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Abstract

This paper studies the role of pensions and income taxes in determining homeownership and household wealth. It provides a cross-country analysis, using tax and pension policy designs in Germany, the US and Australia. These developed nations have similar incomes per capita but very different homeownership rates, with the US and Australia having much higher homeownership compared to Germany. The question is to what extent the observed differences in homeownership are induced by national tax and transfer policies. To that end, we develop a stochastic, overlapping generations (OLG) model with tenure choice. The model is calibrated to Germany featuring German statutory public pension and dual income tax systems, and then applied to study the effects of alternative income tax and pension policy structures. Our simulation results indicate that the US and Australian policy designs have a dramatic impact on homeownership, explaining more than half of the observed differentials. We also show significant macroeconomic effects due to differences in tax and pension policies.

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

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1 Introduction

Germany, the US and Australia all have ageing societies and are at a comparable stage of economic development but have key differences in their comparative wealth levels and homeownership rates. As shown below, GDP and actual consumption per capita in 2018 were almost the same in Germany and Australia and somewhat higher in the US.[1] However, Germans are older on average and save more than Americans and Australians. One would therefore expect that Americans (and Australians) hold less wealth than Germans. On the contrary, average net wealth in the US and Australia is roughly twice as high as in Germany. The accumulated asset structures also differ significantly across these countries. While in Germany only about 44 percent of households own their place of residence, owner occupied dwellings are the largest asset held by American and Australian households, with over two thirds of households living in their own home. Germans also hold relatively low savings in retirement accounts, while in the US and Australia, private pension entitlements are among the most important financial assets.

The above observations indicate that these gaps in wealth levels and homeownership patterns must be at least partly due to differences in public policies. Comparing the tax structures reveals that the dual income tax in Germany implies proportional and low taxation of capital income, while in the US and Australia, capital income is taxed under their progressive income tax schedules. However, in the US and Australia, old-age savings are taxed at significantly lower rates. Importantly, Germany operates a pay-as-you-go financed public pension system, which absorbs almost 12 percent of GDP, whilst in comparison the US pay-as-you-go pension system is less costly and more redistributive (within cohort) than the German pension system. Australia combines tax-financed and means-tested old-age provisions with a pre-funded, privately administered retirement system financed by mandatory contributions. Interestingly, means-tested assets (that determine public old-age pension benefits) do not include owner-occupied real estate, which provides a clear incentive for homeownership in old-age.

This paper examines the effects of alternative pension and income tax policies on homeownership, household wealth and the economy, employing the pension and tax policy designs in Germany, the US and Australia. Since pension wealth (funded or otherwise) and residential real estate are the most important assets carried through to retirement, our major research objective is to analyze how they interact with each other and the tax system. For this reason, we quantify the extent to which the observed differences in homeownership and wealth are induced by national policies. We also decompose these effects, quantifying the role of key tax and pension policy features in the three countries, such as the progressive income taxation in the US or the mandatory funded retirement system in Australia.

In order to undertake this quantitative analysis, we develop a stochastic general equilibrium model with overlapping generations (OLG) where households have tenure choice and face uncertain labor income and survival. The model is based on stochastic OLG models with tenure choice recently employed by Chambers et al. (2009), Sommer and Sullivan (2018) and Kaas et al. (2021). Our model distinguishes between three sources of household wealth – housing, liquid financial and (illiquid) pension assets. Importantly, it features detailed representations of the income tax and pension policy designs in the considered countries. The initial benchmark equilibrium of the model is calibrated to Germany, applying the German statutory public pension and dual income tax systems. Then, the US

[1] A more detailed discussion of the key economic indicators in the three developed economies is provided in the next section, which also cites relevant data sources.

and the Australian tax and pension structures are implemented to study their economy-wide effects.

Our simulation results indicate that the US and Australian tax and pension designs have a dramatic impact on homeownership, explaining more than half of the observed homeownership rate differentials. The higher homeownership rate under the US policy is driven by their (compared to Germany) less generous and more progressive public pension system (as well as lower labor income and progressive capital income taxes). In Australia, means-tested age pensions (which exempt the principal residence from tested resources) induce higher homeownership, while superannuation (Australia's term for its private funded retirement system) has an insignificant impact on homeownership. The latter, however, contributes to larger household assets and, hence, significantly increases self-funding in retirement. The differences in tax and pension policies in the examined countries are also shown to have significant macroeconomic and fiscal implications.

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) presents a deterministic economy with overlapping generations and tenure choice, and quantifies the distortion of household savings due to non-taxation of housing capital returns and the presence of mortgage interest rate deductibility from the income tax base. Besides the detailed tax system, Gervais' model considers rental market frictions such as minimum house sizes and down-payment constraints as well as the rental agency with an arbitrage condition for the equilibrium rental price. Eliminating the preferential tax treatment of homeownership in this set-up induces substantial long run welfare gains but has surprisingly small distributional implications. Chambers et al. (2009a, b) extend this approach by including uninsurable mortality, labor earnings and house price risk as well as transaction costs that come with the purchase of the property. While Chambers et al. (2009a) model a progressive income tax, which amplifies the distributional implications of the asymmetric tax treatment of housing, Chambers et al. (2009b) also model a financial sector to examine the role of mortgage innovations. The recent study by Ma and Zubairy (2021) shows that binding debt-to-income constraints may explain the observed fall in homeownership rates in the US, especially among younger cohorts, during the period 2005-2015.

Floetotto et al. (2016) extend the analysis of the US government intervention in the housing market to consider the full transitional path between steady states, but their model only considers proportional taxation of labor and capital income. Sommer and Sullivan (2018), using a model that captures in great detail the US progressive income tax system, provide a similar quantitative analysis, focussing on the implications on house prices, rents, homeownership and welfare in the long run and over the transition path. The recent US study by Karlman et al. (2021) also includes a full transition path and combines a progressive labor income tax with detailed modelling of mortgage financing. They show that the long run gains from removing the mortgage interest deduction are mostly due to welfare losses of transitional cohorts. Of course, tax distortions between housing and ordinary assets could also be reduced by lowering taxation of ordinary capital income. Nakajima (2020) shows that the optimal tax on capital income reduces to (almost) zero in a two-asset model with tenure choice calibrated to the US, while it is above 30 percent in the model without housing, as also shown by Conesa et al. (2009). Rotberg (2021) applies an US calibrated model with housing, in order to analyze the macroeconomic and distributional consequences of wealth taxation. He shows that progressive wealth taxation, exempting housing, results in large welfare gains. In contrast to the US, the housing market in Germany is characterized by high transaction costs, a social housing sector and no mortgage interest rate deductions. Kaas et al. (2021) show that these policies generate the low homeownership rate in Germany. Cho et al. (2021) examine the economy-wide effects of removing tax concessions to landloards (or housing investors) in Australia, finding positive (but modest) impacts on homeownership.

With the exceptions of Karlman et al. (2021) and Rotberg (2021), the studies discussed above that aim to quantify the implications of the asymmetric tax treatment of owner-occupied housing hardly pay any attention to the implications of housing for household wealth accumulation, its composition and distribution. Already Silos (2007) has shown that the inclusion of tenure choice improves substantially the replication of empirical wealth data. Similarly, Cho (2012) explains a large fraction of the difference in wealth accumulation and homeownership between Korea and the US, as being due to differences in mortgage markets and rental arrangements. We aim at a similar cross-country comparison, but focus on the differences in income tax and pension designs.

The relationship between the social security system and the housing market has been established by Chen (2010). The paper eliminates social security in a model with tenure choice and shows that such reform has a stronger impact on wealth accumulation in a model with explicit housing choices than in the standard life-cycle economy. Cho and Sane (2013) analyze the exemption of owner-occupied housing in the Australian means-tested age pension system. As it turns out, including housing in the means test would reduce the housing capital to output ratio, but would only marginally lower the homeownership rate due to offsetting interest rate effects. Our contribution is that we account for the detailed modelling of progressive income taxation and mandated pensions, including both public and privately funded pension systems.

Finally, our study is also connected to a large body of literature that examines social security and pension reforms in developed countries using OLG models with very detailed pension systems. For instance, the recent papers include Kitao (2014) and Hosseini and Shourideh (2019) for the US, Fehr et al. (2013) for Germany and Kudrna and Woodland (2018) and Kudrna et al. (2019) for Australia. These papers provide both transitional and long run economic implications of various pension reforms but abstract from the modelling of housing and tenure choice. In our paper, we focus on the long run steady state implications, but our model captures important interactions between pension policy and tenure choice.

The rest of the paper is structured as follows. The next section provides further details on the cross-country economic data comparison and discusses the differences in income tax and pension designs in Germany, the US and Australia. Section 3 develops the quantitative model that captures the interaction between asset accumulation, tenure choice and the public sector. Section 4 explains the calibration of our initial steady state economy and presents the comparison of the benchmark model solution with the German data. Section 5 provides the quantitative analysis of alternative income tax and pension policy settings, drawing on the US and Australian applications. Section 6 then reports some sensitivity analysis. The final section offers some concluding remarks.[2]

2 Taxes and pensions in Germany, the US and Australia

In this section, we model and discussed the public sector in Germany, the US and Australia, focusing on income tax and pensions policies. These policies are then incorporated into the model structure

[2] The paper is also accompanied with several appendices that provide further details on the progressive income tax schedule and pension parameters in the examined countries, the household problem of our OLG model with housing and its calibration to macroeconomic data.

and examined in the following sections of the paper.

Before we describe the policy rules in Germany, the US and Australia, it is useful to compare some central economic indicators and aggregates. Table 1 shows that GDP and consumption per capita are very close in Germany and Australia and both figures are only modestly higher in the US. However, despite the relatively high (10-year average) saving rate of 13.2 percent, household net wealth (reported per adult) and the (average) homeownership rate are much lower in Germany than in the US and Australia.

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]	44.0	64.0	66.2
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]	6.9	140.7	134.4
Dependency ratio (65+/20-64) (%)[e]	35.8	26.8	26.5
Payroll tax (contribution) rate (%)[d,g]	18.6	12.4	9.5
Income tax revenue (% of GDP)[f]	12.6	11.0	17.3

Source: [a] OECD(2021a); [b] OECD (2021b); [c] Credit Suisse (2019); [d] OECD (2019); [e] United Nations (2019); [f] OECD (2020); [g] In Australia, this is the current mandatory superannuation contribution rate.

In the US, financial wealth dominates non-financial wealth and, at least partly, this is due to pension wealth in the form of funded private pension assets. The latter is hardly existent in Germany, while such assets are very significant in the US and Australia. Public pensions are important in Germany, since it has the oldest population among the three considered economies. In 2018, the German old-age dependency ratio (measured as the number of individuals aged 65 years and older per 100 people between aged 20 and 64 years) was at 35.8, while the same figures were at 26.8 and 26.5 in the US and Australia, respectively (United Nations, 2019). The payroll tax rate to finance pensions was 18.6 percent in Germany – much higher than in the US. Australia does not have such payroll tax, but instead we report here the mandatory contribution rate of the Australian superannuation system, which was 9.5 percent of gross wages in 2018. Finally, income tax revenues are highest in Australia and much lower in Germany and the US. However, as we will see below, marginal tax rates are similar in Germany and Australia, but much lower in the US.

In the following, we will describe in detail the differences in income tax and (publicly stipulated) pension systems, which are applied in the simulation model discussed in Section 3. While Germany and the US run a pay-as-you-go financed statutory pension system, Australia provides tax-financed, means-tested old age benefits supplemented by a funded private pension system with mandatory contributions.

2.1 Income taxation

2.1.1 German dual income tax system

Germany operates an effective dual income tax system, so that total income tax revenues are derived from a progressive tax on labor and pension income and a proportional tax on capital income. The annual taxable income $\tilde{y}$ subjected to the progressive tax code is computed from

$$\tilde{y} = y - \tau^p \min[y; 2\bar{y}] + pen - all, \quad (1)$$

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

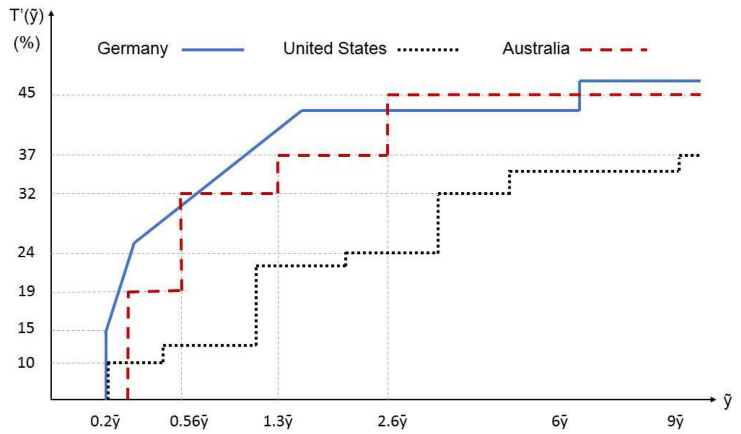
In order to compute individual income tax payments T, we apply the progressive tax code of 2018 $T18(\cdot)$ and add the proportional tax on interest income at rate τ^r from (liquid) financial assets a_l (which can be negative due to mortgages). The German tax system does not allow for mortgage interest deduction, i.e.

$$T = T18(\tilde{y}) + \tau^r r \max(a_l; 0), \quad (2)$$

where r is the interest rate on the capital market.

The marginal tax rate schedule in Germany is shown in Figure 1.[3] Given taxable income $\tilde{y}$, there is a personal exemption which amounts to roughly 20 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 about $0.27\bar{y}$), there is a steep increase of the marginal tax rate to 25.4 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 44.2 percent, which increases to the top marginal tax rate of 47.5 percent for very high incomes of more than $6\bar{y}$.

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



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

2.1.2 US income tax system

We follow Chambers et al. (2009) and Sommer and Sullivan (2018) by imposing the US progressive income tax schedule on the total taxable income. The total taxable income $\tilde{y}$ is the sum of labor earnings (net of payroll tax on earnings up to 2.47 times average labor earnings $\bar{y}$), interest income on financial assets and pension benefits:

$$\tilde{y} = y - \tau^p \min[y; 2.47\bar{y}] + ra_l + pen. \tag{3}$$

Note that in the US, net 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.

The total taxable income $\tilde{y}$ is subject to the 2018 US progressive income tax schedule, which features 7 brackets. The US marginal tax rates are lower than in Germany or Australia, as shown in Figure 1. Starting with a marginal tax rate of 10 percent after a basic exemption of about 23 percent of average income, the top marginal tax rate of 37 percent is applied to taxable income over $9.5\bar{y}$. The total income tax is then

$$T = T18(\tilde{y}). \tag{4}$$

2.1.3 The Australian income tax system

As in the US, labor and capital income are aggregated in Australia and taxed under the progressive income tax schedule. However, mandatory superannuation contributions are taxed differently. Consequently, taxable income $\tilde{y}$ now includes labor earnings, net of mandatory contributions to private pension funds at rate τ^p, returns on positive (non-pension) assets and the age pension *pen* described below, i.e.[4]

$$\tilde{y} = (1 - \tau^p)y + r\max(a_l; 0) + pen. \tag{5}$$

Figure 1 also shows the marginal tax rates derived from the Australian personal tax schedule $T18(\cdot)$. The schedule contains five tax brackets, including tax-free income (with the threshold of about 30 percent of average income) and top marginal tax rate at 45 percent, which is applied to annual income above roughly $2.6\bar{y}$. Note that for lower taxable incomes, the Australian marginal tax schedule is almost always between the German and the US schedule. In contrast to Germany, taxable income $\tilde{y}$ also includes interest income from liquid assets, but mortgage debt is not deductable, as it is in the US.

In addition, Australian households also pay reduced taxes τ^{sa} on contributions to their retirement (superannuation) funds $\tau^p y$. For simplicity, these payments are included in the individual tax burden (while they are in practice paid by employers), so that

$$T = T18(\tilde{y}) + \tau^{sa}\tau^p y. \tag{6}$$

[4] For simplicity, we follow Kudrna and Woodland (2018) and Chambers et al. (2009) and neglect specific tax offsets for seniors in Australia and the U.S.

2.2 Pensions

2.2.1 German statutory pension system

The statutory pension insurance in Germany covers more than 90 percent of the population.[5] It is pay-as-you-go financed, so that contributions are directly used to finance benefits of pensioners. The payroll tax rate is levied on labor income up to the contribution ceiling. The resulting contributions are used to update the retirement assets (or so-called earning points) a_r, which reflect the relative income level of the household in the working population, i.e.[6]

$$a_r^+ = a_r + \min\left[\frac{y}{\bar{y}}; 2\right]. \tag{7}$$

After 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 shows the benefit amount for each individual earning point.[7] For simplicity we define the pension value as a fraction κ of average income $\bar{y}$, so that

$$pen = a_r \times \kappa \times \bar{y}. \qquad \forall j \geq j_R \tag{8}$$

Note that the German pension system is intra-generationally fair, i.e., there is very little redistribution within the cohort, but it redistributes across cohorts when the implicit rate of return (i.e., the growth rate of labor income) differs from the capital market return.

2.2.2 US social security pension system

As in Germany, the US social security program is pay-as-you-go financed, with the contributions of working households funding the pension benefits of the current retirees. It is a defined benefit system, which is much more redistributive than the German pension system.

The US social security benefit is determined as a concave piecewise linear function of the average indexed monthly earnings (AIME). According to the legislation, the average of the 35 highest annual earnings over the individual's working career is used in calculating the AIME, which we capture through the state variable a_r. 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:

$$a_r^+ = a_r + \min[y; 2.47\bar{y}]/(j_R - 1), \tag{9}$$

with the contribution ceiling set to 2.47 times the average earnings in the economy. In addition, we also apply their indexing formula for the income thresholds (or the bend points) to compute the

5 Civil servants who receive tax-financed benefits are included here. Only self-employed are not mandatory insured and may pay voluntary contributions or build up own funds for retirement.

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

7 In practice, there is also an entry factor (set to 1.0 at the normal retirement age), which increases and decreases based on the actual retirement age.

pension benefit[8]

$$pen = \begin{cases} 0.9 \times a_r & \text{if} \quad a_r \leq 0.2\bar{y} \\ 0.18\bar{y} + 0.33 \times (a_r - 0.2\bar{y}) & \text{if} \quad 0.2\bar{y} < a_r \leq 1.24\bar{y} \\ 0.5243\bar{y} + 0.15 \times (a_r - 1.24\bar{y}) & \text{if} \quad a_r > 1.24\bar{y} \end{cases} \quad \forall j \geq j_R \tag{10}$$

Consequently, the marginal replacement rate is 90 percent for an AIME below 20 percent of average (annual) income and decreases to 15 percent for an AIME above 124 percent of average annual income.

2.2.3 Australian pension system

We model the main features of the two publicly stipulated pillars of Australia's retirement income policy. The first is a public "safety net" pillar that is represented by a means-tested Age Pension financed through general tax revenues. The second pillar is a privately managed superannuation system.

Age Pension The expenditure side of the Australian public budget also features Age Pension benefits, which represent the main income source for most retired Australians. Hence, the Age Pension is non-contributory with no dedicated payroll tax or social security contribution financing it. The Age Pension benefit *pen* is needs-based and has always been means-tested.[9] Eligibility is based on age, but not on work history and past earnings. Benefits are linked to average earnings and the tenant status, with the maximal benefit $\bar{p}(h)$ set at 28 percent of average earnings. In addition, renters may be eligible for rent assistance which is added to the maximum rate of homeowners. 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.

$$pen = \max\left[\bar{p}(h) - \max(in, as); 0\right]. \qquad \forall j \geq j_R \tag{11}$$

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 principal residence of an owner is excluded. The asset disregard $\bar{a}(h)$ distinguishes between homeowners and renters, where in 2018 homeowners had a threshold at less than five times average earnings, while renters had a threshold of less than eight

8 In 2018, the US national wage index was 52,145 USD (p.a.) and maximum taxable earnings were 128,400 USD (p.a.). The two bend points for the marginal replacement rates of monthly earnings were 895 USD and 5,397 USD.

9 The details and the figures for the Age Pension rules provided in this sub-section are based on OECD (2019) and Chomik et al. (2018a).

times average earnings. Beyond the disregard, the maximal annual pension is currently reduced at the rate of 7.8 cents for every extra dollar of assessable assets, i.e.

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

The final pension benefit paid to an eligible household is then determined by the test that results in a lower pension amount. In 2018, about 70 percent of the age-eligible population received some Age Pension, with the remaining 30 percent being fully self-funded. Out of the age pensioners over 60 percent received the maximum benefit (full pension) and the rest received a smaller benefit (part pension). Overall government expenditures on public pensions (including the Age Pension) stood at roughly 4.3 percent of GDP in 2018, see OECD (2019b).

Superannuation Australia's superannuation with assets under management around 150 percent of GDP (fifth largest private pension assets in the world and expected to more than triple by 2040) relies predominantly on compulsory superannuation contributions.[10] The Superannuation Guarantee (SG) 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 by 2024. Mandatory superannuation is an employment-related, privately managed scheme that covers almost 95 percent of employees.[11]

Superannuation contributions accumulate in the superannuation accounts that are owned by members and managed by private superannuation funds. These accounts are preserved in the funds until they are withdrawn. The earliest age at which benefits can be withdrawn is 57 years but increasing for cohorts born in and after 1962 up to age 60. The superannuation benefits can be accessed as both lump-sums and income streams. Whereas in the past (10 years ago) lump-sums represented the dominant option, currently around 65 percent of superannuation assets are draw down gradually as pension phased withdrawals.

Australia taxes its superannuation system under a comprehensive income tax regime, which sees contributions and fund earnings taxed (at concessional flat rates), but benefits are generally tax-exempt. Taxes on mandatory contributions are paid in our model by employees (see (6)), so that superannuation retirement assets a_r accumulate as

$$a_r^+ = (1 - \zeta)(1 + r(1 - \tau^r))a_r + \tau^p y, \tag{12}$$

where ζ denotes the (age-specific) drawdown fraction from the superannuation fund after retirement and τ^r only applies during the employment phase (when ζ is zero). As already discussed above, superannuation assets a_r are subject to the Age Pension means testing, when individuals reach the Age Pension eligibility age. Since superannuation savings decrease during the retirement phase, Age Pension benefits increase steadily. Note that in Germany and the US, pay-as-you-go financed pensions are flat during the retirement phase. While unfunded pensions cannot be left to heirs, superannuation wealth can be bequeathed.

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[10] The details and the figures for the superannuation rules provided in this subsection are drawn from Chomik et al. (2018b). Further details can be obtained from that study.

[11] Employees as well as self-employed can also make voluntary superannuation contributions into their superannuation accounts. In this paper, we focus on the publicly stipulated (mandatory) superannuation system and, hence, abstract from voluntary contributions.

3 The model

In this section, we develop 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 and a government sector, where we have already discussed the details of the national tax and pension policies in the previous section. We start by describing the demographic structure and the distributional measure of households on the state space. We then provide an algebraic description of each of the sectors 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 constant population growth rate n and lifespan uncertainty that 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 following periods they can be homeowners or renters, depending 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 start to live from their savings and pension benefits.

Since optimal savings depend on the tenure decision, we have to distinguish 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.[12] 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 $j \in \mathcal{J} = \{1, \ldots, J\}$. During working periods $j < j_R$ households receive labor productivity shocks $\eta \in \mathcal{E}$ and accumulate retirement assets, which determine the pension benefits after retirement. Total savings of the household $a^+ \in \mathcal{A}$ depend on the future tenure state defined by $o^+ \in \mathcal{T} = [O, R]$. We therefore define the individual state

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

which reflects the situation *after* the tenure decision.

Consequently, the initial distributional measure of households at age $j = 1$ depends on the initial distribution skills and productivity shocks. Let $X(z)$ be the corresponding cumulated measure to $\phi(z)$. Since we normalized the cohort size of newborns to be unity,

$$\int_{\mathcal{S} \times \mathcal{E}} \mathrm{d}X(z) = 1 \qquad \text{with} \quad z = (1, 0, 0, 0, \theta, \bar{\eta}) \tag{13}$$

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

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

3.2 Household sector

Agents have preferences over streams of non-housing consumption c and housing consumption $f(h)$.[13] Households maximize the expected discounted lifetime utility function

$$\max E\left[\sum_{j=1}^{J}\beta^{j-1}\left(\prod_{i=1}^{j}\psi_i\right)\frac{(c_j^{\nu}[f(h_j)]^{1-\nu})^{1-\frac{1}{\gamma}}}{1-\frac{1}{\gamma}}\right] \qquad \text{with} \quad f(h)=\begin{cases} h & \text{if } h \geq h_{\text{min}} \\ c_h & \text{otherwise} \end{cases}, \tag{14}$$

where β defines a subjective discount factor, ν the share parameter for ordinary consumption and γ the intertemporal elasticity of substitution. If the household is a homeowner, housing consumption is the value of the house, if the household is a renter, housing consumption c_h is bought at the rental market.

Agents start working at age $j = 1$ and, conditional on surviving, retire at age j_R. In every working period, an agent receives an endowment of productive efficiency units that is inelastically supplied to the labor market at the wage rate w. Efficiency is skill-specific and a function of a deterministic age-profile e and a transitory component η. The latter evolves stochastically over time and is assumed to have an autoregressive structure of degree 1, i.e.

$$\eta^+ = \rho\eta + \epsilon \qquad \text{with} \quad \epsilon \sim N(0, \sigma_\epsilon^2), \tag{15}$$

where ρ is the persistence parameter and ϵ is the innovation of the process. Following Fehr et al. (2013), the autoregressive correlation term ρ as well as the variance of the innovation term σ_ϵ^2 are assumed to be skill-specific. The household's gross labor income y is then given as

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

At the mandatory retirement age j_R, labor income falls to zero and households start to receive pension benefits pen and may (in Australia) withdraw from their private pension account $\zeta(1+r)a_r$. The household's wealth includes as well bequest b and real-estate. In order to finance public expenditures they pay consumption, payroll and income taxes $T(\cdot)$, so that total savings are given by

$$a^+ = (1+r)(a_l + \zeta a_r) + y + b + (1-\delta_o)h + pen - pec - T(\cdot) - pc - p_h c_h, \tag{16}$$

where τ^c is the consumption tax rate, pec are contributions to the pension system, while $p = 1 + \tau^c$ and p_h define prices for ordinary and rental housing consumption, respectively.

Households who want to buy a house have to split up their total (non-superannuation) assets a^+ into the selected house size 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.

$$a^+ = a_l^+ + h^+ + tr(h, h^+) \quad \text{with} \quad a_l^+ \geq -\xi h^+, \tag{17}$$

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.[14] Transaction costs only

[13] In this subsection, we will omit the state index z for every variable whenever possible.

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

apply to homeowners when the either buy or sell their house, i.e.

$$tr(h, h^+) = \begin{cases} \varphi_1 h + \varphi_2 h^+ & \text{if either} \quad h = 0 \quad \text{or} \quad h^+ = 0 \\ 0 & \text{otherwise.} \end{cases}$$

In order to select a specific house size, households choose a share ω^+ of total assets, i.e., $h^+ = \omega^+ a^+$. Given the current house size h, financial assets and transaction cost can be then derived from the above equation (17).

Therefore, agents maximize (14) in order to decide how much to consume and save and whether to rent or become homeowners, taking into account the constraints (16) and (17) as well as the labor productivity process (15). The decision process is explained in more detail in Appendix B.

3.3 Rental agency

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

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

where δ_r denotes the depreciation rate for rental properties. Under the perfect competition a zero profit condition has to hold for the rental agency, i.e., the price p_h of rental properties for households has to equal the marginal cost of the rental agency. The rent is then determined through the following no-arbitrage condition:

$$p_h = r + \delta_r. \tag{18}$$

3.4 Production sector

The production sector is populated by a large number of perfectly competitive, profit-maximizing firms. These firms 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:

$$Y = \varrho K^\alpha L^{1-\alpha}, \tag{19}$$

where α denotes the capital share in production and ϱ is the productivity constant (calibrated so that the market wage rate w is normalized to one). Capital is rented from households at the riskless rate and depreciates at the depreciation rate δ_k. Factor prices are determined competitively by marginal productivity conditions:

$$w = \varrho (1 - \alpha) \left(\frac{K}{L} \right)^\alpha \tag{20}$$

$$r = \varrho \left[\alpha \left(\frac{L}{K} \right)^{1-\alpha} - \delta_k \right]. \tag{21}$$

3.5 Government sector

As already explained in the previous section, we distinguish a tax financed government budget and a budget for the pension system in all three countries. The revenue side of the government budget aggregates revenues from income taxes T_{inc}, consumption taxes $\tau^c C$ and (only in Australia) taxes on return of superannuation funds T_{sa}. Consequently, we neglect corporation taxes and various housing taxes and subsidies. Public expenditures consist of public goods G and interest on public debt rB_G and (only in Australia) means-tested age-pensions P_A.

In per capita terms of the youngest cohort the public budget therefore is given by

$$T_{inc} + T_{sa} + \tau^c C = G + (r - n)B_G + P_A, \tag{22}$$

where n denotes the (population) growth rate of the economy and income tax revenues, taxes from the superannuation fund as well as aggregate pension benefits are defined by[15]

$$\begin{aligned} T_{inc} &= \int_{\mathcal{Z}} T(y(z), a_l(z), h(z), pen(z))\mathrm{d}X(z), \\ T_{sa} &= \tau^r r \int_{\mathcal{Z}} a_r(z)\mathrm{d}X(z), \\ P_A &= \int_{\mathcal{Z}} pen(z)\mathrm{d}X(z). \end{aligned}$$

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 (22).

The budget constraint of the German and US public pension systems balances aggregate benefits P_A by endogenous payroll taxes τ^p levied on the contribution base CB, i.e.

$$\tau^p CB = P_A \qquad \text{with} \qquad CB = \int_{\mathcal{Z}} \min[y(z); y_{\max}]\mathrm{d}X(z), \tag{23}$$

where $y_{\max} = 2\bar{y}$ in the German case and $y_{\max} = 2.47\bar{y}$ in the US case.

Finally, the budget constraint of the Australian superannuation system is derived by aggregating on both sides of the accumulation equation (12) to give

$$\tau^p wL + (r - n)A_R = P_S + T_{sa} \tag{24}$$

where mandatory contributions plus net returns from retirement assets A_R have to finance aggregate pay-outs P_S (after retirement) plus taxes on fund returns (before retirement). Aggregate pay-outs and retirement assets are defined by

$$P_S = (1 + r)\int_{\mathcal{Z}} \zeta(z)a_r(z)\mathrm{d}X(z) \qquad \text{and} \qquad A_R = \int_{\mathcal{Z}} a_r(z)\mathrm{d}X(z).$$

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 $\phi(z), \tilde{\phi}(\tilde{z})$, relative prices of labor and capital w, r such that the following conditions are satisfied:

[15] Note that superannuation returns in Australia are only taxed up to the retirement age.

1. given fiscal policy, factor prices and bequests, households' decision rules solve the households decision problem (14) subject to the constraints (15),(16), (17), (7) and, if applicable (12);
2. factor prices are competitive, i.e. (20), (21);
3. the aggregation holds,

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

and the aggregate capital K is derived from the capital market equilibrium

$$K + B_G + H_R = AL + A_R; \tag{25}$$

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

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

and

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

5. unintended bequest satisfy[16]

$$\int_{\mathcal{Z}} b(z^+)\mathrm{d}X(z^+) = \int_{\mathcal{Z}} (1-\psi_{j+1})\left[(1+r)(a_l^+(z)+a_r^+) + (1-\delta_o)h^+(z)\right]\mathrm{d}X(z);$$

6. the government budgets (22) as well as the budget of the pension systems (23) and (24) are balanced intertemporally;
7. the goods market clears[17]

$$Y = C + (n+\delta_k)K + (n+\delta_o)H_O + (n+\delta_r)H_R + G + TR.$$

4 Calibration and initial equilibrium

The benchmark economy of our stochastic OLG model is calibrated to Germany, utilising demographic and macroeconomic data in 2018, see Appendix C. This section provides the details for the parametrization of this benchmark and compares the resulting equilibrium solution with the German targets.

16 Retirement assets a_r^+ are only inheritable in case of Australian (funded) superannuation assets.

17 In Section 5, several simulations also assume 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.

4.1 Parametrization of benchmark model

We now report and discuss the parameters of the benchmark model, with the key model parameters for demographics, household preferences, labor productivity, production technology, housing market and fiscal policy presented in Table 2.

Demographics. The model's time period is 5 years. Agents start 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,..,95-99) of agents. 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 then 80.8 and 19.2 years, which almost exactly match the respective life expectancies in StaBu (2019). Next, we calibrate the population growth rate to approximate the existing old-age dependency ratio (defined here as age 65+ to ages 20-64) of 36 percent. The model distinguishes three skill levels (i.e. $S = 3$) which are based on the International Standard Classification of Education (ISCED) of the UNESCO.

Household preferences. We assume non-separable Cobb-Douglas preferences, which is standard in the related literature. The preference parameters are selected in order to match the homeownership rates and household asset allocations in the data. The intertemporal elasticity of substitution is set to $\gamma = 0.5$ that is also a typically assumed value in the literature. The non-housing consumption share is set to $\nu = 0.7$, which is close to Kaas et al (2021) and 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 and production technology. Labor productivity of each skill type consists of a deterministic, age-specific part and a transitory component, which follows an AR(1) process. The estimates for respective parameter values are taken from Fehr et al. (2013). The technology level ($\varrho = 1.65$) of the Cobb-Douglas production function is such that the wage rate is unity in the benchmark model. To compute the business capital share of output in the data which corresponds to that in the model, the service flow from housing capital has to be subtracted from total output. This gives a value of $\alpha = 0.35$, see 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) or Chambers et al. (2009) we distinguish between a higher depreciation rate of rental houses $\delta_r = 0.035$ p.a. and a lower depreciation rate of owner-occupied housing $\delta_o = 0.025$ p.a. The maximum loan-to-value ratio is set to 70 percent during the entire working life (i.e., $\xi = 0.7$). Typically, the literature assumes a downpayment ratio of 20 percent, but in Germany financial restrictions are tighter, see Voigtländer (2016). We set the transaction cost when selling the house to $\phi_1 = 0.03$ and when buying the house to $\phi_2 = 0.1$. These values include cost for the land transfer tax, notary fees and land registry, which are high in Germany, see Voigtländer (2016) and may also include the cost for brokers. The assumed costs are therefore higher than typically assumed in the literature but close to Kaas et al. (2021). Finally, the minimum house size h_{min} is calibrated for the model to match the German average homeownership rate. This number is

Table 2: 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^2_ϵ	Transitory variance		Fehr et al. (2013)
	Production sector		
α	Capital share	0.35	Appendix C
δ_k	Capital depreciation rate (annual)	0.05	Appendix C
ϱ	Production constant	1.47	$w = 1.0$
	Housing market		
	Depreciation rate (annual)		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	Voigtländer (2016)
	Transaction cost		Voigtländer (2016)
ϕ_1	... of selling price	0.03	Kaas et al. (2021)
ϕ_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	0.15	Appendix C
κ	Pension accrual rate (annual)	0.012	Appendix C

[a] To target age dependency ratio of 35.8%; [b] To target K/Y; [c] To target homeownership ratio of 44%.

significantly higher than the values typically applied in the literature, but it reflects tighter housing regulations in Germany.

Fiscal policy. With respect to the German government sector, we specify exogenously the ratios of public consumption and public debt to output. The respective values are derived in Appendix C. The nominal withholding tax on interest income in Germany is 25 percent and the statutory corporate tax rate is 15 percent. However, corporations also have to pay trade taxes and a surcharge. On the other hand, we abstract from various allowances for interest and corporate income. The chosen tax rate of 15 percent replicates the tax revenue on capital income, derived in Appendix C. Similarly, the chosen pension accrual rate κ implies a realistic replacement rate of 55 percent for the standard pensioner, with the model closely matching the payroll tax rate and public pension expenditure in Germany.

4.2 Benchmark solution and data comparison

The numerical solution of the model follows the Gauss-Seidel procedure of Auerbach and Kotlikoff (1987) for macro variables, while the numerical solution of household decisions is described in Fehr and Kindermann (2018). For our initial (or benchmark) steady state which reflects the current German fiscal system, we start with a guess for aggregate variables, bequests distribution and exogenous policy parameters. Then, we compute the factor prices and the individual decision rules and value functions. The latter involves the discretization of the state space. Next, we obtain the distribution of households and aggregate assets and consumption as well as the social security tax rate and the consumption tax rate that balance pension and government budgets. This information allows us to update the initial guesses. The procedure is repeated until the initial guesses and the resulting values for capital, labor, bequests and endogenous taxes have sufficiently converged.

The benchmark solution and observed data for the components of aggregate demand, household wealth, and government tax revenues and pension expenditures are reported in Table 3.[18]

As shown in Table 3, the model replicates the German national accounts data fairly well, with the German national account data adjusted for our model structure (assuming a closed economy) and output measured at production prices net of the real estate sector, see Appendix C.[19] On the housing market, we choose a minimum house size h_{min}, in order to match the observed average homeownership ratio of 44 percent and the relative house values and rent payments. Note that despite the transaction cost, households in our model buy houses for two reasons. First, the mark-up on the rental price through higher depreciation provides an incentive to be a homeowner, since it reduces the maintenance cost. Second, since the imputed rent income of homeowners is not taxed, capital income taxation discriminates the returns from other assets.[20]

In the government budget constraint, we target the progressive labor income and flat-rate capital

[18] These figures are obtained by aggregating cohort and skill weighted household life-cycle solutions for consumption, labor income, household wealth and homeownership, which can be requested from the authors. Importantly, the homeownership rate profile is hump-shaped (as shown by others, e.g. Nakijama 2020; Fehr and Hoffmann 2020) and much higher for high skill types (see e.g. Sommer et al. 2013; Sommer and Sullivan 2018).

[19] Note that in Table 1, GDP is measured per capita and net wealth is measured per adult. The absolute wealth figures in Credit Suisse (2019) (which are not reported) fit quite well to the wealth calculations in Appendix C.

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

Table 3: 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	6.6	6.7
in rental housing	3.8	4.0
Housing transactions	0.4	–
Capital and housing markets		
Capital stock	286.9	275.0
Net wealth	680.0	666.0
Owner occupied housing stock	219.3	215.0
Rental housing stock	97.8	99.0
Homeownership rate (%)	44.0	44.0
House value to income ratio	6.9	6.5
Rent to net income ratio (%)	23.7	27.2
Interest rate p.a. (%)	6.6	–
Government policy		
Labor income tax revenue	10.4	10.4
Capital income tax revenue	4.6	4.4
Consumption tax revenue	13.2	12.2
Consumption tax rate (%)	25.9	–
Pension benefits	11.5	11.2
Payroll tax rate (%)	19.8	–

* As a percentage of GDP, if not stated otherwise.
[a] Own calculations derived in Appendix C.

income taxation revenues, with the consumption taxation and specifically the consumption tax rate being derived so that the government budget is balanced.[21] Note that the derived consumption tax rate of 25.9 percent includes value-added taxes and excise taxes while the tax revenues are very realistic. Similarly, pension benefits add up benefits of workers in the statutory pension system and of civil servant who are financed directly by the government. The payroll tax (contribution) rate of the statutory pension system in 2018 reported in Table 1 was 18.6 percent. The higher number reported in Table 3 is nevertheless justified, since benefits of civil servants are on average higher than benefits of workers.

This benchmark model calibrated to Germany (with similar per capita income and consumption but very different tax and pension system and household wealth levels and patterns when compared to Australia and US) is then applied to examine the economy-wide impacts of replacing the German

[21] Capital income tax revenues also include corporate capital income taxes. For that reason, the total income tax revenue is higher than in Table 1.

policy with policy designs in Australia and the US. The results are discussed in the following section on the quantitative analysis (of alternative tax and pension policy designs).

5 Quantitative analysis

This section is split into three parts. First, we concentrate on Germany and simulate sequentially the privatization of public pensions and the elimination of capital income taxation. This analysis gives an idea how the German public system affects asset accumulation and homeownership. In the second part, we start from the equilibrium without public pensions and capital income taxes, and implement sequentially the US income tax and pension systems. In the third part, we introduce in three steps the Australian tax and pension system, again starting from the situation without public pensions and capital income taxation. This procedure is required, in order to isolate the impacts of progressive income taxation and the different pillars of the pension system. Note that we do not adjust other parameters of the model, so that our simulations do not intend to replicate the current economic situation in the US or in Australia. We also keep public consumption and public debt at their initial levels. Our experiments therefore quantify the effects, if Germany would implement the US and Australian fiscal rules. Nevertheless, as discussed above, per capita income and consumption are similar across all three examined advanced economies.

In this paper, we focus on the long run effects of income tax and pension policy alternatives on homeownership, wealth and macroeconomic and fiscal aggregates such as GDP and consumption per capita and pension expenditure.[22]

5.1 Eliminating German pensions and capital income taxes

In this subsection, we eliminate public pensions and capital income taxes in Germany and quantify the long run consequences. Table 4 presents the results of our simulation exercises.

Eliminating public pensions. Although the first policy simulation has been studied extensively in OLG models (e.g., Nishyiama and Smetters, 2007), these studies typically do not consider tenure choice and housing. An exception is Chen (2010) who analyzed the same issue in a model with housing calibrated to the US economy. However, there are some differences which need to be addressed. First, Chen (2010) models a flat pension benefit, neglects the US contribution limit and reduces the replacement rate to generate a payroll tax rate of only 10.7 percent. In addition, Chen (2010) does not consider a minimum house size, so that only the downpayment constraint and housing transaction costs restrict homeownership. Finally (and most importantly), the public sector is only represented by social security, i.e., Chen (2010) completely neglects repercussions by the tax system.

Despite these differences, the economic mechanisms at work are still very similar, as shown in the first column in Table 4, which considers the small open economy (SOE) case with the constant factor prices. The elimination of pension contributions (payroll taxes) increases households' disposable income. Since the households now have to prepare for their own retirement, they accumulate more assets, which are invested in housing and abroad. Higher savings allow especially poorer households

[22] The distributional household behavioral (life cycle) effects can be provided from the authors upon request.

Table 4: Macroeconomic effects of German pensions and capital income taxes*

Variable	Pension privatization[a] SOE[c]	CE[d]	+ no capital income tax[b]
Output (GDP)	0.0	15.0	18.5
Private consumption	51.0	7.5	9.4
Capital stock	0.0	49.2	62.7
Net wealth	83.0	33.5	43.8
Owner occupied housing stock	60.9	65.3	57.1
Rental housing stock	-19.8	-21.7	7.3
Homeownership rate (%)	67.3	73.0	64.3
Interest rate p.a. (p.p.)	0.0	-2.3	-2.7
Wage rate	0.0	15.0	19.0
Income tax revenue (% of GDP)	21.3	15.6	12.5
Consumption tax rate[e] (%)	8.9	14.9	19.6

* Percentage change relative to benchmark, if not stated otherwise; [a] Here $\tau^p = 0$.
[b] Here $\tau^p = \tau^r = 0$.; [c] SOE: Small open economy; [d] CE: Closed economy;
[e] Assumed to balance government budget.

to overcome the downpayment and minimum house size constraints. Consequently, the (average) share of homeowners increases considerably to 67.3 percent, as does the owner-occupied housing stock. On the other hand, the rental housing stock decreases by almost 20 percent. Since also foreign assets increase (not shown), net wealth rises by about 80 percent in the long run. Average incomes remain constant, because foreign investments induce an inflow of interest income from abroad, which finances huge net imports, so that domestic consumption rises by more than 50 percent without any change in output. The increase in savings also leads to a dramatic increase in capital income tax revenues (which almost double) and higher labor income taxes (due to the elimination of deferred taxation of pensions). As a consequence, the consumption tax rate can be reduced by 17 percentage points (p.p.) to 8.9 percent.

When the same reform is implemented in the closed economy, higher savings are invested in domestic capital stock, inducing an increase in output and wages by 15 percent, while the interest rate falls by 2.2 percentage points. As a consequence, net wealth accumulation is dampened (relative to the SOE simulation with the constant interest rate) and the price of housing consumption falls relative to ordinary consumption, which in turn further increases homeownership and the respective housing stock. On the government side, higher wages increase the revenues from the progressive labor income taxation, while the lower interest rate reduces the capital income tax revenue. As a result, income tax revenues to GDP increase only slightly and the endogenous consumption tax rate now falls by 11 percentage points to 14.9 percent.

Eliminating both pensions and capital income taxation. Next, we also eliminate the capital income tax (assuming a closed economy), with both the payroll tax and the capital income tax set to zero under this simulation. The results in the last column of Table 4 indicate that output, private consumption, capital stock, net wealth and wages increase significantly compared to the previous simulation. On the other hand, the homeownership rate falls back to 64.3 percent, while the increase is the owner-occupied housing stock is also smaller than in the previous simulation. However, the reduced fraction of homeowners increases the rental housing stock by more than 7 percent. Note that the shift in the tenure choice is due to the fact that without capital income taxation, the preferential tax treatment of owner-occupied housing (where the imputed returns on investment are not taxed at all) has disappeared.

5.2 Implementing US income taxation and pensions

In this subsection, we discuss the macroeconomic effects of replacing sequentially the income tax and pension policies in Germany with those applied in the US. Starting from a situation without public pension and capital income taxes (i.e. the right column of Table 4), we first substitute the German progressive tax schedule of labor income by the US tax schedule. In the second step, capital income is added to the tax base so that the German income tax system is completely replaced by the US income tax system. Finally, the US fiscal system is completed by adding the US pension system. The macroeconomic effects of the three policy simulations are reported in Table 5.

Table 5: Macroeconomic effects of implementing US policy*

Variable	Sequential introduction of Labor income tax[a]	 + capital income tax[b]	 + public pensions[c]
Output (GDP)	19.8	13.9	2.2
Private consumption	8.0	4.9	-0.4
Capital stock	67.7	45.0	6.3
Net wealth	49.3	33.7	6.4
Owner occupied housing stock	80.3	80.1	27.6
Rental housing stock	-1.0	-25,3	-12.5
Homeownership rate (%)	71.5	76.7	55.4
Interest rate p.a. (p.p.)	-3.9	-2.1	-0.4
Wage rate	20.0	14.0	2.0
Income tax revenue (% of GDP)	8.2	11.5	12.5
Consumption tax rate (%)[d]	28.6	24.6	29.9
Payroll tax rate (%)[d]	0.0	0.0	13.3

* Percentage change relative to benchmark, if not stated otherwise; [a] Here $\tau^p = \tau^r = 0$;
[b] US income tax with $pen = \tau^p = 0$; [c] US policy; [d] Assumed to balance government and pension budgets.

US labor income taxation. The first simulation in Table 5 abstracts from a public pension system and capital income taxes, and implements the US progressive tax schedule for labor income. We can directly compare the first column of Table 5 with the last column of previous Table 4. Due to lower marginal tax rates (as shown in Figure 1), the income tax revenue is much lower now and the consumption tax rate has to increase by almost 3 percentage points to 28.6 percent to balance the budget (instead of being reduced by 6.3 p.p. to 19.9 percent in Table 4). Since households hold more disposable income, net wealth accumulation is now much stronger, increasing the capital stock and wages, and reducing the interest rate further than before. The lower interest rate tilts the portfolio structure towards housing. Therefore, the homeownership rate now increases to 71.5 percent (compared to 64.3 percent before) and the owner-occupied housing stock rises by 80.3 percent (instead of 57.1 percent before).

US income taxes. The next column also incorporates capital income (net of mortgage cost) into the income tax base. The income tax revenue, therefore, increases compared to the previous simulation and the consumption tax is reduced by 4 p.p. to 24.6 percent. The higher taxation of capital income clearly dampens the accumulation of net wealth, but also induces a further shift from rental housing towards homeownership. Consequently, the rental housing stock decreases now much stronger than in the previous simulation and the capital stock dynamics is also dampened significantly. Note that the owner-occupied housing stock almost remains unaffected by the capital income tax, since reduced aggregate wealth and the shift in the portfolio composition towards housing neutralize each other. US income taxes increase the homeownership rate to more than 76 percent (which is higher than 73 percent under the German income tax system with no social security reported in Table 4).

US public pensions and overall policy. Finally, we also introduce the US public pension system, with the results for this overall US policy (including its income taxation) provided in the last column of Table 5. Since payroll taxes reduce disposable income, net wealth accumulation is dampened, so that the capital stock and owner occupied housing stock fall compared to the previous simulation. Note that the ratio of the income tax revenue to GDP increases (because of lower GDP), but the income tax revenue falls due to the deferral of the tax base into the retirement phase.

The main objective of this paper is to compare the overall tax and pension systems in the considered countries. Compared to the German benchmark in Table 3, the average homeownership rate increases by over 11 percentage points to 55.2 percent under the US policy, as shown in the last column of Table 5. This increased homeownership is due to both lower income tax and payroll tax burdens. In our model setup, they both are still higher than the current US (income and payroll tax) rates, since we capture neither the lower level of public goods nor the lower old-age dependency ratio in the US. Nevertheless, we capture a significant part of the difference between the US and German homeownership rates.

5.3 Implementing Australian income taxes and pensions

We now introduce the Australian income tax and pension policy sequentially, starting with the Australian income tax system, then incorporating the non-contributory and means-tested Age Pension and finally adding the mandatory superannuation system. As before, we also neglect corporate taxes and assume the consumption tax rate to balance the government budget under all Australian policy reform simulations.

In order to implement the Australian tax and pension systems, we need to specify values of the policy parameters described in Section 2. As discussed, the progressive personal income tax schedule in 2017-18 is used (see the Australian tax marginal tax rates in Figure 1 and the Australian tax schedule provided in Appendix A). The parameters for the Australian public and private pension systems are also reported and discussed in Appendix A. The long run macroeconomic implications are presented in Table 6. For the economic interpretation, it is useful to compare with the last column of Table 4.

Table 6: Macroeconomic effects of implementing Australian policy*

	Sequential introduction of			
	income tax system	+ Age Pension	+ Super-annuation[a]	
Variable	CE[b]	CE[b]	CE[b]	SOE[c]
Output (GDP)	6.3	-2.9	5.8	0.0
Private consumption	2.4	-5.0	0.7	17.2
Capital stock	19.1	-8.2	17.5	0.0
Net wealth	12.9	-3.9	16.7	38.9
Owner occupied housing stock	51.0	28.4	32.9	41.0
Rental housing stock	-38.0	-30.5	9.0	3.5
Homeownership rate (%)	72.0	61.5	60.6	63.9
Interest rate p.a. (p.p.)	-1.0	0.5	-1.0	0.0
Wage rate	6.0	-3.0	6.0	0.0
Income tax revenue (% of GDP)	21.4	24.7	17.1	19.3
Consumption tax rate (%)[d]	8.5	19.2	26,6	21.0
Self funded retirees (%)	–	26.2	32.4	41.1
Retirees on full pension (%)	–	38.7	72.4	55.6

* Percentage changes relative to benchmark if not stated otherwise; [a] Australian policy with income tax, Age Pension and mandatory superannuation; [b] CE: Closed economy; [c] SOE: Small open economy; [d] Assumed to balance the government budget.

Australian income tax system. Since this simulation of implementing the Australian income tax system assumes no pensions, it is useful to compare the results with the corresponding results in the second column of Table 4 for the German income tax system with no public pensions. As already explained, capital (or interest) income in Australia is aggregated with labor income and public pensions and taxed progressively under the personal income tax schedule (shown in Figure 1). Therefore, the first column of Table 6 reports a much higher tax revenue from income taxes and a much lower consumption tax rate compared to Table 4. Of course, this dampens the capital accumulation so that output, capital stock, net wealth and wages are much lower than in the second simulation of Table 4. At the same time, the increased taxation of capital income distorts the tenure choice and induces a shift towards homeownership so that now 72 percent of households own their property. The owner occupied housing stock falls slightly, so that average house values decrease.

Means-tested Age Pension. When the Age Pension is introduced, output, private consumption, capital stock, net wealth and wages as well as homeownership fall relative to the previous scenario with no public pension (comparing columns 2 and 1 of Table 6). This is not surprising given the (opposite) results for privatising social security, discussed above. Regarding the Age Pension, there are two opposing effects on homeownership. On the one side, the fall in savings reduces homeownership.

On the other side, the exclusion of housing assets from the pension means test increases it. Overall, the first effect dominates and the owner occupied housing stock as well as the homeownership rate fall by roughly 10 percentage points.

Importantly, when compared to the benchmark scenario (with pay-as-you-go public pensions), the homeownership rate under (the Australian income tax and) the Age Pension scenario is significantly higher at 61.5 percent and the owner occupied housing stock increases by almost 30 percent. This is because the Age Pension is: (i) non-contributory (there is no payroll tax financing the pension expenditure that instead is included in the government budget and financed by the consumption tax rate, allowing more working age households to own their homes), and (ii) means tested with a more modest maximum pension benefit (implying a partial privatisation of social security and its support for homeownership). In addition, the homeownership rate is supported by the full exemption of owner-occupied housing from the pension means test. We will investigate these features of the Australian pension system in further detail in the sensitivity analysis section.

Superannuation and overall Australian policy. The consequences of implementing the superannuation (private pension) system and the overall Australian policy are reported in the two right columns of Table 6, under both the closed economy and small open economy market structures.[23] In a model without any capital market frictions, forced savings would have no effect. However, in our model with housing expenditures, especially younger households are liquidity constrained and, therefore, the introduction of the superannuation guarantee fund increases savings and output significantly. Consequently, (gross investment and) capital and housing stocks increase compared to the previous simulation, while the homeownership rate decreases slightly in the closed economy. The higher capital stock increases wages, but progressive income tax revenues fall, since contributions to the fund are now taxed at lower rates. Note that due to forced savings, Age Pension expenditures decrease significantly, with the fraction of pensioners that do not qualify for Age Pensions goes up to 32 percent, from 26 percent in the previous simulation.

In the small open economy (with constant factor prices), the forced savings are (mainly) invested abroad so that the capital stock remains constant. Due to the higher interest rate (kept at the German benchmark interest rate), owner occupied housing becomes more attractive than in the closed economy. As a consequence, the owner occupied housing stock and the homeownership rate increases, while the rental housing stock decreases. The higher interest rate also explains the rise in net wealth, the higher fraction of retirees without an Age Pension and the shift from consumption towards income taxation compared to the previous simulation.

The generated long-run equilibrium values of the superannuation system are larger than in real data from Australia, since the system there is still maturing. For example, in our model the superannuation funds amount to over 300 percent of GDP, while in reality this figure is currently around 150 percent (Chomik et al., 2018b).[24] However, our other figures are close relative to Australian data. Expenditures on Age Pensions are now about 4.1 percent of GDP (under the closed economy simulation), compared to 4.3 percent reported in OECD (2019). We also closely match the Age Pension participation rate (68 percent), the proportions of those receiving full pension (65.8 percent) and part

[23] Following Kudrna and Woodland (2013) and Kudrna et al. (2019), we also include the small open economy simulation for the Australian policy.

[24] A detailed analysis of the Australian Age Pension and the transition path for the superannuation system can be found in Kudrna and Woodland (2011, 2018).

pension (34.2 percent). The homeownership rate is hardly affected by the compulsory superannuation system, and that is despite the reduction in disposable income due to the mandatory contributions. Interestingly, the proportion of homeowners with the mortgage roughly doubles compared to the German benchmark (not shown), increasing from 13.1 to 28.6 and 23.1 percent in the closed and small open economy, respectively. In addition, the rental housing stock rises significantly compared to the previous simulation. The reason is that renters in retirement spend their superannuation payouts for bigger rented houses instead of becoming homeowners and paying high transaction costs. As a consequence, the share of rent payments in available income increases from 23.7 to 26 percent (not shown).

Comparing the overall Australian policy with the German benchmark reveals that the average homeownership rate increases by 16.6 p.p. to 60.6 percent in the closed economy and by almost 20 p.p. to 63.9 percent in the small open economy case. Hence, the model explains more than two thirds of the observed difference between the Australian and German homeownership rates. Interestingly, when comparing the results for the closed and small open economy cases in Table 6, it seems that higher net wealth in Australia is always associated with a rising homeownership rate (which is not necessarily the case in Germany, as shown in Table 4). This must be due to the specific incentive structure of the Australian Age Pension system, which is further explored in the sensitivity analysis section.[25]

6 Sensitivity analysis: What drives homeownership?

This section provides some sensitivity analysis with respect to some modifications of US tax, pension and housing parameters as well as the Australian Age Pension and other housing parameters. In summary, the results confirm that income tax and particularly pension policy designs have significant impacts on homeownership, household wealth and the economy.

6.1 US policy and housing market

We now carry out the sensitivity analysis of several modifications of the main US policy simulation (with both the US income tax and pension systems). The following modifications are examined: (i) removal of the mortgage interest deduction from the income tax base; (ii) reducing public consumption expenditures; and (iii) alternative values for housing transaction costs. The macroeconomic results for these sensitivity scenarios are presented in Table 7 as percentage changes relative to the German benchmark equilibrium, but the discussion of the results is centred around the comparison with the main US policy results in the last column of Table 5.

Abolishing mortgage interest deduction. When we remove the current net mortgage payments from the income tax base in the first column of Table 7 the changes compared to the last column in Table

[25] Note that for all the German, US and Australian policy alternatives studied in this section, we have also calculated the distributional welfare effects in the long run, which we do not report in the paper but they can be obtained upon request. Importantly, these welfare effects (for German future born households if either the US or Australian tax and pension policy alternatives were implemented) are qualitatively the same as the long run welfare effects from related studies. For example, the long run welfare effects are positive due to lower capital income taxation (as in e.g. Nakajima 2020), due to less generous social security (as in e.g. Auerbach and Kotlikoff (1987); Chen 2010) and due to the introduction of (or increasing contributions to) private pensions (e.g. İmrohoroğlu et al. (1998); Kudrna and Woodland, 2013).

Table 7: Macroeconomic effects of alternative US parameters*

Variable	No mortgage interest tax deduction	Public consumption adjustment	US housing transaction costs
Output	2.5	2.2	2.0
Private consumption	0.1	23.1	-0.6
Capital stock	7.4	6.4	5.8
Net wealth	9.8	9.9	11.2
Owner occupied housing stock	23.5	27.7	39.1
Rental housing stock	-6.3	-12.5	-25.9
Homeownership rate (%)	53.7	55.4	62.5
Interest rate p.a. (p.p.)	-0.4	-0.4	-0.3
Wage rate	3.0	2.0	2.0
Income tax revenue (% of GDP)	12.5	12.5	12.4
Consumption tax rate[a] (%)	29.4	5.0	30.2
Payroll tax rate[a] (%)	13.3	13.3	13.3

* Percentage changes relative to benchmark, if not stated otherwise;

[a] Assumed to balance government and pension budgets.

5 are rather modest. Income tax revenues relative to GDP hardly change and the consumption tax rate only decreases by 0.5 percentage points. Of course, in our model only about 20 percent of homeowners hold a mortgage in the US case, while a realistic US share is much higher, see Sommer et al. (2013) or Sommer and Sullivan (2018). The average homeownership rate declines (but only slightly) to 53.7 percent and the owner occupied housing stock decreases relative to the baseline US policy scenario. Note that Sommer and Sullivan (2018) even found higher homeownership as a result of that counter-factual policy using an OLG model with endogenous house price.

Public consumption adjustment. Since the German public sector is much bigger than the US one, the German consumption tax revenue is much higher than in the US. In order to generate a realistic US consumption tax rate, we therefore reduce public consumption spending to about 10 percent of GDP in the second column of Table 7.[26] When comparing the results in Tables 7 and 5, the macroeconomic effects of this alteration are shown to be small, except for the increase in private consumption that substitutes public consumption.

US housing transaction costs. As also emphasized by Kaas et al. (2021), Germany features fairly high transaction cost especially when buying a house. In order to check the importance of these parameters, we apply next the transaction cost parameters from Sommer and Sullivan (2018), where the costs are set at $\phi_1 = 0.07$ (when selling the house) and to $\phi_2 = 0.025$ (when buying the house). As shown in the last column of Table 7, the transaction cost have positive and significant effect on the housing market. Because of the reduced costs of buying the house, the homeownership rate increases

[26] A similar ratio has been applied by Chambers et al. (2009), Sommer and Sullivan (2018) and Hosseini and Shourideh (2019).

to 62.5 percent and the owner-occupied housing stock is up by over 39 percent (compared to the 28 percent increase in the last column of Table 5. [27] However, the effects on the economy (e.g., output, household net wealth) and the fiscal implications are hardly affected by the changes in transaction cost.

6.2 Australian policy and housing market

Next we examine the sensitivity of our results with respect to the institutional setting of the Australian Age Pension and other housing parameters. With respect to the former, we simulate two alternative scenarios: (i) including (owner-occupied) housing wealth in the means test and (ii) abolishing means testing completely. With respect to the latter, we now focus on (iii) lower minimum house size, but also briefly discuss other housing parameters. The results for key macroeconomic variables are reported in Table 8.

Table 8: Macroeconomic effects alternative Australian parameters*

Variable	Real estate included in means test	Complete means test removal	Lower minimum house size
Output	7.0	5.3	6.3
Private consumption	2.8	1.8	1.5
Capital stock	21.3	15.8	19.1
Net wealth	18.4	14.1	20.3
Owner occupied housing stock	20.0	14.4	41.9
Rental housing stock	19.6	18.6	-9.6
Homeownership rate (%)	56.5	55.2	68.9
Interest rate p.a. (p.p.)	-1.1	-0.9	-1.0
Wage rate	7.0	5.0	2.0
Income tax revenue (% of GDP)	17.0	15.1	17.0
Consumption tax rate (%)[a]	23.6	22.3	26.3
Public pension expenditure (% of GDP)	3.2	6.7	4.2

* Percentage changes relative to benchmark, if not stated otherwise; [a] Assumed to balance government budget.

Omission of owner occupied housing from means-testing. The exemption of owner occupied housing from the means test of the Age Pension provides a strong incentive for homeownership. Already Cho and Sane (2013) studied this feature, but they only accounted for asset test of the Age Pension and neglected the superannuation and tax systems. Nevertheless, they computed similar effects as those reported in Table 8. Again, changes here are reported relative to the benchmark equilibrium, but our reference point is the Australian fiscal setting in the closed economy (i.e. third column in Table 6).

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

When housing assets are included in the means test, the number of self funded retirees increases to almost 50 percent, which reduces Age Pension expenditures to 3.2 percent of GDP, so that the consumption tax rate falls by three percentage points (i.e. two percentage points relative to the benchmark equilibrium). Net wealth hardly changes but households now save more in physical capital stock so that output as well as wages and private consumption increase. With respect to the tenure decision there is a clear shift towards renting, the homeownership rate declines from 60.6 to 56.5 percent, the rental housing stock increases and the owner occupied housing stock declines relative to the reference situation in Table 6. This clearly isolates the impact of the Age Pension on homeownership. Interestingly, among those now qualifying for the Age Pension, the proportion receiving the maximum rate rises to 75 percent. This is due to the fact that more age pensioners are now renters at older ages with income and assets below the respective thresholds. The stricter means test also increases long run welfare due to the more efficient asset allocation.

Universal Age Pension funded by payroll tax. The second reform introduces a flat pension at the maximum rates (defined in Table 9 below) funded by a tax on labor earnings.[28] Compared to the results for the current Australian system (in Table 6), this policy reform now reduces savings and net wealth as well as the distortion of tenure choice, so that owner occupied housing stock and the homeownership rate decline even further than before (as shown in the second column of Table 8). The lower capital stock decreases output and wages, while private consumption increases (all relative to the corresponding results in Table 6). The latter is due to the redistribution toward elderly who have a higher consumption share. The payroll tax rate to finance universal benefits is 10.4 percent.[29]

Minimum house size. The last simulation in this section keeps the current Australian fiscal system (i.e. as in third column of Table 6), but reduces the minimum house size by roughly 20 percent. The right column of Table 8 shows that this adjustment could bridge the remaining gap in the homeownership rate which now increases to 68.9 percent. Relaxed housing standards would also increase the owner occupied housing stock significantly, while reducing the rental housing stock. This is not surprising since this housing market modification basically represents a more affordable housing environment, allowing younger and low skilled households to buy their own homes. The long run implications for many other variables, including output, private consumption, capital stock and the welfare are also positive but fairly small. Interestingly, despite the higher number of homeowners, the fraction of self funded retirees decreases slightly (in turn increases public pension expenditures slightly). This clearly shows that many pensioners are now homeowners with lower financial wealth.

We have also examined other housing market specifications, including a higher loan-to-value ratio and lower transaction cost. These modifications generate quite similar behavioural adjustments, but the generated increase in the homeownership rate is less significant.

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[28] The idea of this (means test removal) reform is to mimic a typical flat benefit system. However, note that the German pension system is quite different due to the accumulation of individual earnings points.

[29] Cho and Sane (2013) also study a similar reform to a flat benefit system, but they adjust the benefit level to balance the budget. For this reason, their computed effects can hardly be compared to our results.

7 Conclusion

This paper has examined the impacts of alternative pension and income tax policies on homeownership, household wealth and the economy, using cross-country analysis of policy designs in Germany, the US and Australia. We have shown that our model (featuring tenure choice and three sources of household wealth - housing equity, liquid financial and pension assets) can isolate the main mechanics, which drive the gaps in homeownership and wealth between Germany and the US and Germany and Australia. Differences in income tax and pension systems can explain more than half of the observed gap in homeownership rates between Germany and the US and more than two thirds of the observed gap between Germany and Australia. In the US, the higher homeownership rate is due to a lower burden of pension contributions and also progressive (and for many households higher) capital income taxation. The same also holds for Australia, but here the non-contributory, means-tested Age Pension system is shown to be the most important policy responsible for the higher homeownership ratio. Interestingly, the Australian superannuation (private pension) funds have only a small impact on homeownership, but they increase savings significantly and contribute to larger household assets which are spent in retirement.

We have shown the importance of social security arrangements for homeownership and household wealth accumulation. This is also highlighted by Fehr and Hofmann (2020), but they focus on long term care policy. This link between pension policy and tenure choice has so far gained little attention in the literature - a gap we address in this paper.

Of course, there are many other differences in the economic structures of the examined developed countries which likely also affect homeownership and wealth accumulation. As already mentioned above, the US and the Australian populations are much younger compared to the population in Germany. Whilst upon initial consideration this may itself tend to reduce homeownership, the interplay between demography and homeownership is much more complicated. Recent studies by Fischer and Gervais (2011) and Fischer and Khorunzhina (2019) highlight how changes in marriage and divorce patterns affect tenure choice and homeownership. Besides demography, we do not take into account differences in rental market regulations in Germany, the US and Australia. Kindermann and Kohls (2018) argue that such differences (and wealth distribution patterns) are central drivers for homeownership rates among EU member states. Our simulation model also disregards specific housing taxes and subsidies such as social housing, which directly affect tenure choice (see Kaas et al., 2021). Finally, since our focus is on publicly stipulated pension pillars, we abstract from the modelling of any voluntary pension systems that often benefit from preferential tax arrangements (see e.g. İmrohoroğlu, et al. (1998)).

The future work will extend the current analysis of alternative tax and pension policy designs and the OLG model with housing to account for demographic transition, in order to quantify the economy-wide policy effects under population ageing. In that paper, we will focus on the welfare and aggregate efficiency implications of income tax and pension reforms.

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Appendix

This appendix has three parts. In Appendix A, we provide more details about 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. Finally, in Appendix C we explain in great detail our approach and data work for the calibration of our housing OLG model to the German macroeconomic and fiscal data.

Appendix A: Progressive income tax schedules and Australian pension parameters

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. The German progressive tax code (multiplied by the solidarity surcharge of 5,5%) with the tax base $\tilde{y}$ that includes labor earnings (net of payroll taxes) and public pension but excludes capital income can be expressed as:

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

y= $(\tilde{y} - \text{€ } 9{,}000)/10^4$, z= $(\tilde{y} - \text{€ } 13{,}996)/10^4$.

In the model simulation for the German policy design, 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:

$$T18(\tilde{y}) = \begin{cases} 0 & \text{if } \tilde{y} \leq 0.225\bar{y} \\ (1052.7\text{y} + 1.477)\text{y} & \text{if } 0.225\bar{y} < \tilde{y} \leq 0.35\bar{y} \\ (232.24\text{z} + 2.529)\text{z} + 0.0253\bar{y} & \text{if } 0.35\bar{y} < \tilde{y} \leq 1.37\bar{y} \\ 0,443\tilde{y} - 0.221\bar{y} & \text{if } 1.37\bar{y} < \tilde{y} \leq 6.51\bar{y} \\ 0,475\tilde{y} - 0.432\bar{y} & \text{if } \tilde{y} > 0.651\bar{y} \end{cases}$$

$y = (\tilde{y} - 0.225\bar{y})/10^4, z = (\tilde{y} - 0.35\bar{y})/10^4.$

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

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

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 2018 exchange rate of 1.18 USD = 1 EUR)[30], with the income tax schedule expressed as follows:

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

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:

$$T18(\tilde{y}) = \begin{cases} 0 & \text{if } \tilde{y} \leq \$18,200 \\ 0.19(\tilde{y} - \$18.200) & \text{if } \$18,200 < \tilde{y} \leq \$37,000 \\ \$3,572 + 0.325(\tilde{y} - \$37,000) & \text{if } \$37.000 < \tilde{y} \leq \$90,000 \\ \$20,797 + 0.37(\tilde{y} - \$90,000) & \text{if } \$90.000 < \tilde{y} \leq \$180,000 \\ \$54,097 + 0.45(\tilde{y} - \$180,000) & \text{if } \tilde{y} > \$180,000 \end{cases}$$

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 2018 exchange rate of 1.62 AUD = 1 EUR), with the income tax schedule expressed as follows:

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

[30] Note that $\bar{y} = 52,145$ USD is also used when calculating US social security benefit, defined in Section 2.

Australian pension policy parameters in 2018. Table 9 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 $\bar{p}(h)$ as well as the asset test threshold $a(h)$ are higher for renters ($h = 0$) than for homeowners ($h > 0$).

Table 9: Pension policy parameters in Australia 2018

Symbol	Description	Value
	Age Pension	
$\bar{p}(h)$	Maximum pension benefit[a]	$[0.49\bar{y}; 0.44\bar{y}]$
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 about $0.28\bar{y}$; [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 $j \geq j_R$.

The Age Pension parameters include the maximum pension benefit $\bar{p}(h)$, the threshold for the income test y_{min}, the deeming threshold a_{min}, as well as the asset test thresholds $\bar{a}(h)$ differ for single and couple pensioners, with the values presented in Table 9. Applying population weights of 44 and 56 percent for single and couple pensioners, respectively, we compute a maximum pension benefit of 44 percent of average income for homeowners in year 2018. Renters may be eligible for rent assistance when the rent exceeds a specific amount. The maximum amount of the assistance in 2018 was roughly 5 percent of average labor income, so that the maximum pension benefit for renters is set at 49 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 (see discussion above). The income test threshold is about 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.

With respect to the superannuation system, we model mandatory contributions made at a given rate of 8 percent from gross labor earnings (the average mandatory superannuation rate since 1992 when the system was legislated). 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 therefore apply an effective rate of 7 percent, as in Kudrna et al. (2019). Investment earnings on assets during the retirement phase are tax free. Finally, funds cannot be withdrawn before retirement, the payout fraction then increases gradually in the first four years of retirement.[31]

Appendix B: Household's optimization problem

At any state $z = (j, a_l, h, a_r, \theta, \eta)$, households have to 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 (i.e. $\omega^+ a^+ = h^+$), the remaining fraction finances transaction cost and financial assets (or mortgages) (i.e. $(1-\omega^+)a^+ = tr(h,h^+) + a_l^+$). Consequently, total savings a^+ are defined by

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

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 savings after transaction cost on 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

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

where $c_h(0) > 0$ and $c_h(h) = 0$ if $h > 0$ and

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

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

$$tr(h,h^+) = \begin{cases} \varphi_1 h + \varphi_2 h^+ & \text{for } h = 0 \text{ or } h^+ = 0 \\ 0 & \text{otherwise.} \end{cases}$$

Households make decisions on consumption, future total assets, whether to rent or own a house and the share of total assets used to pay for the down payment. The expectation operators E are with respect to 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 if the agent is investor or debtor), gross labor income net of payroll tax $y - pec$, pension benefits pen, housing assets net of depreciation $(1-\delta_o)h$ 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 households when they either become homeowners or renters. Renters have to pay rent p_h per housing unit, where the rental price is linked to the return of financial assets via the arbitrage condition

$$p_h = r + \delta_r,$$

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

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

31 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 about half of total benefit payments were drawn as lump sums and the other half as phased withdrawals (commonly called allocated pensions in Australia), see OECD (2019).

1. *Wealth exposure in housing:* Given a current state $\tilde{z} = (j, a^+, h, o^+, a_r, \theta, \eta)$, we need to split total savings a^+ 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. $h^+ = 0$) have to sell their house (in case they are owners) and pay the resulting transaction cost. We can define

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

   where we need to make sure that

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

   and that the retirement asset accumulation follows equations (7) or (12).

   Households who want to become (or remain) a homeowner (i.e. $h^+ \geq h_{min}$) need to split up their total savings a^+ between future housing assets, making sure that the minimum house requirement is fulfilled and again that the transaction cost are taken into account. 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

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

   and again the earnings point accumulation (7) or (12). Note that the restriction on $a_l^+ \geq -\xi h^+$ automatically includes $a^+ \geq (1 - \xi) h_{min} + tr(h, h_{min})$. The solution to this problem gives us $\omega(\tilde{z})$.

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 in order to get $c(z, o^+)$, $c_h(z, o^+)$ and $a^+(z, o^+)$.

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

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

   In case of a future owner we have to make sure that savings cover at least the down payment for the minimum house size plus transaction cost, i.e.

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

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

The current renters have to decide how to split their resources between ordinary consumption, housing consumption and savings and therefore maximize

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

Again, in case of a future owner we have to make sure that savings at least cover the down payment for the minimum house size plus transaction cost, i.e.

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

From the first-order condition we get

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

After substituting into the budget constraint optimal consumption is

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

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

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

Appendix C: Housing and renting in GDP data

This appendix consists of three parts. We first derive from a simplified theoretical model of a closed economy the GDP expression which includes housing expenditures. Then we compute the values of these variables from data of the Statistical Office (StaBu) of Germany in 2018. Of course, 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 which are matched by the baseline equilibrium of the numerical model.

Budget constraints and GDP accounting

The simplified version of the theoretical model consists of two overlapping cohorts, which are renters in the first period and homeowners in the second period. We assume population growth with rate n

so that $N_1 = (1+n)N_2$ and a rental rate p_h that covers interest cost r and depreciation δ_r. Together with the two budget constraints we therefore have

$$p_h = r + \delta_r \tag{26}$$

$$wL - T_w = pc_1 + p_h H^R + a + h^O \tag{27}$$

$$(1+r)a - T_r + (1-\delta_o)h^O = pc_2 \tag{28}$$

where $p = 1 + \tau^c$ is the consumer price of consumption goods, which includes consumption taxes. Aggregating the two budget constraints (27) and (28) 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 get

$$wL - T_w + (1+r)A - T_r + (1-\delta_o)H^O = C + \tau^c C + p_h H^R + (1+n)(A + H^O) \tag{29}$$

as 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 $A = K + H^R + B_G$ so that we have

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

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

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

Finally, adding on both sides depreciation for capital as well as rented and owner occupied houses and substitute the arbitrage conditions for capital stock $F_K = r + \delta_k$ and the rental price (26) gives

$$wL + F_K K + (p_h H^R + p_o H^O) = (C + p_h H^R + p_o H^O) + G + \underbrace{(n+\delta_r)H^R + (n+\delta_o)H^O + (n+\delta)K}_{I^{br}}$$

where $p_o = r + \delta_o$ defines the imputed cost of homeowners. On both sides of the accounting equation the value added of the real estate sector $p_h H^R + p_o H^O$ is now isolated. Both 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 date has to 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 exactly the 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 10 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 have to split up developed real estate and add it to residential and commercial buildings. This split is computed according to the fractions of residential and commercial buildings in the respective sector, see (5a) and (5b). The adjusted values for housing are now

Table 10: 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 ($H^R + H^O$)	8470	935	7535
	Rented housing property (H^R)	2670	935	1735
	Owner occupied property (H^O)	5800	–	5800
(1)-(7)	Capital stock (K)	7427		

*Source: Statistisches Bundesamt (2019a).

reported in the lower part of Table 10. The derived total property value for housing of EUR 8470 bn still need to be split between rented residential buildings (H^R) and owner occupied residential buildings (H^O). The problem is that many private households also rent housing property so that the figure of the household sector includes a large fraction of rented property. One option is to use the fraction of commercial rented homes to private rented homes (0.35 : 0.65) from Deutscher Bundestag (2017, 41). Assuming that commercial rented homes are EUR 935 bn, this would lead to a total number of EUR 2670 bn for rented homes and EUR 5800 bn for owner occupied homes. Alternatively one could also multiply the number of households with home ownership (about 18.2 million)[32] with the average values of owner occupied homes in 2017 of EUR 260,000 reported in Deutsche Bundesbank (2019a, 27). This would give a number of roughly EUR 4800 bn for H^O. However, it seems that the estimates from this study are very low. Average reported net wealth per household is there EUR 232,000, see Deutsche Bundesbank (219a, 32). If we divide total wealth from Table 10 by the number of households, we would arrive at EUR 420,000.

The numbers presented in Table 10 are also yield consistent values when we assume a depreciation rate of 2.5% for owned property (δ_o), 3.5% for rented property (δ_r) and an imputed interest rate of roughly 3.5%. With respect to homeowners we assume that the imputed rental cost only include the depreciation cost ($\delta_o H^O$) which then amount to EUR 145 bn. Rental income ($p_h H^R$) amounts to EUR 190 bn which is exactly split in half between depreciation cost and imputed interest cost (i.e. both EUR 95 bn).

Table 10 also does not reveal the value of retirement assets held by German households. The study of the Deutsche Bundesbank (2019a, 40) also reveals that about 43 percent of German households hold retirement assets in so-called Riester- or Rürup-plans.[33] 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

[32] Total number of households is 41.4 mio. in 2018 and home ownership fraction is 44 percent.

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

GDP.

Table 11 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, the expenditure measure and the distribution measure. The central data of all three measures are summarized in Table 11 below.

Table 11: 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 sector "real estate and rental" 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, see StaBu (2019b, 28). Consequently, the previous back of the envelope calculation is quite accurate and slightly rescaling the above figures gives now values of $\delta_0 H^O$ =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. About EUR 210 bn of gross investment are residential buildings, see StaBu (2019b, 96).

It is useful for later reference to derive the sectoral balances for corporate sector, the government, the household sector (including business partnerships and self employed) and the foreign sector as shown in Table 12.

The corporate sector includes also insurance companies and banks. For that reason part of social security contribution and transfers are included there. Most of the figures in Table 12 are 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 about EUR 78 bn. is already included in gross investment.[34]

In the following section we adjust Table 12 in various directions in order to align the GDP figures with the model restrictions.

[34] Most of government investment is spent on non-residential buildings and weapons.

Table 12: 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 12 the following adjustments need to be computed:

- The production sector aggregates corporations, business partnerships and 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 13 first derives net value added in the production sector. This value is split up in labor income and net business surplus which together with asset income from the government bonds sum up to aggregate income (Volkseinkommen) of households. Interest cost of the government are computed as follows: the debt level in 2018 amounts to EUR 2060 bn, see Deutsche Bundesbank

(2019b, 58). Related to GDP at market prices from Table 2 this would be roughly 60 percent. Assuming a slightly lower interest rate on public debt of 3% yields for rB an amount of roughly EUR 60 bn. This figure seems too high given the figure in Table 12. In 2018 the official interest payments of the government amounted to roughly EUR 40 bn, see Deutsche Bundesbank (2019, 59). However, we also exclude income from abroad so that EUR 60 bn is reasonable. In addition, the resulting aggregate income of EUR 2463 bn is only slightly below the respective figure of EUR 2503 bn in Table 10.

Table 13: 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 13 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, 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) (see Deutsche Bundesbank, 2019, 60*, 61*), so that we end up at EUR 118 bn. Social security in the model only reflects the public pension system. The latter includes pensions paid to former employees and civil servants (and survivors benefits) and amount to EUR 378 bn in 2018, see StaBu (2019b, 297). However, about 20 percent of benefits are not contribution related (benefits 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 12. The difference is only EUR 2071 - 2065 = 39 bn.

Available income is spent on ordinary consumption (incl. consumption taxes), renting (incl. imputed rents of home owners) and savings. Of course the resulting (household and government) savings figures are much smaller than in reality, but the positive government savings in 2018 were unusual and the household figure reflects the closed economy.

For the model we need the GVA net of the real estate sector which gives a value of EUR 2696 bn reported in the left part of Table 14. This figure is used to compute the asset to output values

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

which sum up to net wealth as reported above. The output value also 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 also taken from Table 13. Net investment expenditures are derived from subtracting depreciation from gross investment. Depreciation cost 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 from Table 1 gives a growth rate of 0.75 % which is quite realistic since 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 14.

Table 14: 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 $(n + \delta_r)H^R$	110	4.0		
			in $(n + \delta_o)H^O$	180	6.7		
GVA	Y	2696		2696	100.0		2696

*Own calculations.

Finally the right part of Table 14 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 14 allows to compute the capital share in the Cobb-Douglas function α and the depreciation rate δ_k 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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