Pensions, Income Taxes, and Homeownership: A Cross-country Analysis

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Abstract

This paper studies the role of pensions and income taxes in determining homeownership and household wealth. It provides a macroeconomic and distributional analysis of specific tax and pension policies and captures the interaction between them to examine the extent to which they influence cross- and within-country homeownership. Accordingly, we developed a stochastic, overlapping generations (OLG) model with tenure choice calibrated to Germany and then simulated with alternative income tax and pension policy structures from the US and Australia, since these developed nations have similar incomes per capita, but highly different homeownership rates. Our simulation results highlight that the pension system and its financing have decisive, long-term effects on homeownership. The latter is even more significant than that of income tax, where labor and capital income taxation affect homeownership in opposite directions. While the generosity of the pay-as-you-go pension system decreases homeownership, a higher progressivity amplifies the positive correlation between income and homeownership. Overall, the US and Australian fiscal policy designs explain over half (in the case of the US) and two-thirds (in the case of Australia) of the observed differentials with Germany.

Keywords: Housing demand, social security, income taxation, stochastic general equilibrium

JEL Classifications: R21, H55, H31, H24, C68

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1 Introduction

Homeownership carries significant implications for a society's economic, political, and social dynamics. It serves as a major source of income security, especially in aging populations with strained social security systems. However, homeownership rates vary widely among industrialized nations – ranging from 40-50 percent in Austria, Germany, and Switzerland, to nearly 70 percent in Australia, Canada, and the US, and even surpassing 70 percent in Eastern Europe.[1]

Various factors, including housing tax treatment, transaction costs, national rental and financial regulations, and geographical, cultural, and historical contexts, may explain this divergence. Surprisingly, relatively few studies have explored the interplay between housing tenure choice and public tax-social security systems. On the one hand, a high-income tax burden and a generous public pension system hinder the savings and wealth accumulation needed for homeownership. On the other, a high taxation of capital income induces a portfolio shift towards homeownership and ample pension benefits may foster homeownership in old age. Accordingly, several key questions emerge: How important are differences in fiscal policies for the determination of homeownership? Does the tax system have a stronger impact on homeownership rates than the pension system? How does the design of the tax and social security systems affect homeownership within specific groups, such as low-income households? Finally, how important is the fiscal system compared to other factors, such as transaction costs or housing regulations?

To answer these questions, we develop a stochastic general equilibrium model with overlapping generations where households, spanning different skill levels, face uncertain labor incomes and survival rates. Following Chambers et al. (2009a, b), Sommer and Sullivan (2018), Kaas et al. (2021) and Rotberg (2022), households have a tenure choice. Importantly, we extended our model to include pension assets, and thus differentiate housing, liquid financial and (illiquid) pension assets. We applied our approach to Germany, the US, and Australia – economies at comparable stages of economic development with similar per capita income and consumption, yet differing significantly in wealth levels and homeownership rates. The structure of the US pension system shares similarities with Germany's, in terms of benefit calculation and PAYG financing. However, the Australian pension system is fundamentally different, featuring means tested pension benefits financed from general taxes instead of contributions or payroll taxes, with a mandatory private savings system supplementing modest government pensions. Presumably, the implications of such a system for homeownership would be quite different.

The initial equilibrium of our model is calibrated to Germany, incorporating its statutory public pension and income tax systems. We then introduce alternative tax and pension structures inspired by the US and Australian contexts to examine their macroeconomic effects and distributional consequences for different skill groups.

Our simulations demonstrate the importance of fiscal policy design on homeowership rates across and within countries. The results highlight that the pension system and its financing have more significant long-term effects on homeownership than income taxation. While higher pension contributions clearly reduce homeownership, higher taxes on labor and capital income affect homeownership in opposite directions. Somewhat surprisingly, the progressivity of the pension system seems to amplify the positive correlation between income and homeownership. Overall, our model simula-

[1] Detailed cross-country data (for Germany, the US, and Australia, with data sources) are provided in Section 2.

tions indicate that the US and Australian fiscal policy designs explain over half or two-thirds of the observed differentials with Germany. The remaining differences – and especially the homeownership of low-income households – may be explained by housing regulations that determine minimum housing expenditure levels.

Related literature. Our study builds on the recent literature that applies general equilibrium life-cycle models to study the interaction between tenure choice and public policies. The seminal work of Gervais (2002) presented a deterministic economy featuring overlapping generations and tenure choice, and quantified the distortion of household savings due to the non-taxation of housing capital returns and mortgage interest rate deductibility from the income tax base. Besides the detailed tax system, Gervais (2002) considered rental market frictions such as the minimum house size and down payment constraints, as well as the rental agency with an arbitrage condition for the equilibrium rental price. He found that eliminating preferential tax treatment for homeownership yielded substantial long run welfare gains, while its distributional implications were surprisingly modest. Chambers et al. (2009a, b) extended this approach by including uninsurable mortality, labor earnings and house price risk, as well as transaction costs associated with property purchases. More specifically, Chambers et al. (2009a) introduced a progressive income tax, which amplified the distributional implications of housing's asymmetric tax treatment, while Chambers et al. (2009b) also modelled a financial sector to examine the role of mortgage innovations. More recently, Ma and Zubairy (2021) highlighted how binding debt-to-income constraints might explain the observed decline in US homeownership rates between 2005-2015, especially among younger cohorts.

Floetotto et al. (2016) extended the analysis of US governmental intervention in the housing market, encompassing the transitional path between steady states. However, their model only considered the proportional taxation of labor and capital income. Sommer and Sullivan (2018), using a model that captured the US progressive income tax system in great detail, provided a similar quantitative analysis, focusing on the implications on house prices, rents, homeownership, and welfare in the long run and over the transition path. In a recent US-based study, Karlman et al. (2021) also included a full transition path and combined a progressive labor income tax with detailed mortgage financing. They found that the long-term gains obtained from removing the mortgage interest deduction were mostly due to the welfare losses of transitional cohorts. Naturally, tax distortions between housing and ordinary assets could also be reduced by lowering taxation of ordinary capital income. In a two-asset model with tenure choice calibrated to the US, Nakajima (2020) demonstrated that the optimal tax on capital income reduced to almost zero, in stark contrast to the model without housing, where it remained above 30 percent, consistent with Conesa et al. (2009). Rotberg (2022) applied a US-calibrated model with housing to analyze the macroeconomic and distributional consequences of wealth taxation. He showed that progressive wealth taxation (excluding housing) can lead to large welfare gains. In contrast to the US, Germany's housing market is characterized by high transaction costs, a social housing sector, and no mortgage interest deductions, which Kaas et al. (2021) cited as responsible for Germany's low homeownership rate. Cho et al. (2023) examined the economy-wide effects of removing tax concessions to landlords (housing investors) in Australia, finding positive (yet modest) impacts on homeownership.

With the exception of Karlman et al. (2021) and Rotberg (2022), the above-mentioned studies mentioned above (applied to quantify the implications of the asymmetric tax treatment of owner-occupied housing) have paid little attention to the effects of housing on household wealth accumulation, its composition, and distribution. Silos (2007) highlighted that the inclusion of tenure choice significantly improves the replication of empirical wealth data. Similarly, Cho (2012) attributed a substantial portion of the wealth accumulation and homeownership differentials between Korea and the US to disparities in mortgage markets and rental structures. While our objective aligns with similar cross-country comparisons (though between different countries), we focus on the differences in income tax and pension designs.

Chen (2010) established a relationship between the social security system and the housing market. Indeed, the paper eliminated social security in a model with tenure choice and showed that such a reform has a stronger impact on wealth accumulation in a model with explicit housing choices than in the standard life-cycle economy. Examining the Australian means-tested age pension system, Cho and Sane (2013) analyzed the exemption of owner occupied housing. They found that including housing in the means test can reduce the housing capital to output ratio, but only marginally lowers the homeownership rate due to offsetting interest rate effects. In our contribution, we account for the detailed modelling of progressive income taxation and mandated pensions, encompassing both public and privately-funded pension systems.

Finally, our study connects to an extensive literature employing OLG models with highly detailed pension systems to analyze social security and pension reforms in developed countries. Recent examples include Kitao (2014) and Hosseini and Shourideh (2019) for the US, Fehr et al. (2013) for Germany, and Kudrna et al. (2019, 2022) for Australia. While these studies provided transitional and long-term economic implications of diverse pension reforms, they omitted housing and tenure choice modelling. Our paper, on the other hand, delves into the long-term steady-state implications, capturing crucial interactions between pension policies and tenure choices.

The remainder of the paper is structured as follows. The following section describes our comparative analysis of key economic indicators across three advanced economies – Germany, the US, and Australia – laying the groundwork for our quantitative exploration. We discuss variations in their income tax and pension systems. Section 3 introduces our quantitative model, which captures the interplay between asset accumulation, tenure choices, and the public sector. Following this, Section 4 explains the calibration of our initial steady-state economy and compares the benchmark model solution with German data. Section 5 provides the quantitative analysis of alternative income tax and pension policy settings. Section 6 then presents the results from sensitivity analyses. The final section offers concluding remarks.[2]

2 Cross-country differences in housing, pensions, and income taxes

As indicated above, individual tenure choice is determined by a multitude of economic, historical, cultural, and political factors. Therefore, it is unsurprising that empirical studies involving many different countries have typically failed to identify the systematic link between homeownership and the public pension system (see, for instance, Causa et al., 2020, p.21f).

However, this lack of systematic correlation might not hold true for specific countries where both taxation and pension systems either incentivize or discourage homeownership. In the subsequent

[2] For additional insights, the paper is accompanied by appendices. Appendix A offers further details on the progressive income tax schedule and pension parameters in the examined countries. Appendix B details our model's household problem. Appendix C focuses on the calibration of our benchmark model to German macroeconomic data. Appendix D provides additional simulation results.

analysis, we concentrate on three advanced economies – Germany, the US, and Australia – countries that are similar in terms of central macroeconomic indicators but substantially differ regarding their taxation and pension policies.

Table 1 highlights the proximity of GDP and consumption per capita between Germany and Australia, with the US only marginally surpassing these figures. However, despite Germany's relatively high (10-year average) saving rate of 13.2 percent, household net wealth (reported per adult) and the average homeownership rate fall substantially behind those of the US and Australia. Moreover, this difference is especially pronounced for low-skilled households, particularly in the Australian case.[3]

Table 1: Key economic indicators for Germany, the US, and Australia in 2018

	Germany	United States	Australia
GDP per capita (USD)[a]	54,955	59,801	53,062
Consumption per capita (USD)[a]	35,794	44,319	35,223
Net saving rate (%)[a]	13.2	3.8	6.5
Homeownership rate (%)[b]	44.8	65.3	65.1
- low-skilled	21.4	54.7	58.7
- middle-skilled	48.0	66.9	72.1
- high-skilled	58.0	80.7	81.0
Net wealth (per adult) (USD)[c]	213,410	420,386	414,730
- financial assets	103,190	355,225	207,369
- non-financial assets	140,543	126,048	303,141
- debt	30,323	60,887	95,780
Funded pension assets (% of GDP)[d]	8.2	169.9	131.7
Dependency ratio (65+/20-64) (%)[e]	35.8	26.8	26.5
Public pension/GDP (%)[f]	12.0	7.1	4.0
Income tax revenue (% of GDP)[g]	12.6	11.0	17.3
Average capital income tax rates (1965-1991, %)[h]	26.8	42.7	40.7

Source: [a] OECD(2021a); [b] OECD (2021b); HFCS 2017, SCF 2019, HILDA 2018; [c] Credit Suisse (2019); [d] OECD (2021c), p.211; [e] United Nations (2019); [f] OECD (2021c), p.199; [g] OECD (2020); [h] Mendoza et al. (1997), Table 2, p.113.

In the US, financial wealth dominates non-financial wealth, which is, at least partly, due to the presence of pension wealth in the form of funded private pension assets. Whilst such assets are highly

[3] Note that these distributional effects on homeownership rate are based on our empirical analysis, using three household data surveys – the Household Finance and Consumption Survey (HFCS) (2017 wave with data for Germany) (as documented by European Central Bank (ECB), 2020), the Survey of Consumer Finances (CFS) (2019 wave with data for the US) (as documented by Bhutta et al., 2020), and the Household, Income and Labour Dynamics in Australia (HILDA) survey (2018 wave with data for Australia) (as documented by Summerfield et al., 2019). The skill-specific homeownership rates reported in Table 1 are computed from these three household surveys that apply a similar skill definition, but different age and skill fractions. Therefore, for comparing across countries, we use average homeownership rates in 2018 from Organisation for Economic Co-operation and Development (OECD) (2021b) that (because of the above) tend to show somewhat lower homeownership than distributional household surveys. Nevertheless, this distributional analysis indicates that although homeownership in the US and Australia is higher than in Germany across the skill distribution, the change/increase in homeownership (in the US and especially Australia, relative to Germany) is shown to be more significant for low- and middle-skilled households than for the high-skilled.

significant within Australia and the US, they hardly exist in Germany. Notably, Germany's public pension expenditure as a fraction of GDP stands at 12 percent – i.e., much higher than in the US and Australia. This partly reflects the greater generosity of public pensions in Germany, but is also influenced by a comparatively higher old-age dependency ratio.

Examining historical trends, average tax rates on capital income between 1965-1991 were considerably higher in the US and Australia than in Germany. We present these past capital income tax rates for two primary reasons. First, they have influenced past tenure decisions that determine the current homeownership rate. Second, although Germany introduced a 25 percent flat-rate income tax on all capital income and capital gains for individual investors in 2009, historical rates underscore Germany's longstanding tradition of low capital income taxation.

To encapsulate these disparities, Table 2 provides an overview of the central distinctions in public pension and income tax systems across these three countries, which determines the structure of the pension and income tax systems analyzed by our simulation model, as described in the next section.

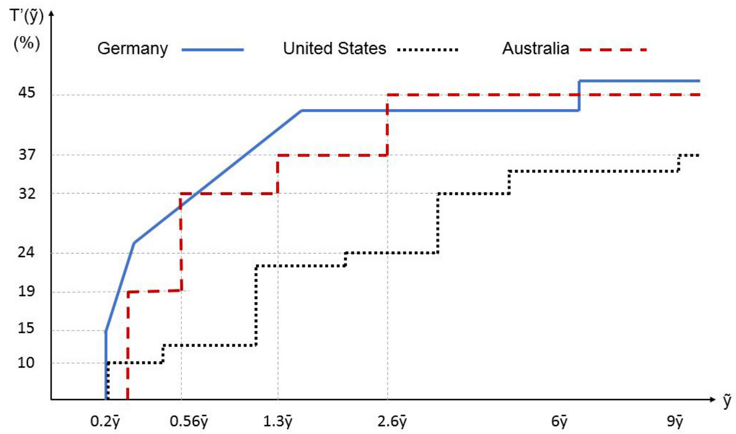
Table 2: Pensions and capital income taxation in Germany, the US, and Australia

	Germany	United States	Australia
Pension system			
Generosity	high	modest	low
Progressive/proportional	proportional	progressive	progressive
Funded/unfunded	unfunded	unfunded	unfunded/funded
Means-tested	no	no	yes
Capital income taxation			
Progressive/proportional	proportional	progressive	progressive
Mortgage interest rate deductible	no	yes	no
Labor income taxation			
Level/progressivity	high	modest	high

Germany operates a financed, pay-as-you-go (PAYG) public pension system, where pension benefits are closely linked to previous contributions. With relatively generous replacement rates (particularly when contrasted with the US and Australia), the payroll tax rate approaches approximately 19 percent. In contrast, the US employs a comparatively less-costly and generous PAYG pay-as-you-go pension system, yet one which is more redistributive within a given cohort compared to Germany's. Turning to Australia, its approach combines tax-financed (non-contributory) and means-tested provisions for old-age support, alongside a privately-administered retirement system financed through mandatory contributions. Notably, means-tested assets, which determine public old-age pension benefits, do not encompass owner-occupied real estate – a factor that provides a clear incentive for homeownership in old-age.

In Germany and the US, public pension contributions are exempt from progressive income taxation, whereas benefits are taxed in retirement. In Australia, the mandatory private contributions are taxed at reduced rates, while retirement withdrawals are entirely tax-exempt. As for the taxation of other savings, Germany operates the aforementioned dual income tax structure, which entails a relatively low, proportional tax on capital income. In contrast, both the US and Australia subject capital income to their progressive income tax schedules. In the US, net mortgage payments by owner-occupiers can be fully deducted from taxable income, which is prohibited in both Germany or Australia. Finally, as shown in Figure 1, marginal income tax rates are similar in Germany and Australia, but much lower in the US.[4]

Figure 1: Marginal tax rates in Germany, the US and Australia in 2018



Note: Based on the income tax schedule and income tax base in each country provided in Appendix A.

In light of the above, we can deduce that in the US and Australia, the pension provision and the taxation of capital income should foster homeownership. The model presented in the next section is applied to quantitatively examine these hypotheses – of (separating and combining) income tax and pension alternatives, and capturing/examining both aggregate and distributional observations/effects regarding homewnership.

3 The model

This section describes the development of a general equilibrium OLG model of a closed economy with tenure choice, where households face labor income and lifespan uncertainty. The model consists of a household sector, a rental agency, a production sector for ordinary consumption goods, and a government sector capturing income tax and pension policies. We begin by describing the demographic structure and the distributional measure of households on the state space. We then provide an algebraic description of each sector and define the steady-state equilibrium of the model.

3.1 Demographics and distributional measure of households

The model economy is assumed to be populated by J overlapping generations of heterogeneous households. Upon entering the model economy at age $j = 1$, each household is assigned a permanent skill level $\theta \in \mathcal{S} = \{1, \ldots, S\}$ according to the probability distribution ϖ_θ. The model assumes a

[4] The progressive income tax schedules for Germany, the US, and Australia (both in national currency and relative to average labor income) are provided in Appendix A.

constant population growth rate n and incorporates lifespan uncertainty, which is described by age-dependent survival probabilities ψ_j – conditional probabilities of surviving from age $j-1$ to age j with $\psi_{J+1}=0$. In the first period, all households are assumed to be renters, but in the subsequent periods, they can choose to be homeowners or renters based on their housing tenure choice made in the previous period. The model assumes inelastic labor supply during working periods and an exogenous retirement age j_R when households stop working and rely on their savings and pension benefits. In each period, the new cohort entering the economy grows with the growth rate n, which captures changes in population and productivity.

Since optimal savings depend on the tenure decision, we have to distinguish between two individual state vectors. *Before* the tenure decision, the individual state is defined by:

$$z=(j,a_l,h,a_r,\theta,\eta)\ \in\ \mathcal{Z}=\mathcal{J}\times\mathcal{A}\times\mathcal{H}\times\mathcal{P}\times\mathcal{S}\times\mathcal{E},$$

where $a_l\in\mathcal{A}=[-\infty,\infty]$, $h\in\mathcal{H}=[0,h_{min},..,\infty]$ and $a_r\in\mathcal{P}=[0,\infty]$ denote *current* financial, housing and retirement assets, respectively.[5] While financial assets might be negative due to mortgages, housing and pension assets are initially zero and then restricted to be non-negative throughout the whole life cycle $j\in\mathcal{J}=\{1,\dots,J\}$. During working periods $j<j_R$, households receive labor productivity shocks $\eta\in\mathcal{E}$ and accumulate retirement assets, which determine the post-retirement pension benefits. Total savings of the household a^+ depend on the future tenure state defined by $o^+\in\mathcal{T}=[O,R]$. We therefore define the individual state as:

$$\tilde{z}=(j,a^+,h,o^+,a_r,\theta,\eta)\quad\in\quad\tilde{\mathcal{Z}}=\mathcal{Z}\times\mathcal{T},$$

which reflects the situation *after* the tenure decision.[6]

Consequently, the initial distributional measure of households at age $j=1$ depends on the initial distribution of skills, as well as on productivity shocks. Let $X(z)$ be the corresponding cumulative measure to $\phi(z)$. Since aggregate variables are normalized per capita of newborns,

$$\int_{\mathcal{S}\times\mathcal{E}}\mathrm{d}X(z)=1\qquad\text{with}\quad z=(1,0,0,0,\theta,\bar{\eta})\tag{1}$$

must hold, where $\bar{\eta}$ denotes the (exogenously specified) initial productivity shock.

3.2 Household sector

Household preferences. Agents have preferences over streams of non-housing consumption c and housing consumption $f(h)$.[7] Households maximize the expected discounted lifetime utility function

$$\max\ E\left[\sum_{j=1}^{J}\beta^{j-1}\left(\prod_{i=1}^{j}\psi_i\right)\frac{(c_j^{\nu}[f(h_j)]^{1-\nu})^{1-\frac{1}{\gamma}}}{1-\frac{1}{\gamma}}\right]\qquad\text{with}\quad f(h)=\begin{cases}h & \text{if } h\geq h_{\min}\\ c_h & \text{otherwise}\end{cases},\tag{2}$$

where β defines a subjective discount factor, ν is the share parameter for ordinary consumption, and γ is the intertemporal elasticity of substitution. If the household is a homeowner, housing consumption

5 Note that $h=0$ indicates an agent who is currently a renter and h_{min} defines the minimum house size.

6 In the following, the index "+" always indicates the variable's value in the next period.

7 In this subsection, we omit the state index z for every variable whenever possible.

is the house's value. If the household is a renter, housing consumption c_h is bought at the rental market.

Labor income and household budget constraint. Agents start working at age $j = 1$ and, conditional upon survival, retire at age j_R. In each working period, an agent receives an endowment of productive efficiency units, which are inelastically supplied to the labor market at the wage rate w. Efficiency is specific to skills and is determined by a deterministic age-earnings profile e with a transitory component η. The latter component stochastically evolves over time and is assumed to have an autoregressive structure of degree 1, i.e.,

$$\eta^+ = \rho\eta + \epsilon \qquad \text{with} \quad \epsilon \sim N(0, \sigma_\epsilon^2), \tag{3}$$

where ρ is the persistence parameter and ϵ is the innovation of the process.[8] The household's gross labor income y is determined as follows:

$$y = \begin{cases} w \cdot e \cdot \exp(\theta + \eta) & \text{if } j < j_R \\ 0 & \text{otherwise.} \end{cases}$$

Upon reaching the retirement age j_R, labor income ceases and households start receiving pension benefits pen. Further to their financial assets a_l, households also receive bequests b and have real estate. To fund public expenditures, they bear the burden of consumption taxes (at the rate τ^c), payroll taxes (at the rate τ^p on gross labor income, capped at x percent of average earnings), and income taxes $T(\cdot)$. Consequently, after deducting consumption expenditures, the total savings are given by the following per-period household budget constraint:

$$a^+ = (1+r)a_l + y + b + (1-\delta_o)p_h h + pen - \tau^p \min[y; x\bar{y}] - T(\cdot) - pc - p_r c_h, \tag{4}$$

where r is the interest rate on the capital market, δ_o is the depreciation rate applicable to owned properties $p_h h$, while p_h, $p = 1 + \tau^c$ and p_r define prices for houses (normalized to 1 in the main part), ordinary consumption, and rental housing consumption, respectively.

Housing demand and housing market frictions. Households wishing to purchase a house must split up their total assets a^+ into the selected house size $p_h h^+$, the resulting transaction costs $tr(h, h^+)$ of changing the house and (liquid) financial assets (if $a_l^+ > 0$) or debt (if $a_l^+ < 0$), i.e.,

$$a^+ = a_l^+ + p_h h^+ + tr(h, h^+) \quad \text{with} \quad a_l^+ \geq -\xi p_h h^+, \tag{5}$$

where debt is always restricted to the maximum mortgage set by the maximum loan-to-value ratio ξ. Note that homeowners either hold mortgages or positive financial assets.[9] Transaction costs only apply to homeowners when they either buy or sell their house, i.e.,

$$tr(h, h^+) = \begin{cases} \mu_1 h + \mu_2 h^+ & \text{if either} \quad h = 0 \quad \text{or} \quad h^+ = 0 \\ 0 & \text{otherwise.} \end{cases}$$

[8] Following Fehr et al. (2013), both the autoregressive correlation term ρ as well as the variance of the innovation term σ_ϵ^2 are assumed to be contingent on skill levels.

[9] Consequently, homeowners in our model run down their mortgages faster than in reality, which dampens the impact of the mortgage interest rate deduction applicable in the US.

To determine a particular house size, households choose a share ω^+ of total assets, thus setting $p_h h^+ = \omega^+ a^+$. With the current house size h, one can derive transaction costs and calculate financial assets a_l^+ by using equation (5). Thus, in our model, household demand for homeownership is subject to three housing market frictions: maximum loan-to-value ratio, transaction costs, and minimum house size. Moreover, it is impacted by government policy (the modelling for which is provided in Section 3.6).

Optimization problem. Agents maximize the expected discounted lifetime utility, as defined by equation (2), in order to decide how much to consume and save, as well as whether to rent or become homeowners, taking into account the constraints given by (4) and (5), the labor productivity process (3), as well as the pension earning point accumulation (14) (elaborated upon below). The decision-making process is further explained in Appendix B.

3.3 Rental agency

Following Gervais (2002), the rental housing supply is facilitated by a two-period-lived rental agency. The agency operates as follows. In the first period, the agency receives deposits from households, which are used to purchase rental properties $p_h H_R$. These are immediately rented out. In the second period, the rental agency receives rent payments for rental units $p_r H_R$ and sells the undepreciated component of the rental stock, but must pay deposits, including interest, back to households. The respective optimization problem of the rental agency can be formulated as follows:

$$\max_{H_R} \quad p_r H_R + (1-\delta_r) p_h H_R - (1+r) p_h H_R.$$

Under perfect competition, a zero profit condition must hold for the rental agency, meaning that the price p_r of rental properties for households must equal the marginal cost of the rental agency. The rental price is then determined through the following no-arbitrage condition:

$$p_r = p_h(r + \delta_r), \tag{6}$$

where p_h is the house price that in the main analysis section is exogenous and set to 1.[10]

3.4 Production sector

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

$$Y = \varrho K^\alpha L^{1-\alpha}, \tag{7}$$

where α denotes the capital share in production and ϱ is the productivity constant (calibrated so as to normalize the market wage rate w to one). Capital is rented from households at the risk-less rate

[10] Note that we deviate from this assumption in one of the sensitivity checks in Section 6 where we allow for endogenous house price, drawing on Sommer and Sullivan (2018) and Rotberg (2022).

and depreciates at the rate δ_k. Factor prices are competitively determined by marginal productivity conditions:

$$w = \varrho(1-\alpha)\left(\frac{K}{L}\right)^{\alpha} \tag{8}$$

$$r = \varrho\alpha\left(\frac{L}{K}\right)^{1-\alpha} - \delta_k. \tag{9}$$

3.5 Government sector

This section introduces public policies and fiscal constraints that are relevant for the government, drawing on benchmark equilibrium designs for Germany, as well as policy alternatives based on the US and Australia. We begin by outlining the modeling of income taxation and pension systems. Regarding pensions, we consider different approaches, including PAYG public pensions based on either German or US policy rules, as well as non-contributory public pensions, financed through tax revenues and means-tested, and complemented by mandatory superannuation (i.e., forced saving private pensions), as applicable in Australia. Finally, we present fiscal constraints for government and pension budgets.

3.5.1 Income taxation

Initial equilibrium. In the initial equilibrium, we assume the German dual income tax system, with the total income tax $T(\cdot)$ (in the household budget constraint (4)) derived from a progressive tax on labor and pension income, and a proportional tax on capital income. The taxable income (or income tax base) $\tilde{y}$ subjected to the progressive tax code is computed from

$$\tilde{y} = y - \tau^p \min[y; 2\bar{y}] + pen - all, \tag{10}$$

so that payroll taxes at the rate τ^p (applicable up to a contribution limit set at double the average income $\bar{y}$) are subtracted from the gross labor income y, while pension benefits received during retirement *pen* are fully taxed. The allowances *all* are subtracted to account for income splitting within households and to calibrate a realistic income tax revenue in the initial equilibrium.

We apply the 2018 German progressive tax code to the taxable income and add a proportional tax on interest income from (liquid) financial assets a_l – which might be negative due to mortgages. The income tax revenue is given by

$$T(\tilde{y}, a_l) = T18_{GER}(\tilde{y}) + \tau^r r \max(a_l; 0), \tag{11}$$

where, in the second term, τ^r represents the flat tax rate on capital (interest) income and this second term can not be negative (since the German income tax system does not allow for mortgage interest deduction).[11]

Alternative income tax designs. In line with alternative income tax designs from the US and Australia, the respective tax schedule (either $T18_{US}(\cdot)$ or $T18_{AUS}(\cdot)$) applies to the total (including capi-

[11] In the initial equilibrium, we calibrate τ^r for the model to match German tax revenues from capital income taxes (to GDP ratio).

tal) taxable income. The total taxable income $\tilde{y}$ can be expressed as

$$\tilde{y} = \begin{cases} y - \tau^p \min[y; 2.47\bar{y}] + ra_l + pen & \text{if United States} \\ (1-\tau^p)y + r\max(a_l; 0) + pen & \text{if Australia,} \end{cases} \tag{12}$$

with the income tax revenue T given by

$$T = \begin{cases} T18_{US}(\tilde{y}) & \text{if United States} \\ T18_{AUS}(\tilde{y}) + \tau^{sa}\tau^p y & \text{if Australia.} \end{cases} \tag{13}$$

For modeling US federal income taxes, we followed Chambers et al. (2009a) and Sommer and Sullivan (2018), and imposed the US progressive income tax schedule on the total taxable income. As indicated above, the total taxable income $\tilde{y}$ is now given by the sum of labor earnings (net of payroll tax on earnings up to 2.47 times the average labor income $\bar{y}$), interest income from financial assets, and pension benefits. Further note that, for the US, mortgage payments by owner-occupiers (if $a_l < 0$) can be fully deducted from the taxable income, which is not allowed in Germany and Australia.

In the context of modeling Australian income tax policy, labor and capital income are also aggregated and subject to taxation under the progressive personal income tax schedule, which is notably more progressive compared to that of the US. Furthermore, within the pension counterfactual involving mandatory superannuation (based on Australia's forced saving private pension pillar), mandatory contributions and earnings of private pension funds are taxed differently. Consequently, the taxable income $\tilde{y}$ now includes labor earnings, net of mandatory contributions to private pension funds, returns on positive (non-pension) assets and the age pension pen. Similar to Germany, mortgage debt (related to owner-occupied housing) in Australia is not tax-deductible. As indicated above, Australian households also pay reduced taxes τ^{sa} on their contributions $\tau^p y$ to their superannuation funds, but the withdrawals are completely tax exempted. Importantly, in the Australian case, there is no payroll tax financing of public pensions. Instead τ^p now represents the mandatory contribution rate (imposed on gross earnings) paid to illiquid superannuation accounts.

3.5.2 Pensions

Initial equilibrium. In the initial equilibrium, we modelled the statutory pension insurance in Germany – a system that covers over 90 percent of the population.[12] The German statutory pension insurance operates on a PAYG financing principle, where contributions (or payroll taxes) are directly channelled to finance pension benefits for retirees. The payroll tax rate is levied on labor income up to the contribution ceiling (twice the average income $2\bar{y}$). These contributions are then used to update the retirement assets (or earning points) a_r, which reflect the household's income level relative to the working population. This is achieved through the following formula:

$$a_r^+ = a_r + \min\left[\frac{y}{\bar{y}}; 2\right]. \tag{14}$$

12 Civil servants who receive tax-financed benefits are included here, while only self-employed individuals are not mandatorily insured and may pay voluntary contributions or build up their own retirement funds.

Upon reaching the retirement age j_R, pension benefits pen are computed as the product of the accumulated retirement assets a_r and the so-called pension value, which gives the benefit amount for each individual earning point. For simplicity, we define the pension value as a fraction κ of average income $\bar{y}$, so that the pension benefits could be expressed as

$$pen = a_r \times \kappa \times \bar{y} \qquad \forall j \geq j_R. \tag{15}$$

This earnings point system makes the German pension system intra-generationally fair, i.e. there is very little redistribution within the cohort based on public pension income. As mentioned earlier, we also consider policy counterfactuals based on the US and Australia's publicly-stipulated pension systems. The modelling details are provided below.

US social security system. The US social security system is similar to that of Germany in that it is contributory and PAYG financed, with benefits linked to former earnings. However, it is less generous, with a lower payroll tax rate, and less intra-generationally fair, as it applies a progressive pension benefit formula. Specifically, the US social security benefit is determined as a concave piecewise linear function of the average indexed monthly earnings (AIME). Following Hosseini and Shourideh (2019), we compute the average annual earnings up to the contribution ceiling over the entire working life as proxies for AIME, which are captured in the state variable a_r:

$$a_r^+ = a_r + \min[y; 2.47\bar{y}]/(j_R - 1). \tag{16}$$

When households retire at the age j_R, we apply the US social security formula with the income thresholds, also known as bend points, to compute the pension benefit:

$$pen = \begin{cases} 0.9 \times a_r & \text{if} \quad a_r \leq 0.2\bar{y} \\ 0.18\bar{y} + 0.33 \times (a_r - 0.2\bar{y}) & \text{if} \quad 0.2\bar{y} < a_r \leq 1.24\bar{y} \\ 0.5243\bar{y} + 0.15 \times (a_r - 1.24\bar{y}) & \text{if} \quad a_r > 1.24\bar{y} \end{cases} \qquad \forall \quad j \geq j_R. \tag{17}$$

Note that the marginal replacement rate is 90 percent for AIME below 20 percent of average annual income and decreases to 15 percent for AIME above 124 percent of average annual income.

Australian Age Pension. The Australian Age Pension provides benefits to the elderly population, which are financed by general taxes.[13] Eligibility is based on age, but not on work history or past earnings. Pension benefits are now needs-based and means-tested, with maximum benefit $\bar{p}(h)$ linked to the current average earnings and tenure status. For single homeowners, it stands at approximately 28 percent of average earnings. Renters may be eligible for rent assistance, which is added to the maximum rate of homeowners. The Age Pension benefits are subject to both income and asset tests, where the highest of the two computed reductions in and as is applied, i.e.,[14]

$$pen = \max\left[\bar{p}(h) - \max\left(in, as\right); 0\right] \qquad \forall \quad j \geq j_R. \tag{18}$$

The pension financing through general tax revenues (in our case, via consumption tax adjustments) is described below, when discussing the government constraints.

Australian superannuation. In Australia, the means-tested Age Pension pillar is supplemented by a compulsory funded pension pillar based on the Superannuation Guarantee (SG) legislation, which

[13] The details and figures for the Age Pension rules are based on OECD (2021c) and Chomik et al. (2018a).

[14] The exact modeling of each test is explained in Appendix A.

was introduced over 30 years ago.[15] This legislation mandates employers to make superannuation contributions on behalf of their workers. The SG rate is currently 9.5 percent of gross wages, legislated to increase to 12 percent after 2024. Mandatory superannuation is an employment-related, privately managed scheme that covers almost 95 percent of employees. Superannuation contributions accumulate in the superannuation accounts owned by members and managed by private superannuation funds. These individual accounts are preserved in the funds until age 65 (at and after 65, withdrawals can be made without having to retire from the workforce). The superannuation benefits can be accessed as both lump-sums and income streams.

Superannuation contributions and fund earnings are taxed at concessional flat rates, but benefits are generally tax-exempt. Consequently, superannuation retirement assets a_r (with the same notation as for the PAYG pension accumulation) accumulate and de-cumulate as follows:

$$a_r^+ = \begin{cases} (1 + r(1 - \tau^r))a_r + (1 - \tau^{sa})\tau^p y, & \text{if } j < j_R \\ (1 - \zeta)(1 + r)a_r, & \text{otherwise,} \end{cases} \tag{19}$$

where ζ denotes the (age-specific) draw-down fraction from the superannuation fund after retirement, and τ^r only applies during the employment phase (when ζ is zero). Note that, in contrast to unfunded pensions, the superannuation wealth of the deceased is part of bequest redistribution b in the household budget constraint (4).

3.5.3 Fiscal constraints

We distinguish between a tax-financed government budget and one for PAYG pensions and a superannuation fund constraint (in case of modeling mandatory private pensions).

Government budget constraint. The revenue side of the government budget aggregates revenues from income taxes T_{inc} and consumption taxes $\tau^c C$. We excluded other corporation taxes and various housing taxes and subsidies. Public expenditures consist of public goods G and interest on public debt rB_G. In per capita terms of the youngest cohort, the public budget is given by:

$$T_{inc} + \tau^c C = G + (r - n)B_G, \tag{20}$$

where income tax revenues are defined as:

$$T_{inc} = \int_{\mathcal{Z}} T(\tilde{y}(z), a_l(z))\mathrm{d}X(z).$$

We specify the debt-to-output ratio B_G/Y and the public consumption-to-output ratio G/Y, and use the consumption tax rate τ^c to balance the government budget in (20). In the case of Australian policy, the right-hand side of the government budget also includes the Age Pension expenditure P_A and the income tax revenue also includes superannuation taxes T_{sa}, defined below.

PAYG pension budget constraint. Based on German and US PAYG systems, we modeled a PAYG pension budget constraint that balances aggregate benefits P_A by adjusting the payroll tax rate τ^p levied on the contribution base CB, i.e.,

$$P_A = \tau^p CB \qquad \text{with} \qquad CB = \int_{\mathcal{Z}} \min[y(z); x\bar{y}]\mathrm{d}X(z) \qquad \text{and} \qquad P_A = \int_{\mathcal{Z}} pen(z)\mathrm{d}X(z), \tag{21}$$

[15] The details and figures for the superannuation rules are drawn from Chomik et al. (2018b).

where x gives the percentage (of average earnings) capped for annual payroll tax payments – either 2 in the German benchmark or 2.47 for the US.

Superannuation fund constraint. In the case of Australia's mandatory superannuation, we modeled a budget constraint of the superannuation fund, expressed as:

$$\tau^p wL + (r - n)A_R = P_S + T_{sa}, \tag{22}$$

where mandatory contributions $\tau^p wL$ plus net returns from retirement assets A_R have to finance aggregate payouts P_S (after retirement) plus taxes on fund returns (before retirement) T_{sa}. Aggregate superannuation payouts, taxes on fund returns, and retirement assets are defined by:

$$P_S = (1+r)\int_{\mathcal{Z}} \zeta(z)a_r(z)\mathrm{d}X(z), \quad T_{sa} = \tau^r r \int_{\mathcal{Z}} a_r(z)\mathrm{d}X(z) \quad \text{and} \quad A_R = \int_{\mathcal{Z}} a_r(z)\mathrm{d}X(z). \tag{23}$$

3.6 Equilibrium conditions

Given the fiscal policy $\{G, B_G, T(\cdot), \kappa, \tau^c, \tau^p, \tau^r, \tau^{sa}\}$, a stationary recursive equilibrium is a set of value functions $V(z)$, household decision rules $\omega^+(\tilde{z}), c(z), a^+(z), o^+(z)$, distribution of unintended bequest $b(z)$, time-invariant measures of households $\phi(z), \tilde{\phi}(\tilde{z})$, house and rental prices p_h, p_r, and relative prices of labor and capital w, r, such that the following conditions are satisfied:

1. Households solve their decision problem (2) subject to constraints (3), (4), (5) and (14);
2. Rental price is derived from (6);[16]
3. Factor prices are competitive, i.e., determined by (8) and (9);
4. The aggregation holds,

$$\begin{aligned}
L &= \int_{\mathcal{J}\times\mathcal{S}\times\mathcal{E}} e(z)\cdot\exp(\theta+\eta)\mathrm{d}X(z) \\
C &= \int_{\mathcal{Z}} c(z)\mathrm{d}X(z) \\
A_L &= \int_{\mathcal{Z}} a_l(z)\mathrm{d}X(z) \\
H_R &= \int_{\mathcal{Z}} c_h(z)\mathrm{d}X(z) \\
H_O &= \int_{\mathcal{Z}} h(z)\mathrm{d}X(z) \\
TR &= \int_{\mathcal{Z}} tr(z)\mathrm{d}X(z),
\end{aligned}$$

and the aggregate capital stock K is derived from the capital market equilibrium[17]

$$K + B_G + p_h H_R = A_L; \tag{24}$$

[16] As indicated, we assume perfectly elastic housing supply with exogenous house price normalized to 1. In the sensitivity analysis section, we incorporate housing construction company and endogenize house price.

[17] For modeling Australia's mandatory superannuation, the right hand side of (24) also includes the private pension assets A_R.

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

$$\tilde{\phi}(\tilde{z}) = \int_{\mathcal{Z}} \mathbf{1}_{a^+=a^+(z)} \times \mathbf{1}_{o^+=o^+(z)} \mathrm{d}X(z)$$

and

$$\phi(z^+) = \frac{\psi_{j+1}}{1+n} \int_{\tilde{\mathcal{Z}}} \mathbf{1}_{a_l^+=(1-\omega^+(\tilde{z}))a^+} \times \mathbf{1}_{h^+=\omega^+(\tilde{z})a^+} \times \mathbf{1}_{a_r^+=a_r^+(\tilde{z})} \times \pi(\eta^+|\eta)\, \mathrm{d}X(\tilde{z});$$

6. Unintended bequests satisfy[18]

$$\int_{\mathcal{Z}\setminus\mathcal{S}} b(z^+)\mathrm{d}X(z^+) = \int_{\mathcal{Z}\setminus\mathcal{S}} (1-\psi_{j+1})\big[(1+r)a_l^+(z) + (1-\delta_o)p_h h^+(z)\big]\mathrm{d}X(z), \tag{25}$$

where $\mathcal{Z} \setminus \mathcal{S}$ indicates that bequest are separately distributed within each skill class;

7. The government budget (20) and the PAYG pension budget (21) are balanced;

8. The goods market clears

$$Y = C + (n+\delta_k)K + (n+\delta_r)H_R + (n+\delta_o)H_O + G + TR, \tag{26}$$

with investment in capital stock $(n+\delta_k)K$, rental housing $(n+\delta_r)H_R$, and owner-occupied housing $(n+\delta_o)H_O$.[19]

4 Calibration and performance of initial equilibrium

The benchmark economy of our stochastic OLG model is calibrated to Germany, using demographic and macroeconomic data from 2018, as well as household survey data for Germany. This section provides detailed parametrization of the benchmark model and compares the resulting equilibrium solution with the German targets.[20]

4.1 Parametrization of benchmark model

We now report and discuss the parameters of the benchmark model, with Table 3 presenting the key model parameters for demographics, household preferences, labor productivity, production technology, housing market, and fiscal policy.

[18] For modeling Australia's mandatory superannuation, bequests also include superannuation assets a_r of those who do not survive to age $j+1$ (expanding the right hand side of (25)).

[19] In the sensitivity analysis section, we also assume a small open economy, with constant factor prices and the capital market and goods market equilibrium conditions extended to include net foreign assets and net export, respectively.

[20] Further details on the calibration of the benchmark model to German macroeconomic data are provided in Appendix C, which is frequently referred to in this section.

Table 3: Parameter values of the benchmark model

Symbol	Definition	Value	Source
	Demographics		
ψ_j	Survival probabilities		StaBu (2019)
n	Population growth rate (p.a.)	0.00615	Calibrated[a]
ϖ_θ	Skill distribution	[0.2,0.5,0.3]	Fehr et al. (2013)
	Household preferences		
γ	Intertemporal elasticity of subst.	0.5	Kaas et al. (2021)
ν	Ordinary consumption share	0.70	Kaas et al. (2021)
β	Time discount factor (p.a.)	0.991	Calibrated[b]
	Labor productivity		
e_j	Productivity of agent at age j		Fehr et al. (2013)
ρ	AR(1) correlation		Fehr et al. (2013)
σ_ϵ^2	Transitory variance		Fehr et al. (2013)
	Production sector		
α	Capital share	0.35	Appendix C
δ_k	Capital depreciation rate (p.a.)	0.05	Appendix C
ϱ	Production constant	1.47	$w = 1.0$
	Housing market		
	Depreciation rate (p.a.)		Chen (2010)
δ_o	... in owner occupied housing	0.025	
δ_r	... in rental housing	0.035	
ξ	Maximum loan-to-value ratio	0.7	Voigtlï¿½nder (2016)
	Transaction cost		Voigtlï¿½nder (2016)
μ_1	... of selling price	0.03	Kaas et al. (2021)
μ_2	... of buying price	0.10	Kaas et al. (2021)
h_{min}	Minimum house size	$4\bar{y}$	Calibrated[c]
	Policy parameters		
G/Y	Fraction of public consumption	0.23	Appendix C
B_G/Y	Debt to output ratio	0.76	Appendix C
τ^r	Capital income tax rate	0.135	Appendix C
κ	Pension accrual rate (p.a.)	0.012	Appendix C
x	Contribution (payroll tax) ceiling	$2\bar{y}$	Appendix C
all	Income tax allowance/exemption	$0.17\bar{y}$	Calibrated[d]

[a] To target age dependency ratio of 35.8%; [b] To target K/Y; [c] To target homeownership ratio of 44% (averaged over population aged 30+); [d] To target labor income tax revenue.

Demographics. The model's time period is 5 years. Agents begin life at age 20 ($j = 1$), retire at age 65 ($j_R = 10$), and can live up to the maximum age of 99 years ($J = 16$). Hence, the model is populated with 16 age groups (20-24, 25-29, ..., 95-99). We assume a stationary demographic structure with time-invariant survival probabilities ψ_j and population growth rate n that jointly determine the sizes of different age cohorts. The age-specific survival probabilities are taken from the 2016/18 Life Tables for Germany. The resulting average life expectancy at birth and at age 65 is approximately 80.8 and 19.2 years, respectively, which closely match the respective life expectancies recorded in StaBu (2019). Next, we calibrate the population growth rate to approximate the existing old-age dependency ratio (defined here as ages 65+ to ages 20-64) of 36 percent. The model distinguishes three skill levels (i.e., $S = 3$), based on UNESCO's International Standard Classification of Education (ISCED).

Household preferences. As per the relevant literature, we assume non-separable Cobb-Douglas preferences. The preference parameters are selected to match the homeownership rates and household asset allocations observed in the data. The intertemporal elasticity of substitution is set to $\gamma = 0.5$, i.e., a commonly assumed value in the literature. The non-housing consumption share is set to $\nu = 0.7$, in line with Kaas et al. (2021). The annual time discount factor is set to $\beta = 0.991$, in order to approximate the capital-output ratio derived in Appendix C.

Labor productivity. The labor productivity of each skill type consists of a deterministic and age-specific component, and a transitory component following an AR(1) process. The parameter values for these components are taken from Fehr et al. (2013). [21]

Production technology. In the Cobb-Douglas production function, the technology level ($\varrho = 1.65$) is set such that in the benchmark model, the wage rate is normalized to unity. To calculate the business capital share of output in the data, which corresponds to that in the model, the service flow from housing capital needs to be subtracted from total output. This results in a value of $\alpha = 0.35$, as derived in Appendix C. Similarly, the depreciation rate of the capital stock $\delta_k = 0.052$ is also derived in Appendix C based on German national account data.

Housing market. Following Chen (2010) and Chambers et al. (2009a), we differentiate between a higher depreciation rate for rental houses ($\delta_r = 0.035$ per annum) and a lower depreciation rate for owner-occupied housing ($\delta_o = 0.025$ per annum). The maximum loan-to-value ratio is set at 70 percent throughout the working life ($\xi = 0.7$). While previous studies have typically assumed a downpayment ratio of 20 percent, financial restrictions in Germany tend to be tighter (Voigtlï¿½nder, 2016). We set the transaction costs for selling and buying a house (μ_1, μ_2) at 3 and 10 percent of the house value, respectively. These values include land transfer tax, notary fees, and land registry, which are relatively high in Germany (for further details, see Voigtlï¿½nder, 2016) and may also encompass brokerage fees. Therefore, the assumed costs are higher than typically used in the literature, but close to Kaas et al. (2021). The minimum house size (h_{min}) is calibrated to match the (low) average

[21] More specifically, in our model, deterministic labor productivity is almost identical across the skill types for those aged less than 30, but the gap expands as households age, peaking at age 50, with high-skilled workers' productivity at almost 2 times of that of low-skilled workers. The estimated variance term in the stochastic component is also higher for the high-skilled, at approximately 1.5 times of that of the low-skilled, implying more earnings uncertainty faced by high-skilled workers in our model.

homeownership rate in Germany. h_{min} is significantly higher than the values commonly used in the literature, reflecting Germany's tighter housing regulations.[22]

Fiscal policy. Regarding the German government sector, we exogenously specify the ratios of public consumption and public debt to output (see Appendix C). The nominal withholding tax on interest income in Germany is set to 25 percent, with the statutory corporate tax rate being 15 percent. However, corporations are also subject to trade taxes and a surcharge, while various allowances for interest and corporate income are abstracted from in the model. The chosen tax rate of 13.5 percent replicates the tax revenue from capital income, as derived in Appendix C. Similarly, the chosen pension accrual rate (κ) implies a realistic replacement rate of 54 percent for the standard pensioner, with the model closely matching the payroll tax rate and public pension expenditure in Germany. Finally, we abstract from any social transfers to households and to generate a realistic income tax revenue, 17 percent of taxable income is tax exempt.[23]

4.2 Benchmark solution and data comparison

For the model's numerical solution, we follow the Gauss-Seidel procedure of Auerbach and Kotlikoff (1987) for macro variables, as described in Fehr and Kindermann (2018, p.512f). For our initial (or benchmark) steady state that reflects the current German fiscal system, we begin with guesses for aggregate variables, bequests distribution and exogenous policy parameters. Then, we compute the factor prices and individual decision rules and value functions.[24] Next, we obtain the distribution of households and aggregate assets and consumption, as well as the social security and consumption tax rates that balance pension and government budgets. This information allows us to update the guesses, and repeat the procedure until guesses and the resulting values for capital, labor, bequests, and endogenous tax taxes sufficiently converged.

The benchmark solution and observed German data for (i) the components of aggregate demand, household wealth, and government tax revenues and pension expenditures are reported in Table 4; and (ii) homeownership and household wealth over the lifecycle are depicted in Figure 2.

Macroeconomic solutions. As shown in Table 4, the model closely replicates the German national accounts data, which we adjust for our model structure (assuming a closed economy), and measured output at production prices net of the real estate sector (see Appendix C).[25] Regarding the housing market, we choose a minimum house size, h_{min}, to match the observed average homeownership ratio of 44 percent and the relative house values and rent payments. Compared to the data, more low-skilled households in the model are homeowners and more middle-skilled types are renters. However, the model effectively captures the general homeownership pattern across skill classes.[26]

[22] Given that $\bar{y}$ in Germany is approximately 40,000 euros, h_{min} is roughly 160,000 euros.

[23] The impact of this tax allowance or exemption is analyzed in detail in Sections 5.3 and 5.4.

[24] Details on the household optimization problem and the numerical implementation are provided in Appendix B.

[25] Note that in Table 1, GDP was measured per capita while net wealth was measured per adult. The absolute wealth figures in Credit Suisse (2019) (which are not reported) fit reasonably well with the wealth calculations in Appendix C.

[26] As indicated in Section 2, we use HFCS wave 2017 data for Germany (ECB, 2020) to calculate skill specific homeownership rates.

Table 4: Model solution and targets for Germany 2018*

Variable	Model	Target[a]
Expenditures on GDP		
Private consumption	51.0	48.4
Government consumption	23.0	24.6
Gross investment		
in capital stock	15.2	16.3
in owner occupied housing	6.5	6.7
in rental housing	3.9	4.0
Housing transactions	0.4	–
Capital and housing markets		
Capital stock	286.8	275.0
Net wealth	702.0	660.0
Owner occupied housing stock	215.1	215.0
Rental housing stock	100.9	99.0
Homeownership rate (%)	44.0	44.0
low-skilled	31.5	21.4[b]
middle-skilled	40.6	48.0[b]
high-skilled	58.0	58.0[b]
House value to income ratio	6.2	6.5
Rent to income ratio (%)	19.3	20.5
Interest rate p.a. (%)	6.6	–
Government policy		
Labor income tax revenue	10.4	10.4
Capital income tax revenue	4.5	4.4
Consumption tax revenue	13.3	12.2
Consumption tax rate (%)	26.2	–
Pension benefits	11.9	11.2
Payroll tax rate (%)	19.8	–

* As a percentage of GDP, if not stated otherwise; [a] Own calculations derived in Appendix C; [b] As reported in Table 1, using HFCS 2017 for Germany's skill-specific homeownership rates of those aged 30+.

It should be noted that, despite the transaction costs, households in our model buy houses for two reasons. First, the mark-up on the rental price through higher depreciation incentivizes homeownership, as it reduces the maintenance cost. Second, since the imputed rent income of homeowners is not taxed, capital income taxation discriminates against returns from other assets.[27]

In the government budget constraint, we target progressive labor income and flat-rate capital income taxation revenues, with the consumption taxation, and in particular the consumption tax rate being derived in order to balance the government budget. The consumption tax rate of 26.2 percent includes value-added and excise taxes, and the consumption tax revenues are highly realistic. Similarly, pension benefits include both benefits of workers in the statutory pension system and and government-financed civil servants. The payroll tax rate of the statutory pension system in 2018 was 18.6 percent. The higher number reported in Table 4 is nevertheless justified, since benefits of civil servants are, on average, higher than those of workers.[28]

Life cycle solutions. In Figure 2, we plot the model-generated solutions for (a) homeownership and (b) net wealth over the life cycle, and by skill type and provide comparison with the average homeownership and household net wealth derived from HFCS 2017 for Germany (ECB, 2020).[29]

As shown in the left part of Figure 2, the model effectively matches average homeownership rates over the life cycle. Similar to the data, the average homeownership profile is hump-shaped, increasing significantly at younger working ages and slowly declining at older ages. We have also plotted the model-generated profiles for homeownership of low-, middle- and high-skilled households. As expected, the high-skilled type are found to have higher homeownership rates compared to their low- and middle-skilled counterparts (and the gap between homeownership rates would likely increase if calculated for different income or asset classes). Note that in the HFCS data, the gap in homeownership between those in the bottom 20 percent income distribution and those in the 80-90 percent income distribution exceeds 40 percentage points.

As for net household wealth, the model approximates a hump-shaped profile over the life cycle observed from the HFCS data, with the peak at the 60-64 age group. The model-generated net wealth (expressed as a ratio of economy-wide average earnings) is slightly above the data points. Importantly, the model closely matches net-wealth differences by tenure status, which in the data is, on average, roughly 4 times larger for homeowners compared to renters (see ECB 2020, Table A4). A similar gap between net wealth of homeowners and renters can be observed in the right part of Figure 2 for households aged 60-64.

In the following section, we apply this benchmark model calibrated to Germany to examine the economy-wide impacts of replacing either income taxation or pensions or both, drawing on the US and Australia as alternative policy designs.

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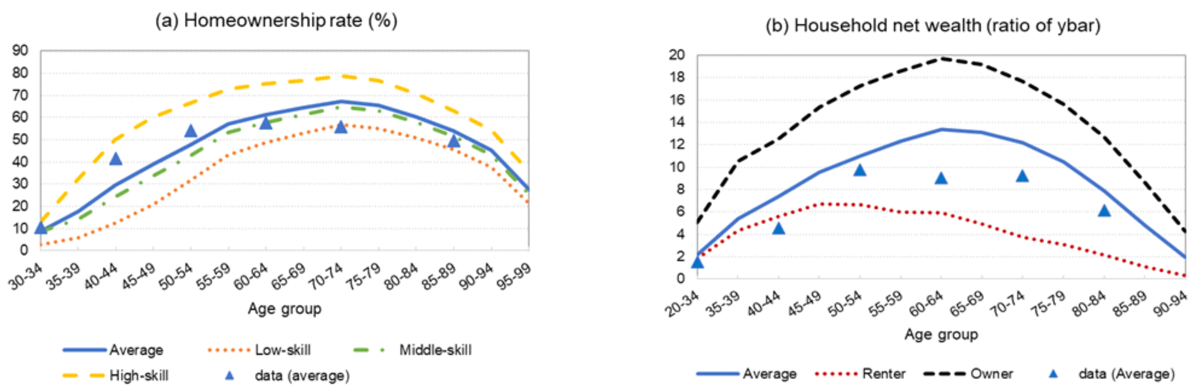
[27] Consequently, with $\delta_o = \delta_r$ and $\tau^r = 0$, all households would become renters.

[28] German pensions also contain benefits that are not liked to former contributions, such as mothers' pensions etc. These non-contributory benefits, which comprise roughly one third of the pension budget are financed by general tax revenues. In our model, we neglect such benefits entirely.

[29] Note that the data points from HFCS 2017 are averages for age groups 16-34, 35-44, 45-54, 55-64, 65-74 and 75+.

Figure 2: Life cycle solutions and German data



Note: German life cycle data derived from HFCS data for 2017 (ECB, 2020).

5 Quantitative analysis

This section presents a quantitative analysis of the steady state effects of alternative tax and pension designs on homeownership, household wealth, and the economy. The model, calibrated to Germany, is applied here to quantify macroeconomic and distributional effects of replacing the existing German policy – with either 5.1 alternative income taxes or 5.2 alternative pension policy, and – with overall policy designs (that encompass both income tax and pensions) based on developed country examples for 5.3 the US or 5.4 Australia.

In the first two subsections, we analyze the effects of changing income taxation and PAYG pensions individually, with a focus on capturing systems' level, generosity and progressivity. For the pension alternatives, we also examine the steady state effects of replacing PAYG pensions with non-contributory means-tested age pensions.

The last two subsections assess the interactions between two sets of policies within the overall fiscal systems, drawing on examples from the US and Australia, and to report on how much of the observed difference in homeownership and household wealth between the pairs of countries (Germany vs. the US and Germany vs. Australia) can be explained by our model.

In all the counterfactual scenarios analyzed in this section, we maintain public consumption and public debt at their initial levels, and the government budget and the PAYG pension budget are balanced by adjustments in the consumption and payroll tax rates, respectively.

5.1 Income taxation and homeownership: Tax base, level, and progressivity effects

We now present and discuss the macroeconomic and distributional results of alternative tax systems for capital and labor income. While the main objective is to highlight the difference between the two tax bases, we also examine the progressivity and level effects of the income tax.

In the first counterfactual scenario presented in this section, we consider capital income tax changes – eliminating the dual tax system and taxing aggregate income from capital and labor under the benchmark progressive tax schedule. Consequently, the progressivity of capital income taxation increases considerably. In this scenario, we also scale down the benchmark tax schedule to eliminate any income effect from broadening the income tax base – with the aim to isolate the compensated effects of higher and more progressive capital income taxation.

The second counterfactual scenario highlights the differential effects of higher income tax progressivity on housing. To isolate the latter, labor and capital income are taxed under the US tax schedule, but the latter is scaled upwards to generate the same tax revenue as in the benchmark.[30] The adjusted US federal income tax schedule still features eight tax brackets, but a lower initial marginal tax rate and a higher top rate than the adjusted German schedule.

The third counterfactual scenario isolates the impact of the income tax level on homeownership, with labor and capital income taxed under the (existing) US schedule.[31] The steady state results obtained from the main three counterfactuals are reported in Table 5.

Table 5: Macroeconomic and distributional effects of implementing alternative taxation policies*

	Labor and capital income taxed with		
	adjusted German	adjusted US	US
Variable	progressive tax schedule T18		
Output (GDP)	-3.1	-4.0	0.2
Consumption	-3.5	-4.5	-1.8
Capital stock	-8.7	-11.0	0.5
Net wealth	-3.3	-4.5	5.1
- low-skilled	-2.8	-0.7	5.0
- middle-skilled	-3.8	-3.1	4.6
- high-skilled	-2.9	-8.2	6.0
Housing stock (Owner)	8.1	7.7	16.9
Housing stock (Renter)	-14.8	-15.6	-3.0
Homeownership rate (p.p.)[a]	5.3	5.1	5.5
- low-skilled (p.p.)	4.8	5.6	4.4
- middle-skilled (p.p.)	6.1	5.8	6.4
- high-skilled (p.p.)	4.3	3.6	4.6
Interest rate p.a. (p.p.)	0.6	0.7	0.0
Wage rate	-3.1	-4.0	0.2
Income tax revenue	0.0	0.0	-38.1
Marginal capital tax rate (p.p)[b]	4.0	9.6	1.5
Consumption tax rate (p.p.)[c]	2.1	2.8	11.7

*Percentage change relative to benchmark if not stated (p.p.) representing percentage point change;
[a] Share of homeowners in the population aged 30 years and over; [b] Cohort-weighted average over the life cycle, with marginal capital income tax rate set to zero for all those with zero or negative liquid assets;
[c] Assumed to balance government budget.

30 Note that here we keep the German tax base, i.e., we abstract from mortgage payment deductions and keep the allowance and the contribution ceiling for payroll taxes.

31 With marginal tax rates increasing from 10 percent to the top rate at 37 percent (see Appendix A).

Taxation of capital income. In the initial simulation, the income tax base is expanded to also include capital income, which is taxed progressively under the adjusted benchmark tax schedule. This involves removing the flat tax rate applied to capital income in the benchmark model. Additionally, we scale down the benchmark tax schedule by a factor of 0.75, thus neutralizing the impact of broadening the tax base on household income. Therefore, as shown in the first column of Table 5, the overall burden of the income tax remains unchanged. However, the (cohort-weighted average) marginal tax rate on capital income increases significantly – rising by 4 percentage points compared to the benchmark equilibrium.[32]

The increased taxation of capital income reduces savings and future net wealth by 3.3 percent. More importantly, it also induces a strong portfolio shift from capital towards owner-occupied housing stock. While the former decreases by 8.7 percent, the latter increases by 8.1 percent. Former renters become homeowners so that the (average) rate of homeownership increases by 5.3 percentage points, while the stock of rental housing diminishes by 14.8 percent, compared to the benchmark equilibrium. These changes imply increased demand for housing at both extensive (homeownership rate) and intensive margins (housing stock for homeowners). At the same time the lower capital stock in the new long-run equilibrium reduces aggregate output, consumption and wages. Consequently, the consumption tax rate has to increase by 2.1 percentage points to finance government expenditures.

It should be noted that, although we keep the income tax revenue constant, the considered policy change still redistributes tax burdens across skill types. Consequently, the disaggregated changes in net wealth and homeownership have to be explained by income and substitution effects. As shown, the reduction in net wealth and the increase in homeownership is relatively less pronounced for low- and high-skilled individuals compared to their middle-skilled counterparts. The latter react most strongly due to having lower rates of homeownership (and thus more financial wealth) in the benchmark compared to high-skilled workers, while they are simultaneously less restricted by the minimum house size compared to the low-skilled.

Income tax progressivity. When taxing labor and capital income under the adjusted US schedule, we scale up the existing schedule by a factor of 1.64 to generate the same tax revenue as in the benchmark. Compared to the first simulation with the adjusted German tax schedule, the income tax system becomes more progressive with lower marginal tax rates for lower incomes, but higher top marginal tax rates. The middle column of Table 5 shows that the redistribution of tax burdens from (mainly) low-skilled towards (mainly) high-skilled households improves the wealth accumulation of low- and middle skilled households, but reduces the net wealth of the highly-skilled. Consequently, aggregate net wealth, capital stock, output, consumption, and the wage rate further decline (compared to the first column). Despite the reduction in net wealth, the housing stock and aggregate homeownership rate remained largely unchanged. This is due to the offsetting reactions of low- and high-skilled households with respect to tenure choice. Rising tax progressivity increases homeownership of the former, but reduces it for the latter. However, the impact of tax progressivity on skill-specific homeownership is found to be modest, since income and substitution effects move in opposite directions for all households (i.e., generating negative income and positive substitution effects).

[32] When calculating (cohort-weighted average) marginal tax rates on capital income, we considered those households with zero or negative liquid wealth, but facing zero capital income tax rates. If we solely considered those with positive liquid wealth, the marginal capital tax rate's increase would be further amplified.

Income tax level. In the third simulation of Table 5 reported in the right column, labor and capital income are taxed under the existing US schedule. This considerably reduces income tax revenues by almost 40 percent, while the consumption tax rate increases by almost 12 percentage points. The lower income tax burden increases aggregate net wealth, housing, and capital stock compared to the previous simulation, inducing higher wages, consumption, and output. Note that net wealth that net wealth saw a much higher increase than aggregate homeownership. Lower capital taxes clearly induce higher savings, but income and substitution effects compensate each other with respect to homeownership.

The last column of Table 5 also reveals that, compared to the second simulation, high-skilled individuals increase their savings much more than low- and middle-skilled types. While all households experience lower marginal taxes on capital income (compared to the previous simulation), high-income households also face a reduction of tax burdens shifted towards low-income households. This can also explain why homeownership decreases for low-skilled types, but increases for high-skilled types compared to the previous simulation.

In summary, we have shown that the taxation of capital income (in particular) has a significant effect on homeownership. A higher level of capital income taxation induces a portfolio shift towards housing to benefit from the (implicit) tax subsidies to owner-occupied housing. Surprisingly, the level and progressivity of income taxation have only a modest effect on aggregate homeownership. This reflects the fact that labor and capital income taxation work in opposite directions.[33]

5.2 Pensions and homeownership: Generosity, progressivity and means-testing

This section analyzes the steady-state effects of alternative pension schemes on wealth and homeownership. The first part studies the impact of generosity and progressivity of contribution-related pension benefits (i.e., – that depend on labor earnings) by replacing the benchmark pension system in two steps with a less generous and more progressive pension system based on the US social security. In the first step, the contribution ceiling is increased and the replacement rate of benefits is reduced until pension expenditure is similar to the US. In the second simulation, we keep the payroll tax (and hence the average benefit)the same as under the previous counterfactual, but introduce the (more progressive) benefit formula of the US social security design (in the model section, given by equations (16) and (17), respectively). In the second part, the benchmark benefit system is replaced by a means-tested benefit, drawing on the Australian system (i.e. given by equation (15) determining the age pension) but financed either by payroll or consumption taxes.

The macroeconomic and distributional effects of the four counterfactual pension scenarios (relative to the benchmark model) are provided in Table 6. As with the income taxation discussed above, we first outline the macroeconomic effects, including general equilibrium and fiscal implications, and then provide the distributional effects, with a focus on household net wealth and homeownership. We begin by discussing the results for the changes in pension generosity and progressivity.

[33] Appendix D provides simulations where labor income taxation is analyzed in isolation. When capital taxes remain unchanged, a reduction of labor income taxes significantly increases aggregate homeownership. High-skilled households react more strongly due to the progressive tax schedule.

Table 6: Macroeconomic and distributional effects of implementing alternative pension policies*

Variable	Contribution-related benefits: reduced generosity	Contribution-related benefits: + increased pro-gressivity	Means-tested benefits: payroll financed	Means-tested benefits: consumption tax financed
Output (GDP)	3.8	3.6	4.2	5.1
Consumption	2.3	2.2	1.3	0.3
Capital stock	11.1	10.8	12.6	15.3
Net wealth	9.0	8.9	13.1	19.3
- low-skilled	9.7	7.4	3.4	8.2
- middle-skilled	9.5	8.7	10.9	16.2
- high-skilled	8.0	10.0	20.9	28.8
Housing stock (Owner)	15.8	15.0	26.2	45.6
Housing stock (Renter)	-4.9	-3.5	-3.6	-11.3
Homeownership rate (p.p.)[a]	7.9	7.4	9.7	16.6
- low-skilled (p.p.)	6.5	5.4	4.6	12.6
- middle-skilled (p.p.)	8.4	7.6	10.0	18.2
- high-skilled (p.p.)	8.0	8.5	12.5	16.6
Interest rate p.a. (p.p.)	-0.6	-0.6	-0.7	-0.9
Wage rate	3.8	3.6	4.2	5.1
Income tax revenue	4.6	3.8	6.8	16.7
Pension expenditure	-27.9	-28.1	-59.2	-58.4
Replacement rate - low-skilled (p.p.)	-18.3	-15.4	-21.9	-21.7
Replacement rate - high-skilled (p.p.)	-18.3	-20.7	-40.2	-40.1
Payroll tax rate (p.p.)[b]	-6.5	-6.5	-12.6	-19.8
Consumption tax rate (p.p.)[c]	-3.1	-2.7	-3.6	3.1

*Percentage change relative to benchmark if not stated (p.p.) representing percentage point change; [a] Share of homeowners in the population aged 30 years and over; [b] Assumed to balance PAYG pension budget; [d] Assumed to balance government budget.

Pension generosity and progressivity. The first column of Table 6 presents the results for the effects of increasing the contribution ceiling and reducing the benefit level to match the US payroll tax rate while keeping the German point system (i.e. actuarial fairness) for calculating benefits (linked to former earnings). This leads to a 27.9 percent reduction in pension expenditure, a payroll tax rate falls of 6.5 percentage points and and a decrease of 18.3 percentage points for the replacement rate for all household types.[34] As households prepare for their future retirement (with lower public pensions and payroll taxes), they increase their savings, which, in turn, boosts net wealth and the physical capital stock, thereby inducing higher wages, output, and consumption. Income tax revenues increase by 4.6 percent due to the higher tax base (i.e. lower deductions of pension contributions), so that the consumption tax can be reduced by 3.1 percentage points. Due to the higher contribution ceiling, high-skilled individuals increase net wealth relatively less than their middle- and low-skilled

[34] Note that this payroll tax rate is quite realistic for the US, as Hosseini and Shourideh (2019) also used a 12.4 percent rate in their analysis.

counterparts.[35] Our model provides additional insights regarding the reaction of housing assets and homeownership. The (partial) privatization of pensions significantly increases the homeownership rate by 7.9 percentage points, while the owner-occupied housing stock does so by 15.8 percent. Since home-owners invest more into housing, the owner-occupied housing stock increases much more strongly than net wealth and the physical capital stock. Table 6 also documents that a rise in home-ownership for middle- and high-skilled individuals in particular, although both types show a weaker savings reaction than low-skilled types. Moreover, while higher bequests increase the available resources of all younger households, middle- and high-skilled types are found to be still more able to finance a house compared to the low-skilled.

The second column of Table 6 also applies the previously-mentioned progressive pension formula (17), but keeps the pension expenditure level of the last simulation (and thus the payroll tax rate) constant. The rise in pension progressivity is found to affect the replacement rates of low- and high-skilled individuals in opposite directions. However, higher pension progressivity only slightly dampens the macroeconomic effects of reduced generosity observed in the first column. Disaggregation reveals that low-skilled individuals now accumulate less net wealth than before (due to having higher pension benefits), while high-skill individuals accumulate more net wealth (due to now lower pension benefits). Consequently, the homeownership rate of high-skilled individuals is found to slightly increase, while that of low- and middle-skilled types reduced compared to the previous simulation.

Means-tested pensions. The third column of Table 6 examines the effects of (replacing the benchmark pension system with) a means-tested pension system, similar to the Australian Age Pension described in equation (18), but financed by payroll taxes.[36] Such a system is less generous and more progressive than the one analyzed above, due to a modest maximum benefit (set at roughly 30 percent of average earnings) and a significant fraction of the eligible population receiving no or reduced pension benefits (due to means testing). As such, the public pension expenditure and payroll tax rate are more than halved, and the pension replacement rates decline significantly more than before, particularly for high-skilled individuals (only at approximately 15 percent under this counterfactual). Lower benefits and more disposable income encourage more savings, thereby increasing net wealth, physical capital, and homeownership (the latter seeing an average increase of 9.7 percentage points). As in the previous simulation, the owner-occupied housing stock rises more than the physical capital stock. Lower tax deductions and higher savings increase income tax revenues, so that the budget-balancing consumption tax rate reduces by 3.6 percentage points.

As for the distributional effects, net wealth increases more profoundly with the skill level than in the previous simulation. This is due to the amplified benefit progressivity (due to means-testing). Low-skilled households who receive means-tested benefits tend to have lower incentives to increase savings, while high-skilled households (many receiving hardly any pension benefits) increase their savings significantly. The skill-specific savings responses also explain the changes in homeownership compared to the previous column. Middle- and high-skilled households further increase their homeownership, while low-skilled households further reduce homeownership.

[35] In addition, due to the contribution ceiling, pensions are less important in old age for those households, which also dampens their savings reaction.

[36] Payroll financing may not be realistic, but allows better comparisons with the previous scenarios, where pension benefits were tied to previous earnings.

In the last simulation, we substitute the payroll tax financing of the age pension by general taxes, with age pension expenditures included in the government budget balanced by adjusting the consumption tax rate. Income tax revenues are found to increase significantly as contributions are no longer deducted from the income tax base. However, higher income tax revenues do not balance higher expenditures that now include age pensions, meaning that the consumption tax rate is found to increase by 3.1 percentage points relative to the benchmark equilibrium. The shift in pension financing from payroll contributions towards consumption taxation increases disposable incomes of younger households and tax burdens of older cohorts. Consequently, net wealth, capital accumulation, and homeownership saw significant rises for all skill types. Since the elimination of payroll taxes tends to increase the income tax burden for high-skilled households in particular, low- and middle-skilled households display much stronger reactions.[37]

In sum, we can conclude that a reduced pension generosity increases homeownership significantly, especially for high-skilled individuals who would otherwise not be able to afford it. Quite surprisingly on first sight, pension progressivity increases the positive correlation between income and homeownership due to the induced asymmetric savings reactions. Finally, financing pensions through consumption tax also increases homeownership since it shifts the tax burden from younger cohorts towards the elderly.

These findings shed light on how tax and pension policies affect wealth accumulation and homeownership, both at the aggregate level and across different skill types. The subsequent sections combine these tax and pension alternatives so as to capture the interactions between income taxation and pensions within overall reform counterfactuals, and examine the extent to which our model can explain observed cross-country differences in homeownership.

5.3 US policies and homeownership

In this section, we implement the US policy in four steps. First, we combine the two previous simulations from the last column in Table 5 and the second column of Table 6. Second, we remove the tax exemption (of 17 percent in the benchmark income tax base). Third, we introduce mortgage interest deductions to reach the US income tax base given by (12) in the model section. Fourth, we reduce the minimum house size by 20 percent in order to account for lower housing regulations in the US. The results for selected macroeconomic and distributional effects of (replacing the benchmark policy with) the overall US policy are presented in Table 7 .

As shown in the first column of Table 7, combining the US tax and pension policies from the two previous simulations summarizes their macroeconomic effects. Higher savings increase net household wealth by 15.5 percent, capital stock by 12.6 percent, and homeownership by 13.6 percentage points. Higher capital stock increases wages and output by 4.2 percent. Note that income tax revenues now decrease significantly stronger than in the respective simulations of Table 5, thus reflecting the higher contribution ceiling in the US. While the aggregate effects on net wealth can be explained by the combination of the two previous effects, the skill-specific reaction is more complicated. Low-skilled households increase net wealth (as to be expected given the results of Tables 5 and 6), but high-skilled households appear to have a stronger reaction, which can reflect the interplay between

[37] In Appendix D, we show the effects of several modifications to consumption tax financed non-contributory pensions, including (a) the case with no means testing, and (b) the case with housing fully assessed through means testing.

Table 7: Macroeconomic and distributional effects of implementing US tax and pension policy*

Variable	US taxes and pensions[i]	+ removed tax exemption[ii]	+ interest deduction[iii]	+ lower minimum house size
Output (GDP)	4.2	2.1	2.0	1.9
Consumption	0.4	-0.7	-0.8	-0.6
Capital stock	12.6	6.0	5.7	5.5
Net wealth	15.5	10.0	10.0	10.3
- low-skilled	12.4	8.7	8.9	8.1
- middle-skilled	14.7	9.7	9.5	9.6
- high-skilled	18.0	11.0	11.3	12.4
Housing stock (Owner)	35.5	30.2	31.9	42.0
Housing stock (Renter)	-7.2	-14.7	-17.1	-35.8
Homeownership rate (p.p.)[a]	13.6	13.8	14.7	25.8
- low-skilled (p.p)	12.7	13.0	13.1	27.0
- middle-skilled (p.p.)	14.7	15.3	16.2	28.6
- high-skilled (p.p.)	12.5	11.9	13.2	20.1
Interest rate p.a. (p.p.)	-0.7	-0.4	-0.3	-0.3
Wage rate	4.2	2.1	2.0	1.9
Income tax revenue	-38.6	-17.2	-17.7	-18.8
Pension expenditure	-27.5	-29.2	-29.3	-29.3
Payroll tax rate (p.p.)[b]	-6.5	-6.5	-6.5	-6.5
Consumption tax rate (p.p.)[c]	9.8	4.6	4.8	5.1

*Percentage change relative to benchmark if not stated otherwise; [i] US pensions and income taxation with modified tax base; [ii] US pensions and income taxation with increased tax base; [iii] Overall US pension and income taxation; [a] Share of homeowners in the population aged 30+ (%); [b] Assumed to balance PAYG pension budget; [c] Assumed to balance government budget.

reduced tax and increased pension progressivity. At the same time, the average homeownership rate is slightly higher (again, as expected from Tables 5 and 6, which is primarily driven by stronger reactions of low- and middle-skilled types. The higher contribution ceiling dampens the rise in the capital income tax only for the high-skilled, which thus dampens their incentive for homeownership.

In the second step, the removal of the tax exemption increases the income tax base and induces a shift from consumption towards (progressive) income taxation. This reduces the accumulation of net wealth and capital stock, so that the increase in wages and output is dampened. However, as shown in the second column, this change in the tax structure has a negligible effect on aggregate homeownership rate, since the effects of higher labor and capital income taxation again (almost) offset each other.

Adding the deduction of mortgage interest slightly shifts tax revenues back from income towards consumption taxes. The aggregate effects are very modest, but there is a significant increase in homeownership, especially for the middle- and high-skilled households who benefit most from this additional reform. It is worth noting that, in our model, only approximately 20 percent of homeowners hold a mortgage in the US case, while a more realistic share in the US would be much higher, as reported by Sommer et al. (2013) and Sommer and Sullivan (2018).

In our final simulation, we consider the fact that US housing regulations (in terms of the house size) are far less pronounced than in Germany. In order to account for this, we simulate the overall US policy in combination with a 20 percent reduction of the minimum house size. As the right column in Table 7 reveals, the minimum house size has very modest effects on aggregate variables – indeed, even net wealth increases only slightly. However, the changes in the level and structure of homeownership are rather more dramatic. Since many former renters become homeowners, the homeownership rate increases by over 25 percentage points relative to the benchmark model (over 10 percentage points higher relative to the overall US policy in the third column). This change appears mainly driven by low- and middle-skilled households, who face greater housing regulation restrictions than the high-skilled.[38]

Overall, it can be concluded that replacing the German fiscal system with the US tax and public pension policy settings can explain over half of the observed 20 percentage point differential in the homeownership rate between the US (at 64 percent) and Germany (at 44 percent). The increase in the homeownership rate is mostly due to the pension system, and far less so due to the income tax level and progressivity. However, the US' relatively high homeownership of low-skilled households cannot be explained by the fiscal system alone. Indeed, more lenient housing regulations that allow low-income households (in particular) to become homeowners could explain this.

5.4 Australian policies and homeownership

Similar to the previous subsection, we now introduce a combination of Australian income tax and pension policies. In the first simulation, we combine the Australian income tax (keeping the income tax exemption at 17 percent), with an age pension financed by general tax revenues. In the second, we eliminate the tax exemption. Finally, we keep the eliminated tax exemption and introduce mandatory contributions to the superannuation fund. The results for the macroeconomic and distributional effects are presented in Table 8.

As discussed in Section 2, the Australian income tax is more progressive than its German equivalent. In addition, interest income is included in the income tax base. Consequently, comparing the first column of Table 8 with the forth column of Table 6, a clear increase in income tax revenues can be seen, which dampens net wealth and capital accumulation, the wage rate, output, and consumption. Due to the increase in marginal capital income tax, households adjust their wealth portfolios towards housing so that the homeownership rate increases significantly and the capital stock increases only modestly. As a result, factor prices adjust only slightly. This may appear surprising at first sight, as the consumption tax is higher than in respective simulation of Table 6, although income tax revenues increase considerably. However, the latter effect is overcompensated by the reduction in the consumption tax base, which raises the tax rate.

As mentioned previously, the Australian age pension mainly induces middle- and low-skilled households to reallocate their portfolios towards homeownership. However, the difference in the skill-specific homeownership rates is still fairly small compared to the data reported in Table 1. In order

[38] In Appendix D, we also analyze a reduction in transaction costs. This also increases homeownership rates, but without significant differences across skill classes.

to further increase the progressivity of the Australian tax system, we next eliminate the tax exemption. Consequently, a strong shift can be seen from consumption to income taxation, with a near 60-percent increase to income tax revenues. The progressive income tax reduces the wealth accumulation of high-skilled households in particular. Homeownership is also reduced, but much less than the net wealth, since higher capital income taxes induce a portfolio shift towards homeownership. As such, the spread between the skill-specific homeownership rates increases only slightly.

Table 8: Macroeconomic and distributional effects of implementing Australian tax and pension policy*

Variable	Australian taxes and age pension[i]	Elimination of tax exemption[ii]	+ mandatory superannuation[iii]
Output (GDP)	1.1	-3.1	5.7
Consumption	-3.3	-5.5	0.5
Capital stock	3.1	-8.7	17.3
Net wealth	13.1	1.9	20.1
- low-skilled	4.2	-4.0	12.9
- middle-skilled	11.1	1.0	19.2
- high-skilled	20.0	5.9	24.6
Housing stock (Owner)	49.8	32.9	38.6
Housing stock (Renter)	-27.6	-33.5	2.5
Homeownership rate (p.p.)[a]	22.3	19.1	19.4
- low-skilled (p.p)	22.1	19.8	22.3
- middle-skilled (p.p.)	24.6	21.2	21.7
- high-skilled (p.p.)	18.5	15.2	13.8
Interest rate p.a. (p.p.)	-0.2	0.6	-1.0
Wage rate	1.1	-3.1	5.7
Income tax revenue	20.2	58.7	18.6
Pension expenditure	-61.7	-62.4	-64.0
Consumption tax rate (p.p.)[b]	3.7	-6.2	1.1

*Percentage change relative to benchmark if not stated otherwise; [i] Australian income tax schedule and consumption tax financed age pension; [ii] Australian age pension and income taxation without tax exemption; [iii] Overall Australian policy; [a] Share of homeowners in the population aged 30+ (%); [b] Assumed to balance government budget.

In the final simulation (Table 8), we add the Australian mandatory superannuation policy to complement the means-tested public pension. Implementing this scenario is more complex as it requires the introduction of superannuation asset accumulations in equation (19), the budget constraint of the superannuation fund in equation (19), and the modification of the capital market equilibrium condition in equation (24) and bequests in equation (25) to include these private pension assets. The rate of the superannuation contribution mandate is set to 8 percent, with superannuation taxation (in equation (19)) based on the Australian private pension tax regime with a 15 percent contribution tax rate and a 7 percent fund earnings tax rate. Finally, the payout fraction ζ increases gradually after the retirement age so that funds are exhausted at age 85.[39]

Note that the superannuation system interacts with the means-tested age pension, so that age pension benefits tend to be initially low, but increase during retirement due to drawdowns of superannuation assets. This effect is partly compensated by the pension benefit increase due to the higher average income (inducing a re-indexing of the maximum pension rate). The superannuation system also reduces the income tax base since contributions to the private fund are taxed at a lower rate and interest earned is either taxed at lower rate (during accumulation) or - as well as draw-downs during retirement – not taxed at all. All these effects partly compensate the increased income tax base due to the elimination of the exemption. Overall, income tax revenues are almost the same as in the first simulation, but the consumption tax rate is smaller due to higher consumption and lower age pension expenditure. The mandatory savings increase net wealth of all household types in a similar magnitude. However, the latter does not apply to the homeownership rate. While aggregate homeownership hardly changes due to mandatory savings, the skill-specific ones react rather differently. Indeed, compared to the previous simulation, low-skilled households increase homeownership and high-skilled households now reduce it. The low-skilled benefit from higher bequest at younger ages, while high-skill households liquidate their houses earlier in life in order to better smooth consumption in old age when they draw down their superannuation assets.[40]

Comparing the overall Australian policy with the German benchmark reveals that the average homeownership rate increases by 19.4 percentage points to 63.4 percent, explaining almost the entire difference between average homeownership in Australia (at roughly 65 percent) and Germany (at 44 percent) in Table 1.[41] For the increased homeownership rate, the result is due predominately to the age pension that (compared to German public pensions) is less generous, means-tested, and non-contributory (in our model, consumption tax financed). The progressive taxation of capital income in Australia also increases homeownership, while the effect of mandatory superannuation on homeownership may explain why under the Australian case many low-income households can afford a house.[42]

6 Sensitivity analysis

This section checks the robustness of our results in a small open economy (SOE) setting and in an economy with a construction sector where house prices become endogenous, with the sensitivity results for the overall US and Australian policy reported in Table 9.

SOE setting. For simulating the overall US and Australian policies in an SOE, we begin from the same initial equilibrium as before, but allow capital inflows and outflows to balance the capital mar-

[39] Further details for the parametrization of Australia's age pension and superannuation policy are provided in Appendix A.

[40] Simulations of the superannuation system with complete flexible payouts and different bequest distributions show no significant macroeconomic effects.

[41] Note that using HILDA 2018, skill and population weights, the observed average homeownership rate was approximately 72 percent in Australia, thus the model explaining over two-thirds of this difference compared to Germany.

[42] In Appendix D, we also show that lower housing regulations (i.e. lower minimum house size) may also explain why the skill-specific gap is much smaller than in Germany.

ket and to keep the factor prices and output constant. We can directly compare the SOE simulations of Table 9 with the respective closed economy simulations reported in the third columns of Tables 7 and 8. In the closed economy simulations, the interest rate declines while the wage rate increases. Consequently, the simulation of the same policies in an SOE induces capital outflows, which further increase the long run net wealth of the elderly. The higher net wealth due to foreign bonds (not due to domestic physical capital) allows the financing of imports of goods and services so that aggregate consumption increases. It also increases the income tax revenues so that the consumption tax declines relative to the respective closed economy simulation. However, the SOE's impact on homeownership and the housing market is found to be rather modest in both fiscal systems. For the Australian policy, the average homeownership rate increases by approximately 3 percentage points when comparing the SOE and the closed economy, which is mainly due to higher bequests in the SOE framework.

Table 9: Sensitivity of macroeconomic effects and homeownership*

	US policy		Australian policy	
Variable	SOE[i]	Endogeneous house price	SOE[i]	Endogeneous house price
Output (GDP)	0.0	2.0	0.0	5.6
Consumption	4.6	0.3	16.8	2.0
Capital stock	0.0	5.9	0.0	16.9
Net wealth	15.8	10.0	40.1	19.7
- low-skilled	15.5	9.1	35.0	12.7
- middle-skilled	15.7	9.4	40.4	18.6
- high-skilled	16.0	11.1	42.1	24.4
Housing stock (Owner)	32.7	23.3	47.1	22.4
Housing stock (Renter)	-18.6	-15.9	-2.8	4.3
Homeownership rate (p.p.)[a]	14.4	11.8	22.6	14.1
- low-skilled (p.p)	13.1	10.1	25.4	15.5
- middle-skilled (p.p.)	15.6	12.9	25.1	16.1
- high-skilled (p.p.)	13.3	10.9	16.5	9.7
House price	0.0	4.7	0.0	8.6
Interest rate p.a. (p.p.)	0.0	-0.4	0.0	-0.9
Wage rate	0.0	2.0	0.0	5.6
Income tax revenue	-12.2	-17.3	26.9	19.5
Pension expenditure	-30.9	-29.3	-71.1	-63.8
Payroll tax rate (p.p.)[b]	-6.5	-6.5	-19.8	-19.8
Consumption tax rate (p.p.)[c]	2.3	3.1	-4.7	-1.2

*Percentage change relative to benchmark if not stated otherwise; [i] Small open economy; [a] Share of homeowners in the population aged 30+ (%); [b] Assumed to balance pension budget; [c] Assumed to balance government budget.

Endogenous house price. Finally, we analyze the impact of the overall US and Australian policies in a model with the housing construction sector and endogenous housing prices. Drawing on Rotberg (2022) and Kaas et al. (2021), we integrate a construction sector responsible for supplying housing and featuring convex construction costs. When investment I^H is directed to new owned and rented housing stock, the construction company receives payments amounting to $p_h I^H$. However, it also incurs the following costs:

$$CO(I^H) = c_0 \frac{(I^H)^{1+\frac{1}{\varphi}}}{1+\frac{1}{\varphi}},$$

where φ denotes the elasticity of housing supply and c_0 is a cost parameter. Denoting H_O and H_R as existing owned and rented housing stocks, the stock-flow relationship in the long-run equilibrium are defined by:

$$I^H = (n+\delta_r)H_R + (n+\delta_o)H_O,$$

where δ_r denotes the depreciation rate for rental properties. The construction company must then face the issue of choosing investment to maximize profits, as in:

$$\Pi_h = \max_{I^H} \; p_h I^H - CO(I^H) \quad \Rightarrow \quad p_h = c_0 (I^H)^{\frac{1}{\varphi}}. \tag{27}$$

Following Rotberg (2022), we set the housing supply elasticity parameter φ to 1.75 and calibrate the cost parameter c_0 in (27), so that we would still reach $p_h = 1$ in the initial German benchmark equilibrium. Finally, we assume that the profits Π_h generated by the construction company are completely taxed away by the government, and thus would need to be added to the left-hand side of the government budget constraint in (20), and the housing construction company expenditure $CO(I^H)$ would need to be included in the goods market clearing condition (26). Note that due to the profits of the construction sector assumed to be fully taxed away by the government, the initial consumption tax rate (in the new, re-calibrated benchmark equilibrium) is now 8.7 percentage points lower than before and overall consumption is 7.4 percent higher (not shown). All other variables hardly change compared to those reported in Table 3 for the benchmark model. When simulating the overall policy counterfactuals, c_0 remains unchanged, with the house price endogenously responding to increased demand for housing.

As shown in the second column of Table 9, the house price increases by 4.7 percent as a result of the overall US policy. This reduces the average homeownership rate by (14.7-11.8=) 2.9 percentage points and the owner occupied housing stock declines by 8.6 percentage points (compared to the results in Table 7). Higher house prices shift resources from younger ages (when people tend to purchase properties) to the elderly (who tend to sell them). Higher consumption and profits of the construction sector then induce a significant decline in the consumption tax rate. However, the macroeconomic effects on GDP, capital stock, and household net wealth are found to be highly similar to those from the previous section, where we used the model with an exogenous house price.

In the Australian overall policy counterfactual, the house price even increases by 8.6 percent, inducing a much stronger reduction in homeownership rate by 5.3 percentage points and a decline in the owner occupied housing stock by 16.2 percentage points (compared to the results in Table 8). Again, the consequences for the macroeconomy appear rather modest.

We can thus conclude that endogenous house prices may dampen the effects of the analyzed policy scenarios, but the significant impact of pension and tax policies on homeownership still remains.

7 Conclusion

This paper has examined the impacts of alternative pension and income tax policies on homeownership, household wealth and the broader economy. Our model simulations highlight the different impacts of capital and labor income taxation. While both dampen the accumulation of net wealth and the capital stock, capital income taxation induces a shift towards homeownership (where returns remain tax-exempt), whereas labor income taxation reduces homeownership. Consequently, higher and more progressive income taxation has only a modest effect on homeownership since labor and capital income taxes change homeownership in opposite directions.

Furthermore, we isolated the importance of social security arrangements for the level and distribution of homeownership. A wealth of literature demonstrated how generous PAYG financed pension system can curtail net wealth accumulation, which in turn also diminishes homeownership. Our simulations reveal that the pension level has a stronger impact on homeownership than the income tax system. In addition, a more progressive pension system further increases the uneven distribution of homeownership within cohorts. Interestingly, since households liquidate homeownership in old age so as to smooth consumption, a natural limit exists in homeownership. Accordingly, policy interventions – e.g., mandatory funded pension systems – that increase private savings may even reduce homeownership, if this natural limit has already been reached. Applying our model to a cross-country analysis of policy designs in Germany, the US, and Australia, our approach isolates the main forces, which drive the gaps in homeownership and wealth between Germany and the US, as well as between Germany and Australia. Differences in income tax and pension systems can explain over half of the observed gap in homeownership rates between Germany and the US, and over two thirds of the gap between Germany and Australia.

The importance of social security arrangements for tenure choice has also been highlighted by Fehr and Hofmann (2020), but their focus was on long-term care policy. While pensions and long-term care policies may not be directly oriented towards housing, we posit that such policies can exert a quantitatively significant indirect impact. Typically, countries apply specific housing policies, such as mortgage interest deductions (Sommer and Sullivan, 2018; Karlmann et al., 2022) or social housing (Kaas et al., 2021), which directly impact tenure choice. However, there are many other social and economic drivers of homeownership and wealth accumulation. For example, recent studies by Fisher and Gervais (2011) and Fisher and Khorunzhina (2019) highlighted how shifts in marriage and divorce patterns impact tenure choice and homeownership. Grevenbrock et al. (2023) showed that differences in the proportions of young adults residing with their parents may explain variations in European homeownership rates. Kindermann and Kohls (2022) pointed out differences in rental market regulations as explanatory factors for European homeownership patterns.

Notwithstanding these valuable contributions, we believe that the pension design channel has not yet received adequate attention. Accordingly, we plan to explore these issues in future research by incorporating endogenous labor supply and tax-favored voluntary pension systems (e.g., İmrohoroğlu, et al., 1998) to focus on the welfare and aggregate efficiency implications of tax and pension reforms.

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Appendix

This appendix has four parts. Appendix A details the progressive income tax schedules in Germany, Australia, and the US, and the pension parameters in Australia. Appendix B then provides a detailed technical description of the household's optimization problem. Appendix C meticulously describes our approach and data work for the calibration of our housing OLG model to the German macroeconomic and fiscal data. Finally, Appendix D provides some additional data and simulations.

Appendix A: Institutional details

The progressive income tax schedules in 2018 for Germany, Australia and the US are provided with two schedules for each country: (i) using the local currency and (ii) indexing the taxes paid and thresholds to the country's average labor income $\bar{y}$ (which, as given below, is very similar across the three examined countries). Note that the latter (with the indexing of taxable income) is used to produce Figure 1.

German progressive income tax code in 2018. In the benchmark model, we use the German progressive tax code (multiplied by the solidarity surcharge of 5.5%), with the tax base $\tilde{y}$ that includes labor earnings and public pensions net of payroll taxes and a calibrated tax exemption of 17%. It can be expressed as:

$$T18(\tilde{y}) = \begin{cases} 0 & \text{if } \tilde{y} \leq \text{€ } 9{,}000 \\ (1052.7x + 1.477)x & \text{if € } 9{,}001 < \tilde{y} \leq \text{€ } 13{,}996 \\ (232.24z + 2.529)z + \text{€ } 1000 & \text{if € } 13{,}997 < \tilde{y} \leq \text{€ } 54{,}949 \\ 0.443\tilde{y} - \text{€ } 9{,}095 & \text{if € } 54{,}950 < \tilde{y} \leq \text{€ } 260{,}532 \\ 0.475\tilde{y} - \text{€ } 17{,}341 & \text{if } \tilde{y} > \text{€ } 260{,}533 \end{cases}$$

where $x = (\tilde{y} - \text{€ } 9{,}000)/10^4$ and $z = (\tilde{y} - \text{€ } 13{,}996)/10^4$. Note that in the benchmark model simulation, we index the income thresholds to the annual average earnings of $\bar{y}$ = € 40,000 in 2018, with the income tax schedule expressed as follows:

$$T18(\tilde{y}) = \begin{cases} 0 & \text{if } \tilde{y} \leq 0.225\bar{y} \\ (1052.7x + 1.477)x & \text{if } 0.225\bar{y} < \tilde{y} \leq 0.35\bar{y} \\ (232.24z + 2.529)z + 0.0253\bar{y} & \text{if } 0.35\bar{y} < \tilde{y} \leq 1.37\bar{y} \\ 0.443\tilde{y} - 0.221\bar{y} & \text{if } 1.37\bar{y} < \tilde{y} \leq 6.51\bar{y} \\ 0.475\tilde{y} - 0.432\bar{y} & \text{if } \tilde{y} > 6.51\bar{y} \end{cases}$$

so that $x = (\tilde{y} - 0.225\bar{y})/10^4$ and $z = (\tilde{y} - 0.35\bar{y})/10^4$.

As indicated, there is no tax payable on taxable income $\tilde{y}$ up to approximately 22 percent of average income $\bar{y}$. Then, the marginal tax rate jumps to 14.8 percent. In the so-called first progressive zone (up to roughly $0.35\bar{y}$), there is a steep increase of the marginal tax rate to 25.3 percent, followed by a flatter increase in the second progressive zone up to about $1.4\bar{y}$. The proportional zone starts with a marginal tax rate of 44.3 percent, which increases to the top marginal tax rate of 47.5 percent for incomes of over $6.5\bar{y}$.

US progressive income tax schedule in 2018. The US total taxable income $\tilde{y}$ (including labor income, asset income and social security pension) is subject to the 2018 US progressive income tax schedule, which can be expressed (with all tax amounts and income thresholds in USD and including the standard deduction of $ 12,000) as:[43]

$$T18(\tilde{y}) = \begin{cases} 0 & \text{if } \tilde{y} \leq \$12,000 \\ 0.1\tilde{y} & \text{if } \$12,000 < \tilde{y} \leq \$21,525 \\ \$952 + 0.12(\tilde{y} - \$21,525) & \text{if } \$21,525 < \tilde{y} \leq \$50,700 \\ \$4,453 + 0.22(\tilde{y} - \$50,700) & \text{if } \$50,700 < \tilde{y} \leq \$94,500 \\ \$14,089 + 0.24(\tilde{y} - \$94,500) & \text{if } \$94,500 < \tilde{y} \leq \$169,500 \\ \$32,089 + 0.32(\tilde{y} - \$169,500) & \text{if } \$169,500 < \tilde{y} \leq \$212,000 \\ \$45,689 + 0.35(\tilde{y} - \$212,000) & \text{if } \$212,000 < \tilde{y} \leq \$512,000 \\ \$150,689 + 0.37(\tilde{y} - \$512,000) & \text{if } \tilde{y} > \$512,000 \end{cases}$$

In the model simulation for the US policy designs, we index the tax payable and income thresholds to the annual average earnings of $\bar{y} = 52,145$ USD in 2018 (or $44,190$ EUR, using the 2018 exchange rate of 1.18 USD = 1 EUR)[44], with the income tax schedule expressed as follows:

$$T18(\tilde{y}) = \begin{cases} 0 & \text{if } \tilde{y} \leq 0.23\bar{y} \\ 0.1\tilde{y} & \text{if } 0.23\bar{y} < \tilde{y} \leq 0.41\bar{y} \\ 0.041\bar{y} + 0.12(\tilde{y} - 0.41\bar{y}) & \text{if } 0.41\bar{y} < \tilde{y} \leq 0.97\bar{y} \\ 0.085\bar{y} + 0.22(\tilde{y} - 0.97\bar{y}) & \text{if } 0.97\bar{y} < \tilde{y} \leq 1.81\bar{y} \\ 0.270\bar{y} + 0.24(\tilde{y} - 1.81\bar{y}) & \text{if } 1.81\bar{y} < \tilde{y} \leq 3.25\bar{y} \\ 0.615\bar{y} + 0.32(\tilde{y} - 3.25\bar{y}) & \text{if } 3.25\bar{y} < \tilde{y} \leq 4.06\bar{y} \\ 0.876\bar{y} + 0.35(\tilde{y} - 4.06\bar{y}) & \text{if } 4.06\bar{y} < \tilde{y} \leq 9.82\bar{y} \\ 2.890\bar{y} + 0.37(\tilde{y} - 9.82\bar{y}) & \text{if } \tilde{y} > 9.82\bar{y} \end{cases}$$

Consequently, the 2018 US progressive income tax schedule begins with a marginal tax rate of 10 percent after a basic exemption of roughly 23 percent of average income, while the top marginal tax rate of 37 percent is applied to taxable income over $9.82\bar{y}$.

Australian progressive personal income tax schedule in 2018. The Australian progressive personal income tax schedule with the tax base $\tilde{y}$ (that includes labor earnings net of mandatory superannuation contributions, capital income and public pension) can be expressed (with all tax amounts and income thresholds in AUD) as:

$$T18(\tilde{y}) = \begin{cases} 0 & \text{if } \tilde{y} \leq \$18,200 \\ 0.19(\tilde{y} - \$18,200) & \text{if } \$18,200 < \tilde{y} \leq \$37,000 \\ \$3,572 + 0.325(\tilde{y} - \$37,000) & \text{if } \$37,000 < \tilde{y} \leq \$90,000 \\ \$20,797 + 0.37(\tilde{y} - \$90,000) & \text{if } \$90,000 < \tilde{y} \leq \$180,000 \\ \$54,097 + 0.45(\tilde{y} - \$180,000) & \text{if } \tilde{y} > \$180,000 \end{cases}$$

[43] We used the US tax schedule applicable for singles, with the standard deduction for singles. Hence, the schedule has one more bracket, with zero percent rate.

[44] Note that $\bar{y} = 52,145$ USD was also used when calculating US social security benefit, as defined in Section 5.1.

In the model simulation for the Australian policy design, we index the income thresholds to the annual average earnings of 69,215 AUD in 2018 (or 42,913 EUR using the 2018 exchange rate of 1.62 AUD = 1 EUR), with the income tax schedule expressed as follows:

$$T18(\tilde{y}) = \begin{cases} 0 & \text{if } \tilde{y} \leq 0.28\bar{y} \\ 0.19(\tilde{y} - 0.28\bar{y}) & \text{if } 0.28\bar{y} < \tilde{y} \leq 0.56\bar{y} \\ 0.0532\bar{y} + 0.325(\tilde{y} - 0.56\bar{y}) & \text{if } 0.56\bar{y} < \tilde{y} \leq 1.32\bar{y} \\ 0.3002\bar{y} + 0.37(\tilde{y} - 1.32\bar{y}) & \text{if } 1.32\bar{y} < \tilde{y} \leq 2.62\bar{y} \\ 0.7812\bar{y} + 0.45(\tilde{y} - 2.62\bar{y}) & \text{if } \tilde{y} > 2.62\bar{y} \end{cases}$$

Consequently, the Australian personal tax schedule contains five tax brackets, including tax-free income (with the threshold of roughly 30 percent of average income) and a top marginal tax rate at 45 percent, which is applied to annual income above approximately $2.62\bar{y}$. In addition, Australian households also pay reduced taxes of 15 percent on contributions to their retirement (superannuation) funds. During the accumulation phase, investment earnings of the superannuation funds are also taxed at 15 percent, but the effective rate is much lower due to imputation credits (see below).

Australian pension policy parameters in 2018. As explained within the main text (see Section 3.5.2), the Age Pension is subject to both income and asset tests, where the highest of the two computed reductions *in* and *as* is applied, i.e.,

$$pen = \max\left[\bar{p}(h) - \max\left(in, as\right); 0\right] \qquad \forall \quad j \geq j_R.$$

The tests are shaped around the maximal benefit, the disregard up to which the maximal benefit is paid, and the taper at which the pension benefit is withdrawn. The income test induces a 50 percent offset in the maximum payment for every dollar of assessable income $\hat{y}$ above the threshold y_{min}. The returns from financial assets are deemed at a fixed progressive rate schedule, where the rates of return of 3.25 and 1.75 percent are applied above and below the asset threshold a_{min}, respectively. Given the sum of financial and superannuation assets $\tilde{a} = \max(a_l; 0) + a_r$, the income test is derived from:

$$in = \max\left[0.5(\hat{y} - y_{min}); 0\right] \quad \text{with} \quad \hat{y} = 0.0325(\tilde{a} - \min\left[\tilde{a}; a_{min}\right]) + 0.0175 \min\left[\tilde{a}; a_{min}\right].$$

The asset test is comprehensive, although the owner's principal residence is excluded. The asset disregard $\bar{a}(h)$ distinguishes between homeowners and renters. Beyond the disregard, the maximal annual pension is currently reduced at 7.8 cents for every extra dollar of assessable assets, i.e.,

$$as = \max\left[0.078(\tilde{a} - \bar{a}(h)); 0\right].$$

Table 10 presents the values of the Australian pension and superannuation parameters used in the model. All pension parameters are calculated as averages of single and couple rates in 2018. The maximum pension benefit $\bar{p}(h)$ and the asset test threshold $a(h)$ are higher for renters ($h = 0$) than for homeowners ($h > 0$).

The Age Pension parameters including the maximum pension benefit $\bar{p}(h)$, the threshold for the income test y_{min}, the deeming threshold a_{min}, and the asset test thresholds $\bar{a}(h)$ differ for single and

Table 10: Pension policy parameters in Australia 2018

Symbol	Description	Value
	Age Pension	
$\bar{p}(h)$	Maximum pension benefit[a]	$[0.32\bar{y}; 0.28\bar{y}]$
y_{min}	Income test threshold	$0.09\bar{y}$
a_{min}	Deeming threshold p.a.	$0.98\bar{y}$
$\bar{a}(h)$	Asset test threshold p.a.	$[7.71\bar{y}; 4.71\bar{y}]$
	Superannuation	
τ^p	Mandatory contribution rate[b]	0.08
τ^{sa}	Tax on mandatory contributions	0.15
τ^r	Effective tax rate on fund returns[c]	[0.07; 0.0]
ζ	Payout fraction[d]	[0.0; 0.25; 0.35; 0.5; 1.0]

[a] Effective maximum benefit for a single household is roughly $0.28\bar{y}$; [b] Average rate since introduction in 1992; [c] $\tau^r = 0.07$ for $j < j_R$ and $\tau^r = 0$ for $j \geq j_R$;
[d] $\zeta = 0$ for $j < j_R$ and increasing for $j \geq j_R$.

couple pensioners. We apply population weights of 44 and 56 percent for single and couple pensioners, respectively, to compute a maximum pension benefit of 28 percent of average income for homeowners (per individual retiree) in 2018. Renters may be eligible for assistance when the rent exceeds a specific amount. In 2018, the maximum amount of this assistance was roughly 4 percent of average labor income, so that the maximum pension benefit for renters is set at 32 percent of $\bar{y}$. The income test and deeming thresholds are independent of homeownership, while the thresholds for the asset test are significantly lower for homeowners compared to renters. The income test threshold is roughly 6 and 11 percent of average income for singles and couples, respectively, while the respective percentages for the deeming threshold are 70 and 120 percent.

Regarding the superannuation system, we modelled mandatory contributions made at a given rate of 8 percent from gross labor earnings (the average mandatory superannuation rate since the system's legislation in 1992). When employers make these so-called concessional contributions (i.e. for which they claim a tax deduction), a tax of 15 percent is levied on the contribution. Investment earnings of the superannuation fund are also taxed at 15 percent during the accumulation phase, but the effective rate is much lower due to imputation credits, etc. We thus applied an effective rate of 7 percent, as per Kudrna et al. (2019). Investment earnings on assets during the retirement phase are tax free. Finally, funds cannot be withdrawn before retirement, and we assumed the payout fraction would gradually increase in the first four periods of retirement.[45]

Appendix B: Household's optimization problem and computation

At any state $z = (j, a_l, h, a_r, \theta, \eta)$, households must split up their current resources into consumption (c and c_h) and total savings a^+. A fraction ω^+ of total savings is then used to finance the new house

[45] The accumulated superannuation savings can be withdrawn as a lump-sum or an income stream including a range of products such as phased withdrawals and annuities. In 2018, roughly half of the total benefit payments were drawn as lump sums, with the other being phased withdrawals (commonly called allocated pensions in Australia, OECD, 2021c).

(i.e. $\omega^+ a^+ = p_h h^+$), with the remainder used to finance transaction costs and financial assets (or mortgages) (i.e., $(1-\omega^+)a^+ = tr(h,h^+) + a_l^+$). Consequently, total savings a^+ are defined by

$$a^+ = a_l^+ + p_h h^+ + tr(h,h^+),$$

where $a_l^+ \gtrless 0$ identifies whether the household is in debt or not. Households who become renters (i.e. $\omega^+ = 0$) invest all their post-transaction cost savings in the financial market, i.e. $a_l^+ = a^+ - tr(h,0)$.

Let $V(z)$ define the current value function of a household, then the household's optimization problem is given by:

$$V(z) = \max_{c,a^+,\omega^+,o^+} u(c, f(h)) + \beta\psi_{j+1} E[V(z^+)|\eta]$$

subject to:

$$pc + p_r c_h(h) + a^+ = (1+r)(a_l + \zeta a_r) + y + b + pen + (1-\delta_o)p_h h - pec - T,$$

where $c_h(0) > 0$ and $c_h(h) = 0$ if $h > 0$, $\zeta = 0$ in Germany and the US, pec defines the national payroll taxes and:

$$\underline{\omega}(a^+) \leq \omega^+ \leq 1, \quad a^+ \geq (1-\xi)p_h h^+ + tr(h,h^+), \quad p_h h^+ = \omega^+ a^+ \geq p_h h_{min},$$

so that $\underline{\omega}(a^+) = p_h h_{min}/a^+$ and $a^+ = a_l^+ + p_h h^+ + tr(h,h^+)$ with

$$tr(h,h^+) = \begin{cases} \mu_1 h + \mu_2 h^+ & \text{for } h = 0 \text{ or } h^+ = 0 \\ 0 & \text{otherwise.} \end{cases}$$

Households make decisions on consumption, future total assets, whether to rent or own a house, and the share of total assets used for the down payment. The expectation operators E concern the stochastic labor productivity process η. The current resources on the right hand side of the periodic budget constraint are represented by the sum of financial assets (or debt) a_l and funded pensions ζa_r, interest received or paid (depending on if the agent is an investor or debtor), gross labor income net of payroll tax $y - pec$, pension benefits pen, housing assets net of depreciation $(1-\delta_o)p_h h$ and bequests b from previous generations. Households who buy a house are restricted to a maximum loan-to-value ratio ξ, a minimum house size h_{min}, and face transaction costs $tr(h,h^+)$. The latter only apply to those who become either homeowners or renters. Renters must pay rent p_r per housing unit, where the rental price is linked to the return of financial assets via the arbitrage condition:

$$p_r = p_h(r + \delta_r),$$

which ensures that renters implicitly bear all maintenance cost of the house.

The above-defined optimization problems can be solved in three steps:

1. *Wealth exposure in housing:* Given a current state $\tilde{z} = (j, a^+, h, o^+, a_r, \theta, \eta)$, total savings a^+ must be slit between financial wealth and housing assets, which yields $\omega^+ = \omega(\tilde{z})$. In case of a future renter household, we simply set $\omega^+ = 0$.

   Households who want to become renters (i.e. $h^+ = 0$) must sell their house (if they are owners) and pay the resulting transaction costs. We can define:

$$Q(\tilde{z}) = \psi_{j+1} E\left[\, (V(z^+)|\eta)\,\right],$$

where we must ensure that:

$$a_l^+ = a^+ - tr(h, 0) \geq 0$$

and that the retirement asset accumulation a_r^+ follows national rules.

Households who wish to become (or remain) homeowners (i.e. $h^+ \geq h_{min}$) must split their total savings a^+ between future housing assets, ensuring that the minimum house requirement is fulfilled and that the transaction costs are again considered. The sub-optimization problem is now:

$$Q(\tilde{z}) = \max_{\underline{\omega}(a^+) \leq \omega^+ \leq 1} \psi_{j+1} E\left[\, (V(z^+)|\eta) \, \right]$$

subject to:

$$\begin{aligned} p_h h^+ &= \omega^+ a^+ \\ a_l^+ &= (1 - \omega^+) a^+ - tr(h, h^+) = a^+ - p_h h^+ - tr(h, h^+) \gtrless 0, \end{aligned}$$

and again the respective earnings point accumulation. Note that the restriction on $a_l^+ \geq -\xi p_h h^+$ automatically includes $a^+ \geq (1 - \xi) p_h h_{min} + tr(h, h_{min})$. The solution to this problem yields $\omega(\tilde{z})$.

2. *The consumption-savings decision:* Given a current state z and the optimal split between financial and housing assets $\omega(\tilde{z})$, we can solve the consumption savings decision to reach $c(z, o^+)$, $c_h(z, o^+)$ and $a^+(z, o^+)$.

   Knowing $\omega(\tilde{z})$, we can established the consumption-savings problem for *current* homeowners and renters separately. The former have already decided on their home investments in the previous period, and thus own a positive housing stock $h \geq h_{min}$, which they consume (i.e. $f(h) = h$). They maximize:

$$\begin{aligned} \widetilde{V}(z, o^+ = O) &= \max_{c, a^+} \frac{\left(c^\nu h^{1-\nu}\right)^{1-\frac{1}{\gamma}}}{1 - \frac{1}{\gamma}} + \beta Q(\tilde{z}) \\ \text{s.t. } a^+ &= (1 + r)(a_l + \zeta a_r) + y + b + pen + (1 - \delta_o) p_h h - pec - T - pc. \end{aligned}$$

   In case of a future owner, we must ensure that savings cover at least the down payment for the minimum house size plus transaction costs, i.e.,

$$a^+ \geq (1 - \xi) p_h h_{min} + tr(h, h_{min}),$$

   while in the case of a future renter, the savings must cover at least the transaction costs of selling the house, i.e. $a^+ \geq tr(h, 0)$.

   Current renters must decide on how to split their resources between ordinary consumption, housing consumption, and savings, and thus maximize:

$$\begin{aligned} \widetilde{V}(z, o^+ = R) &= \max_{c, c_h, a^+} \frac{\left(c^\nu c_h^{1-\nu}\right)^{1-\frac{1}{\gamma}}}{1 - \frac{1}{\gamma}} + \beta Q(\tilde{z}) \\ \text{s.t. } a^+ &= (1 + r)(a_l + \zeta a_r) + y + b + pen - pec - T - pc - p_r c_h = y_v - pc - p_r c_h. \end{aligned}$$

Again, for future owners, we must ensure that savings at least cover the down payment for the minimum house size plus transaction costs, i.e.,

$$a^+ \geq (1-\xi)p_h h_{min} + tr(0, h_{min}).$$

From the first-order condition, we get

$$p_r c_h = \frac{1-\nu}{\nu} pc.$$

After substituting into the budget constraint, optimal consumption is:

$$\begin{aligned} c_h &= (1-\nu)(y_v - a^+)/p_r \\ c &= (y_v - p_r c_h - a^+)/p. \end{aligned}$$

3. *The tenant decision:* Finally, given optimal consumption and savings for both tenure options $o^+ = O$ and $o^+ = R$, we can determine the respective value functions and select the optimal future home ownership $o^+(z)$. Therefore, the final value function is derived from:

$$V(z) = \max_{o^+} [\widetilde{V}(z, o^+ = O), \widetilde{V}(z, o^+ = R)].$$

Numerical implementation. Solving the household problem involves two steps: computing the value and policy functions and deriving a distribution of households over the state space that is consistent with the decisions made at each element of the state space z. In order to compute policy functions and the household distribution, we must discretize the state space, which has up to seven dimensions. Besides age and skill level (already specified above), we must choose proper values along the different asset dimensions a, a_l, a_r, and h, and discretize the transitory productivity component η. The transitory shock component is discretized into ten realizations $\hat{\eta}_g$ and a transition matrix π_{gg^+} using the Rouwenhorst method (Fehr and Kindermann 2018, p.344f). We chose discrete gridpoints $\hat{a}$ for aggregate and $\hat{a}_l$ for liquid wealth, which form a growing grid with identical bounds, and 30 realizations using the subroutine `grid_Cons_Grow`. Retirement assets $\hat{a}_r$ were similarly discretized on a grid that exhibiting growing distance between gridpoints. We used a total of 40 gridpoints to discretize this state. Finally, the housing gridpoints $\hat{h}$ were equidistant, starting with $\hat{h}_{min}$ and 20 realizations using the subroutine `grid_Cons_Equi`. The upper bounds of all grids were selected so that they would never become binding for individuals.

The subroutine `solve_household` was used to organize the calculation of policy functions starting at the last age $j = J$ and ending at $j = 1$. At each age j, it is divided into three distinct phases, which follow the three step structure of the solution algorithm already discussed above:

1. In the first step, given decisions (and value functions) in period $j+1$, total savings $\hat{a}^+$ and the tenure decision o^+, the subroutine `solve_omega` determines the optimal split $\omega^+(\tilde{z})$ of total savings $\hat{a}^+$ for future owners for each level of total savings, housing and retirement assets as well as productivity using the function minimization subroutine `fminsearch` (see Fehr and Kindermann 2018, p.63f). Using linear interpolation, this procedure yields the values of $Q(\tilde{z})$, at each grid point for future owners and renters separately.

2. In the second step, given the expected value functions of future owners and renters for each grid point of total assets $\hat{a}^+$, the consumption-savings decision is determined in the subroutine `solve_consumption`, again using subroutine `fminsearch` at each grid point of the state z. This procedure gives consumption and savings functions $c(z, o^+), c_h(z, o^+), a^+(z, o^+)$, and the value functions $\widetilde{V}(z, o^+)$. Again we use linear interpolation to compute the latter.

3. Finally, the tenure decision is determined by comparing the two value functions $\widetilde{V}(z, o^+)$ for future owners and renters, i.e. $V(z) = \max \widetilde{V}(z, o^+)$. Given the tenure decision, the final policy functions $c(z), c_h(z), a^+(z)$ are easily derived using optimal o^+.

This paper is accompanied with two codes – `GermUSHouse.f90` for German-US counterfactuals, and `GermAUSHouse.f90` for German-Australian counterfactuals, and corresponding modules (that define global variables, functions and subroutines) and readme files (that describe the simulation approach). The output files provided for benchmark and all counterfactuals generated by the two codes include detailed outputs, and the results as percentage or p.p. changes in the model's main variables under each counterfactual, relative to the benchmark model, reported in each column of the result tables in Sections 5 and 6.

Appendix C: Housing and renting in GDP data

Appendix C consists of three parts. Initially, we derive the GDP expression (which includes housing expenditures) from a simplified theoretical model of a closed economy. Then, we compute the values of these variables from 2018 StaBu data. It should be noted that Germany is an open economy where the (positive) trade balance is roughly 6 percent of GDP. Consequently, we need to adjust the statistical data and derive a consistent data set, which can be reconciled with the theoretical model. The adjusted data then provides the target ratios and parameter values, matched by the benchmark equilibrium of the numerical model.

Budget constraints and GDP accounting

The simplified version of the theoretical model consists of two overlapping cohorts, namely renters in the first period and homeowners in the second. We assume population growth with rate n so that $N_1 = (1+n)N_2$ and a rental rate p_r covers interest cost r and depreciation δ_r. Together with the two budget constraints, we therefore have:

$$p_r = p_h(r + \delta_r) \tag{28}$$

$$wL - T_w = pc_1 + p_r H^R + a + p_h h^O \tag{29}$$

$$(1+r)a - T_r + (1-\delta_o)p_h h^O = pc_2, \tag{30}$$

where $p = 1 + \tau^c$ is the consumer price of consumption goods, which includes consumption taxes. Aggregating the two budget constraints (29) and (30) and defining aggregate variables in per capita of the young cohort $A = a/(1+n), H^O = h^O/(1+n), C = c_1 + c_2/(1+n)$, we reach:

$$wL - T_w + (1+r)A - T_r + (1-\delta_o)p_h H^O = C + \tau^c C + p_r H^R + (1+n)(A + p_h H^O), \tag{31}$$

which is the resource constraint of the household sector. Note that consumption taxes are not levied on rental cost. Next, we substitute the capital market equilibrium condition $A = K + p_h H^R + B_G$ to yield:

$$wL - T_w + (1+r)(K + p_h H^R + B_G) - T_r + (1-\delta_o) p_h H^O = \\ C + \tau^c C + p_r H^R + (1+n)(K + p_h H^R + B_G + p_h H^O).$$

Substituting the budget constraint of the government $T_w + T_r + \tau^c C + \Pi_h = G + (r-n)B_G$, we get

$$wL + r(K + p_h H^R) = C + p_r H^R + G + n(K + H^R) + (\delta_o + n)H^O.$$

Finally, adding depreciation for capital on both sides and substituting the arbitrage conditions for capital stock $F_K = r + \delta_k$ and the rental price (28) yields:

$$wL + F_K K = C + G + \underbrace{CO(I^H) + (n + \delta_k)K}_{I^{br}}$$

where we also used the definition $\Pi_h = p_h I^H - CO(I^H)$, where $I^H = (n+\delta_r)H^R + (n+\delta_o)H^O$. In the national accounting data, the value added of the real estate sector $p_r H^R + (r + \delta_o) p_h H^O$ is added on both sides of this accounting equation. Consequently, the rental income and the imputed housing consumption of home owners are included in output and private consumption expenditures. In the numerical model, this value is subtracted on both sides so that output is defined as:

$$Y = wL + F_K K = C + G + I^{br}.$$

Therefore, the national accounting data must be re-scaled in order to make it compatible with the model.

StaBu data for Germany 2018

The data for asset values and capital stock is derived from StaBu (2019a). This data set has two advantages. First, all values are reported net of depreciation at current market prices, which gives the exact current value. Second, detailed wealth accounts are compiled not only for the whole economy, but also for four institutional sectors: non-financial corporations, financial corporations (banks), the government, and private households. Table 11 reports some original values from this data set, from which the values for privately-owned and rented housing are then derived.

In order to derive housing values, we split up developed real estate and added it to residential and commercial buildings. This split was computed according to the fractions of residential and commercial buildings in the respective sector, see (5a) and (5b) in Table 11. The adjusted values for housing are reported in the lower part of Table 11. The derived total property value for housing of EUR 8470 bn still needed to be split between rented residential buildings ($p_h H^R$) and owner occupied residential buildings ($p_h H^O$). Since many private individuals also rent out properties, the figure of the household sector includes a large fraction of rented property. One option is to use the fraction of commercially-rented to privately-rented homes (0.35 : 0.65) from Deutscher Bundestag (2017, p.41). Assuming that commercial rented homes are EUR 935 bn, this would lead to a total number of EUR 2,670 bn for rented homes and EUR 5,800 bn for owner occupied homes. Alternatively, one could also multiply the number of households with home ownership (roughly 18.2 million)[46], with the average values of owner occupied homes in 2017 of EUR 260,000, as reported in Deutsche Bundesbank

[46] Total number of households was 41.4 million in 2018 and homeownership fraction was 44 percent.

Table 11: Wealth values for Germany 2018 (in bn EUR)*

		Aggregate economy	Corporations & government	Household sector
(1)	Tangible assets	15897		
(2)	of which			
(3)	residential buildings	5460	725	4735
(4)	commercial buildings	3441	3084	357
(5)	developed real estate	4363	1352	3011
(5a)		3010	210	2800
(5b)		1353	1142	211
(6)	Net foreign assets	1895		
(1)+(6)	Total wealth	17792		
(7)=(3)+(5a)	Adj. residential buildings ($p_h(H^R + H^O)$)	8470	935	7535
	Rented housing property ($p_h H^R$)	2670	935	1735
	Owner occupied property ($p_h H^O$)	5800	–	5800
(1)-(7)	Capital stock (K)	7427		

*Source: Statistisches Bundesamt (2019a).

(2019a, p.27). This would give a number of roughly EUR 4,800 bn for $p_h H^O$. However, the estimates from this study appear to be very low. Indeed, average reported net wealth per household was EUR 232,000, see Deutsche Bundesbank (2019a, p.32). If we were to divide the total wealth from Table 11 by the number of households, we would arrive at EUR 420,000.

The numbers presented in Table 11 also yield consistent values when we assume a depreciation rate of 2.5 percent for owned property (δ_o), 3.5 percent for rented property (δ_r) and an imputed interest rate of roughly 3.5 percent. Regarding homeowners, we assumed that the imputed rental cost would only include the depreciation cost ($\delta_o p_h H^O$), which then amounts to EUR 145 bn. Rental income ($p_r H^R$) amounts to EUR 190 bn, which is exactly split in half between depreciation cost and imputed interest cost (i.e., both EUR 95 bn).

Using the average house values of owner occupied homes, which range between EUR 260,000 and EUR 318,500 and dividing this number by the average income of EUR 40,630, the house value to income ratio is roughly:

$$\frac{p_h h^O}{y} = 6.5 - 7.8.$$

Similarly, dividing aggregate rental income of EUR 190 bn by the number of renters (41.4 m - 18.2 m = 23.2 m), the average annual rant amounts to EUR 8,200. Dividing this number by the average income yields an average-rent-to-income ratio of:

$$\frac{p_r c_h}{y} = 0.205.$$

These figures are targeted in the benchmark equilibrium.

Note that Table 11 does not reveal the value of retirement assets held by German households. Indeed, Deutsche Bundesbank (2019a, p.40) revealed that approximately 43 percent of German households hold retirement assets in so-called Riester- or Rï¿½rup-plans.[47] The average savings in these plans amount to EUR 33,200, so that aggregate savings amount to roughly EUR 600 bn, i.e., less than 20 percent of GDP.

Table 12 reports the official national income and product accounting data for Germany in 2018. The GDP at market prices is computed in three different ways: the output measure, expenditure and distribution measures.

Table 12: National accounting in Germany 2018 (in EUR bn)*

Output measure		Expenditure measure			Distribution measure	
Gross value added	3012	Private consumption	1744	(1)	Labor cost	1771
real estate & rental	316	Government consumption	665	(2)	Capital income	732
Goods taxes ($\tau^c C$)	332	Gross investment	729	(3)=(1)+(2)	Aggregate income	2503
		resid. buildings	210	(4)	Production taxes	326
		Trade balance	206	(5)=(3)+(4)	NNI	2829
				(6)	Depreciation	609
				(7)=(5)+(6)	GNI	3438
				(8)	Net income ROW	-94
GDP	3344		3344	(9)=(7)+(8)		3344

*Source: Statistisches Bundesamt (2019b).

Note that the value added in the "real estate and rental" sectors are very close to the above rough estimate of EUR 335 bn. This sector includes all rental income (commercial and private) and some imputed value added of owner occupied housing (StaBu 2019b, p.28). Consequently, the previous back of the envelope calculation is quite accurate, and rescaling the above figures gives values of $\delta_o H^O$ =EUR 136 bn for imputed cost of homeowners and a rental income $p_h H^R$ = EUR 180 bn, which is again split up in half between depreciation and interest cost. Approximately EUR 210 bn of gross investment are residential buildings (StaBu 2019b, p.96).

It would be useful for later reference to derive the sectoral balances for the corporate sector, the government, the household sector (including business partnerships and the self employed), and the foreign sector, as shown in Table 13.

The corporate sector includes also insurance companies and banks, meaning that part of social security contribution and transfers are also included. Most of the figures in Table 13 were derived by aggregating the origin (Aufkommen) and the destination (Verwendung) of payments in every sector. Only labor cost (origin) and labor income (destination) are provided as disaggregated numbers. Note that government investment of roughly EUR 78 bn is already included in gross investment.[48]

In the following section, we adjust Table 13 in various directions in order to align the GDP figures with the model.

[47] These savings plans are tax favoured, but restrict withdrawal before a specific retirement age.

[48] The majority of government investment is spent on non-residential buildings and weapons.

Table 13: Transactions and sectoral balances in 2018 (in EUR bn)*

		Economy	Corporate	Government	Households	Foreign
(1)	Gross value added	3012	2050	330	632	-206
(2)	Depreciation	609	350	75	183	
(3)=(1)-(2)	Net value added	2403	1700	255	449	
(4)	Other sub.-tax	4	12	-	-8	
(5)	Labor cost	1770	1281	259	230	14
(6)=(3)+(4)-(5)	Net business surplus	637	431	-4	211	-220
(7)	Asset income	94	-252	-10	356	-94
(8)	Labor income	1771			1771	13
(9)	Prod. taxes-sub	326		326		2
(10)=(6)+(7)+(8)+(9)	Net national income	2829	179	311	2339	-299
(11)	Income taxes	10	-96	445	-339	-10
(12)	Ss contributions	1	134	572	-705	-1
(13)	Ss transfers	-7	-65	-520	578	7
(14)	Other transfers	-48	-23	-50	25	48
(15)=(10)-(14)	Available income	2785	128	759	1898	-256
(16)	Business pensions		-60		60	
(17)	Consumption	2409		665	1744	
(18)=(15)+(16)-(17)	Savings	376	68	93	214	-256
(19)	Asset transfers	-4	16	-28	8	4
(20)=(18)+(19)	Gross savings	372	84	65	222	-252
(21)	Gross investment	729	435	78	216	
(22)=(20)+(2)-(21)	Saldo	252	1	62	189	-252

*Source: Statistisches Bundesamt (2019b), pp. 40-43.

Adjusting the data to match the model

Starting from Table 13, the following adjustments need to be computed:

- The production sector aggregates corporations, business partnerships and the self-employed;
- The government sector does not produce output;
- Social security includes only pensions, no health and long-term care and no unemployment benefits;
- Government transfers (i.e. family benefits, social assistance, etc.) are neglected;
- Closed economy model, no foreign sector.

As before, Table 14 first derives net value added in the production sector. This value is split between labor income and net business surplus, which together with asset income from the government bonds, sum up to the aggregate income (Volkseinkommen) of households. Government interest cost are computed as follows. First, the debt level in 2018 amounts to EUR 2,060 bn (Deutsche Bundesbank 2019b, p.58). This would be roughly 60 percent of GDP at market prices from Table 12. Assuming that a slightly lower interest rate on public debt of 3 percent would yield roughly EUR 60 bn for rB, this figure seems too high given the figure in Table 13. In 2018, the official interest payments of the government amounted to roughly EUR 40 bn (Deutsche Bundesbank 2019, p.59). However, we also excluded income from abroad, meaning that EUR 60 bn appears to be a reasonable figure. In addition, the resulting aggregate income of EUR 2,463 bn is only slightly below the respective figure of EUR 2,503 bn in Table 11.

Table 14: Transactions and sectoral balances in the model (in EUR bn)*

		Production	Government	Households	reporting
(1)	Gross value added	3012			Employees:
(2)	Depreciation	609			40,631,000
(3)=(1)-(2)	Net value added	2403			Gross income:
(4)	Labor cost	-1765		1765	1460 bn
(6)=(3)-(4)	Net business surplus	-638		638	p.c.: 40,630
(7)	Asset income		-60	60	
(8)	Aggregate income	–	-60	2463	
(9)	Labor income tax		280	-280	10.4% of Y
(10)	Capital income tax		118	-118	4.4 % of Y
(11)	Pension contrib.			-300	11.2 % of Y
(12)	Pension benefits			300	
(13)	Available income		338	2065	
(14)	Consumption taxes		330	-330	12.2% of Y
(15)	Ordinary consumption		665	-1302	
(16)	Renting			-316	
(17)	Savings/Investment	-120	3	117	

Own calculations.

The right column of Table 14 reports the number of employees and the gross labor income (after employer social security contributions) from which the annual labor income per capita of EUR 40,630 can be derived. Labor income taxes amount to EUR 238 bn. (StaBu 2019b, p.51) plus taxes on pensions and other transfers which we estimate at EUR 42 bn. Capital income taxes include the corporate tax, (EUR 33 bn) the flat rate withholding tax (EUR 30 bn) and trade taxes (EUR 55 bn) (Deutsche Bundesbank, 2019, pp.60-61), so that we arrive at EUR 118 bn. Social security in the model only reflects the public pension system, which includes pensions paid to former employees and civil servants (and survivors benefits) and amount to EUR 378 bn in 2018 (StaBu 2019b, p.297). However, roughly 20 percent of benefits are not contribution related (e.g., those for child rearing, etc.) and need to be subtracted. The resulting available income of the household sector now also includes corporate available income from Table 13. The difference is only EUR 2,071 - 2,065 = 39 bn.

For the model, we needed the GVA net of the real estate sector, which gives a value of EUR 2,696 bn reported in the left part of Table 15. We used this figure to compute the asset to output values:

$$\frac{B_G}{Y} = 0.76 \qquad \frac{K}{Y} = 2.75 \qquad \frac{p_h H^O}{Y} = 2.15 \qquad \frac{p_h H^R}{Y} = 0.99 \qquad \frac{W}{Y} = 6.60$$

which, as reported above, sum up to net wealth. The output value needs to be computed with the expenditure and distribution calculation. Ordinary private consumption (at producer prices) has a value of EUR 1302 bn. Gross investment expenditures and government consumption are taken from Table 14. Net investment expenditures are derived from subtracting depreciation from gross investment. Depreciation costs are split between depreciation of rental homes (EUR 90 bn), owner occupied homes (EUR 136 bn), and the residual depreciation of capital stock (EUR 383 bn). Dividing the amount of net investment (i.e., EUR 120 bn) by the value of tangible assets gives a growth rate of 0.75 percent, which seems relatively realistic given that the TFP growth rate has to be reduced by negative population growth. Consequently, gross investment of capital amounts to EUR 383 + 56 = 439 bn, gross investment of rental property sums up to EUR 90 + 20 = 110 bn, and the gross investment of owner-occupied housing is the residual of EUR 180 bn, as shown in Table 15.

Table 15: Revised national accounts in Germany 2018 (in EUR bn)*

	Output measure		Expenditure measure		(in %)	Distribution measure	
(1)	Output	2696	Private consumption(C)	1302	48.4	Labor income (wL)	1766
(2)			Government consumption (G)	665	24.6	Capital income (rK)	547
(3)			Gross investment (I^{br})	729	27.0	Depreciation ($\delta_k K$)	383
(4)			in $(n + \delta_k)K$	439	16.3		
(5)			in $(n + \delta_r)p_h H^R$	110	4.0		
			in $(n + \delta_o)p_h H^O$	180	6.7		
GVA	Y	2696		2696	100.0		2696

*Own calculations.

Finally, the right part of Table 15 shows the values for primary incomes. Net business surplus needs to be adjusted for rental (EUR 90 bn) income, which gives EUR 547 bn. The right part of Table 15 allows for the capital share in the Cobb-Douglas function α and the depreciation rate δ_k to be computed as:

$$\alpha = \frac{F_K K}{Y} = 0.35 \qquad \text{and} \qquad \delta_k = \frac{\delta_k K}{K} = 0.052.$$

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Appendix D: Additional robustness checks

This appendix provides supplementary findings pertaining to tax and pension adjustments in the main text. Firstly, we present supplementary outcomes for the distributional impacts on homeownership and tax rates within the context of the capital and labor tax simulations in Section 5.1. Secondly, we delve into further simulations regarding means-tested benefits, which are connected to the third simulation discussed in Section 5.2. Finally, we consider alternative parametrization of the housing market within overall US and Australian policy designs, with the results comparable to Sections 5.3 and 5.4.

D.1 Additional results and simulations with respect to Table 5

Further to capital income taxation, it is interesting to highlight the differential effects of labor income taxes on housing. Accordingly, we kept the taxation of capital income as the German benchmark in Table 16, but set labour income as being taxed under the US schedule. In the first simulation, the schedule is adjusted by a factor of 2.25 to generate the benchmark labor income tax revenue, while the second simulation applies the US tax schedule from Figure 1. As in Section 5.1, we kept the German tax base, i.e., we abstracted from deductions of mortgage payments and kept the existing exemption and contribution ceiling.

The first simulation reported in Table 16 shows hardly any effect on aggregate variables and homeownership. With constant labor income tax revenues, the adjusted US tax schedule is only slightly more progressive than the previous German schedule. This explains the asymmetric net wealth accumulation of skill types.

More interesting is the second column, where the flat taxation of capital income is maintained as in the benchmark, but the less progressive US tax schedule is applied to labor income. In Table 5, the reform also included capital income and had a very modest effect on homeownership. In contrast, the increase in ownership reported in Table 16 is rather more significant and applies to all skill types. Younger households have more disposable income, which leads to a 6.5 percent increase in savings and net wealth and a 5.9 percentage point increase in the (average) homeownership rate. Without the dampening effect from lower capital taxation, the high-skilled react significantly stronger than low-skilled households due to reduced tax progressivity. Higher homeownership also increases the share of households with 0 or negative liquid assets, which explains the modest 0.4 percentage point reduction of the marginal tax rate on capital income.

D.2 Additional simulations for Table 6

We conducted additional simulations concerning the means-tested age pension, related to the fourth counterfactual pension scenario discussed in Table 6 of Section 5.2. Specifically, we examined the following scenarios with the age pension where we also: (a) removed the means test, and (b) means-tested housing. Moreover, we also substituted the benchmark public pension system by a compulsory funded pension, drawing on Australia's mandatory superannuation system.

It is useful to compare the effects of the first two scenarios in Table 17 with the last simulation in Table 6. The removal of the means test increased pension expenditure and, somewhat surprisingly, also net wealth (which increased by 20.3 percent compared to 19.3 percent in Table 6). The increase in net wealth is mostly driven by low- and middle-skilled households, who are no longer incentivized

Table 16: Macroeconomic and distributional effects of labor income taxes*

Variable	Labor income taxed with progressive adjusted US	US tax schedule T18[i]
Output (GDP)	-0.1	1.1
Consumption	-0.1	-0.9
Capital stock	-0.2	3.1
Net wealth	0.0	6.5
- low-skilled	1.0	3.0
- middle-skilled	0.7	4.5
- high-skilled	-1.5	10.9
Housing stock (Owner)	0.8	17.6
Housing stock (Renter)	-1.3	-2.9
Homeownership rate (p.p.)[a]	0.8	5.9
- low-skilled (p.p.)	0.6	3.7
- middle-skilled (p.p.)	0.9	6.3
- high-skilled (p.p.)	0.8	6.5
Interest rate p.a. (p.p.)	0.0	-0.2
Wage rate	0.1	1.1
Income tax revenue[b]	0.0	-39.1
Marginal capital tax rate (p.p)[c]	0.0	-0.4
Consumption tax rate (p.p.)[d]	0.1	11.4

*Percentage change relative to benchmark if not stated (p.p.) representing percentage point change; [i] In the first simulation, the US tax schedule is scaled up to neutralize labor tax revenue effects; [a] Share of homeowners in the population aged 30 years and over; [b] Tax base includes labor and capital income; [c] Cohort-weighted average over the life cycle, with marginal capital income tax rate set to zero for all those with zero or negative liquid assets; [d] Assumed to balance government budget.

to save less in order to escape the means test. High-skilled households save less either due to higher consumption tax burdens or higher pensions in old age. Higher savings also increase the homeownership rate (by 17.7 percentage points compared to 16.6 percentage points in Table 6). In particular, low-skilled households were found more likely to become homeowners due to higher savings.

Table 17: Macroeconomic and distributional effects of additional changes to pensions*

Variable	Consumption tax financed Means test eliminated	Consumption tax financed Housing means-tested	mandatory super annuation
Output (GDP)	6.7	8.2	18.1
Consumption	2.2	4.4	9.1
Capital stock	20.2	25.3	60.9
Net wealth	20.3	20.3	45.9
- low-skilled	11.0	6.5	40.2
- middle-skilled	18.2	16.7	45.0
- high-skilled	27.9	31.7	49.8
Housing stock (Owner)	40.7	27.5	70.2
Housing stock (Renter)	-7.4	6.0	-13.8
Homeownership rate (p.p.)[a]	17.7	12.9	31.4
- low-skilled (p.p.)	14.6	7.0	35.1
- middle-skilled (p.p.)	19.3	13.9	34.6
- high-skilled (p.p.)	17.2	15.2	23.6
Interest rate p.a. (p.p.)	-1.1	-1.3	-2.6
Wage rate	6.7	8.2	18.1
Income tax revenue	17.6	19.0	23.6
Pension expenditure	-40.8	-71.1	-100.0
Replacement rate - low-skilled (p.p.)	-16.8	-28.2	-55.9
Replacement rate - high-skilled (p.p.)	-34.4	-45.9	-55.9
Payroll tax rate (p.p.)[b]	-19.8	-19.8	-19.8
Consumption tax rate (p.p.)[c]	5.9	-2.3	-12.9

*Percentage change relative to benchmark if not stated (p.p.) representing percentage point change; [a] Share of homeowners in the population aged 30 years and over; [b] Assumed to balance PAYG pension budget; [c] Assumed to balance government budget.

In the next simulation, housing is included in the pension means test, which reduces the incentive for homeownership. Interestingly, the extension of the means test increases aggregate net wealth in a rather similar fashion to its elimination. However, compared to the last column in Table 6, the net wealth of low-skilled households in particular reduced, while that of the high-skilled increases significantly. The low- and middle-skilled are also mostly responsible for the lower homeownership rate, which increases only by 7 percentage points (compared to 12.6 percentage points in Table 6). Note that the removal of the housing exemption decreases pension expenditure, leading to a lower consumption tax rate. The latter mainly benefits the elderly and has only a minor effect on homeownership. If the removal of the housing means test exemption reduces income taxes, this would counteract the reduced incentive for homeownership, so that the policy would have only modest effects on homeownership (Cho and Sane, 2013).

In the last simulation of Table 17, we introduce the mandatory superannuation system, where households must contribute 8 percent of gross wages into the superannuation fund that is illiquid until age $j_R = 65$. At and after j_R, households are assumed to draw down a fraction of their superannuation asset balance (increasing to 100 percent at age 85). During the accumulation phase, contributions and fund investment earnings are taxed at concessional flat tax rates, while payouts are tax-free. It needs to be pointed out that the results in the last column of Table 17 can hardly be compared with the simulations of Table 6 since we completely eliminate unfunded pensions. This public pension privatization with mandatory contributions was found to boost the net wealth of households by 46 percent, homeownership by roughly 31 percentage points, and the physical capital stock by 61 percent. The latter induces an increase in wages by 18 percent and income taxes by 23.6 percent. The strong increase in income tax revenues is mainly due to the fact that far fewer contributions are deducted from the income tax base, despite their being taxed at a reduced rate. Moreover, higher wages increase income tax revenues despite the indexation of the progressive tax function. Higher income tax revenues allow for the consumption tax rate to be reduced by 12.9 percentage points. Note that superannuation assets are not annuitized. Consequently, forced savings induce a strong increase in bequest towards younger households, thus improving their financial means to purchase a property.

The disaggregation in Table 17 shows that the net wealth increase rises with skills, but homeownership increases less for the high-skilled. This difference can be explained by the following reasons: First, the higher savings of the high-skill households are preserved in the superannuation fund and cannot be used for real estate. In addition, since our model features no bequest motive, households have less incentive to hold real estate in old age when their superannuation assets become liquid. This is especially applicable to high-skilled individuals who are already homeowners in the benchmark.

D.3 Additional simulations with lower transaction cost and minimum house size

As emphasized by Kaas et al. (2021), Germany has fairly high transaction costs, especially when buying a house. In order to examine the importance of these parameters, we applied the transaction cost parameters from Sommer and Sullivan (2018), where the costs are set at $\mu_1 = 0.07$ (when selling) and $\mu_2 = 0.025$ (when buying) in the benchmark simulation.

The first column of Table 18 considers lower transaction cost in the US system, so that it should be compared with the third simulation of Table 7. It can be seen that the changes in transaction costs have very minor effects on the macroeconomy (e.g., output, consumption, etc.) and hardly any fiscal implications. However, there is a significant positive effect on the housing market. Due to the reduced costs of buying a house, the homeownership rate increases by over 7 percentage points (i.e. from an increase of 14.7 in Table 7 up to 22 percentage points) and the owner-occupied housing stock sees a greater rise of over 13 percent.[49] Note that in contrast to the simulation with the lower house size, lower transaction costs generate a similar increase in the homeownership of all skill types.

Finally, the two last simulations complement the Australian discussion by considering lower transaction costs and lower housing regulations within overall policy design. The results in the last two columns of Table 18 should be compared to the results in the last column of Table 8 (for the overall

[49] We also simulated an isolated decrease in the buying cost, which had highly similar effects.

Table 18: Macroeconomic and distributional effects of alternative housing market parameters*

Variable	US fiscal system[i]	Australian fiscal system[ii]	
	lower transaction costs	lower transaction costs	lower minimum house size
Output (GDP)	2.0	5.9	6.1
Consumption	-0.8	0.7	1.2
Capital stock	5.8	17.7	18.4
Net wealth	12.0	21.9	20.4
- low-skilled	9.8	14.8	13.7
- middle-skilled	11.4	20.9	19.6
- high-skilled	13.8	26.7	24.6
Housing stock (Owner)	45.3	50.5	45.2
Housing stock (Renter)	-31.3	-10.0	-12.2
Homeownership rate (p.p.)[a]	22.0	25.5	27.4
- low-skilled (p.p)	20.0	29.0	33.7
- middle-skilled (p.p.)	23.2	28.3	30.7
- high-skilled (p.p.)	21.2	18.6	17.7
Interest rate p.a. (p.p.)	-0.3	-1.0	-1.0
Wage rate	2.0	5.9	6.1
Income tax revenue	-18.5	18.1	18.2
Pension expenditure	-29.3	-64.0	-63.8
Payroll tax rate (p.p.)[b]	-6.5	-19.8	-19.8
Consumption tax rate (p.p.)[c]	5.0	0.9	0.9

*Percentage change relative to benchmark if not stated (p.p.) representing percentage point change; [i] Overall US policy with lower transaction costs; [ii] Overall Australian policy with either lower transaction costs or minimum house size; [a] Share of homeowners in the population aged 30+ (%); [b] Assumed to balance PAYG pension budget; [c] Assumed to balance government budget.

Australian policy design). As in the US, the impact on macroeconomic variables is modest. While both housing market changes increase aggregate homeownership significantly, skill-specific homeownership is impacted in a very different way. While lower transaction costs have highly similar impacts for all skill classes, lower housing regulations mainly affect low- and middle-skilled households, but impact the high-skilled to a far lesser extent.