 0$, and $0 \leq s \leq (1-\tau)w$. Taking first-order conditions yields optimal saving

$$s = \frac{\beta\pi}{1+\beta\pi}(1-\tau)w - \frac{1}{1+\beta\pi}\frac{P}{1+r}, \tag{2}$$

and corresponding consumption

$$c_1 = \frac{1}{1+\beta\pi}\left[(1-\tau)w + \frac{P}{1+r}\right], \qquad c_2 = \frac{(1+r)\beta\pi}{1+\beta\pi}\left[(1-\tau)w + \frac{P}{1+r}\right]. \tag{3}$$

To summarize the intertemporal allocation, define the present value of lifetime consumption as

$$C \equiv c_1 + \frac{c_2}{1+r}. \tag{4}$$

Substituting optimal choices yields

$$C = (1-\tau)w + \frac{P}{1+r}. \tag{5}$$

Thus, in this logarithmic environment, the present value of lifetime consumption is equal to the present value of disposable income plus the discounted pension benefit.

**Public pension only.** Consider a pure public PAYG pension system balanced every period:

$$\tau w_{t+1} N_{t+1} = P_{t+1}\,\pi N_t. \tag{6}$$

Using $w_{t+1} = (1+g)w_t$ and $N_{t+1} = (1+n)N_t$ implies

$$P_{t+1} = \tau w_t \frac{(1+g)(1+n)}{\pi}, \tag{7}$$

so the implicit gross return on PAYG contributions is $\frac{(1+g)(1+n)}{\pi}$. Substituting into (5) gives

$$C = w + \left[ \frac{\frac{(1+g)(1+n)}{\pi}}{1+r} - 1 \right] \tau w. \tag{8}$$

Equation (8) shows that PAYG raises lifetime resources when $\frac{(1+g)(1+n)}{\pi} > 1+r$ and lowers them when $\frac{(1+g)(1+n)}{\pi} < 1+r$, consistent with the Aaron–Samuelson logic (Aaron (1966); Samuelson (1958)).

**Mixed public and private pensions.** Now combine PAYG with a funded pillar. Let $\theta \in [0,1]$ be the share of compulsory contributions allocated to PAYG and $(1-\theta)$ the share allocated to a funded account earning return $r^s$:

$$P_{t+1} = \tau w_t \left[ \theta \frac{(1+g)(1+n)}{\pi} + (1-\theta)(1+r^s) \right]. \tag{9}$$

Substituting into (5) yields

$$C = (1-\tau)w + \frac{\tau w}{1+r} \left[ \theta \frac{(1+g)(1+n)}{\pi} + (1-\theta)(1+r^s) \right]. \tag{10}$$

If $r^s = r$, then

$$C = w + \theta \tau w \left[ \frac{\frac{(1+g)(1+n)}{\pi}}{1+r} - 1 \right], \tag{11}$$

which nests the pure PAYG case ($\theta = 1$) and the fully funded case ($\theta = 0$). In this deterministic setting, the return comparison alone implies corner solutions: increasing $\theta$ is desirable only when the PAYG return exceeds the market return. This benchmark highlights why a mixed system is hard to rationalize using return comparisons alone.

However, this benchmark abstracts from redistribution and means testing. In practice, the public pillar often provides a minimum-income floor and withdraws benefits as private retirement resources rise. We incorporate this feature in reduced form.

**Mixed system with means-tested pension floor.** Assume the public pillar is means tested on retirement assets:

$$P_{t+1}^{\text{pub}}(s) = \max \left\{ 0,\ \bar{P} - \Phi(1+r)s \right\}, \tag{12}$$

where $\bar{P} > 0$ is the full pension and $\Phi \geq 0$ is an asset-test taper rate.[4] The funded component is contributory and earns return $r^s$:

$$P_{t+1}^{\text{fund}} = (1+r^s)(1-\theta)\tau w_t. \tag{13}$$

[4] For simplicity, we abstract from the precise tax financing of the public floor in this section; in the quantitative model below, the government budget constraint determines the tax adjustment required to finance the means-tested pension.

Total pension income is

$$P_{t+1}(s) = \theta P^{\text{pub}}_{t+1}(s) + P^{\text{fund}}_{t+1}, \tag{14}$$

so that

$$C(s) = (1-\tau)w + \frac{1}{1+r}\left[\theta P^{\text{pub}}_{t+1}(s) + (1+r^s)(1-\theta)\tau w\right]. \tag{15}$$

Because $P^{\text{pub}}_{t+1}(s)$ declines with assets, additional saving reduces public entitlements. The taper rate $\Phi$ therefore acts as an implicit marginal tax on retirement saving, lowering the effective return to funded accumulation, especially for households near the means-test threshold. Although this simple framework abstracts from the financing feedback (lower benefits would reduce required taxes), it highlights the key trade-off: even when $1+r$ exceeds the implicit return of the public pillar, a positive public share $\theta > 0$ can be desirable because the public pillar provides redistribution and minimum-income insurance, while the funded pillar delivers capital-market returns. In the presence of heterogeneity in lifetime earnings or retirement wealth, the insurance value of the floor can raise ex-ante expected utility despite its lower financial return.

**Remark.** Public and private pensions are complementary when they insure different risks and perform distinct economic functions. The public pillar provides social insurance against longevity and earnings risks, while the funded pillar delivers market returns and enforces saving discipline. Because these risks and functions are imperfectly correlated, combining the public and private pillars can improve both redistribution and efficiency. The strength of this complementarity depends critically on institutional settings, particularly the structure of public pension means testing.

## 2.2 Institutional settings and pension complementarity

Advanced economies exhibit a wide range of mixed public and private pension systems with varying degrees of complementarity. Public schemes typically provide a basic, redistributive income floor in old age, while private pensions accumulate funded savings that are more closely tied to past earnings. The strength of public–private pension complementarity depends on how the public pension is targeted and how private saving is treated in the tax and transfer system. When public benefits are explicitly conditioned on private resources, private saving and public support are closely linked, and changes in private pension mandates can have large effects on public pension coverage, benefit levels, and fiscal costs.

This subsection describes the Australian case of *strong* complementarity and briefly contrasts it with the Dutch and US systems, which exhibit *weaker* complementarity. Table 1 summarizes the key institutional differences across the three systems.

**Strong complementarity.** Australia combines a means-tested public age pension (first pillar) with a mandatory private pension system (second pillar) based on superannuation. The age pension is financed from general tax revenues and pays a modest benefit (around 30% of average earnings) that is independent of contribution history but subject to detailed income

Table 1: Key Features of Three Pension Systems

| | **Australia** | **Netherlands** | **United States** |
|---|---|---|---|
| **Complementarity** | Strong | Moderate | Weak |
| **Public pensions** | | | |
| Means testing | Yes | No | No |
| Benefit level | Modest | Modest | More generous |
| Earnings-related | No | No | Yes |
| Expenditure | 3% of GDP | 5% of GDP | 7% of GDP |
| Financing | General revenue | Payroll tax | Payroll tax |
| **Private pensions** | Mandatory | Quasi-mandatory | Largely voluntary |

*Note:* The "Benefit level" row refers to gross public pension replacement rates relative to average earnings. Australia and the Netherlands provide approximately 28%, while the US Social Security system provides roughly 40%.

*Source:* Organisation for Economic Cooperation and Development (OECD) (2023). Institutional features broadly reflect pension designs prevailing during the 2018-2020 period.

and asset tests. These tests determine whether individuals receive the full benefit, a reduced benefit, or no benefit at all. Crucially, for our analysis, private pension assets, including superannuation balances at older ages, are fully included in the means test, creating a strong negative correlation between private pension wealth and public pension entitlements.

The mandatory private pension pillar is built around a defined contribution system of individual superannuation accounts. Under the Superannuation Guarantee (SG), employers must contribute a fixed share of employees' gross wages to privately managed funds. The SG rate has gradually increased from around 3–4% of wages in 1992 to 9% in 2001-02, rising to 9.5% from 2015 and reaching 10% in 2021-22, with further legislated increases to 12% by 2025-26. Superannuation assets are largely illiquid during the accumulation stage and preserved until the preservation age (currently 65, and there is no mandatory annuitization requirement), after which retirees typically draw down their balances gradually.

The superannuation system is tax-favored relative to ordinary income, and it currently operates under a $ttE$ regime. Here, lower-case $t$ denotes taxation at preferential flat rates (rather than at progressive income tax rates $T$), while $E$ denotes exemption at withdrawal. Specifically, contributions are taxed at 15%, fund earnings at an effective rate of around 7% during accumulation, and most retirement benefits are tax-free (see Kudrna and Woodland (2018)). We take this regime as given in our quantitative analysis.

Before the SG was introduced, voluntary private pension coverage was limited and skewed toward higher-earning, white-collar workers, with less than 30% of the workforce covered. Since the introduction and gradual increase of the SG, coverage has become nearly universal – now close to 95% of employees, excluding self-employed workers who are not subject to the mandate. The maturation of the system has led to substantial increases in superannuation assets, which have tripled over the last two decades and now amount to around 150% of GDP (Chomik et al. (2018b)). While coverage is broad, higher contributions and tax concessions for higher earners imply that superannuation asset holdings are particularly large for higher-skilled types.

The interaction between the means-tested age pension and the maturing mandatory private pension system generates strong complementarity. In the 1980s, prior to the SG, public pension coverage in Australia was close to 90% of the age-eligible population. Today, after roughly three decades of mandatory superannuation, this share has fallen to around 75%. Based on data for 2016 from the Department of Social Services, approximately 45% of age-eligible individuals receive the full age pension, about 30% receive a partial benefit, and the remaining 25% receive no public pension at all.

This pattern reflects a growing group of partly or fully self-funded retirees whose superannuation (and other financial) assets trigger the income and asset tests, reducing or eliminating their age pension entitlement. As a result, the age pension in Australia is highly progressive relative to many social security systems. The total expenditure on public pensions is less than 3% of GDP and, despite the aging of the population, is projected to remain broadly stable as a share of GDP over the next four decades, partly because the maturing mandatory private pension scheme shifts some of the financing burden from the public to the private pillar. In other words, stronger private saving – driven by SG contributions – feeds back into lower average public benefits and a rising share of partly or fully self-funded retirees.[5]

These institutional features motivate our modeling of *strong complementarity*: private pensions enter both household budget constraints and the public pension means test, so changes in the mandatory contribution rate affect not only household wealth and consumption, but also the distribution and fiscal cost of public pensions. Our quantitative analysis asks whether this interaction allows a government to shift retirement financing from the public to the private pillar while improving efficiency and maintaining redistribution.

**Weaker complementarity.** To assess how institutional design shapes the scope for Pareto-improving reforms, we contrast the Australian system with two alternative mixed pension arrangements that feature weaker public-private complementarity.

In the Netherlands, the first pillar is a universal, flat-rate public pension financed primarily through payroll taxes. It provides a modest benefit level – similar to Australia – but public benefits are not means-tested, and are therefore independent of private (or occupational) pension wealth. The second pillar consists of quasi-mandatory occupational pensions that are collectively managed and earnings-related. Because public benefits do not adjust to private pension accumulation, changes in occupational pension contributions have virtually no direct fiscal feedback on the public pillar. As a result, the interaction between the two pillars is limited, implying substantially weaker complementarity than in Australia.[6]

In the US, public pensions take the form of a PAYG Social Security system financed through

[5] Appendix A provides a concise, model-focused description of the Australian tax and retirement-income system, including the institutional features of the Age Pension and superannuation that are incorporated in our quantitative framework.

[6] Denmark provides an intermediate case. Its public pension consists of a universal basic benefit combined with income-tested supplements, alongside large quasi-mandatory funded occupational pensions (see Andersen et al. (2024)). Because only part of the public benefit is means-tested against private resources, fiscal feedback from private saving to public pension expenditures is weaker than in Australia, but stronger than in fully universal systems such as the Netherlands.

payroll taxes and providing earnings-related benefits that are more generous than those in Australia or the Netherlands. Private pensions are largely voluntary, including employer-sponsored plans and individual retirement accounts with tax-favored treatment. Social Security benefits depend on lifetime earnings and are independent of private pension wealth. While individuals with higher private pensions typically also receive higher Social Security benefits due to stronger earnings histories, there is no institutional mechanism linking private accumulation to public entitlements. Redistribution occurs within the public pillar through the progressive benefit formula, but it is not conditioned on private wealth. As shown in Table 1, this design implies weak complementarity and limited fiscal feedback from private saving to public pension expenditures.

These institutional differences imply distinct responses to policies that increase reliance on private pensions. In Australia, a higher private pension mandate directly affects both private retirement income and public pension entitlements through the means test, with potentially large effects on redistribution and fiscal costs. In the Netherlands and the US, higher private saving expands retirement resources but has much weaker feedback on public pensions.

Our quantitative OLG framework captures these differences by embedding alternative public pension rules within a model calibrated to Australia, allowing us to isolate the role of institutional design while holding all other structural parameters fixed. This allows us to evaluate how the strength of public–private complementarity shapes the macroeconomic, welfare, and aggregate efficiency consequences of shifting retirement financing from public to private pensions.

Before introducing the formal model, we document key empirical patterns from Australian microdata that motivate the model's heterogeneous life-cycle structure and inform its calibration.

## 2.3 Stylized facts from Australia

We use micro-level data from the Household, Income and Labour Dynamics in Australia (HILDA) Survey (Summerfield et al., 2019). We focus primarily on the 2018 wave for income, labor supply, and asset profiles. For Age Pension participation and benefits at advanced ages, we pool waves 2001-2018 to ensure sufficient sample size.

We restrict the sample to non-students and non-self-employed individuals with valid income and wealth information. Skill types are defined by educational attainment (low = high-school dropouts; medium = high-school graduates and vocational certificate holders; high = university degree), consistent with Section 4. All monetary variables are expressed in 2018 Australian dollars.[7]

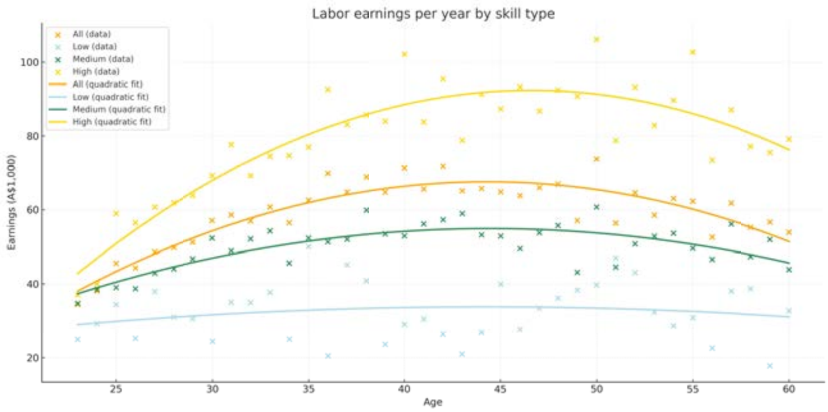
**Labor income, heterogeneity, and life-cycle dynamics.** Figure 1 presents age profiles of hourly wages, labor supply, and earnings by skill type. Wages, which measure individual labor productivity in the model, exhibit the familiar hump-shaped life-cycle pattern, rising steeply

[7] Appendix B provides additional details on data construction, and additional figures for wage dispersion (variance of log wages) and working-age social transfers by skill type.

until midlife and gradually declining thereafter. The slope of this profile is markedly steeper for high-skilled individuals, generating a widening skill premium over the working life.


(a) Wage per hour


(b) Labor supply (hours per week)



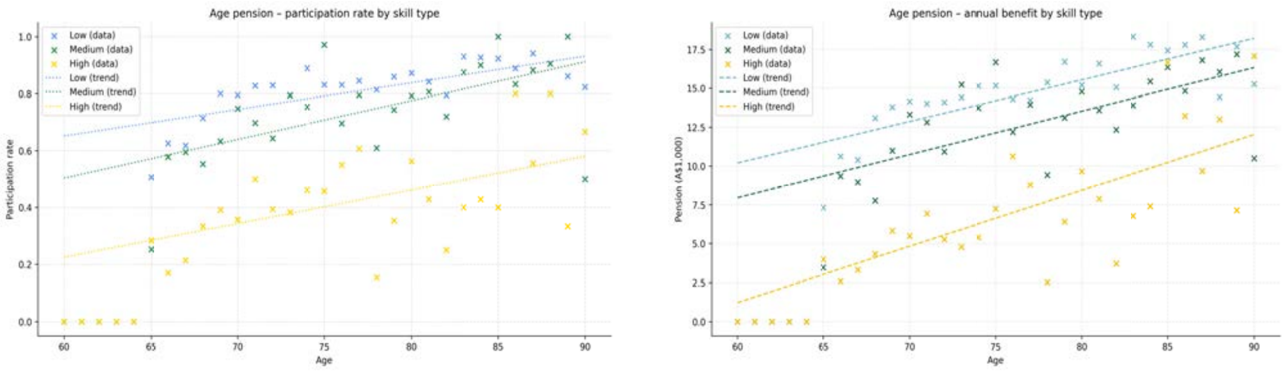

(c) Labor earnings per year (A$1,000)

Figure 1: Labor productivity, supply and earnings by skill type

Weekly hours worked decline gradually with age and are persistently lower for low-skilled individuals, reinforcing differences in lifetime earnings and retirement wealth accumulation. The gap in labor supply widens after age 55, reflecting earlier labor force withdrawal among lower-skilled workers. As a result, annual earnings display substantial heterogeneity: high-skill workers earn significantly more at all ages, and the earnings gap expands over the life cycle.

These patterns motivate the model's multi-skill structure and the calibration of deterministic productivity profiles. The widening skill premium and differential labor supply behavior are central for generating persistent lifetime income inequality and heterogeneous retirement wealth accumulation.

**Public pension participation and benefits.** Figure 2 reports Age Pension participation rates and benefits by skill group. Across all skill types, pension participation increases with age, reflecting both eligibility at the statutory age and the gradual depletion of private assets in retirement. However, the levels differ substantially by skill. Low-skilled retirees exhibit high participation rates shortly after eligibility and receive significantly larger average benefits at all ages. By contrast, high-skilled individuals display lower participation and smaller average benefits, reflecting greater accumulated assets and private income that reduce eligibility under the means test. Medium-skilled individuals display intermediate participation and benefit levels, with patterns that more closely resemble low-skilled retirees than high-skilled retirees, reflecting more limited asset accumulation relative to the top skill group.



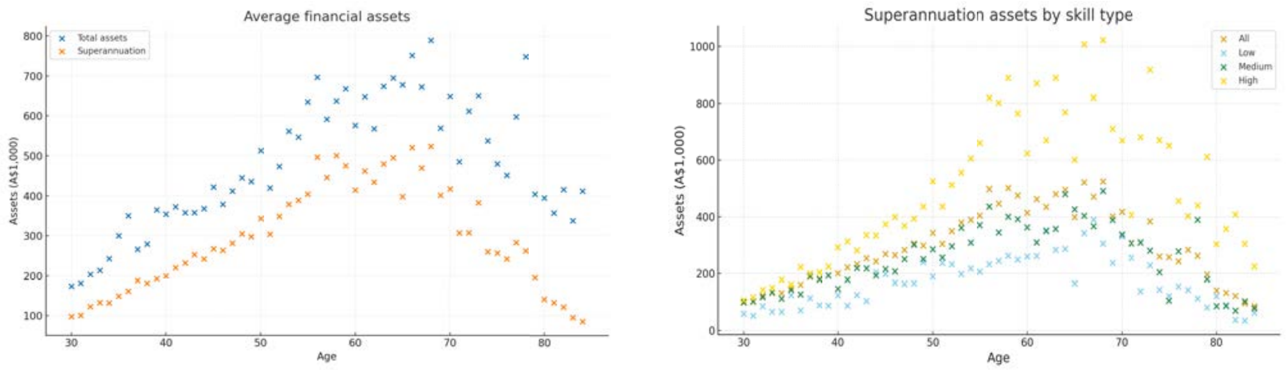

(a) Pension participation rate

(b) Pension benefit per year (A$1,000)

Figure 2: Age Pension participation and benefits by skill type

These profiles confirm the strongly redistributive nature of Australia's means-tested age pension. The public pension adjusts systematically to private resource levels, providing substantial insurance to low-wealth retirees while reducing payments to those with significant superannuation balances. This empirical relationship directly motivates modeling the age pension as explicitly contingent on private asset holdings, capturing strong public-private complementarity.

**Financial assets and superannuation accumulation.** Figure 3 presents life-cycle profiles of total financial assets and superannuation (private pension) balances by skill type. Financial assets follow a pronounced hump-shaped pattern: accumulation during working years, peaking near pension eligibility age, and gradual decumulation thereafter. Asset levels remain sizable at advanced ages, consistent with precautionary saving or bequest motives.




(a) Financial assets (A$1,000)

(b) Superannuation by skill type

Figure 3: Financial assets by skill type

Superannuation balances display strong heterogeneity. High-skilled individuals accumulate substantially larger balances throughout their working life, reflecting higher earnings and the proportional nature of mandatory contributions. The skill gap widens over time and persists into retirement.

These differences in retirement wealth are critical for understanding pension participation patterns. Because superannuation balances enter the age pension means test, greater private accumulation directly reduces public transfers through the asset test. This mechanism is central to the model's fiscal feedback channel linking private saving to public pension expenditure. The dispersion in superannuation wealth across skill groups therefore generates heterogeneous reliance on the public pillar and shapes the distributional and fiscal consequences of changes in mandatory contribution rates.

**Summary.** The empirical evidence reveals three central stylized facts that guide the quantitative model: (*i*) steep and skill-dependent life-cycle earnings profiles; (*ii*) substantial heterogeneity in private retirement wealth accumulation; and (*iii*) strong targeting of public pension benefits toward lower-wealth retirees through means testing.

Australia exemplifies this mixed architecture: a means-tested Age Pension provides a tax-financed safety net, while the Superannuation Guarantee mandates funded retirement saving. These empirical patterns illustrate the tight interaction between private superannuation and the public age pension in Australia. To quantify the economic mechanisms underlying this interaction, we next formulate a full dynamic general equilibrium model and examine how the interaction between compulsory funded accumulation and means-tested public benefits shapes the optimal mix and the distributional and fiscal consequences of pension reforms.

# 3 Quantitative Model

This section develops a dynamic general equilibrium overlapping-generations (OLG) model with heterogeneous households, a representative firm, and a government sector capturing the key features of Australia's tax and retirement income system. The framework builds on Kitao (2014), Hosseini and Shourideh (2019), and Kudrna et al. (2022), and extends them by incorporating both liquid assets and illiquid private pension accounts within a means-tested public pension system. This structure allows us to evaluate the macroeconomic, welfare, and efficiency consequences of changes in mandatory contributions under strong public-private complementarity.

We first summarize the main ingredients of the model, then describe the demographic structure and the household, firm, and government sectors, and finally define equilibrium.

## 3.1 Overview

The model economy consists of overlapping generations of heterogeneous households who differ by permanent skill type and face idiosyncratic labor productivity risk. Over the life cycle, households choose consumption, saving in liquid assets, labor supply, and retirement timing, subject to borrowing constraints and the institutional rules of the tax and pension systems.

Key features of the model include:

- overlapping cohorts (ages 20-99) and three skill types based on educational attainment;
- skill-specific stochastic labor productivity calibrated to Australian micro data;
- endogenous labor supply and retirement decisions;
- a two-asset structure with liquid assets and illiquid private pension (superannuation) accounts;
- accidental and intended bequests following De Nardi (2004);
- a policy environment featuring a means-tested public pension, mandatory private contributions, and progressive income, consumption, and corporate taxation;
- general equilibrium determination of factor prices, aggregates, and government budget balance in steady state and along transition paths.

## 3.2 Demographics

Time is discrete, and individuals may live for up to $J$ periods. Households are indexed by age $j \in \mathcal{J} = \{1, \ldots, J\}$ and permanent skill type $i \in \mathcal{I} = \{1, 2, 3\}$. At entry ($j = 1$), agents draw skill type $i$ with probability $\varpi_i$. The skill types are endowed with different labor productivity and social transfer profiles, discussed below. Note that we distinguish between the pension access age $j_R$ and the retirement age $j_{\overline{R}}$ (with $j_{\overline{R}} > j_R$). Retirement is endogenous: households may continue working after reaching pension eligibility age $j_R$, up to the mandatory retirement age $j_{\overline{R}}$.[8]

We assume a stationary demographic structure. The population growth rate $n$ equals the fertility rate, which in the model corresponds to the growth rate of newborn cohorts $n_1$. Lifespan uncertainty is governed by age-dependent survival probabilities $\psi_j$, defined as the conditional probability of surviving from age $j-1$ to age $j$, with $\psi_1 = 1$ and $\psi_{J+1} = 0$. In this stationary environment, cohort masses satisfy

$$m_j = \frac{\psi_j m_{j-1}}{1+n} \quad \text{with} \quad m_1 = 1, \tag{16}$$

which implies constant population shares $\mu_j = m_j / \sum_k m_k$.

Although we compute transition paths for policy reforms, demographic parameters remain fixed throughout the analysis, so the population structure is stationary along the transition.

## 3.3 Household

**Preferences.** Households have preferences over streams of consumption $c_j$ and leisure $l_j$ as well as from leaving bequests upon death.[9] The expected discounted lifetime utility function is

[8] This type of retirement modeling has been used, e.g., by Kitao (2014).

[9] The full household state vector is defined in the distribution of households at the end of this subsection. In the description of the household sector provided below, the state index $z$ and time period $t$ are omitted, with agents only distinguished according to their age $j$.

given by

$$E\left[\sum_{j=1}^{J}\beta^{j-1}\left(\prod_{o=1}^{j}\psi_o\right)\left\{u(c_j,l_j)+\beta(1-\psi_{j+1})\mathcal{B}(\bar{b}_{j+1})\right\}\right], \tag{17}$$

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 parameters of the period utility function include the Cobb-Douglas consumption share parameter denoted by $\nu$, the coefficient of relative risk aversion $\sigma$ and the equivalence scale parameter $\mu_j$ calibrated following Kaas et al. (2021). Lifetime utility is discounted by both time preference $\beta$ and survival probabilities $\psi_j$. 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 $\sigma_b$ governs the relative risk aversion for the bequest. Bequests consist of total remaining liquid and private pension assets left upon death, $\bar{b}_{j+1}=(1+g)(a_{j+1}+s_{j+1}))$.

**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 given by a skill-specific deterministic age profile $e_j$ and a stochastic component $\eta_j$ evolving according to:

$$\eta_j=\rho\eta_{j-1}+\epsilon_j \quad \text{with} \quad \epsilon_j\sim N\left(0,\sigma_\epsilon^2\right) \quad \text{and } \eta_0=0, \tag{18}$$

where $\rho$ is the persistence parameter and $\epsilon_j$ is the innovation of the AR(1) process. The idiosyncratic innovation term $\epsilon_j$ is normally distributed with mean zero and variance, $\sigma_\epsilon^2$.

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. Given the market wage rate, labor productivity and hours worked, households' gross labor income $le_j$ 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 bequests $b_j$. Aggregate bequests are redistributed by skill type and, within each skill type, across recipient ages according to exogenously

specified age weights.[10] Those aged $j < j_R$ also make mandatory private pension contributions $sc_j$ from their gross (pre-tax) earnings, $le_j$. Older households aged $j \geq j_R$ can continue working (only if aged $j < j_{\overline{R}}$), they no longer pay contributions but they 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 $\tau^c$ and progressive income taxation $T(\cdot)$, while superannuation taxes (collected by the private pension fund) are of lower rates compared to $T(\cdot)$.[11]

The periodic budget constraint of households (with liquid assets at the beginning of $j+1$ denoted by $a_{j+1}$ adjusted for the economic growth rate $g$) can be expressed as

$$\begin{aligned}(1+g)a_{j+1} = (1+r)a_j + (le_j - sc_j) + b_j + st_j \\ + ap_j + sp_j - T(\cdot) - (1+\tau^c)c_j,\end{aligned} \tag{19}$$

The right-hand side includes asset income, labor income net of mandatory pension contributions, transfers and pensions, minus taxes and consumption expenditures. We also assume that households are subject to the borrowing constraint $a_j \geq 0$ to prevent working-age households from borrowing against their illiquid private pension assets.

**Distributional measure of households.** The household 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 are restricted throughout the 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 private pension assets $s_j \in \mathcal{S} = [0, \infty]$, which are preserved in the superannuation fund for $j < j_R$. Productivity follows a finite-state Markov process; agents observe current shocks and form expectations over future states.

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

$$\int_{\mathcal{I} \times \mathcal{E}} \mathrm{d}X_t(z_1) = 1 \qquad \text{with} \quad z_1 = (1, i, 0, 0, \eta_1) \tag{20}$$

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

[10] The age distribution of bequest receipts is calibrated to match the empirical timing of inheritances (see Section 4).

[11] Tax and pension policy settings are discussed in more detail in the subsection below on the government sector.

measure of households at age $j+1$ follows

$$\phi_{t+1}(z_{j+1}, Z_{t+1}) = \frac{\psi_{j+1}}{1+n} \int_{\mathcal{Z}} \mathbf{1}_{a_{j+1}=a_{j+1}(z_{j+1},Z_{t+1})} \times \mathbf{1}_{s_{j+1}=s_{j+1}(z_{j+1},Z_{t+1})} \times \pi(\eta_{j+1}|\eta_j) \mathrm{d}X_t(z_j), \quad (21)$$

where $\pi(\cdot)$ denotes the transition probabilities for labor productivity of workers from one period to the next and $Z_t = (\phi_t(z), \Psi_t)$ denotes the state of the economy in period $t$, with $\Psi_t$ capturing government policy and other aggregate variables relevant for household decisions.

### 3.4 Firm

The production sector consists of a representative, perfectly competitive firm. The firm rents capital $K_t$ and hires effective labor $L_t$ to produce a single output good according to the Cobb-Douglas production technology:

$$Y_t = \kappa K_t^{\alpha} L_t^{1-\alpha}, \quad (22)$$

where $\alpha$ denotes the capital share in production and $\kappa$ is the productivity variable (assumed to grow at a constant progress rate $g$). Capital is rented from households at a risk-less rate and depreciates at the depreciation rate $\delta$. Firms pay corporate taxes $T_k = \tau^k[Y_t - w_t L_t - \delta K_t]$, where the corporate tax rate $\tau^k$ is applied to output net of the labor cost and capital depreciation. Factor prices are determined competitively by marginal productivity conditions:

$$w = (1-\alpha)\kappa \left(\frac{K}{L}\right)^{\alpha}, \quad (23)$$

$$r = (1-\tau^k)\left[\alpha\kappa \left(\frac{L}{K}\right)^{1-\alpha} - \delta\right]. \quad (24)$$

### 3.5 Government

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 pension and the mandatory private pension scheme. The modeling of fiscal and pension policies is described in more detail below, starting with public and private pensions.

**Public pension.** The first 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 access age ($j \geq j_R$), with the benefit subject to the following asset test:

$$ap_j = \begin{cases} 0, & \text{for } j < j_R \\ \max\left\{\min\left\{\overline{p}, \overline{p} - \Phi\left(ta_j - a_{\min}\right)\right\}, 0\right\}, & \text{for } j \geq j_R \end{cases}, \quad (25)$$

where assessable assets $ta_j = a_j + s_j$ include ordinary private and superannuation assets. The full pension $\overline{p}$ is paid when assessable assets $ta_j$ are below the threshold $a_{min}$ and is withdrawn at taper rate $\Phi$ above that threshold.

The total expenditure on public pensions is given by $P_t = \sum_{j\geq j_R}^{J} \int_{\mathcal{X}} ap(z_j, Z_t)\mathrm{d}X_t(z)$.

**Private pension.** The second pillar of the Australian pension system is based on mandatory contributions under the Superannuation Guarantee (SG) legislation.

The model assumes that mandatory superannuation contributions $sc_j$ are made by households aged $j < j_R$, subject to a legislated cap on contributions. Specifically, gross contributions are given by

$$sc_j = \min\{\tau^p le_j, \overline{sc}\},$$

where $\tau^p$ denotes the mandatory contribution rate and $\overline{sc}$ is the cap on tax-favored contributions. Contributions are taxed at the flat rate $\tau^s$, so that net inflows into superannuation equal $(1-\tau^s)sc_j$. Superannuation assets earn the after-tax return $(1-\tau^r)r$ during the accumulation phase and are preserved until the access age $j_R$. For those aged $j \geq j_R$, we assume age-specific draw-down rates $\zeta_j$, so that withdrawals are given by $sp_j = \zeta_j(1+r)s_j$.

The superannuation asset accumulation and decumulation equation is given by

$$(1+g)s_{j+1} = \begin{cases} (1+(1-\tau^r)r)s_j + (1-\tau^s)sc_j, & \text{if } j < j_R, \\ (1-\zeta_j)(1+r)s_j, & \text{if } j \geq j_R. \end{cases} \tag{26}$$

**Social transfers.** The government also runs a social transfer program that pays social transfers $st_j$ to households aged $j < j_R$.[12] The total social transfer expenditure (excluding the age pension) is given by $ST = \sum_{j=1}^{j_R-1} \int_z st(z)\mathrm{d}X(z)$.

**Taxes.** 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 tax function and flat tax rates on other revenue sources.

The household taxable income $\tilde{y}_j$ comprises gross labor earnings, net of mandatory private pension contributions $le_j - sc_j$, and returns on liquid ordinary private assets $ra_j$, i.e., $\tilde{y}_j = (le_j - sc_j) + (1-\upsilon)ra_j$, where $\upsilon$ denotes a fraction of investment income exempt from income taxation. Following Heathcote et al. (2017) and Hosseini and Shourideh (2019), we adopt the income tax function:

$$T(\tilde{y}) = \tilde{y} - \lambda\,\tilde{y}^{1-\tau}, \tag{27}$$

[12] Transfers aggregate unemployment, family, and disability payments and are calibrated using age-skill profiles from HILDA (see Section 4).

where $\tau$ governs the progressivity of the tax schedule, while $\lambda$ is the tax-level parameter that shifts the overall level of household income taxation.[13]

The total government tax revenue $TR_t$ is made up of revenues from various taxation sources, including the progressive income tax $T_t^Y$, consumption tax $T_t^C$, tax-favored superannuation taxes $T_t^S$, and the corporate tax paid by firms $T_t^K$. These tax receipts can be expressed as

$$\begin{aligned} T_t^Y &= \int_{\mathcal{Z}} T(\tilde{y}(z_j, Z_t))\mathrm{d}X_t(z), \\ T_t^C &= \tau_t^c \int_{\mathcal{Z}} c(z_j, Z_t)\mathrm{d}X_t(z), \\ T_t^S &= \textstyle\sum_{j=1}^{j_R-1} \int_{\mathcal{X}} [\tau^s sc(z_j, Z_t) + \tau^r rs(z_j, Z_t)]\mathrm{d}X_t(z), \\ T_t^K &= \tau^k [Y_t - w_t L_t - \delta K_t]. \end{aligned} \tag{28}$$

**Government budget constraint.** The government issues new debt and collects taxes from both households and firms (with total tax revenue $TR_t$), to finance various expenditures such as general government expenditure $G_t$, transfer payments $P_t + ST$, and interest payments on its debt $r_t B_t^G$. The accumulation of government debt can be expressed as

$$(1+g)(1+n)B_{t+1}^G = (1+r_t)B_t^G + G_t + P_t + ST - TR_t. \tag{29}$$

In the benchmark steady state equilibrium, we target a debt-to-output ratio $b_y$ and adjust public consumption $G$ to satisfy the government budget constraint. We also use four adjustment parameters ($f^{ap}$, $f^{st}$, $f^c$, $f^k$) calculated to match the observed ratios of the given expenditure or tax revenue to output. These adjustment parameters alter the effective (tax or transfer) rates, with $f^{ap}$, $f^{st}$, $f^c$ included in the household optimization problem and $f^k$ in the firm's marginal productivity of capital condition.

In the policy simulations, the government budget is balanced by adjusting the tax-level parameter $\lambda_t$ in (27), while the progressivity parameter $\tau$, public consumption $G_t$, public debt $B_t^G$, and the remaining policy parameters are held fixed at their benchmark values.

## 3.6 Equilibrium

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

1. households make optimal consumption and labor decisions by maximizing (17) (as indicated above, we derived value functions that are) subject to the household budget constraint (19), the borrowing constraint $a_j \geq 0$, the time constraint $l_j \leq 1$ and the non-negativity constraint on consumption and leisure;

[13]The corresponding average and marginal tax rates are given by $\mathrm{ATR}(\tilde{y}) = \frac{T(\tilde{y})}{\tilde{y}} = 1 - \lambda\tilde{y}^{-\tau}$ and $\mathrm{MTR}(\tilde{y}) = \frac{dT(\tilde{y})}{d\tilde{y}} = 1 - (1-\tau)\lambda\tilde{y}^{-\tau}$, respectively.

2. the domestic interest and wage rates are determined according to (23) and (24);
3. the aggregation holds

$$L_t = \int_{\mathcal{Z}} e_j \cdot \exp[\eta_j]\, ls(z_j, Z_t) \mathrm{d}X_t(z_j),$$
$$C_t = \int_{\mathcal{Z}} c(z_j, Z_t) \mathrm{d}X_t(z_j),$$
$$A_t = \int_{\mathcal{Z}} a(z_j, Z_t) \mathrm{d}X_t(z_j),$$
$$S_t = \int_{\mathcal{Z}} s(z_j, Z_t) \mathrm{d}X_t(z_j);$$

4. the law of motion (20) and (21) for the measure of households hold;
5. bequests satisfy

$$(1+n)(1+g) \int_{\mathcal{Z}} b(z_j, Z_{t+1})\, dX_{t+1}(z_j) = \int_{\mathcal{Z}} (1-\psi_{j+1}) \Big[(1+r)(a_{j+1}(z_j, Z_{t+1}) + s_{j+1}(z_j, Z_{t+1}))\Big]\, dX_t(z_j$$

where accidental and intended bequests consist of both liquid and superannuation assets held at death and are redistributed across households by skill type and recipient age.[14]

6. the government budget (29) is balanced by choosing $G_t$ in the benchmark equilibrium or $f_t^y$ in the reform simulations);
7. the capital market clears

$$K_t = A_t + S_t - B_t^G; \tag{30}$$

8. the goods market clears

$$Y_t = C_t + I_t + G_t, \tag{31}$$

with $I_t$ as the gross investment.[15]

# 4 Calibration and Benchmark Model Performance

We calibrate the benchmark economy to Australia in a stationary steady state, targeting macroeconomic and fiscal aggregates averaged over the five years ending in June 2018, together with micro-level moments from the 2018 HILDA Survey (as documented in Section 2.3).

Our calibration proceeds in two steps. Demographic parameters are pinned down directly from the data, while parameters governing technology, preferences, and institutional features are either taken from the literature or informed by empirical evidence. The remaining preference and technology parameters and fiscal scalars are then calibrated internally to match key

[14]Bequests are first aggregated within each skill type and then redistributed across recipient ages according to exogenously specified age weights (see Section 4).

[15]Note that $I_t = (1+g)(1+n)K_{t+1} - (1-\delta)K_t$ (or in a steady state $I_t = I = (g+n+ng-\delta)K$) and in a small open economy, equation (30) also includes foreign assets (or debt) $B_t^F$ and equation (31) is extended to include net export $NX_t = (1+g)(1+n)B_{t+1}^F - (1+r)B_t^F$ (or in a steady state $NX_t = NX = (g+n+ng-r)B^F$).

macroeconomic and microeconomic moments, including the capital-output ratio, average labor supply (overall and by skill), public pension expenditure, and the share of self-funded retirees.

This section first describes the benchmark parameterization and then evaluates model performance by comparing steady-state outcomes to Australian data targets.

## 4.1 Parameterization

Tables 2 and 3 report the benchmark parameters. Table 2 summarizes demographics, skills and labor productivity, preferences, and production technology, while Table 3 reports pension and tax policy parameters.

Table 2: Key Parameter Values of Benchmark Model

| **Definition** | **Value** | **Source** |
|---|---|---|
| *Demographics* | | |
| Maximum life span | 16[1] | |
| Retirement age | 14[1] | |
| Pension access age | 10[1] | |
| Survival probabilities | [2] | ABS data |
| Population growth rate (p.a.) | 0.016 | Calibrated[3] |
| *Skills and Labor Productivity* | | |
| Number of (inborn) skills | 3[4] | |
| Skill distribution | [0.19,0.50,0.31] | HILDA18 |
| Deterministic productivity profile | [5] | HILDA18 |
| AR(1) correlation | 0.95 | Freestone (2018) |
| Transitory variance | 0.017 | Freestone (2018) |
| *Household Preferences* | | |
| Risk aversion coefficient | 2 | Kudrna et al. (2022) |
| Consumption weight parameter | [0.36,0.37,0.38] | Calibrated[6] |
| Time discount factor (p.a.) | 0.989 | Calibrated[7] |
| Bequest motive parameter | -9 | De Nardi (2004) |
| Bequest luxury good parameter | 10.6 | De Nardi (2004) |
| *Technology* | | |
| Capital share | 0.38 | Calibrated[8] |
| Capital depreciation rate (p.a.) | 0.054 | Calibrated[8] |
| Production constant | 1.58 | Calibrated[8] |
| Economic growth rate (p.a.) | 0.015 | |

*Notes:* [1] Model periods correspond to actual age groups 20-24, .., 95-99, with pension access age at 65-69 and full retirement at 85-89. [2] Survival rates are from Australian Bureau of Statistics (ABS) (2019c), averaged across males and females and adjusted to the five-year model period. [3] Population growth targets the old-age dependency ratio. [4] Skill types (low, middle, high) are defined by highest education level for individuals aged 20-64 in HILDA18. [5] Skill-specific age-productivity profiles are reported in Appendix D. [6] The consumption weight parameter is calibrated to match average hours worked by the working-age population. [7] The time discount factor is calibrated to match the capital-output ratio. [8] Production parameters are jointly calibrated to match key production-sector aggregates.

Table 3: Policy Parameterization of Benchmark Model

| Definition | Value | Source |
|---|---|---|
| *Public Pension*[1] | | |
| Maximum benefit | $0.34\bar{y}$ | Data |
| Asset test taper (withdrawal) rate (p.a.) | 0.068 | Data |
| Asset test threshold (disregard) | $6\bar{y}$ | Calibrated[2,3] |
| *Private pension* | | |
| Mandatory contribution rate | 8% | Calibrated[4] |
| Cap on contributions | $0.4\bar{y}$ | Data |
| Contribution tax rate | 15% | Data |
| Fund earnings tax rate (effective) | 7% | Data |
| *Tax System* | | |
| Government debt to output ratio (p.a.) | 0.20[3] | Data target |
| Income tax function - $\lambda$ | 0.714 | Calibrated[6] |
| Income tax function - $\tau$ | 0.2 | Data |
| Investment income exemption from income tax base - $\upsilon$ | 0.4 | Data |
| Statutory corporate tax rate | 30% | Data |
| Statutory consumption tax rate | 10% | Data |
| Social transfers | [5] | HILDA18 |
| *Fiscal Adjustment Parameters* | | |
| Public age pension | 0.802 | Calibrated[6] |
| Corporate tax | 0.700 | Calibrated[6] |
| Consumption tax | 1.075 | Calibrated[6] |

*Notes:* [1] All monetary values are derived for single pensioners. [2] The asset test threshold is set to target the share of self-funded seniors (not receiving any age pension). [3] Ratios are adjusted (divided by 5) to account for the five-year model period. [4] The mandatory contribution rate targets the superannuation assets to output ratio and is close to the average mandatory rate between 1992 and 2018. [5] Skill-specific age-profiles of social transfers are derived from HILDA18 and scaled to match the social transfers to output ratio. [6] Fiscal adjustment parameters are calibrated to target given government expenditure or tax revenue to output ratios. $\bar{y}$ denotes annual average earnings (approximately A$64,000).

### 4.1.1 Demographics, preferences, labor productivity and technology

**Demographics.** The model period spans five years. Individuals enter the economy at age 20 (model age $j = 1$) and can live up to age 99 ($J = 16$), corresponding to five-year age groups from 20-24 to 95-99. Households become eligible for public and private pensions at age 65-69 ($j_R = 10$) and are exogenously retired by age 85-89 ($j_{\overline{R}} = 14$).

We assume a stationary demographic structure characterized by age-specific survival probabilities $\psi_j$ and a constant population growth rate $n$ (equal to the fertility rate $n_1$), which jointly determine cohort sizes $m_j$. Survival probabilities are constructed from the 2016-18 ABS life tables (Australian Bureau of Statistics (ABS), 2019c), averaging male and female survival rates from ages 20 to 100 and aggregating them into five-year age groups. The implied life expectancies at ages 20 and 65 are 62.2 and 20.2 years, respectively, closely matching ABS targets.

The population growth rate $n$ is calibrated to match the old-age dependency ratio of 0.26 in 2018 (Australian Bureau of Statistics (ABS), 2019d).[16] This implies an annual population growth rate of $n = 0.016$, which closely aligns with the observed growth rate in 2018.

**Preferences.** Households have non-separable Cobb–Douglas preferences over consumption and leisure, a standard specification in the social security literature. Following Kudrna et al. (2022), we set the coefficient of relative risk aversion to $\sigma = 2$. The discount factor $\beta = 0.989$ is calibrated to match the aggregate capital-output ratio of 3.3, consistent with Australian macroeconomic averages over 2014-2018 (Australian Bureau of Statistics (ABS) (2019a)).

The consumption weight parameter $\nu_i$ is allowed to vary by skill type and is set to $\nu_i = (0.364, 0.374, 0.384)$ for low-, middle-, and high-skilled households, respectively. The middle-skilled value $\nu_{i=2} = 0.384$ is chosen to match average hours worked by the working-age population (0.31 of the normalized time endowment, approximately 33 hours per week Australian Bureau of Statistics (ABS) (2019b)). The values for low- and high-skilled households are adjusted to replicate observed skill differences in labor supply. We also incorporate age-specific consumption equivalence following Kaas et al. (2021). Life-cycle equivalence scales are based on the OECD-modified scale, with $\mu_j = (1, 1.4, 1.9, 1.75, 1.65, 1.56)$ for the age groups 20–24, 25–34, 35–44, 45–54, 55–64, and 65+, respectively.

The bequest motive follows a luxury bequest specification of De Nardi (2004), with parameters set to $q_1 = -9$, $q_2 = 10.6$, and $\sigma_b = 1.5$.

**Bequest distribution.** In addition to the aggregate bequest flow implied by the model, we introduce a structured redistribution of bequests across households. Following a common assumption in the quantitative life-cycle literature, aggregate bequests are first allocated by skill (or income) type, reflecting differences in lifetime earnings and wealth accumulation. This approach is standard in recent studies, including Kudrna et al. (2022), Fehr et al. (2025) and Wheadon et al. (2025), and is supported by empirical evidence indicating that inheritances are positively correlated with lifetime income and wealth.

Relative to these studies, which typically assume a uniform redistribution of bequests across recipient ages within each skill group, we introduce an age-dependent redistribution. Specifically, within each skill type, bequests are distributed across recipient ages using exogenously specified weights calibrated to match the empirical timing of inheritances. Using unpublished CEPAR analysis based on HILDA data, we assign bequest weights over ages 45-69 (corresponding to model ages $j = 6, \ldots, j_R$) given by $w^{beq}(6{:}j_R) = (0.11,\ 0.21,\ 0.31,\ 0.20,\ 0.17)$, which implies that inheritances peak around ages 55-59 and are concentrated in late working life. This pattern is also consistent with earlier findings for the US, such as Hansen and İmrohoroğlu (2008), who modeled bequest receipts that tend to peak around age 60.

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

**Skills, labor productivity and labor supply.** Individuals are assigned at entry to one of three permanent skill types, using educational attainment as a proxy for skill. Based on HILDA18 data for individuals aged 20–64, we classify households as *low*-skilled (less than 12 years of schooling), *middle*-skilled (completed high school or vocational qualification but no bachelor degree), and *high*-skilled (bachelor degree or higher). The resulting skill distribution is (0.19, 0.50, 0.31) for low-, middle-, and high-skilled types, respectively.

Labor productivity consists of a deterministic age profile and an idiosyncratic stochastic component. The deterministic age-wage profiles are estimated separately for each skill group using HILDA18 and normalized for model consistency (see Appendix D). These profiles capture the pronounced skill-dependent life-cycle wage gradients documented in Section 2.3. The stochastic component follows a skill-invariant AR(1) process. We adopt the autocorrelation and variance parameters reported in Table 2, based on Freestone (2018). While wage dispersion differs slightly across skill groups in the data, these differences are modest (as shown in Figure B.1). We therefore impose a common stochastic process across skills and allow deterministic profiles to generate the primary cross-skill heterogeneity.

Labor supply is modeled as a discrete choice, as is common in the quantitative life-cycle literature (see, e.g., Conesa et al. (2009)). Specifically, individuals choose from a grid of 21 labor supply points ranging from zero to 0.5 of the time endowment, equally spaced in increments of 0.025. The benchmark calibration targets an average labor supply of 0.31, corresponding to approximately 33 hours per week. Consistent with empirical evidence, average labor supply differs across skill types, with lower (higher) targets for low-skilled (high-skilled) individuals.

**Technology.** Production follows a standard Cobb–Douglas specification. The capital share is set to $\alpha = 0.38$, consistent with Australian national accounts data. The depreciation rate $\delta = 5.4\%$ (p.a.) is calibrated to match the observed investment–output ratio of $I/Y = 0.26$, while the implied steady-state interest rate is approximately 4.8% per year.[17] The productivity constant $\kappa = 1.58$ is chosen to normalize the steady-state wage to one. All macroeconomic targets are based on five-year averages from the Australian National Accounts ending in 2018 (Australian Bureau of Statistics (ABS) (2019a)). Trend productivity growth is set to $g = 1.5\%$ (p.a.).

### 4.1.2 Government

This subsection describes the benchmark parameterization of the public pension, mandatory private pension, social transfers, and the tax system. Parameter values are reported in Table 3.

[17] The implied interest rate is consistent with recent quantitative studies of the Australian economy. In particular, Kudrna et al. (2022) and Wheadon et al. (2025) employ benchmark interest rates close to 5% in structurally similar life-cycle models. More broadly, it is in line with standard calibrations in the international literature, where interest rates of approximately 5% are commonly used, for example in Conesa et al. (2009), Heathcote et al. (2010), and da Costa and Santos (2018).

**Public pension.** The Australian Age Pension is a non-contributory, means-tested transfer financed from general taxation. Households become eligible at $j_R = 10$ (representing the age group 65-69).

Pension benefits are determined by the asset test in equation (25), characterized by the maximum benefit $\bar{p}$, the asset threshold $\widehat{a}_{\min}$, and the taper rate $\Phi$. The maximum pension $\bar{p} = 0.34\bar{y}$ (for single pensioners) is payable when assessable assets $ta_j = a_j + s_j$ do not exceed $\widehat{a}_{\min}$. For assets above the threshold, benefits are reduced at the taper rate $\Phi = 0.068$ (p.a.) until eligibility is exhausted.[18] Because private pension assets enter assessable wealth, changes in mandatory contributions directly affect public pension eligibility.

The asset threshold $\widehat{a}_{\min}$ is calibrated to approximate the observed share of retirees receiving the full (maximum) pension benefit.[19] To ensure that aggregate pension expenditure equals $P = 2.93\%$ of GDP, we apply a proportional adjustment factor $f^{ap} = 0.8017$ to pension payments. This scaling reflects our use of the maximum pension rate for single pensioners, which exceeds the per-person maximum benefit for pensioner couples (with the maximum pension for each member of a couple equal to approximately 75% of the single rate). The adjustment implies a maximum pension replacement rate of approximately 28% of average labor income in the benchmark economy.

**Private pension.** Mandatory superannuation contributions are set at $\tau^p = 8\%$ of gross labor earnings for households below the pension access age. This rate approximates the historical average since the introduction of the Superannuation Guarantee in 1992 and helps replicate private pension assets of approximately 150% of GDP in 2018 (see Chomik et al. (2018b)). Contributions are subject to a legislated cap on tax-favored contributions. In the model, this is implemented as a cap on contribution flows, $sc_j = \min\{\tau^p le_j, \overline{sc}\}$, where $\overline{sc}$ is set to $0.4\bar{y}$, corresponding to the concessional contribution cap of approximately A\$25,000 relative to average earnings in 2018.

During the accumulation phase ($j < j_R$), contributions and fund earnings are taxed at flat rates $\tau^s = 15\%$ and $\tau^r = 7\%$, respectively.[20] Pension assets are illiquid prior to eligibility.

From age $j \geq j_R$, households withdraw age-specific fractions $\zeta_j = (0.25, 0.35, 0.5, 1)$, corresponding to ages 65–69, 70–74, 75–79, and 80+, respectively. Consistent with post-2007 legislation, withdrawals are tax-free.

[18] Based on Australian legislation, the asset test withdraws pension benefits at a rate defined in terms of a reduction in fortnightly payments per \$1,000 of assets above the threshold. Prior to 2008 and again since 2017, the taper reduced the pension by A\$3 per fortnight for each A\$1,000 of excess assets, corresponding to an annual taper rate of approximately 0.078 (i.e., $3 \times 26/1000$). Between 2008 and 2016, a lower taper of A\$1.5 per fortnight applied, implying an annual rate of approximately 0.039 (see Chomik et al. (2018a)). In the model, we set the annual taper rate to $\Phi = 0.068$, which lies between these two policy regimes and, in the benchmark calibration, helps match the observed share of self-funded retirees (i.e., those not receiving the Age Pension).

[19] In the Australian system, the asset test distinguishes between four thresholds depending on household type (single or couple) and housing status (homeowner or non-homeowner). For single pensioners in 2018, the relevant thresholds were approximately $4.1\bar{y}$ for homeowners and $7.3\bar{y}$ for non-homeowners, with higher thresholds applying to couple households. In the model, we abstract from this heterogeneity and use a single threshold calibrated to match the observed incidence of full pension receipt.

[20] Note that $\tau^r$ is the effective fund's earnings tax, with the value set zero for $j \geq j_R$, as in Kudrna and Woodland (2018).

**Social transfers.** Working-age households ($j < j_R$) receive age- and skill-specific transfers calibrated from HILDA18, capturing unemployment benefits, family payments, and disability support. These profiles are reported in Appendix D. A proportional adjustment ensures that aggregate transfer expenditure equals $ST = 4.5\%$ of GDP. Transfers are exogenous and remain fixed across pension policy counterfactuals.

**Taxes.** The model includes four revenue sources: personal income taxes, superannuation taxes, corporate taxes, and consumption taxes. The personal income tax base $\tilde{y}$ includes labor earnings net of mandatory contributions and ordinary asset income (with a 40% exemption, reflecting that capital income is already taxed at the corporate level, so that only part of household-level asset returns enters the personal income tax base).

We adopt the Heathcote et al. (2017) tax function calibrated to the 2017–18 Australian schedule. The progressivity parameter $\tau$ is set to match the curvature of the statutory schedule, while the tax-level parameter $\lambda$ is calibrated to match aggregate personal income tax revenue, which amounts to 11.4% of GDP in the data.

Superannuation (private pension) taxation is preferential relative to personal income taxation, with contribution and earnings tax rates $\tau^s = 15\%$ and $\tau^r = 7\%$ during accumulation. Corporate and consumption taxes are set at statutory rates, with effective rates adjusted by scalars $f^k = 0.7$ and $f^c = 1.075$ to match observed revenue ratios of output.

In the benchmark steady state, net government debt is set to the observed ratio $b_y = 0.20$ of GDP, and government consumption $G$ adjusts to satisfy the government budget constraint in (29).

## 4.2 Benchmark model performance

The model is solved numerically in Fortran using a Gauss–Seidel procedure following Auerbach and Kotlikoff (1987) and Fehr and Kindermann (2018) for stochastic implementations. For the steady-state benchmark, we iterate on aggregate variables, household decision rules, the distribution of households, and the government budget-balancing instrument until convergence.[21]

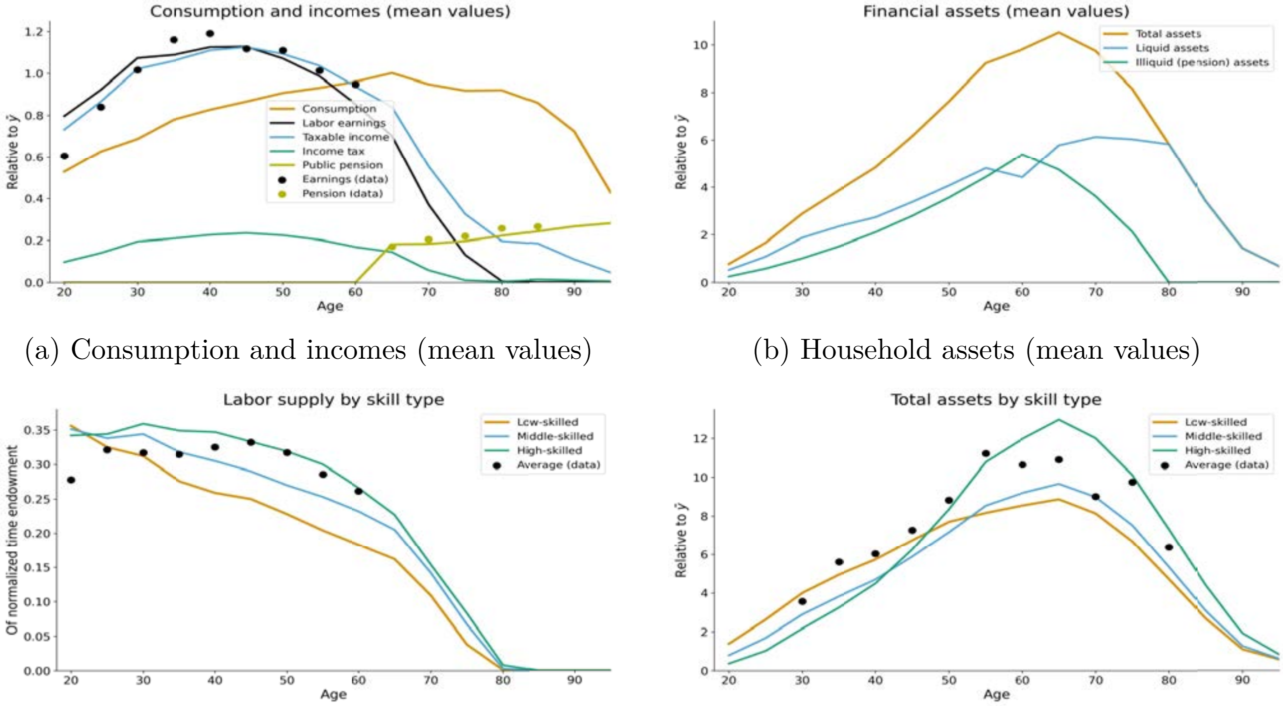
In the following, we evaluate the benchmark economy along two dimensions: ($i$) life-cycle profiles of key household variables, and ($ii$) aggregate macroeconomic and fiscal outcomes. In both cases, model outcomes are compared with Australian data.

**Life-cycle solutions.** Figure 4 reports selected life-cycle profiles from the benchmark economy.[22] Panels 4a and 4b show mean consumption, income, and financial assets averaged across skill types, while panels 4c and 4d report labor supply and total assets by skill type. Observed

[21] Appendix C provides a detailed description of the solution algorithm for both steady-state and transition simulations.

[22] All variables are expressed relative to average economy-wide labor income, which is A$64,000 in the data. Labor supply is measured as a share of the time endowment, which is normalized to one and corresponds to 105 non-sleeping hours per week (or 5,460 hours per year), consistent with Kudrna et al. (2022).

HILDA18 means for earnings, pension benefits, labor supply, and total assets are included as reference points.




(a) Consumption and incomes (mean values)

(b) Household assets (mean values)

(c) Labor supply by skill type

(d) Total assets by skill type

Figure 4: Life-cycle solutions of benchmark model

Most variables display the expected hump-shaped patterns: earnings and saving rise over the working life, assets peak near retirement (pension access age), and decumulation occurs thereafter. Low- and middle-skilled households supply fewer hours and accumulate substantially less wealth, generating persistent skill-based asset gaps into retirement.

The model closely replicates the empirical life-cycle profiles. The levels and shapes of earnings and labor supply are broadly consistent with the data, with some minor deviations at young ages reflecting the absence of education choice and labor-market frictions. Total financial assets align well with observed wealth accumulation, including the pronounced hump near retirement.

Importantly, the model reproduces the increasing age-pension profile observed in the data. As households decumulate assets in retirement, assessable wealth declines and eligibility for means-tested benefits expands. This mechanism is central to the model's representation of public–private complementarity.

**Aggregate solutions.** Table 4 compares aggregate macroeconomic and fiscal outcomes in the benchmark economy with Australian data targets (mostly expressed as % of GDP).[23]

The model matches the main macro aggregates closely. Private consumption, investment, labor supply, and major tax revenue categories align well with observed data. The capital stock

[23] Foreign assets are set to zero in the benchmark, ensuring a common steady-state starting point for both small-open and closed-economy transition experiments.

Table 4: Benchmark Aggregate Solutions and Targets

| **Variable** | **Model** | **Data target**[1] |
|---|---|---|
| *Aggregate demand* | | |
| Private consumption | 57.7 | 56.9 |
| Government consumption | 15.4 | 18.3 |
| Gross investment | 26.9 | 25.3 |
| *Capital market* | | |
| Capital stock | 329.8 | 329.54 |
| Total assets | 349.8 | |
| Liquid ordinary | 207.0 | |
| Private pension assets | 142.8 | 150[2] |
| Government (net) debt | 20 | 20 |
| Interest rate p.a. (%) | 4.8 | – |
| Share of liquidity-constrained households (%)[3] | 21.3 | – |
| *Labor market* | | |
| Labor supply[3,4] | 0.31 | 0.31 |
| *Government Policy*[5] | | |
| Income tax revenue | 11.4 | 11.4 |
| Marginal income tax rate (%)[3] | 29.3 | |
| Consumption tax revenue | 6.2 | 6.2 |
| Corporate tax revenue | 4.6 | 4.6 |
| Social transfers | 4.5 | 4.5 |
| Public pension expenditure | 2.9 | 2.9 |
| Share of elderly without pension (%) | 22.7 | 18–25[6] |
| Share of elderly receiving full pension (%) | 48.7 | 45–52[6] |

*Notes:* [1] Most targets are from Australian Bureau of Statistics (ABS) (2019a), 2014-2018 average; variables are expressed as a percentage of GDP unless stated otherwise. [2] Private pension assets target from Chomik et al. (2018b). [3] Calculated for the working-age population. [4] Labor supply refers to average hours worked relative to the normalized time endowment. [5] Government policy targets are from Australian Government (2019), 2014-2018 average. [6] Share of self-funded elderly and full pensioners based on Chomik et al. (2018a), ranges over 2009-2016.

and government debt ratios are calibrated to their empirical counterparts, and the model reproduces the structure of household balance sheets, including the magnitude of private pension assets.

The benchmark also captures key institutional features of the Australian retirement system. In particular, the model matches public pension expenditure (2.93% of GDP) and closely replicates the distribution of pension receipts, including both the share of elderly without pension (approximately 23%) and the share receiving the full pension (approximately 48%). These margins are central to the functioning of the means-tested system and its interaction with private saving.

In addition, the model closely approximates the share of liquidity-constrained households, defined as those holding liquid assets sufficiently close to zero. The benchmark value of 21.3% (for the working-age population, and 17.6% for the population as a whole) is consistent with empirical evidence for Australia reported by La Cava and Wang (2021), and with the broader literature on hand-to-mouth households, such as Kaplan et al. (2014). In the terminology of Kaplan et al. (2014), most liquidity-constrained households in the model correspond to *wealthy* hand-to-mouth agents, who hold low liquid assets but substantial illiquid wealth in the form of private pension accounts. Mandatory superannuation contributes to this pattern by shifting savings into illiquid form. While the introduction of age-dependent bequest redistribution mitigates liquidity constraints to some extent, these transfers are concentrated among older working-age households and therefore do not fully eliminate liquidity frictions earlier in the life cycle.[24]

Together with the model's fit to distributional moments (including skill-specific labor supply and inequality in income and wealth) reported in Appendix D.6, these results indicate that the framework provides a quantitatively credible representation of Australia's mixed public–private pension system. The benchmark therefore serves as a disciplined quantitative environment for evaluating how changes in mandatory private pension contributions affect economic efficiency and redistribution under strong public–private complementarity.

# 5 Quantitative Results

Building on the benchmark economy, which closely replicates Australia's key life-cycle, fiscal, and distributional features, we now quantify how changes in the mandated private pension contribution rate affect macroeconomic outcomes, welfare, and efficiency in a means-tested public pension system. We consider permanent reforms that change the contribution rate from its benchmark value of $\tau^p = 8\%$ to $\{0\%, 4\%, 10\%, 12\%, 14\%, 16\%\}$.[25]

The key mechanism is the interaction between mandatory saving and the Age Pension asset test: higher contributions raise private retirement assets and reduce pension eligibility, while also reallocating income into tax-favored accounts and potentially tightening liquidity

[24] Aggregate bequests amount to approximately 13.3% of GDP in the benchmark economy, consistent with the model's life-cycle saving, bequest motive, and mortality structure.

[25] In the figures below, we focus on a subset of counterfactuals $\tau^p \in \{0\%, 4\%, 10\%, 12\%, 14\%\}$, spanning both reductions relative to the benchmark and increases in the mandated contribution rate.

constraints during working life. All reforms are evaluated in a small open economy (SOE) with perfect capital mobility, so that the interest rate and wage rate remain fixed. The government budget is balanced each period through adjustments in the parameter $\lambda$ of the income tax function (27) in response to changes in pension expenditure and other fiscal flows, while government consumption and net public debt are held at their benchmark levels.[26]

Given the breadth of the analysis, we proceed in two steps. We first examine the long-run steady-state implications of changes in the mandated contribution rate, focusing on macroeconomic aggregates and welfare outcomes across skill types. We then turn to the transition dynamics following each reform, where we quantify the short- and medium-run macroeconomic adjustments, intergenerational welfare effects, and aggregate efficiency. In the latter, we use compensating transfers in the spirit of a Lump-Sum Redistribution Authority (LSRA) – a hypothetical mechanism that redistributes resources across cohorts while satisfying the government's intertemporal budget constraint – to assess whether reforms generate net aggregate efficiency gains once distributional impacts are taken into account.

## 5.1 Long-run (steady-state) implications

Table 5 summarizes the long-run steady-state effects of alternative contribution rates relative to the benchmark $\tau^p = 8\%$. The results reflect the interaction between mandatory private saving and the asset-tested public pension: higher contributions increase private retirement wealth and reduce pension eligibility, while lower contributions shift retirement financing toward the public system.

First, increasing the mandatory contribution rate above the benchmark raises long-run private wealth and consumption while reducing reliance on the public age pension. As $\tau^p$ increases, household financial assets rise substantially, which translates into higher private consumption in retirement. At the same time, the asset test becomes more binding, increasing the share of self-funded retirees and lowering public pension expenditure. This is reflected in the sharp rise in the share of elderly without pension benefits and the corresponding decline in full pension recipients. Reducing $\tau^p$ below the benchmark produces the opposite pattern: eliminating the mandate lowers household assets by roughly one-third, reduces consumption, and increases public pension costs by over 20%. Thus, across reforms, stronger mandatory saving shifts retirement financing toward private assets and away from the public pension, whereas weaker mandates increase fiscal pressure.

Second, the results highlight two additional mechanisms operating through the tax base and household liquidity. Higher contribution rates reduce taxable income, as a larger share of labor earnings is diverted into tax-favored retirement accounts. At the same time, they increase the share of liquidity-constrained households, reflecting the illiquidity of mandatory pension savings during working life. This tightening of liquidity constraints provides an important countervailing force to the long-run gains from higher retirement wealth. Conversely, reducing

[26] As robustness checks in the next section, we consider alternative specifications with (i) a less distortionary consumption tax instrument used to balance the government budget and (ii) fully endogenous factor prices in a closed economy setting.

Table 5: Long-run steady-state effects of alternative contribution rates*

| **Variable** | **Mandated contribution rate** | | | | |
|---|---|---|---|---|---|
| | $\tau^p = 0\%$ | $\tau^p = 4\%$ | $\tau^p = 10\%$ | $\tau^p = 12\%$ | $\tau^p = 14\%$ |
| *Macroeconomic outcomes* | | | | | |
| Private consumption | -4.54 | -2.46 | 0.97 | 1.81 | 2.74 |
| Effective labor supply[1] | -0.68 | -0.42 | 0.00 | -0.11 | -0.18 |
| Labor supply (hours)[2] | -1.74 | -1.07 | 0.16 | 0.43 | 0.66 |
| Household financial assets | -31.62 | -16.62 | 8.19 | 16.38 | 24.88 |
| Taxable income | 8.36 | 4.04 | -2.25 | -4.57 | -6.74 |
| *Fiscal and distributional margins* | | | | | |
| Liquidity-constrained households (%)[3] | 6.71 | 18.40 | 23.99 | 26.92 | 28.77 |
| Tax-function parameter, $\lambda$[4] | 0.712 | 0.712 | 0.714 | 0.713 | 0.713 |
| Public pension cost | 21.69 | 10.63 | -4.87 | -9.56 | -14.04 |
| Share of elderly with no pension (%) | 6.71 | 14.83 | 26.34 | 29.85 | 33.21 |
| Share of elderly on full pension (%) | 56.80 | 52.81 | 46.82 | 45.14 | 43.47 |
| *Welfare*[5] | | | | | |
| Average welfare | -0.79 | -0.42 | 0.17 | 0.31 | 0.46 |
| Low-skilled | -0.58 | -0.32 | 0.12 | 0.21 | 0.32 |
| Middle-skilled | -0.71 | -0.38 | 0.15 | 0.28 | 0.43 |
| High-skilled | -1.06 | -0.56 | 0.23 | 0.42 | 0.60 |

*Notes:* *Unless otherwise indicated, entries report percentage changes relative to the benchmark economy with $\tau^p = 8\%$. [1]Effective labor supply is defined as hours worked adjusted for labor productivity. [2]Labor supply measured as hours worked among the working-age population. [3]Share of liquidity-constrained households in the working-age population. [4]Level of the tax-function parameter $\lambda$, which adjusts to balance the government budget in each steady state. [5]Hicksian equivalent variation (HEV) measure.

$\tau^p$ expands the tax base and relaxes liquidity constraints, but at the cost of lower private saving and higher reliance on the public pension.

Despite these offsetting forces, the tax-function parameter $\lambda$ changes only modestly across steady states. While higher $\tau^p$ reduces the tax base, it also lowers public pension expenditure. These two effects largely offset each other, implying only small adjustments in the overall level of income taxation required to balance the government budget. Similarly, when $\tau^p$ is reduced, the expansion of the tax base is largely offset by higher pension spending.

Third, the welfare measures in Table 5 show long-run welfare gains from raising the contribution rate and welfare losses from lowering it.[27] Increasing $\tau^p$ above the benchmark leads to positive welfare effects, while reducing it generates losses. The gains are largest for high-skilled households, who face higher marginal tax rates and accumulate larger private pension balances, making them the primary beneficiaries of tax-favored contributions. Conversely, welfare losses from lower contribution rates are also largest for the high-skilled.

Finally, the labor-supply response is modest and reflects offsetting substitution and income effects. While effective labor supply changes little and becomes slightly negative at higher contribution rates, hours worked increase, indicating that behavioral responses occur primarily along the intensive margin of labor supply among the working-age population. This divergence reflects compositional effects, with increased labor input partly offset by shifts toward lower-productivity ages or states. As in Kudrna and Woodland (2013), tax-favored contributions raise the after-tax return to labor income (substitution effect). In our model, the income effect dominates for effective labor at higher contribution rates in the long run, as labor supply increases at younger ages but declines at older (lower and falling productivity) ages, leading to lower productivity-adjusted labor input despite higher hours worked among the working-age population.

## 5.2 Transition dynamics

We now examine the transition dynamics following an unexpected and permanent change in the mandatory contribution rate. Each reform is implemented at time $t = 1$, and we compute the full transition path until the economy converges to its new steady state. We focus on three dimensions: (i) macroeconomic and fiscal dynamics; (ii) intergenerational and skill-specific welfare effects; and (iii) aggregate efficiency effects under compensating transfers that quantify Pareto gains or losses.

### 5.2.1 Macroeconomic and fiscal effects

Figure 5 reports the transition dynamics of key macroeconomic and fiscal variables – household financial assets, private consumption, effective labor supply, hours worked (working-age

[27] We calculate the Hicksian equivalent variation (HEV), measured as the proportional change in consumption and leisure required for households in the benchmark economy to attain the level of lifetime utility realized under the policy experiment. Positive values therefore indicate welfare gains relative to the benchmark $\tau^p = 8\%$, while negative values represent welfare losses.

population), the income tax base, and public pension expenditures – for alternative contribution rates. All variables are expressed as percentage deviations from the benchmark model with contribution rate $\tau^p = 8\%$. The transition dynamics reflect the complementarity between private pension accumulation and the means-tested public pension, whereby higher private balances reduce pension eligibility and public expenditure. Because private wealth is a stock variable that adjusts gradually over the life cycle, these fiscal and macroeconomic responses unfold slowly over time, generating transitional paths that differ quantitatively from the eventual long-run steady-state effects discussed above. Additional transition dynamics for fiscal and distributional margins (including liquidity constraints and pension receipt shares) are reported in Appendix E.

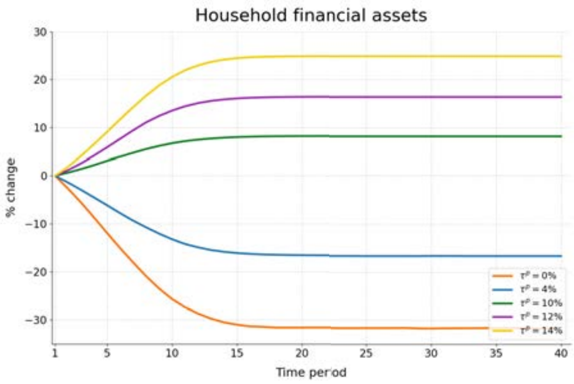
Across the macro aggregates, three main patterns emerge. First, household financial assets respond strongly to changes in the mandatory contribution rate. Higher contribution rates (10%, 12% or 14%) increase compulsory saving, leading to a gradual accumulation of private pension wealth and higher aggregate assets over the transition. Conversely, lowering $\tau^p$ to 4% or eliminating the mandate (0%) reduces long-term saving and depresses aggregate wealth.

Second, these wealth dynamics translate into corresponding effects on aggregate consumption. As households accumulate larger pension balances, lifetime resources increase and consumption rises over time. While higher contribution rates reduce disposable income and consumption in the short run, aggregate consumption increases gradually as higher accumulated wealth supports greater retirement consumption. In contrast, lower contribution rates lead to weaker wealth accumulation and lower consumption in the medium and long run.

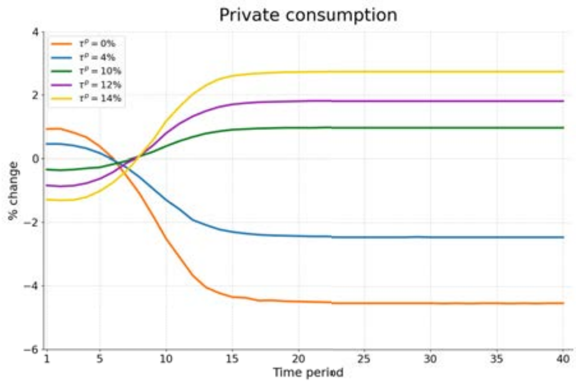
Third, labor supply responses differ depending on the measure considered. Effective labor supply and hours worked display similar dynamics in the short run, reflecting immediate behavioral responses to changes in disposable income and incentives. In the long run, however, the two measures diverge. Effective labor supply incorporates changes in productivity and the age composition of employment, whereas hours worked capture only the intensive margins of labor supply among the working-age population. As a result, shifts in labor across cohorts and productivity profiles generate differences between the two measures over time.

Turning to fiscal outcomes, the income tax base and public pension expenditures respond in opposite directions. Higher contribution rates reduce taxable income in the short run, as a larger share of earnings is diverted into tax-favored pension accounts. Over time, however, increased private wealth reduces reliance on the public pension system through the asset test, leading to a gradual decline in pension expenditures. Lower contribution rates generate the reverse pattern: an expansion of the tax base followed by rising pension costs as more retirees qualify for public support.

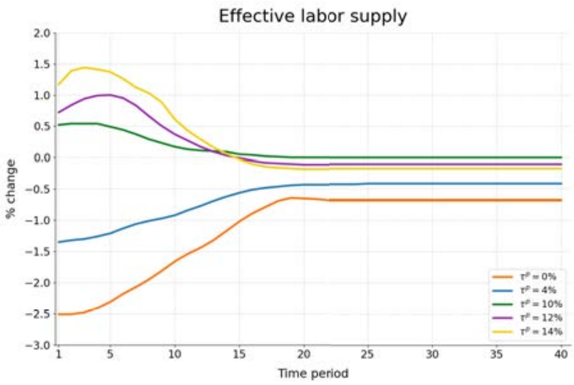
The budget-balancing income-tax parameter adjusts in response to these opposing forces (see Figure E.4d in Appendix E). In the long run, the scalar remains largely unchanged due to offsetting effects between the income tax base and pension expenditures. In the short and medium run, however, the adjustment is more pronounced. When $\tau^p$ increases, taxable income falls immediately while pension savings materialize only gradually, requiring higher tax rates (lower $\lambda$). Conversely, when $\tau^p$ is reduced, the tax base expands quickly, allowing for lower tax



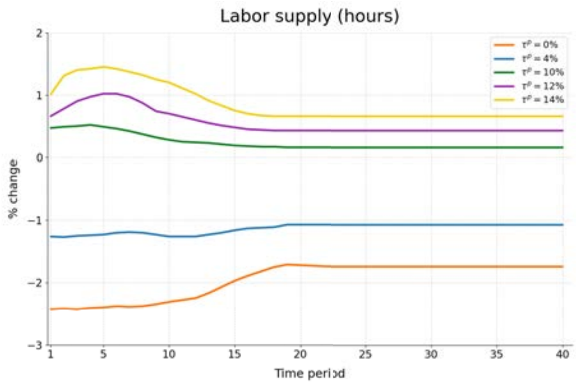

(a) Household financial assets



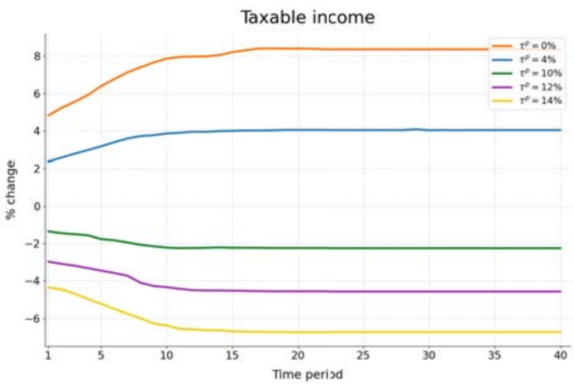

(b) Private consumption



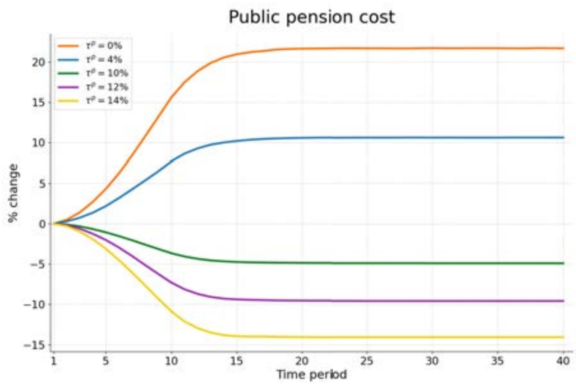

(c) Effective labor supply




(d) Labor supply (hours)




(e) Income tax base




(f) Public pension cost

Figure 5: Transition dynamics of macro variables under different contribution rates

rates initially, although rising pension expenditures eventually reverse part of this effect.

Overall, the transition dynamics highlight how mandatory saving reshapes private wealth accumulation, labor supply, pension eligibility, and fiscal pressures under strong public–private complementarity. Increasing (reducing) the contribution rate raises (lowers) private wealth, consumption, and self-funded retirement, while reducing (increasing) reliance on the public pension system.

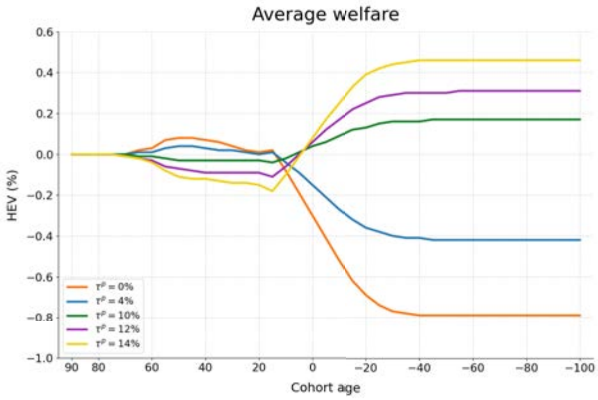
### 5.2.2 Intergenerational and distributional welfare effects

We next examine the welfare consequences of varying $\tau^p$. Figure 6 reports both average and distributional welfare effects across cohorts. The top panel presents average welfare effects, measured using Hicksian equivalent variation (HEV), defined as the percentage change in consumption and leisure required for each cohort in the benchmark economy to attain the level of lifetime utility realized under the policy experiment (see Appendix C, subsection C.3 for details). The horizontal axis identifies cohorts by their age at the time of the policy change ($t = 1$). The youngest currently alive cohort is aged 20, while all cohorts younger represent future-born generations. The long-run welfare effect is approximately attained for cohorts born around 60 years after the reform, by which time the economy has largely converged to its new steady state.

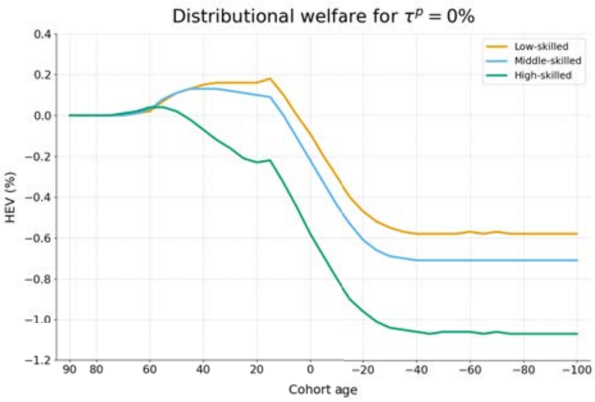
The average welfare dynamics reflect the intergenerational redistribution embedded in changes to the mandatory contribution rate. Increasing $\tau^p$ generates welfare losses for currently working cohorts, who face higher contributions and higher effective tax burdens but have limited time to accumulate and benefit from larger pension balances. These short-run losses are visible for cohorts alive at the time of the reform and are largest for middle-aged workers. In contrast, future generations benefit from higher lifetime resources due to increased private wealth and reduced reliance on public pension, leading to positive long-run welfare gains. Lowering $\tau^p$ produces the mirror image: short-run gains for existing cohorts, followed by long-run welfare losses for future generations.

The remaining panels of Figure 6 decompose these welfare effects by skill type for selected contribution rate increases. The results are reported for $\tau^p = 0\%$, 4%, 10%, and 12%, illustrating how the reform affects low-skilled, middle-skilled, and high-skilled households differently. These distributional patterns reflect the interaction between mandatory private saving, the progressive income tax system, and the means-tested public pension. Higher-skilled households benefit more from increases in $\tau^p$, as they face higher marginal tax rates and accumulate larger tax-favored pension balances. Low-skilled households, by contrast, rely more heavily on the public pension and face tighter liquidity constraints, which limits their ability to benefit from higher mandatory saving and results in smaller gains or persistent losses for some cohorts.[28]

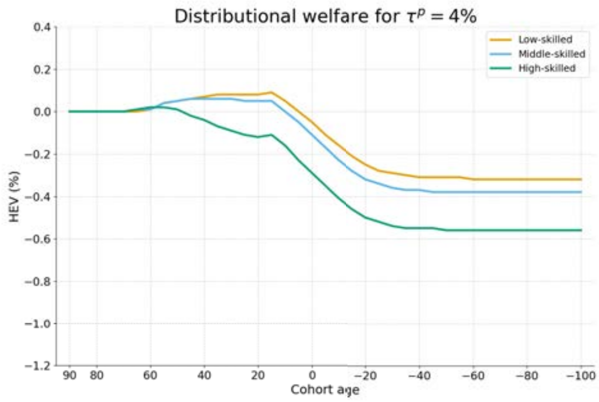
[28] Although not shown in the figure, we also compute distributional welfare effects for higher contribution rates ($\tau^p = 14\%$ and 16%). The qualitative pattern remains the same as for $\tau^p = 10\%$ and 12%, but the magnitudes are amplified. In particular, higher contribution rates lead to larger short-run welfare losses for currently alive cohorts and larger long-run gains for future generations. For example, under $\tau^p = 14\%$, the short-run welfare loss for low-skilled households reaches approximately 0.4%, while the long-run gain for high-skilled households is around 0.7%. These results are summarized in the next subsection.



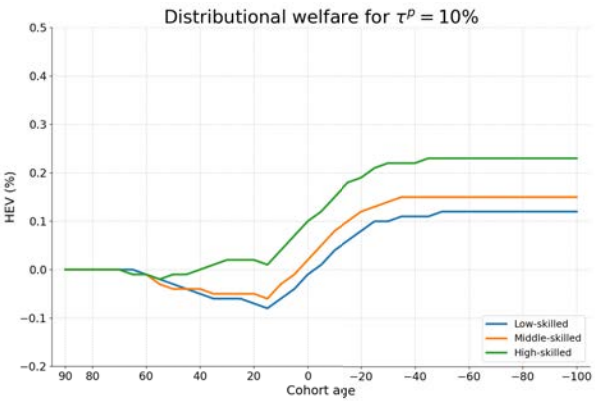

(a) Average welfare



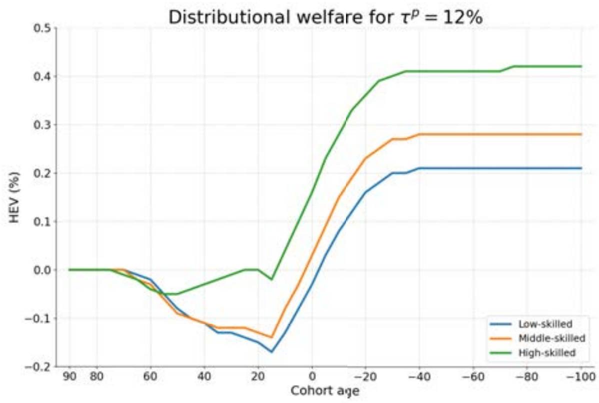

(b) $\tau^p = 0\%$




(c) $\tau^p = 4\%$




(d) $\tau^p = 10\%$




(e) $\tau^p = 12\%$

Figure 6: Intergenerational and distributional welfare effects for alternative contribution rates

Overall, the welfare results highlight the intergenerational and distributional trade-offs associated with adjusting the mandatory private pension contribution rate. Higher contribution rates generate long-run welfare gains, particularly for future high-skilled cohorts, but impose short-run costs on existing workers. Lower contribution rates shift the welfare profile in the opposite direction, improving short-run welfare at the expense of future generations. These findings underscore how strong public–private complementarity shapes both intergenerational redistribution and skill-specific welfare outcomes following pension reform.

### 5.2.3 Aggregate efficiency and Pareto implications

To assess the efficiency implications of changes in the mandatory contribution rate, we introduce a system of lump-sum transfers administered by a hypothetical Lump-Sum Redistribution Authority (LSRA). The LSRA redistributes resources across cohorts so that: $(i)$ all households alive at the time of the reform are held at their pre-reform lifetime utility, and $(ii)$ all future-born cohorts experience the same proportional change in lifetime utility. The sequence of transfers is constructed such that its present value at the time of reform is zero. Under this compensation scheme, a uniform increase in lifetime utility for future-born cohorts represents an aggregate efficiency gain, and the reform is weakly Pareto improving. See Appendix C, subsection C.3 for details.

Table 6 reports short-run and long-run welfare effects (without LSRA) alongside LSRA-based aggregate efficiency outcomes for alternative contribution rates. The short-run and long-run welfare measures summarize the intergenerational patterns discussed in the previous subsection and provide a useful benchmark for interpreting the efficiency results. Our focus here is on the LSRA measure, which abstracts from redistribution and isolates net efficiency effects.

Table 6: Welfare and aggregate efficiency effects of alternative contribution rates*

| **Welfare measure** | **Mandated contribution rate** | | | | | |
|---|---|---|---|---|---|---|
| | $\tau^p = 0\%$ | $\tau^p = 4\%$ | $\tau^p = 10\%$ | $\tau^p = 12\%$ | $\tau^p = 14\%$ | $\tau^p = 16\%$ |
| No-LSRA – Short-run welfare | 0.080 | 0.040 | -0.040 | -0.110 | -0.180 | -0.310 |
| No-LSRA – Long-run welfare | -0.790 | -0.420 | 0.170 | 0.310 | 0.460 | 0.540 |
| LSRA – Aggregate efficiency | -0.557 | -0.290 | 0.090 | 0.158 | 0.233 | 0.201 |

*Notes:* *Entries are Hicksian equivalent variation (HEV) measures in percent relative to the benchmark contribution rate of $\tau^p = 8\%$. The no-LSRA short-run welfare row reports the average welfare effect for current generations most affected at the time of reform, while the no-LSRA long-run welfare row reports the steady-state welfare effect for newborn cohorts. The LSRA aggregate efficiency row is computed using compensating transfers along the transition path and reports the uniform gain or loss assigned to all generations born in period $t = 1$ and thereafter.

The results indicate a clear non-linear relationship between the contribution rate and aggregate efficiency. Reducing $\tau^p$ below the benchmark leads to substantial efficiency losses: aggregate efficiency declines by $-0.557\%$ at $\tau^p = 0\%$ and $-0.290\%$ at $\tau^p = 4\%$. These losses reflect the increased reliance on the public pension system, which raises fiscal pressure and amplifies distortions associated with income taxation.

In contrast, increasing the contribution rate above the benchmark generates positive efficiency gains. The gains are modest but economically meaningful, reaching 0.090% at $\tau^p = 10\%$, 0.158% at $\tau^p = 12\%$, and peaking at 0.233% for $\tau^p = 14\%$. These improvements arise because higher mandatory saving strengthens the complementarity with the means-tested pension system: larger private balances reduce pension eligibility and public expenditure, thereby alleviating fiscal pressure and reducing the need for distortionary taxation.

However, the efficiency gains do not increase monotonically. At $\tau^p = 16\%$, aggregate efficiency declines slightly to 0.201%. This reflects diminishing returns to higher mandated saving. While stronger contributions continue to reduce pension expenditures, they also further erode the taxable income base and tighten liquidity constraints for working-age households. In addition, the contribution cap becomes increasingly binding at higher contribution rates, particularly for high-skilled households with higher earnings. This limits the marginal increase in effective retirement saving and attenuates the reduction in public pension reliance. Together, these forces imply that the efficiency-maximizing contribution rate lies in an interior range, around 14% in this specification.

The magnitude of these aggregate efficiency gains is modest in absolute terms but economically meaningful given the scope of the reform. The analysis considers incremental changes to an already mature mandatory pension system – increasing the contribution rate from 8 percent to 14 percent of gross wages – rather than a large-scale structural reform such as the introduction or privatization of a public pension system. Studies of broader pension reforms typically report larger aggregate efficiency effects, reflecting stronger capital accumulation and labor-supply responses (see, e.g., Hosseini and Shourideh (2019) and **?**). In contrast, the gains identified here arise through a narrower fiscal channel: higher private retirement wealth reduces eligibility for means-tested public pensions and lowers the distortionary taxes required to finance them. Because this mechanism primarily affects households near the pension means-test threshold, the associated efficiency gains are naturally limited in magnitude. Nevertheless, the results show that this complementarity channel alone (holding all other structural features of the retirement system fixed) can generate positive aggregate efficiency gains and support Pareto-improving pension reform.

In summary, the results point to a clear efficiency ranking of policy options. Lower contribution rates are unambiguously efficiency reducing, while moderate increases in $\tau^p$ improve aggregate efficiency. At the same time, the gains are bounded, and very high contribution rates exhibit diminishing efficiency benefits. These findings highlight that, under strong public–private complementarity and income-tax financing, efficiency is maximized at intermediate contribution rates rather than at the upper end of the policy range considered.

# 6 Sensitivity Analysis and Extensions

This section evaluates the robustness of the welfare and aggregate efficiency implications of mandatory private pension contributions to alternative institutional designs, fiscal adjustment mechanisms, and general-equilibrium structure. The baseline results in Table 6 highlight a central finding: moderate increases in the contribution rate generate positive long-run welfare gains and positive aggregate efficiency effects, reflecting strong complementarity between private pension accumulation and the means-tested public pension system.

We assess whether this conclusion holds when (*i*) the public pension system is redesigned and (*ii*) the fiscal adjustment instrument and market structure are altered. In all cases, results are reported relative to the benchmark contribution rate $\tau^p = 8\%$ and include both no-LSRA welfare measures (short-run and long-run) and LSRA-based aggregate efficiency effects.

## 6.1 Alternative public pension designs

We first explore how the welfare and efficiency consequences of mandatory private saving depend on the structure of the public pension system. Starting from the benchmark Australian-style means-tested public pension, we consider three alternative specifications. These specifications are not intended as calibrated models of the Dutch or US pension systems; rather, they represent controlled institutional variations designed to isolate the roles of means testing and benefit generosity in shaping the welfare and efficiency consequences of mandatory private saving. All structural parameters – including preferences, productivity risk, demographics, and the tax function – are held fixed at their Australian benchmark values throughout.

1. a *universal pension* that removes the asset-test taper (i.e., $\Phi = 0$), while holding the maximum pension benefit fixed at the benchmark level. This specification isolates the effect of eliminating means testing while holding benefit generosity constant, capturing a key feature of universal flat-rate pension systems such as that of the Netherlands;

2. a *higher-benefit means-tested pension* that raises the maximum pension from 27 percent to 40 percent of average income while retaining the benchmark means test; and

3. a *universal higher-benefit pension* that combines specifications (i) and (ii), representing a generous universal public pension with aggregate expenditure broadly comparable to that of US Social Security. This specification does not replicate the contributory earnings-linked structure of US Social Security, where benefits are determined through a progressive bend-point formula applied to lifetime earnings (see, e.g., Hosseini and Shourideh (2019)). Instead, it isolates the joint effect of removing means testing and increasing benefit generosity while holding the financing structure fixed. A full modeling of contributory earnings-linked public pensions is left for future work.

For each specification, we recompute a new benchmark steady state under the modified pension rules, holding all structural parameters fixed and maintaining the contribution rate at $\tau^p = 8\%$. Government consumption adjusts to balance the budget in these steady states, so that differences across specifications reflect only changes in pension design.[29]

[29] This implies that throughout, the initial level of income taxation is kept consistent with the benchmark in the previous section. This is important, as higher income taxation (required to fund universal and/or more generous pensions) would itself strengthen incentives for tax-favored mandatory saving, confounding the role of public–private complementarity that is the focus of the analysis.

Removing the means test (under 1.) increases public pension expenditure from 2.9% to approximately 4.1% of GDP, with all retirees receiving the full pension. Raising the maximum benefit while retaining the means test (under 2.) increases pension expenditure further to about 4.8% of GDP. Although the formal structure of the means test is unchanged, the higher benefit level alters the distribution of pension receipt: the share of full pensioners rises to around 60%, while the share of self-funded retirees declines to roughly 15%, reducing the effective strength of the means test. Combining both changes (under 3.) raises public pension expenditure to approximately 6.1% of GDP, approaching the expenditure share observed in the US (see Table 1).

Starting from each of these alternative steady states, we then evaluate changes in the contribution rate $\tau^p$ along transition paths (without and with LSRA), with the income-tax parameter $\lambda$ adjusting to balance the government budget, as in the benchmark economy.

These institutional variations allow us to disentangle how eligibility rules (means testing) and benefit generosity shape the interaction between private saving and public entitlements, and thereby the welfare and efficiency implications of mandatory private pension contributions.

Table 7 reports the welfare and aggregate efficiency effects resulting from the three alternative pension designs at selected contribution rates. Additional short- and long-run macroeconomic and fiscal effects under these alternative pension designs are reported in Appendix F (Table F.3). These results help to rationalize the welfare patterns documented here by illustrating how changes in saving, labor supply, pension expenditure, and income tax adjustment differ across institutional environments.

Relative to the baseline results in Table 6, the role of the means test emerges as central. Under a universal pension, eliminating or reducing the mandate generates positive short-run welfare effects and only modest long-run gains, while aggregate efficiency effects are negative across all contribution rates. In contrast to the baseline – where increasing $\tau^p$ to 10% or 12% yields positive efficiency gains (0.090% and 0.158%, respectively) – the absence of means testing removes the fiscal offset mechanism, so mandatory saving primarily crowds out private saving while increasing distortions.

Raising the maximum benefit while retaining the means test produces a pattern closer to the benchmark. As in Table 6, increasing $\tau^p$ generates long-run welfare gains (e.g., 0.18% and 0.35% at $\tau^p = 10\%$ and 12%) and positive efficiency effects (0.057% and 0.098%), although the gains are smaller. This reflects the weaker effective strength of the means test under higher benefit levels: as a larger share of retirees qualifies for the full pension, the marginal reduction in public expenditure induced by additional private saving is reduced. As a result, the fiscal offset channel is attenuated, dampening the efficiency gains from higher contribution rates. This confirms that the presence – and effective strength – of means testing, rather than the level of benefits per se, is the key driver of complementarity between private saving and public pension expenditure.

The combined universal higher-benefit system further weakens this mechanism. While long-run welfare gains remain positive at higher contribution rates, aggregate efficiency effects are close to zero or negative. Compared to the baseline, this specification dampens the efficiency

Table 7: Welfare and aggregate efficiency under alternative public pension systems*

| **Alternative framework / Welfare measure** | **Mandated contribution rate** | | | |
|---|---|---|---|---|
| | $\tau^p = 0\%$ | $\tau^p = 4\%$ | $\tau^p = 10\%$ | $\tau^p = 12\%$ |
| *1. Universal pension* | | | | |
| No-LSRA – Short-run welfare | 0.120 | 0.050 | -0.110 | -0.230 |
| No-LSRA – Long-run welfare | -0.260 | -0.170 | 0.050 | 0.100 |
| LSRA – Aggregate efficiency | -0.072 | -0.071 | -0.037 | -0.068 |
| *2. Higher benefit level* | | | | |
| No-LSRA – Short-run welfare | 0.170 | 0.080 | -0.090 | -0.200 |
| No-LSRA – Long-run welfare | -0.860 | -0.430 | 0.180 | 0.350 |
| LSRA – Aggregate efficiency | -0.538 | -0.257 | 0.057 | 0.098 |
| *3. Universal higher-benefit pension* | | | | |
| No-LSRA – Short-run welfare | 0.110 | 0.050 | -0.100 | -0.190 |
| No-LSRA – Long-run welfare | -0.200 | -0.110 | 0.060 | 0.140 |
| LSRA – Aggregate efficiency | -0.027 | -0.012 | -0.016 | -0.012 |

*Notes:* *Entries are Hicksian equivalent variation (HEV) measures (in %) relative to the benchmark $\tau^p = 8\%$. No-LSRA short-run welfare reports the average effect for current generations most affected at the time of reform, while no-LSRA long-run welfare reports steady-state effects for newborn cohorts. LSRA aggregate efficiency is computed using compensating transfers and reports the uniform gain or loss for all generations born in period $t = 1$ and thereafter. [1] Models 1–3 evaluate alternative public pension designs: (1) universal pension with the taper set to zero; (2) higher benefit level, where the maximum pension is increased from 27% to 40% of average income while retaining the means test; (3) universal higher-benefit pension combining (1) and (2).

gains from increasing $\tau^p$, highlighting that generous universal provision largely substitutes for private saving.

Overall, the comparison with Table 6 shows that the efficiency gains from mandatory private pensions depend critically on the interaction between private wealth accumulation and means-tested public entitlements. Removing the means test eliminates this channel and largely reverses the efficiency ranking of contribution rates.

## 6.2 Alternative budget financing and market structure

We next assess the robustness of the baseline results to alternative fiscal adjustment mechanisms and general-equilibrium structure. Table 8 reports results for changing $\tau^p$ under (i) consumption-tax financing and (ii) a closed-economy specification with endogenous factor prices.[30] The reported welfare and efficiency effects are directly comparable to the baseline results in Table 6, which are obtained under the small open economy specification with the income-tax-function parameter $\lambda$ adjusting to balance the government budget.

Under consumption-tax financing, the welfare and efficiency results are quantitatively very close to the baseline. Short-run welfare losses for current working cohorts are somewhat smaller, reflecting the less distortionary nature of consumption taxation relative to temporary increases

[30] Additional short- and long-run macroeconomic and fiscal effects for these alternative frameworks are reported in Appendix F (Table F.4), and help to rationalize the welfare patterns documented here.

Table 8: Welfare and efficiency under alternative financing and market structure*

| **Alternative framework / Welfare measure** | **Mandated contribution rate** | | | |
|---|---|---|---|---|
| | $\tau^p = 0\%$ | $\tau^p = 4\%$ | $\tau^p = 10\%$ | $\tau^p = 12\%$ |
| *1. Budget-balancing consumption tax* | | | | |
| No-LSRA – Short-run welfare | 0.080 | 0.030 | -0.030 | -0.070 |
| No-LSRA – Long-run welfare | -0.760 | -0.390 | 0.170 | 0.310 |
| LSRA – Aggregate efficiency | -0.563 | -0.299 | 0.102 | 0.185 |
| *2. Closed economy* | | | | |
| No-LSRA – Short-run welfare | 0.380 | 0.190 | -0.130 | -0.280 |
| No-LSRA – Long-run welfare | -1.540 | -0.720 | 0.310 | 0.610 |
| LSRA – Aggregate efficiency | -0.554 | -0.259 | 0.080 | 0.153 |

*Notes:* *Entries are Hicksian equivalent variation (HEV) measures (in %) relative to the benchmark contribution rate of $\tau^p = 8\%$. No-LSRA short-run welfare reports the average effect for current generations most affected at the time of reform, while no-LSRA long-run welfare reports steady-state effects for newborn cohorts. LSRA aggregate efficiency is computed using compensating transfers and reports the uniform gain or loss for all generations born in period $t = 1$ and thereafter. Framework 1 uses consumption tax adjustments to balance the budget (with $\lambda$ fixed), while Framework 2 assumes a closed economy with endogenous factor prices.

in income taxation (via reductions in $\lambda$). This attenuates the intertemporal wedge faced by workers and results in slightly higher aggregate efficiency gains at higher contribution rates.[31]

The closed-economy specification yields a different transitional profile but similar overall efficiency implications. In the short run, welfare losses are larger than in the small open economy benchmark, driven by stronger income-tax adjustments required to balance the budget. In the long run, however, higher contribution rates lead to substantial capital deepening, raising wages and supporting higher labor supply and earnings (see Table F.4). These general-equilibrium effects translate into significantly larger long-run welfare gains relative to the baseline. Despite these differences, the resulting aggregate efficiency effects remain close to those obtained under the baseline specification.

Overall, both alternative frameworks confirm the robustness of the main finding: moderate increases in the mandatory contribution rate improve aggregate efficiency, while the magnitude of the gains remains broadly similar across alternative financing mechanisms and market structures.

In summary, the sensitivity analysis highlights two key mechanisms underpinning the baseline findings in Table 6: the complementarity between private wealth accumulation and means-tested public pensions, and general-equilibrium feedback effects operating through capital accumulation and factor prices. Together, these channels explain why moderate increases in mandatory contribution rates improve aggregate efficiency, and why this conclusion remains robust across alternative institutional designs, financing mechanisms, and market structures.

[31] The use of consumption taxation as a budget-balancing instrument is common in related literature; see, for example, Hosseini and Shourideh (2019) and Fehr et al. (2025).

# 7 Conclusion

This paper has examined the welfare and efficiency implications of alternative degrees of complementarity between public and private pensions in mixed retirement-income systems. Motivated by the observation that the implicit return on PAYG pensions is constrained by demographic and productivity growth, whereas funded private pensions earn the market return on capital, we asked whether shifting retirement financing toward mandatory private saving can generate Pareto improvements. To address this question, we developed a dynamic overlapping-generations model with heterogeneous households facing idiosyncratic labor productivity risk, progressive income taxation, and a detailed institutional structure combining a means-tested public pension with illiquid, tax-favored private pension accounts. The model was calibrated to the Australian economy using both macro aggregates and micro-level life-cycle evidence on income, transfers, and wealth.

Our quantitative results show that the interaction between private wealth accumulation and means-tested public entitlements is central for welfare and efficiency outcomes. When public pensions adjust endogenously to private saving through an asset test, stronger private saving can reduce fiscal pressure, increase aggregate wealth, and improve long-run welfare across skill groups. In the Australian benchmark, modest increases in the mandatory contribution rate raise aggregate saving and reduce public pension expenditure, allowing for compensating transfers that leave current cohorts unharmed while improving outcomes for future generations. Under this institutional setting, mandatory private saving effectively induces partial privatization of retirement income in a way that preserves redistribution while strengthening efficiency.

By contrast, in systems with weaker or absent means testing, the efficiency case for mandating private saving is substantially diminished. In a universal public pension setting, additional private contributions do not reduce public expenditures and primarily crowd out voluntary saving while tightening liquidity constraints. As a result, aggregate efficiency gains disappear and can turn negative. This comparison highlights that it is not public pension generosity, but the linkage between private wealth and public entitlements, that determines whether mandatory private pensions enhance or reduce welfare. Institutional design – particularly the presence of means testing – plays a pivotal role in aligning incentives with redistribution.

Two limitations are worth noting. First, the model abstracts from owner-occupied housing, which is exempt from the Australian Age Pension asset test and may provide an alternative vehicle for retirement wealth accumulation outside the mandatory pension system. Incorporating housing tenure and housing taxation would allow for a more complete analysis of the interaction between public pensions, private pensions, and housing wealth.[32] Second, the analysis assumes fully rational households and therefore abstracts from behavioral frictions such as present bias and self-control problems, which may strengthen the value of mandatory retirement saving and illiquid pension accounts.[33] We leave these extensions for future research.

[32] Fehr et al. (2025) show that pension arrangements can significantly affect long-run homeownership and housing accumulation decisions.

[33] Wheadon et al. (2025) show that self-control problems can significantly affect the optimal design of public pension means testing in a steady-state model without private pensions.

More broadly, the analysis highlights that the effectiveness of mandatory private pensions depends fundamentally on how they interact with the public pension system. Understanding these complementarities is essential for designing retirement-income systems that balance redistribution, efficiency, and fiscal sustainability.

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# Appendices

The appendices provide additional institutional, empirical, and technical details supporting the quantitative analysis. Appendix A summarizes the institutional features of Australia's tax and pension system as implemented in the quantitative model. Appendix B presents supplementary empirical evidence from HILDA used to discipline key life-cycle inputs. Appendix C describes the numerical solution method and transition algorithm. Appendix D documents the calibration of productivity and transfer profiles used in the benchmark economy and presents selected distributional solutions of the benchmark model. Appendix E reports additional results on transitional dynamics of key fiscal and distributional margins, complementing the main macroeconomic, fiscal, and welfare effects of changes in the mandatory contribution rate, $\tau^p$. Appendix F provides additional quantitative results for the sensitivity analysis.

## Appendix A Australia's Tax and Pension System

This appendix documents the institutional features of the Australian tax and pension systems that are explicitly incorporated into the quantitative model.

### A.1 Tax-transfer system

Government revenue in Australia is raised primarily through personal income taxation, corporate taxation, and indirect consumption taxes. In the model, we incorporate: (i) a progressive personal income tax schedule, (ii) a proportional corporate tax, (iii) a proportional consumption tax, and (iv) targeted social transfers.

**Personal income taxation.** The personal income tax base $\widetilde{y}$ consists of labor earnings (net of mandatory superannuation contributions) and capital income. The statutory 2017-18 income tax schedule can be written as:

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

where income thresholds are indexed to average annual earnings $\overline{y} = \$64{,}000$ in 2018.

In the model, we approximate this schedule using the parametric tax function of Heathcote et al. (2017):

$$T(\widetilde{y}) = \widetilde{y} - \lambda \widetilde{y}^{1-\tau},$$

which delivers smooth average and marginal tax rates given by

$$\text{ATR}(\widetilde{y}) = 1 - \lambda \widetilde{y}^{-\tau}, \qquad \text{MTR}(\widetilde{y}) = 1 - (1-\tau)\lambda \widetilde{y}^{-\tau}.$$

The parameters are calibrated to replicate both the progressivity and the aggregate income tax revenue share observed in the data.

**Other taxes.** The corporate tax rate is set to the statutory 30%. The consumption tax is modeled as a proportional tax calibrated to match aggregate indirect tax revenue. Superannuation taxes are discussed below in the subsection on private pensions.

Unlike many OECD countries, Australia does not levy a payroll tax dedicated to pension financing. Public pension expenditures are funded from general taxation.

## A.2 Public Age Pension

Australia operates a non-contributory, means-tested public pension (Age Pension). Benefits are: (i) independent of employment history, (ii) financed from general tax revenue, (iii) subject to income and asset tests, and (iv) not universally received.

Approximately 75% of age-eligible individuals receive some payment, and roughly 45% receive the maximum benefit. Aggregate expenditure is below 3% of GDP.

**Means test.** The statutory system includes both an income test and an asset test. In the model, we approximate this structure using a calibrated asset test that captures the key interaction between private retirement wealth and pension eligibility.

The modeled pension rule consists of:

- a maximum benefit,
- an asset disregard threshold,
- a taper rate reducing benefits above the threshold.

This formulation replicates aggregate pension expenditure, the share of recipients among the elderly, and the share of self-funded retirees.

The central mechanism captured in the model is that higher private wealth reduces public pension eligibility through the asset test.

## A.3 Mandatory private pension (superannuation)

Australia's second pillar is a mandatory defined-contribution system known as superannuation. Contributions are made to individual retirement accounts under the Superannuation Guarantee (SG), introduced in 1992.

The statutory SG rate increased gradually over time and is legislated to reach 12% of gross wages by 2025-26 (see Table A.1).

In the model:

- the mandatory contribution rate is set to $\tau^p = 8\%$ in the benchmark;
- contributions are proportional to gross labor income;

Table A.1: Mandatory superannuation contribution 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 |
| 2002–2013 | 9 | 9 |
| 2014 | 9.25 | 9.25 |
| 2015–2021 | 9.5 | 9.5 |
| 2021–22 | 10 | 10 |
| 2022–23 | 10.5 | 10.5 |
| 2023–24 | 11 | 11 |
| 2024–25 | 11.5 | 11.5 |
| 2025–26 | 12 | 12 |

*Source:* Australian Taxation Office (ATO).

- funds accumulate at the market return;
- assets are illiquid until retirement;
- withdrawals in retirement are untaxed.

The benchmark contribution rate approximates the average SG rate over the maturation period of the system and replicates the observed aggregate superannuation asset-to-GDP ratio.

**Tax treatment.** Superannuation receives concessional tax treatment:

- 15% tax on contributions,
- approximately 7% effective tax on fund earnings,
- no tax on withdrawals in retirement.

These concessional rates are explicitly incorporated into the model and generate a superannuation tax expenditure relative to the progressive income tax schedule.

**Interaction with the public pension.** Superannuation balances are included in the Age Pension asset test. Consequently, higher private balances reduce public pension eligibility. Mandatory saving therefore affects both private wealth accumulation and public pension expenditure. This interaction is central to the complementarity mechanism analyzed in the paper.

### A.4 Abstractions

The model abstracts from:

- the income-test component of the Age Pension,
- voluntary superannuation contributions,
- heterogeneity in family status,
- payroll-tax instruments.

These simplifications preserve the core interaction between private wealth accumulation and means-tested public pension eligibility, which is the primary focus of the analysis.

# Appendix B Additional Empirical Evidence

This appendix provides additional empirical details underlying the empirical motivation discussed in Section 2.3. In particular, we document patterns in wage dispersion and working-age social transfers that further inform the model's calibration.

## B.1 Data and sample construction

We use micro-level data from the Household, Income and Labour Dynamics in Australia (HILDA) Survey (Summerfield et al., 2019). The primary cross-sectional profiles are constructed using the 2018 wave, while pension participation and benefit patterns at advanced ages use pooled waves 2001-2018 to increase sample size. The sample excludes full-time students, the self-employed, and individuals with missing income or wealth information. Skill groups are defined by educational attainment (low, medium, high), consistent with Section 4. All monetary variables are expressed in 2018 Australian dollars.

## B.2 Wage dispersion and labor productivity risk

In addition to the life-cycle wage profiles presented in the main text, we examine the variance of log hourly wages within age-skill cells as a measure of idiosyncratic labor productivity risk. As shown in Figure B.1, wage dispersion increases over the working life and is somewhat higher for high-skilled individuals, particularly at midlife and older ages. Overall, however, the differences in dispersion across skill groups are modest relative to the strong age pattern.

These empirical patterns motivate the specification of the stochastic productivity process in the model. Rather than estimating separate shock processes by skill type, we adopt a common AR(1) specification calibrated to the estimates of Freestone (2018), who also use HILDA data. The relatively small cross-skill differences in wage dispersion support this parsimonious approach. The calibration targets the overall life-cycle increase in earnings dispersion observed in the data, and the model reproduces this rising age profile of wage variance for the aggregate population.

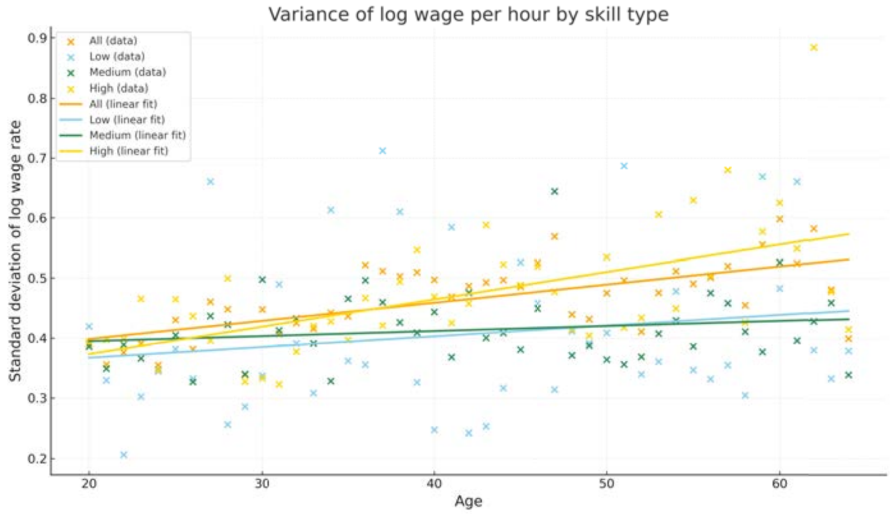
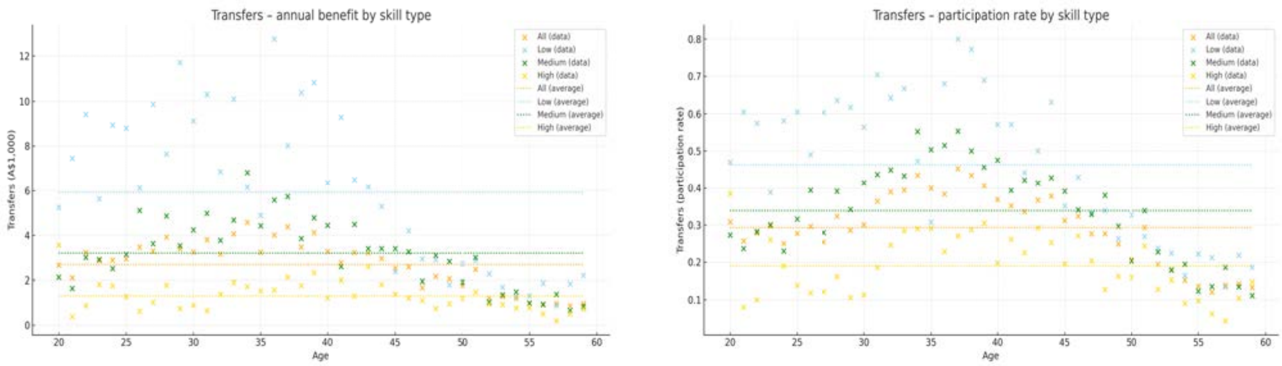



Figure B.1: Variance of log hourly wages by age and skill type

## B.3 Working-age social transfers

We also document social transfers received by working-age individuals. The transfer measure aggregates government cash payments, including unemployment benefits, family payments, and disability-related support. Figure B.2 shows that both transfer participation and average benefit levels are substantially higher among low-skill individuals across the working life, reflecting the strong targeting embedded in Australia's transfer system.




(a) Transfer benefit per year (A$1,000)

(b) Transfer participation rate

Figure B.2: Social transfers by skill type

Transfer participation exhibits a mild hump-shaped pattern over the life cycle, peaking in early midlife and declining thereafter. The gradient across skill types is pronounced: low-skilled individuals display persistently higher participation and benefit levels, while high-skilled individuals receive relatively modest transfers throughout their working years.

These patterns reinforce the progressive structure of the broader Australian tax-transfer system and provide additional discipline for modeling household income processes and redistribution outside retirement.

## B.4 Additional asset detail

Consistent with the main text, financial assets display a pronounced hump-shaped profile over the life cycle. Even after retirement, asset decumulation is gradual, and average wealth remains positive at advanced ages. This persistence is consistent with precautionary motives or bequest considerations and supports the model's treatment of savings behavior in retirement.

Overall, the additional empirical evidence presented here complements the stylized facts in Section 2.3 and provides further quantitative guidance for the calibration of wage risk, transfer receipts, and asset dynamics in the benchmark Australian economy.

# Appendix C Solution Algorithm

The numerical solution of the model is implemented in FORTRAN and follows the Gauss–Seidel procedure of Auerbach and Kotlikoff (1987), as extended to stochastic overlapping-generations models, for example, by Fehr and Kindermann (2018). At a high level, the algorithm iterates between solving household decision problems, updating the distribution of agents over the state space, aggregating to obtain macroeconomic variables, and adjusting government policy instruments until all markets and the government budget constraint are simultaneously satisfied.

The state space for individual households includes age, skill type, idiosyncratic productivity, liquid financial assets, and illiquid private pension (superannuation) balances. For each of these dimensions, we discretize the state space and approximate the associated value and policy functions on finite grids. The solution procedure consists of two main components: (*i*) computation of the benchmark steady state, and (*ii*) computation of the transition paths for each reform scenario.

## C.1 Steady-state equilibrium

For the benchmark steady state, we seek a fixed point in the space of aggregate variables, bequest distributions, and government policy instrument. The algorithm proceeds as follows:

1. **Initialization.** We start with initial guesses for aggregate capital, labor supply, the distribution of bequests, and the government budget-balancing instrument (in the benchmark, the income tax scalar). Policy parameters and demographic structure are held fixed at their baseline values.

2. **Prices and policies.** Given the aggregate capital and labor guesses, we compute the steady-state factor prices (interest rate and wage) from firm's first-order conditions. Using the current guesses for government instruments, we also determine implied taxes, transfers, and public pension rules.

3. **Household problem.** Taking prices and policy functions as given, we solve the household's life-cycle problem. This involves:

    - discretizing the asset and superannuation grids;

- iterating on the value function via backward induction from the terminal age to the first working age; and
- computing optimal decision rules for consumption, saving, labor supply, and retirement for each point in the discrete state space.[34]

The solution yields policy functions and value functions conditional on age, skill, productivity, and asset holdings.

4. **Distribution and aggregation.** Using the policy functions and the exogenous transition probabilities for productivity shocks and demographics, we compute the stationary distribution of households over the state space. We then aggregate individual decisions to obtain aggregate capital, effective labor supply, bequests, consumption, and tax and transfer revenues, including pension expenditures.

5. **Government budget and updating.** Given the aggregate tax payments and expenditures including public pension outlays, we update the government budget-balancing instrument (income tax scalar or consumption tax rate). The new values of capital, labor, bequests, and taxes are combined with the previous guesses using a damped Gauss-Seidel updating scheme.

6. **Convergence check.** We evaluate convergence by checking the goods-market residual (the difference between aggregate output and the sum of aggregate consumption, investment, and government spending). If the deviations fall below a pre-specified tolerance, we declare convergence and record the benchmark steady state. Otherwise, we return to step 2 and repeat the procedure.

This algorithm corresponds to the `get_SteadyState` routine in the code: in each iteration we update prices (`prices`), solve household problems (`solve_household`), compute the distribution (`get_distribution`), aggregate (`aggregation`), and determine government policy (`government`) until the residual `DIFF` is sufficiently small.

## C.2 Transition paths and policy reforms

Each reform scenario – such as a change in the mandatory private pension contribution rate $\tau^p$ – is analyzed by computing a finite-horizon transition path from the benchmark steady state to a new long-run equilibrium. The policy change is implemented at $t = 1$, and all cohorts alive at that date re-optimize given their existing asset and superannuation holdings accumulated under the benchmark regime. The transition path algorithm proceeds as follows:

1. **Initial conditions and policy change.** We take the benchmark steady state as the initial condition at $t = 0$, including the full joint distribution of households by age, skill,

[34] Labor supply is modeled as a discrete choice. Individuals choose from a finite grid of hours, equally spaced between zero and one-half of the time endowment. This discretization follows standard practice in quantitative life-cycle models and facilitates the numerical solution of the household problem.

productivity, and assets. At $t = 1$, the policy change (for example, an increase in $\tau^p$) is implemented and assumed to be permanent. We choose a finite transition horizon $T$ large enough for the economy to be arbitrarily close to the new steady state by $t = T$.

2. **Initial guess for paths.** We initialize the time paths of aggregate capital, labor, factor prices, and government policy instruments (including the income tax scalar) for $t = 1, \ldots, T$. The transition path is initialized using a smooth interpolation between the initial and final steady states. Specifically, for each aggregate variable $X_t$, the initial guess is constructed as

$$X_t = (1 - \omega_t) X_0 + \omega_t X_T,$$

where $X_0$ and $X_T$ denote the initial and final steady-state values, respectively, and the weights follow a convex schedule $\omega_t = (t/T)^2$. This quadratic weighting places more mass on the terminal steady state and improves convergence and reduces oscillations in the early iterations of the transition algorithm. The final steady state $X_T$ is computed for each policy experiment prior to solving for the transition path.

3. **Household problem along the transition.** Given the guessed time paths of prices and policies, we solve the household problem over the entire transition. This is done by:

   - applying backward induction over time, starting from period $T$ and moving back to $t = 1$, to compute value functions and decision rules for each cohort and state; and
   - for each period, solving the intratemporal labor-leisure choice and intertemporal saving decisions on the discretized grids for assets and superannuation.

   This step corresponds to repeated calls of `solve_household` over ages and time in the `get_transition` routine.

4. **Distribution dynamics and aggregation.** Using the decision rules, we simulate the evolution of the distribution of households forward in time from $t = 1$ to $t = T$ (`get_distribution`). For each $t$, we then aggregate individual decisions to obtain paths for aggregate capital, labor, consumption, bequests, tax revenues, and pension expenditures (`aggregation`).

5. **Government budget and updating.** Given the aggregate variables at each date, we recompute government variables, including the policy instrument that balances the budget (the income-tax-function parameter, $\lambda$) and any induced changes in pension outlays (`government`). The new paths for capital, labor, and policy instruments are combined with the previous guesses using a damping parameter to ensure stability of the Gauss-Seidel iterations.

6. **Convergence check.** For each date $t$, we compute the goods-market residual and verify that the government budget constraint is approximately satisfied. We identify the period with the largest relative deviation and use this as the convergence metric. If the maximum deviation across all $t = 1, \ldots, T$ is below the tolerance, we consider the transition path to

have converged and record the time profiles of aggregates and distributions. Otherwise, we update the guessed paths and repeat from step 3.

Because the reform is implemented at $t = 1$, currently alive cohorts face a shorter remaining planning horizon and re-optimize given their existing asset positions. As a result, adjustments in stock variables – especially financial and superannuation assets – are gradual, and the evolution of pension participation and benefit receipt reflects both the means test and the slow changing household wealth.

## C.3 Welfare measurement and aggregate efficiency (LSRA)

For each reform scenario, we compute $(i)$ welfare changes along the transition without compensating transfers, and $(ii)$ aggregate efficiency effects using a Lump-Sum Redistribution Authority (LSRA) that implements compensating transfers.

**Intergenerational welfare (HEV).** Let $V_t^B(z)$ denote the expected remaining lifetime utility of a household with state $z \in \mathcal{Z}$ at time $t$ under the reform (regime $B$), and let $V^A(z)$ denote the corresponding value in the benchmark steady state (regime $A$). We measure intergenerational welfare effects using a Hicksian equivalent variation (HEV), defined as the uniform proportional change in the benchmark consumption–leisure bundle that makes the household indifferent between the benchmark and the reform. With CRRA preferences that are homothetic in the consumption–leisure aggregator,[35] the HEV for a household of cohort age $j$ at the reform date $t = 1$ can be written as

$$\mathrm{HEV}_j(z) = \left( \frac{V_1^B(z)}{V^A(z)} \right)^{\frac{1}{1-\sigma}} - 1. \tag{C.1}$$

The average HEV values of the cohort are obtained by integrating (C.1) with the benchmark distribution $\phi_1(z)$ for each cohort at $t = 1$.

**Aggregate efficiency and the LSRA.** Welfare changes along the uncompensated transition reflect both efficiency effects and intergenerational redistribution. To isolate efficiency, we follow the LSRA approach (Fehr and Kindermann (2018), Ch. 11.2.2) and construct lump-sum transfers that $(i)$ hold all cohorts alive at the reform date at their benchmark utility levels, and $(ii)$ shift the lifetime utility of all future-born cohorts by the same proportional amount.[36]

*Step 1: Compensation of initially alive cohorts.* For each cohort age $j \geq 2$ alive at $t = 1$, the LSRA assigns a cohort- and state-contingent transfer $v_{1,j}(z)$ such that

$$V_1^{B,LSRA}(z; v_{1,j}(z)) = V^A(z), \qquad j = 2, \dots, J, \tag{C.2}$$

[35]This property holds for the preference specification used in the model, where period utility is homogeneous of degree $1 - \sigma$ in the consumption–leisure composite.

[36]The LSRA transfers are added to the household budget constraint as non-distortionary lump-sum payments. In the compensated transition, they enter the period budget constraint for the relevant cohorts and therefore affect optimal consumption, saving, and labor supply decisions.

where $V_1^{B,LSRA}(\cdot)$ denotes the reform value function when LSRA transfers are included in the budget constraint. In practice, we iterate on the transfer schedule until (C.2) holds for all cohorts alive at $t = 1$.

The present value (at $t = 1$) of resources required to compensate initially alive cohorts is

$$PV^{\text{alive}} = \sum_{j=2}^{J} \int v_{1,j}(z)\, d\phi_1(z), \tag{C.3}$$

where $\phi_1(z)$ is the distribution of households at the reform date.

*Step 2: Uniform utility shift for future-born cohorts.* For each future birth date $t \geq 1$, let $V_t^{B,LSRA}(z_1; v_t)$ denote the expected lifetime utility of a newborn with initial state $z_1 = (1, i, 0, 0, \eta_1)$ under regime $B$ when receiving transfer $v_t$ at birth. The LSRA chooses $\{v_t\}_{t\geq 1}$ such that all future-born cohorts experience the same proportional utility shift:

$$V_t^{B,LSRA}(z_1; v_t) = (1 + \Delta)^{1-\sigma}\, V^A(z_1), \qquad t = 1, 2, \ldots, \tag{C.4}$$

where $\Delta$ determines the aggregate efficiency effect.

*Step 3: LSRA intertemporal budget balance.* The LSRA must satisfy a present-value budget constraint. In the small open economy with constant interest rate $r$ and population growth rate $n$, newborn cohort size at date $t$ equals $(1+n)^{t-1}$ relative to the reform cohort. The LSRA budget condition therefore becomes

$$PV^{\text{alive}} + \sum_{t=1}^{\infty} \frac{(1+n)^{t-1} v_t}{(1+r)^{t-1}} = 0. \tag{C.5}$$

Here $v_t$ denotes the per-newborn transfer at date $t$. The first term already reflects cohort sizes through integration over the distribution $\phi_1(z)$ of households alive at $t = 1$.

The scalar $\Delta$ implied by (C.4)–(C.5) is reported as the aggregate efficiency measure. If $\Delta > 0$, the reform is weakly Pareto improving under the LSRA criterion; if $\Delta < 0$, the reform entails an aggregate efficiency loss.

**LSRA debt and capital-market implications.** Compensating initially alive cohorts generally implies a non-zero LSRA net position at $t = 1$. If transfers to current cohorts are positive, the LSRA issues debt; if negative, it accumulates assets. This position evolves over time as interest accrues and newborn transfers are implemented to satisfy (C.5).

In the small open economy, LSRA borrowing or lending is absorbed by foreign asset positions and does not affect domestic capital. In the closed economy, however, LSRA debt or assets enter domestic asset-market clearing alongside government debt and therefore affect the equilibrium capital stock and factor prices. These general-equilibrium feedback effects are incorporated when computing $\Delta$.

**Computation.** For each reform, we first compute the transition path without compensating transfers (`lsra_on = .false.`) to obtain macroeconomic dynamics and HEV measures. We then re-solve the transition with the LSRA activated (`lsra_on = .true.`), iterating on the LSRA transfers jointly with prices and fiscal instruments until (i) initially alive cohorts are held at benchmark utility, (ii) future-born cohorts experience the uniform shift $\Delta$, and (iii) market clearing and the LSRA budget constraint are satisfied.

This two-step procedure underlies the welfare and aggregate efficiency results reported in Sections 5 and 6.

# Appendix D Details on Benchmark Model Calibration

This appendix documents how the deterministic age profiles of labor productivity and working-age social transfers are constructed for the benchmark model. Empirical motivation and descriptive evidence are provided in Section 2.3 and Appendix B; here we focus exclusively on the mapping of those empirical patterns into model inputs. The appendix concludes by presenting selected distributional outcomes of the benchmark model, complementing the life-cycle and aggregate results reported in Section 4.

## D.1 Construction of age-skill profiles

We use HILDA18 to construct age profiles by educational attainment, distinguishing three skill types: low, middle, and high. Individuals are grouped into five-year age groups (20-24, 25-29, ..., 60-64). For each age group and skill type, we compute:

- average hourly wage (proxying for labor productivity), and
- average working-age social transfers.

These grouped averages smooth idiosyncratic variation while preserving systematic life-cycle and cross-skill differences.

## D.2 Functional approximation

To obtain smooth life-cycle inputs for the model, we approximate the grouped empirical profiles using quadratic age polynomials. For each skill type $i \in \{\text{low}, \text{middle}, \text{high}\}$ and each variable $x_{j,i}$ (productivity $e_{j,i}$ or transfers $st_{j,i}$), we estimate:

$$x_{j,i} = \alpha_i + \beta_i j + \gamma_i j^2,$$

where $j$ indexes model age groups. The quadratic specification provides a parsimonious representation of hump-shaped life-cycle patterns while ensuring smoothness for numerical solution.

## D.3 Extrapolation beyond working age

Because HILDA data become sparse at older ages and labor supply declines rapidly around retirement, we impose simple extrapolation rules beyond the estimation range:

- Labor productivity declines linearly after age 65 (age group 65-69) and reaches zero by age 85 (age group 85-89).
- Working-age social transfers decline linearly from age 55 (age group 55-59) and reach zero by age 65 (age group 65-69).

### D.4 Normalization

For numerical stability and comparability across skill types, we normalize the profiles as follows:

- $e_{20,\text{low}} = 1$ (labor productivity of low-skilled workers aged 20-24),
- $st_{20,\text{low}} = 1$ (transfer level of low-skilled workers aged 20-24).

The normalized profiles enter the model as deterministic components of the earnings and transfer processes. Stochastic productivity risk is modeled separately via the AR(1) process described in Section 4.

### D.5 Resulting model inputs

Figure D.3 displays the normalized productivity and transfer profiles used in the benchmark calibration. These inputs preserve the empirically observed life-cycle gradients and cross-skill differences while providing smooth functional representations suitable for numerical solution.

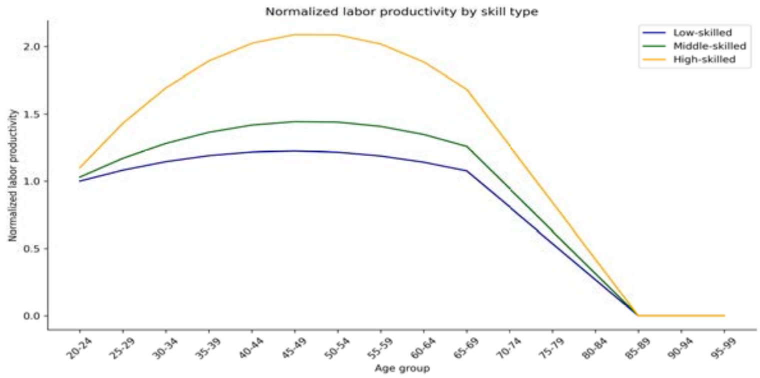
### D.6 Distributional solutions of benchmark model

Table D.2 reports selected distributional outcomes generated by the benchmark model and compares them with their empirical counterparts. The table summarizes (i) average labor supply within each skill group, (ii) inequality in net income and net wealth as measured by Gini coefficients, and (iii) the distribution of the elderly population by public pension status, distinguishing between no pension, full pension, and part pension recipients.

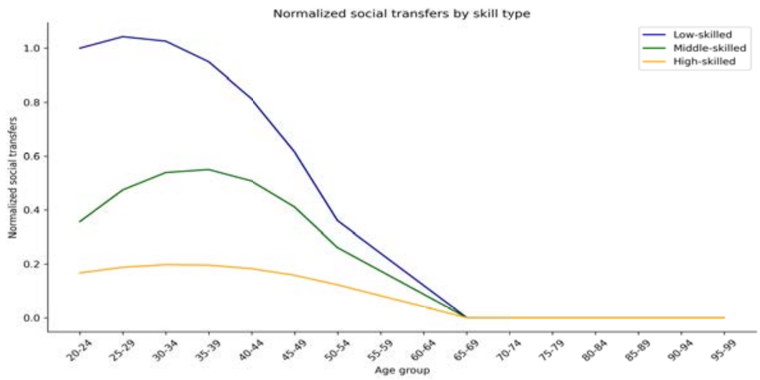
The model matches these distributional moments closely. Labor supply aligns well with the data across skill groups, with only a modest overprediction for low-skilled households and an exact match for middle- and high-skilled groups. The model also reproduces inequality in net income almost exactly, while generating somewhat higher wealth inequality, though still within a plausible empirical range. Finally, the distribution of pension receipt is well captured: the shares of elderly receiving no pension, full pension, and part pension all lie within the empirical bands. These results suggest that the model provides a credible representation of cross-sectional heterogeneity and the institutional features of the Australian retirement system.

## Appendix E Additional Fiscal and Distributional Results

This appendix reports additional results on the transitional dynamics of key fiscal and distributional margins following changes in the mandatory private pension contribution rate, $\tau^p$,




(a) Normalized labor productivity by skill type




(b) Normalized social transfers by skill type

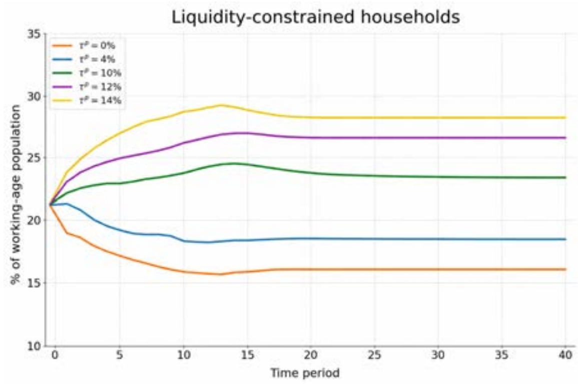
Figure D.3: Labor productivity and social transfers in benchmark model

Table D.2: Distributional Outcomes in Benchmark Model

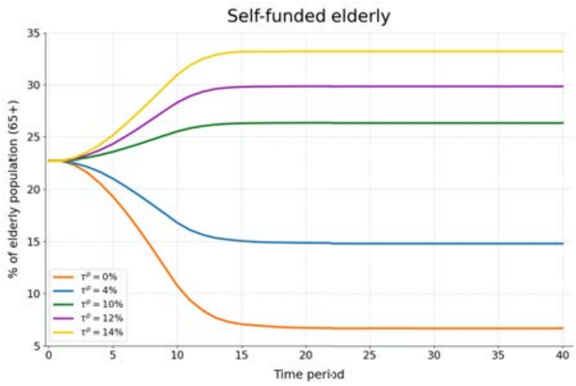
| **Variable** | **Model** | **Data** |
|---|---|---|
| *Labor supply*[1] | | |
| Low-skilled | 0.27 | 0.24 |
| Middle-skilled | 0.30 | 0.30 |
| High-skilled | 0.33 | 0.33 |
| *Inequality measures*[2] | | |
| Gini coefficient (net income) | 0.330 | 0.33 |
| Gini coefficient (net wealth) | 0.658 | 0.62 |
| *Share of elderly by pension status (%)*[3] | | |
| No pension benefit | 22.72 | 18–25 |
| Full pension benefit | 48.68 | 45–52 |
| Part pension benefit | 28.60 | 28–33 |

*Notes:* [1] Labor supply is expressed as a share of the normalized time endowment (105 hours per week). For example, a value of 0.30 corresponds to approximately 31.5 hours per week. Data are derived from HILDA 2018 for both men and women. [2] Inequality measures are based on the ABS Survey of Income and Housing (SIH), 2018. [3] Distribution of pension receipt is based on Chomik et al. (2018a) (Figure 8F), ranges over the period 2009-2016.

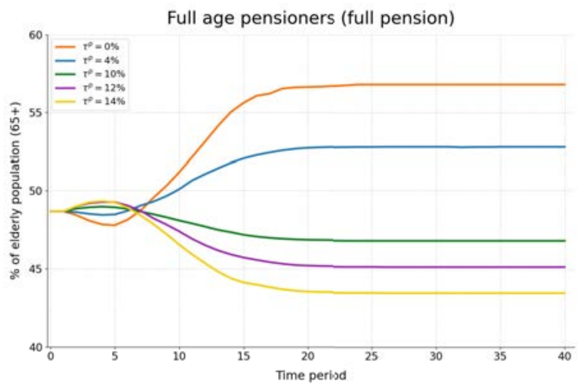
complementing the main results in Section 5. Figure E.4 presents the evolution of four variables: the share of liquidity-constrained households, the share of self-funded elderly (not receiving the Age Pension), the share of elderly receiving the full Age Pension, and the tax-function parameter $\lambda$. The time dimension is aligned with the transition path analysis in the main text. Period $t = 0$ corresponds to the benchmark steady state, while $t = 1$ marks the implementation of the reform. Subsequent periods trace the adjustment towards the new long-run equilibrium.



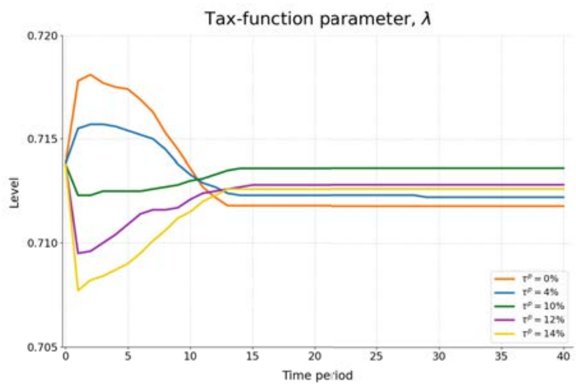

(a) Liquidity-constrained households




(b) Self-funded elderly (no pension)




(c) Full age pensioners (full pension)




(d) Tax-function parameter, $\lambda$

Figure E.4: Transitional dynamics of fiscal and distributional margins

Several patterns emerge from the figure. First, higher contribution rates $\tau^p$ lead to a clear increase in the share of liquidity-constrained households. This reflects the tightening of short-run disposable resources due to higher mandatory contributions, which limits households' ability to smooth consumption using liquid assets.

Second, the share of self-funded elderly rises with $\tau^p$. Stronger accumulation in private pension accounts reduces reliance on public pension, increasing the proportion of retirees who do not receive the Age Pension. This effect is quantitatively substantial and materializes gradually over the transition as cohorts with higher contributions reach the pension access age.

Third, the share of elderly receiving the full Age Pension declines only gradually with higher $\tau^p$. The adjustment along this margin is more muted because the means-tested system reallocates many individuals into partial pension eligibility rather than eliminating pension receipt altogether. As a result, the implied residual category – the share of elderly receiving a part pension (not displayed) – experiences a more pronounced decline under higher $\tau^p$ than the share of full pensioners.

Finally, panel (d) shows the dynamics of the tax-function parameter $\lambda$, which serves as the budget-balancing instrument in the model. While long-run changes in $\lambda$ are relatively small – reflecting offsetting movements in the income tax base and public pension expenditures – the short- and medium-run responses are more pronounced. In particular, higher $\tau^p$ is associated with lower values of $\lambda$ during the transition, implying an increase in effective income taxation. This mechanism contributes to the short-run welfare losses documented in the main text, as households face both higher mandatory contributions and temporarily higher income tax burdens before the long-run fiscal adjustments materialize.

# Appendix F Detailed Results for Sensitivity Analysis

This appendix reports additional macroeconomic and welfare results for selected contribution rate changes under alternative public pension designs and structural model specifications, supporting the sensitivity analyses in Section 6. The analysis focuses on two representative policy experiments — eliminating the mandate ($\tau^p = 0\%$) and increasing it to $\tau^p = 12\%$ — and reports both short-run (impact at $t = 1$) and long-run (steady state at $t = 40$) effects.

## F.1 Alternative public pension designs

Table F.3 reports the macroeconomic and welfare effects of selected contribution rate changes under the three alternative public pension designs. The table presents both the short-run and long-run responses of key macroeconomic aggregates, fiscal variables, and welfare measures when the contribution rate is either eliminated ($\tau^p = 0\%$) or increased to $\tau^p = 12\%$, relative to the benchmark economy with $\tau^p = 8\%$.

Across all specifications, removing the mandate ($\tau^p = 0\%$) reduces household financial assets in the long run, reflecting lower private saving. The decline is particularly pronounced under the higher-benefit system, where weaker incentives for private accumulation amplify the reduction in wealth. Conversely, increasing the mandate to $\tau^p = 12\%$ raises long-run assets, although the magnitude varies with the strength of the public pillar.

Consumption responses mirror these asset dynamics. Under $\tau^p = 0\%$, consumption increases on impact due to higher disposable income, but declines in the long run as lower accumulated wealth reduces lifetime resources. For $\tau^p = 12\%$, consumption falls initially due to higher contributions but rises in the long run as higher pension wealth supports retirement consumption.

Labor supply responses are modest but differ across designs. In the short run, lower contribution rates increase labor supply through higher disposable income, while higher contribution rates reduce it. Over time, these effects attenuate and partly reverse as wealth effects dominate.

Fiscal responses depend critically on the pension design. Under the universal pension, public pension expenditure is unaffected by private saving, and adjustment occurs primarily through the tax system. In contrast, under the higher-benefit specification, pension costs respond

Table F.3: Macro and welfare effects under alternative public pension designs*

| **Alternative framework / Variable** | **Mandated contribution rate** | | | |
|---|---|---|---|---|
| | $\tau^p = 0\%$ | | $\tau^p = 12\%$ | |
| | Short-run | Long-run | Short-run | Long-run |
| *1. Universal pension* | | | | |
| Household financial assets | 0.00 | -21.79 | 0.00 | 12.32 |
| Private consumption | 0.84 | -2.95 | -0.84 | 1.26 |
| Labor supply (hours) | -1.62 | -0.56 | 0.34 | 0.17 |
| Taxable income | 5.44 | 10.12 | -3.31 | -5.13 |
| Public pension cost | 0.00 | 0.00 | 0.00 | 0.00 |
| Tax-function parameter $\lambda$ | 0.72 | 0.73 | 0.71 | 0.71 |
| Average welfare | 0.22 | -0.26 | -0.23 | 0.10 |
| Low-skilled welfare | 0.34 | -0.10 | -0.26 | 0.04 |
| High-skilled welfare | 0.05 | -0.46 | -0.16 | 0.17 |
| *2. Higher benefit level* | | | | |
| Household financial assets | 0.00 | -37.67 | 0.00 | 19.78 |
| Private consumption | 1.57 | -4.64 | -1.29 | 1.95 |
| Labor supply (hours) | -1.43 | -1.52 | 0.12 | 0.48 |
| Taxable income | 5.65 | 8.12 | -3.50 | -4.39 |
| Public pension cost | 0.00 | 21.52 | 0.00 | -9.42 |
| Tax-function parameter $\lambda$ | 0.72 | 0.70 | 0.71 | 0.72 |
| Average welfare | 0.13 | -0.86 | -0.20 | 0.35 |
| Low-skilled welfare | 0.28 | -0.63 | -0.26 | 0.22 |
| High-skilled welfare | -0.11 | -1.16 | -0.12 | 0.48 |
| *3. Universal higher-benefit pension* | | | | |
| Household financial assets | 0.00 | -25.05 | 0.00 | 15.40 |
| Private consumption | 1.00 | -2.41 | -0.66 | 1.41 |
| Labor supply (hours) | -1.87 | -0.05 | 1.04 | 0.25 |
| Taxable income | 5.35 | 10.65 | -2.79 | -4.95 |
| Public pension cost | 0.00 | 0.00 | 0.00 | 0.00 |
| Tax-function parameter $\lambda$ | 0.72 | 0.73 | 0.71 | 0.71 |
| Average welfare | 0.24 | -0.20 | -0.19 | 0.14 |
| Low-skilled welfare | 0.35 | -0.07 | -0.22 | 0.08 |
| High-skilled welfare | 0.07 | -0.40 | -0.13 | 0.21 |

*Notes:* *Values are percentage changes relative to the benchmark with $\tau^p = 8\%$. Welfare effects are Hicksian equivalent variation (HEV) measures (in %). The budget-equilibrating tax-function parameter $\lambda$ is reported in levels.

strongly: removing the mandate increases long-run expenditure, while higher contributions reduce it. These fiscal changes are reflected in adjustments to the tax-function parameter $\lambda$.

Welfare outcomes reflect the interaction between these macroeconomic and fiscal effects. Removing the mandate generates short-run welfare gains but long-run losses across all designs, with larger losses under more generous public pensions. Increasing $\tau^p$ produces the opposite pattern: short-run losses and long-run gains, with stronger gains for higher-skilled households and under designs where private saving remains important. The universal higher-benefit system dampens these effects, reflecting weaker complementarity between private and public pensions.

## F.2 Alternative budget financing and market structure

Table F.4 reports corresponding results under two alternative structural specifications: (i) a budget-balancing consumption tax, and (ii) a closed economy with endogenous factor prices.

Table F.4: Macro and welfare effects under alternative budget financing and market structure*

| **Alternative framework / Variable** | **Mandated contribution rate** | | | |
|---|---|---|---|---|
| | $\tau^p = 0\%$ | | $\tau^p = 12\%$ | |
| | Short-run | Long-run | Short-run | Long-run |
| *1. Budget-balancing consumption tax* | | | | |
| Household financial assets | 0.00 | -31.17 | 0.00 | 16.53 |
| Private consumption | 0.94 | -4.35 | -0.80 | 1.84 |
| Labor supply (hours) | -2.66 | -1.56 | 0.98 | 0.42 |
| Taxable income | 4.60 | 8.54 | -2.68 | -4.53 |
| Public pension cost | 0.00 | 21.39 | 0.00 | -9.63 |
| Consumption tax rate | -0.38 | 0.17 | 0.34 | 0.09 |
| Average welfare | -0.04 | -0.76 | -0.07 | 0.31 |
| Low-skilled welfare | 0.13 | -0.55 | -0.15 | 0.21 |
| High-skilled welfare | -0.28 | -1.03 | 0.02 | 0.43 |
| *2. Closed economy* | | | | |
| Household financial assets | 0.00 | -17.83 | 0.00 | 9.70 |
| Private consumption | 1.00 | -8.74 | -0.71 | 3.90 |
| Labor supply (hours) | -0.23 | -4.07 | -0.03 | 2.10 |
| Wage rate | -0.17 | -6.11 | 0.16 | 3.04 |
| Interest rate (p.p.) | 0.02 | 0.81 | -0.02 | -0.36 |
| Taxable income | 6.91 | 4.02 | -3.60 | -1.46 |
| Public pension cost | 0.00 | 13.34 | 0.00 | -8.47 |
| Tax-function parameter $\lambda$ | 0.73 | 0.69 | 0.71 | 0.73 |
| Average welfare | 0.41 | -1.54 | -0.28 | 0.61 |
| Low-skilled welfare | 0.70 | -0.80 | -0.39 | 0.29 |
| High-skilled welfare | 0.08 | -2.18 | -0.16 | 0.86 |

*Notes:* *Values are percentage changes relative to the benchmark with $\tau^p = 8\%$. Welfare effects are Hicksian equivalent variation (HEV) measures (in %). The tax-function parameter $\lambda$ is reported in levels.

Under consumption-tax financing, macroeconomic responses remain qualitatively similar to the benchmark, but fiscal adjustment operates through the consumption tax rather than the income tax system. Removing the mandate increases the consumption tax rate in the long run due to higher pension expenditure, while raising $\tau^p$ allows for lower tax rates as pension costs decline. These adjustments amplify consumption responses relative to the baseline.

In the closed-economy specification, general equilibrium effects play a central role. Changes in saving behavior translate into movements in factor prices: lower saving under $\tau^p = 0\%$ reduces capital accumulation, lowering wages and raising interest rates, while higher saving under $\tau^p = 12\%$ has the opposite effect. These price adjustments significantly affect labor supply, income, and consumption dynamics.

The resulting welfare effects differ quantitatively from the small open economy benchmark. In particular, long-run welfare losses from eliminating the mandate are larger in the closed economy, reflecting adverse wage dynamics and reduced capital accumulation. Conversely, the long-run gains from higher contribution rates are amplified, especially for higher-skilled households who benefit more from increased returns to saving.

Overall, the results highlight that both institutional design of the public pension system and the broader economic environment shape the transmission of mandatory private saving reforms. While the qualitative intergenerational trade-offs remain robust, their magnitude depends on the strength of public–private complementarity, the fiscal adjustment mechanism, and general equilibrium feedback through factor prices.