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Tenure Choice, Portfolio Structure and Long-term Care - Optimal RiskManagement in Retirement

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Abstract

We study the interplay between tenure decisions, stock market investment and the public social security system. Housing equity not only serves a dual purpose as a consumption good and as an asset, but also provides insurance to buffer various risks in retirement. Our life cycle model captures these links in order to explain why homeownership in Germany is so low. Our simulation results indicate that the public long-term care as well as the pension system reduce the homeownership rate in Germany by 10-15 percentage points.

JEL Classifications: C61, D15, G11, H55

Keywords: Homeownership, Stock market participation, Life-cycle models, Long-term care

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1 Introduction

The importance of housing equity in retirement wealth is documented since a long time. With the notable exception of Germany, Austria and the Netherlands, typically more than 70 percent of households in OECD countries own a home before retirement, see Chiuri and Jappelli (2010, 649). Housing equity is by far the most dominant asset in most developed countries, dwarfing retirement accounts and other financial and nonfinancial assets. Despite its overall importance, the various determinants of homeownership in different countries are still heavily debated. On the one side it is seen as a pure investment vehicle while on the other side its role as a "precautionary savings device" that buffers especially long-term care shocks is highlighted. Our study adds to this literature by providing three main contributions: First, we consider homeownership as a risk management tool in retirement where households face financial risk as well as long-term care (LTC) risks. Second, we highlight the role of the public LTC insurance that reduces homeownership even when no reverse mortgages are available. Third, we isolate a novel mechanism for the impact of the public pension system on housing choices.

Our quantitative analysis focusses on the housing market in Germany, which for various reasons is an especially interesting market to study these issues. On the one side, the German homeownership rate is among the lowest in Europe for many years. Currently only 44% of German households are homeowners compared to 60% in the whole Euro area, see Matthä et al. (2017). Overall, the real estate market in Germany is quite stable with low turnover rates and very modest residential price dynamics. As a consequence, the German housing market was one of the few that avoided a slump in the wake of the 2008-2009 global financial crisis, see Voigtländer (2014) as well as Matthä et al. (2017). On the other side, Germany has a long social insurance tradition and was one of the first countries to introduce a compulsory LTC insurance in 1995. Individuals are eligible to claim benefits if they are in need of care because of an illness or disability. Since the most recent reform in 2017 the condition "in need of care" is derived in five grades which determine the benefit in cash and in kind. At the highest grade – on which we focus in the following – the maximum benefit for inpatient care reaches more than 2000 € per month. As argued by private insurance companies, these LTC benefits cover up to 75% of total care cost at this grade level, see Verband der Privaten Krankenversicherer (2016). The remaining difference between costs of care and LTC benefits has to be financed out-of-pocket. If the care taker has no further resources, the spouse and/or the children have to pay before ultimately social assistance steps in. Our simulations indicate that without the public insurance system, homeownership in Germany would increase substantially by 10-15 percentage points compared to the current situation. In addition, households would also increase their stock market participation significantly. In this sense homeownership serves as a risk management tool in retirement.

Therefore, our paper adds to the literature that focusses on the interplay between homeownership and stock market participation which has a long history, but comes along with rather inconclusive findings. Owning a house introduces asset price risk and may even lead to higher liquidity risk (due to the indivisible and illiquid nature of a house). Consequently, homeownership seems to reduce the demand for risky financial assets, see Hochguertel and van Soest (2001) for the Netherlands or Yamashita (2003) for the U.S. On the other hand, homeowners are perfectly hedged against rent fluctuations (Sinai and Souleles, 2005) and inflation (Wu and Pandey, 2012) which may in turn encourage their risk taking in financial assets. Not surprisingly, Beaubrun-Diant and Maury (2016) present evidence from the Panel Study of Income Dynamics (PSID) in the U.S. that the fraction of stockholders is significantly higher among homeowners than among renters, while Michielsen et al. (2016) find no effect at all of home equity and mortgage debt on the risky asset share of Dutch households. Chetty et al. (2017) argue that an increase in home equity due to rising residential prices reduces stockholding, while an increase in home equity due to a reduction in mortgage debt increases stockholding.

These seemingly contradictory empirical results are also evident in dynamic life-cycle models that highlight the interaction of tenure and portfolio choice. The seminal study in this direction was Cocco (2005), who abstracts from tenure choice and models housing as a durable consumption good and a risky investment. Owning a house generates returns in the form of consumption services from which the investor derives utility. However, house prices are uncertain and homeowners may incur large losses when they sell their house later in life. As a consequence, homeownership crowds out stock market investment and therefore helps to explain the empirically observed low participation rates on stock markets. The combination of house price risk, minimum house size and high transaction cost generates observed patterns of housing consumption over the life cycle and empirically plausible correlations in leverage and stock holdings. Yao and Zhang (2005) extend this approach by incorporating the choice between renting and owning a house. They find that investors choose substantially different portfolio allocations when owning a house versus when renting housing services. Homeowners substitute home equity for risky stocks. Hu (2005) also considers the tenure decision, but in his approach owning a house generates a higher utility than renting it. Again he documents the negative impact of homeownership on stock market participation. Exactly the opposite result is derived by Vestman (2019) in a model with preference heterogeneity, where households with a large savings motive choose to become homeowners and stock market participants, while those with small savings motives become renters and participate much less in the stock market. Our results are more in line with Vestman (2019), since we also find a positive correlation between homeownership and stock market participation. However, this is due to the fact that homeownership in Germany is a rather non-risky investment.

Finally, we also contribute to the literature that highlights the insurance aspect of homeownership. Already Venti and Wise (2004), Painter and Lee (2009) or Poterba et al. (2011) point out that relatively few U.S. retirees tap into their housing equity to finance ordinary consumption needs. Instead it is rather used to buffer shocks to the family status (i.e. divorce, widowhood) or health (i.e. entry to a nursing home). Very similar findings are confirmed for Germany (Keese, 2012) and Great Britain (Banks et al., 2012), while Angelini et al. (2014) provide evidence for 13 European countries using life history data from the Survey of Health, Ageing and Retirement in Europe (SHARELIFE). Davidoff (2009, 2010) was among the first who analyzed in a life-cycle model the role of home equity as an insurance against LTC risk in old age. As already discussed above, home equity is a large fraction of the wealth for the elderly and tends to be liquidated only late in life or when in long-term care. When hit by LTC shocks, homeowners can convert their equity into a reverse mortgage. Consequently, especially illiquid homeowners with pension wealth will hardly demand LTC insurance products on private markets, see also Laferrere (2012). Nakajima and Telyukova (2019) estimate a structural model of saving and housing tenure decisions for retired households who derive utility gains from homeownership and face longevity risk, uncertain medical expenses and borrowing constraints. In this model set-up, homeowners dissave at a slower rate than renters since they prefer to stay in their house as long as possible. Their simulations indicate that, without considering homeownership, retirees' net worth would be 28-53 % lower in the U.S. Using the same model, Nakajima and Telyukova (2017) analyze the welfare consequences of reverse mortgage programs. On average the expected welfare gain of reverse mortgages is equivalent to just $ 252 or 0.84% of annual after-tax income. However, welfare gains are much larger for lower income and for older households. Our model completely abstracts from reverse mortgages and considers only public LTC insurance provision. Nevertheless, we are still able to generate the substitution between LTC insurance and homeownership.

In the following we will present empirical facts reflecting portfolio structures and homeownership patterns in Germany. Afterwards we develop a life-cycle simulation model that captures the interaction between tenure choice, portfolio choice and various financial risks in retirement. In our set-up, home equity is used to buffer LTC and longevity risk, even without reverse mortgage arrangements. The homeownership rate therefore increases substantially by 15-20 percentage points if the public insurance system is eliminated.

2 Homeownership and portfolio choices in Germany

In this section we analyze the second wave of the Eurosystem Household Finance and Consumption Survey (HFCS) which was collected in Germany from 2013 to 2015 and released in December 2016.[1] The HFCS collects household level data on earnings, wealth and consump-

[1] A detailed description of the survey methodology of the HFCS can be found in ECB (2016).

tion in twenty European Union countries which is comparable. Similar to the U.S. Survey of Consumer Finances (SCF), wealthy households are oversampled but the provision of specific household weights allows to cover the total number of households in each country. The German sample of 4,461 households represent more than 40 mio. households. In order to make the sample more comparable with our model, we exclude entrepreneurs, renters that hold real estate and homeowners with a mortgage that is higher than the value of their real estate. This leaves us with 3,577 households which represent more than 33 mio. households in Germany. Table 8 summarizes the key figures of the average portfolio held in the sample by homeowners and renters.[2]

Table 1: Average income and wealth of the German HFCS sample (in €)

	Homeowner	Renter	Total
Annual labor income	36.497	21.289	27.903
Net wealth	303.499	25.916	146.649
Financial assets	71.260	23.480	44.262
low risk assets	55.247	19.637	35.133
high risk assets	16.013	3.843	9.128
Real estate[1]	256.519	0	111.571
Mortgage[2]	35.231	0	15.323
Other real assets	13.931	4.948	8.855
Other debt	2.981	2.512	2.716
Observations (unweighted)	2.114	1.463	3.577
Observations (weighted)	14.487.616	18.821.464	33.309.080
Fractions (in %)	44	56	100
Stock market participation rates (in %)	32	17	24

Source: Own calculations based on second wave of HFCS.

[1] Includes 58.071 € of Other real estate. [2] Includes 5.807 € of mortgages on Other real estate.

Net wealth is defined as the sum of financial assets, real estate and other real assets less mortgages and other debt. With respect to financial assets we distinguish between low risk assets and high risk assets.[3] Real estate consists of the home main residence and investment real estate. Homeowners are therefore defined by having declared part (or all) of their real estate as their home main residence. Table 8 reveals that about 44% of our sample households are homeowners. They have a significantly higher annual labor income than renters and participate more frequently than renters in the stock market. On average, their net wealth is 303.499 € and therefore more than twelve times higher than that of renters. As one would expect, real estate dominates their net wealth while financial assets are mainly held as deposits in checking

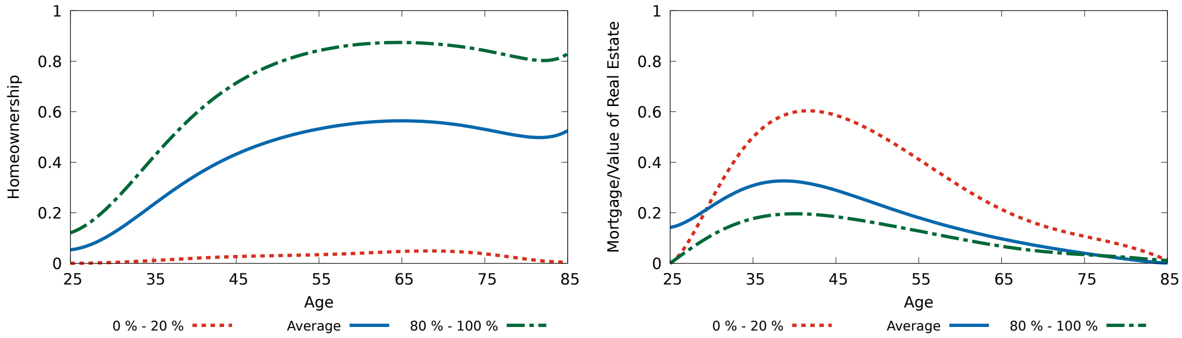
2 The respective table without sample selection can be found in Appendix A.

3 A description of our aggregation procedure can be found in Appendix B.

accounts. Mortgages only amount to roughly 14 % of the value of real estate holdings.

Next we group our observations into 13 data cells of 5-year age groups ranging from 25-29 until 85-89. Then we split each data cell into net wealth quintiles and compute the ownership shares for the whole data cell as well as its top and bottom wealth quintile. The left part of Figure 1 shows the homeownership rates over the life cycle for the three considered groups. Not

Figure 1: Homeownership and mortgages over the life cycle - Data



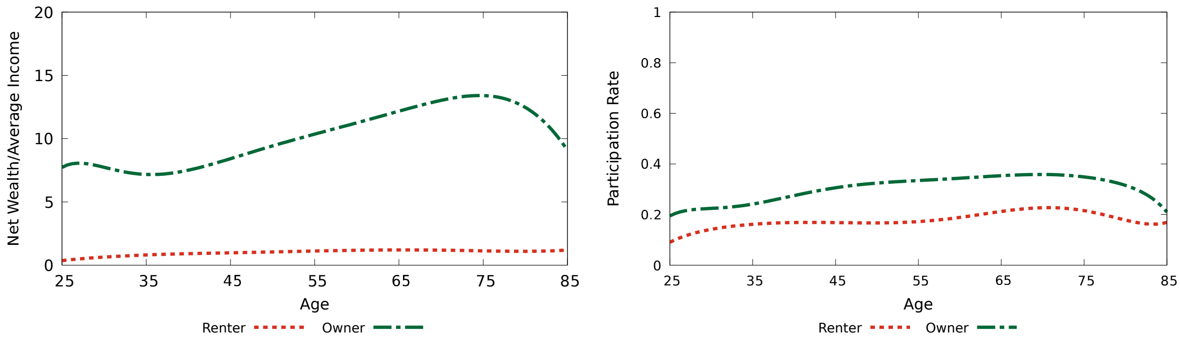
Source: Own calculations with HFCS data and 3-year average smoothing.

surprisingly, homeownership rises at younger ages and reaches an average share of almost 60 per cent in the age groups 55-75. Afterwards it falls again slightly. Figure 1 also documents a striking difference between the top and bottom wealth quintile. While the lowest quintile consists of mainly renters, households in the top income quintile are typically homeowners after age 45.

The right part of Figure 1 considers only homeowners and reports for the respective groups the average share of mortgages as a percentage of the values of the main residence. Of course, depending on the amount of own savings when buying the house, mortgage shares will vary quite substantially across households. In addition, only very wealthy households can buy a house at younger ages so that we observe low mortgage shares below the age of 30. Households with average wealth buy a house later in life so that mortgage shares rise after age 30 and reach for the lowest wealth quintile of homeowners a level of about 70 per cent of the house value at age 35. This fraction then falls in the following years. Of course, for the top wealth quintile the mortgage share decreases considerably and reaches only about 20 per cent at age 40. The profile of average mortgage shares lies in between. After age 65 less then 10 per cent of the house value is burdened with a mortgage.

Next we compare the net wealth profiles (relative to average income of the population) along the life cycle for both owners and renters in the left part of Figure 2. Already at young ages owners have a net wealth of 200,000 € which is roughly seven times average income. After age 35 their net wealth rises up to roughly 300,000 € (or about ten times average income) around age 62 when they retire. After retirement net wealth increases even further until it declines after age 75. In contrast, the net wealth profile of renters is fairly flat around 40,000 €.

Figure 2: Net wealth and participation rates over the life cycle - Data



Source: Own calculations with HFCS data and 3-year average smoothing.

Finally, we compare participation rates in the stock market for homeowners and renters in the right part of Figure 2. Both participation rates seem to be (slightly) higher during retirement than during working years. Homeowners have higher participation rates then renters. On average, homeowners hold higher portfolio shares in risky assets than renters. However, Table 8 also suggests that conditional on participation, homeowners have lower shares in risky assets.

Overall, the picture is therefore mixed. At least the data indicates that homeowners on average do have a higher share of risky assets which is in contrast to the older literature for the U.S. cited before and more in line with Vestman (2019) or Chetty et al. (2017). At least partly this is due to the fairly stable housing market in Germany. In the following section we develop a simulation model that will reproduce these specific features in the benchmark.

3 The Model

Our model is a discrete time life-cycle model where each period corresponds to one year. Households face income, house price, health and lifespan uncertainty and need to decide about consumption, savings, homeownership and stock market participation. During retirement, households may experience an irreversible health shock (think of a stroke which forces them into severe long-term care), which reduces their resources, their life expectancy but also the utility from living in their own house. The latter establishes a link between homeownership and long-term care insurance. As long as they are healthy, households receive more utility from owning a house instead of renting it. Tenure choice is further influenced by transaction costs, the rental price and down payment requirements as well as the minimum housing investment.

3.1 Demographic structure and household preferences

We assume that a household's life starts at age 1 and may finally end at some maximum age J, where $j = 1, \ldots, J$ denotes the actual age. At the beginning of life, individuals are assigned a skill level θ which affects their labor income until forced retirement at age j_r. Survival from one period to the next is stochastic where $\psi_j(s_{j-1})$ denotes the conditional survival probability from age $j-1$ to age j, which depends on the health status $s_{j-1} \in [0,1]$ of the previous age $j-1$ with $\psi_j(0) > \psi_j(1)$ and $\psi_{J+1}(s_J) = 0$.

Households receive utility from ordinary consumption c and housing services c_h. They may also value leaving housing and asset equities to their heirs. The instantaneous utility function is

$$u(c, c_h) = c^\alpha (\chi c_h)^{1-\alpha}$$

where α denotes the Cobb-Douglas expenditure share of ordinary consumption. Consumption of housing services may be derived from ownership or from rental housing and also depends on the health status. Similar to Hu (2005) or Nakajima and Telyukova (2017, 2019), we assume a preference for ownership for healthy households while this preference disappears for households who are in need of long-term care. Homeowners consume their housing equity $h \geq h_{min}$ as housing services (i.e. $c_h = h$), while renters (where $h = 0$) have to purchase housing services on the rental market. The taste parameter is set to $\chi < 1$ whenever the household is either a renter or in bad health (i.e. $s = 1$), in the other case (homeowner in good health) we set $\chi = 1$. This so-called "pride of ownership" term in the utility function is meant to capture insurance properties or tax advantages of homeownership or the full flexibility in house customization. The utility cost from long-term care may reflect the fact that in case of LTC need specific advantages of the own house (think of a nice garden) can no longer be enjoyed.[4]

3.2 Income process over life-cycle

Agents start their working life at age 1 and, conditional on surviving, retire at age j_r. In each period during the working years, an agent receives an endowment of labor productivity, which she can supply to the market at the wage rate w. Labor supply is inelastic and equal to unity, so that changes in labor productivity translate one-to-one into changes in labor income y_j. Labor productivity is a function of a deterministic, skill-specific age-profile of earnings e_j and two transitory components η_j and ζ_j. While the skill-level θ is drawn at the beginning of the life

[4] Rouwendahl and Thomese (2013) find that in the Netherlands homeowners move to nursing homes later than renters. Therefore one may also argue that the utility from the own house even rises following a LTC shock. Of course, this argument may apply to lower grade LTC shocks, but we have in mind higher grade LTC shocks where people cannot live independent of external help any more.

cycle, the second component η_j has an AR(1) autoregressive structure so that

$$\eta_j = \rho\eta_{j-1} + \epsilon_j \quad \text{with} \quad \epsilon_j \sim N(0, \sigma_\epsilon^2) \quad \text{and} \quad \eta_1 = 0.$$

The idiosyncratic innovation term ϵ_j is also normally distributed with mean zero and variance σ_ϵ^2. Both the autoregressive correlation term ρ as well as the variance of the innovation term σ_ϵ^2 are assumed to be skill-specific, see Fehr et al. (2013). In contrast, the white noise component ζ_j is skill-independent and normally distributed with mean zero and variance σ_ζ^2. Household's labor income is therefore

$$y_j = \begin{cases} we_j \cdot \exp(\eta_j + \zeta_j)(1 - \tau^c - \tau^p) & \text{for } j < j_r \\ 0 & \text{otherwise,} \end{cases}$$

where τ^c and τ^p denote the contribution rates to the public LTC and pension insurance. At age j_r the household retires and therefore labor productivity e_j drops to zero. We assume that throughout retirement we have $\eta_{j+1} = \eta_j$. In this phase the agent receives pension income *pen* which is assumed to be a constant fraction of the last working period's gross permanent income, i.e.

$$pen = \begin{cases} \kappa_1 \cdot we_{j_r-1} \cdot \exp(\eta_{j_r-1}) & \text{for } j \geq j_r \\ 0 & \text{otherwise.} \end{cases}$$

During the retirement phase the household may experience a long-term care shock. In this case, health changes to the state $s = 1$, survival probabilities fall and additional cost m will arise for the remaining lifetime. For simplicity we assume that the public insurance only covers a fraction $(1 - \kappa_2)$ of these cost, so that the household faces additional out-of-pocket expenditure of $\kappa_2 m$.

3.3 Transaction cost in the housing and the stock market

In each period, households have to decide how much to consume, how much to save and whether to become a renter or owner in the next period. Households who want to buy a house split up their aggregate savings a^+ into the selected house size h^+, the resulting transaction cost $tr(h, h^+)$ of changing the house size and either mortgage debt or liquid assets. The maximum mortgage is fixed by the exogenously specified maximum loan-to-value ratio ξ. Consequently, the minimum down payment for house size h^+ is given by $(1 - \xi)h^+$. In order to select a specific house size h^+, the household chooses a fraction ω_h^+ of his total assets which is required as minimum down payment, i.e. $h^+ = \frac{\omega_h^+ a^+}{1-\xi}$. The remaining fraction of total assets is then used to finance transaction cost and savings in financial assets a_f^+, i.e. $(1 - \omega_h^+)a^+ = tr(h, h^+) + a_f^+$.

We assume that savings are first used to draw down mortgage debt to zero. When mortgage debt is zero the liquid assets could be invested in the financial market. Consequently, we have

$$a^+ = h^+ + tr(h, h^+) + (a_f^+ - \xi h^+)$$

where the difference between financial assets and maximum mortgage ξh^+ the household could take out against the house determines either the actual mortgage debt or liquid assets which could be invested on the financial market.

Households who become renter (i.e. $\omega_h^+ = h^+ = 0$) can invest all their savings net of transaction cost on the financial market, i.e. $a_f^+ = a^+ - tr(h, 0)$. Transaction cost $tr(h, h^+)$ only apply to homeowners when they change their house value by more than φ per cent:

$$tr(h, h^+) = \begin{cases} 0 & \text{if} \quad h^+ \in [(1-\varphi)h; (1+\varphi)h], \\ \phi_1 h + \phi_2 h^+ & \text{otherwise.} \end{cases}$$

Following Yang (2009) homeowners may change their housing consumption by undertaking housing renovation or by allowing depreciation up to a fraction of φ their house size. Outside of this range, any change in house size is assumed to involve a sale (and potentially a purchase if $h^+ > 0$). In the latter case the household has to pay transaction cost which are a fraction ϕ_1 of its selling value and a fraction ϕ_2 of its buying value.

Financial investors who hold liquid wealth $a_f^+ - \xi h^+ > 0$ may split it up into a fraction ω^+ of stocks and a fraction $1 - \omega^+$ of bonds. In case they invest on the stock market, households must pay a lump sum transaction cost which amounts to $\bar{F}$.

3.4 Financial market and relative prices

The return on households' stock holdings $r(\vartheta)$ evolves stochastically where we assume the following relation between r and the risk free rate r_f:

$$r(\vartheta) - r_f = \mu_r + \vartheta.$$

The excess return of the risky asset over the risk free rate is defined by the risk premium μ_r and the interest rate shock ϑ. Similarly, the house price in the next period p^+ may also evolve stochastically as

$$p^+ = 1 + \mu_h + v,$$

where μ_h defines a deterministic growth rate and v a price shock. The interest rate shock ϑ as well as the house price shock v are both i.i.d. normally distributed with mean zero and variance σ_ϑ^2 and σ_v^2, respectively. In addition they may be correlated with the white noise shock ζ for labor productivity, so that we have

$$\begin{bmatrix}\zeta\\ \vartheta\\ v\end{bmatrix} \sim N\left(\begin{bmatrix}0\\0\\0\end{bmatrix}, \begin{bmatrix}\sigma_\zeta^2 & \varrho_1\sigma_\zeta\sigma_\vartheta & \varrho_3\sigma_\zeta\sigma_v\\ \varrho_1\sigma_\zeta\sigma_\vartheta & \sigma_\vartheta^2 & \varrho_2\sigma_\vartheta\sigma_v\\ \varrho_3\sigma_\zeta\sigma_v & \varrho_2\sigma_\vartheta\sigma_v & \sigma_v^2\end{bmatrix}\right).$$

Consequently, the total value of financial assets in the next period can then be written as

$$R_p(\omega^+, \vartheta^+)(a_f^+ - \xi h^+),$$

where

$$R_p(\omega^+, \vartheta^+) = \begin{cases} 1 + r_f + \omega^+ \cdot (\mu_r + \vartheta^+) & \text{if } a_f^+ > \xi h^+ \\ 1 + r_f + \varpi_m & \text{otherwise} \end{cases}$$

Consequently, with low financial assets (i.e. when $a_f^+ < \xi h^+$) the household reduces mortgage debt where the mortgage premium ϖ_m increases the mortgage interest rate above the risk free rate r_f. When the mortgage is fully eliminated (i.e. when $a_f^+ > \xi h^+$) he starts to invest in the stock market.

3.5 Household's optimization problem

Given the specific structure of the model we can define the problem with cash-on-hand X, so that the state vector is then defined by $z = (j, X, s, \theta, \eta, h)$ where $h = 0$ for a renter. In what follows, we solve the problem recursively defining the set of control variables by $\Omega = (c, a^+, \omega_h^+, \omega^+, I^+)$ where I^+ is a binary variable capturing participation cost so that it changes from zero to one as soon as the investor makes an investment in the stock market. Following Campanale et al. (2015) we also assume that an investor in the stock market has to pay a participation fees $\bar{F}$ in every period.

as Vestman (2019) we assume that every household has Epstein-Zin (1991) preferences over momentary utility and bequest so that the optimization problem of the household then reads

$$V(z) = \max_{\Omega} \left\{ u(c, c_h)^{1-\frac{1}{\gamma}} + \beta \left[\psi_{j+1}(s) \left(\mathbf{1}_{\omega_h^+ > 0} E\left[V(z^+)^{1-\nu}\right]^{\frac{1-\frac{1}{\gamma}}{1-\nu}} + \mathbf{1}_{\omega_h^+ = 0} E\left[V(z^+)^{1-\nu}\right]^{\frac{1-\frac{1}{\gamma}}{1-\nu}} \right) + (1 - \psi_{j+1}(s)) b \left(1 + \frac{a^+}{q}\right)^{1-\frac{1}{\gamma}} \right] \right\}^{\frac{1}{1-\frac{1}{\gamma}}} \quad (1)$$

where β denotes the discount rate, γ is the the intertemporal elasticity of substitution (IES) between momentary utility and expected future utility, E is a conditional expectations operator and ν is the coefficient of relative risk aversion (RRA). The parameters b and q in the bequest function capture the strength of the bequest motive and the luxury good property, see De Nardi (2004).

Current homeowners (i.e. where $h > h_{min}$) are subject to the constraints

$$\begin{aligned} a^+ &= X - c, \quad 0 \le \omega^+, \omega_h^+ \le 1, \qquad a^+ \ge tr(h, h^+), \qquad h^+ = \frac{\omega_h^+ a^+}{1-\xi} \ge h_{min}, \\ a_f^+ &= (1-\omega_h^+)a^+ - tr(h, h^+) \\ X^+ &= R_p(\omega^+, \vartheta^+)(a_f^+ - \xi h^+) + y^+ + pen^+ + (1-\delta_h)p^+h^+ - \mathbf{1}_{s^+=1}\kappa_2 m^+ - I^+\bar{F} \end{aligned}$$

with $\mathbf{1}_{k=x}$ denoting an indicator function that returns 1 if $k = x$ and 0 if $k \neq x$

The expectation operators E in equation (1) are with respect to the stochastic processes of productivity η, health s and house price. Current resources are split between consumption and aggregate assets. Households who buy a house are restricted to a maximum loan-to-value ratio ξ and a minimum house size h_{min}. In case of borrowing, households face a fixed interest rate of $r_f + \varpi_m$. Future resources X^+ are derived from financial assets (including interest), gross labor income, pensions, housing investments net of depreciation δ_h, LTC and stock market participation fees $\bar{F}$.

The objective function of a current renter is quite similar except that we have $h = 0$ so that the current constraint changes to

$$X = c + r_h c_h + a^+.$$

Renters have to pay rent r_h per housing unit c_h. Of course, they face the same restrictions on future resources, future house size and borrowing as current owners. The rental price r_h is linked to the return of financial assets through

$$r_h = r_f + \delta_h + \varpi_h$$

which makes sure that renters implicitly bear the maintenance cost of the house plus some additional surcharge ϖ_h which reflects regulation or market imperfections on the rental market. Consequently, tenure choice and portfolio allocation decisions over a households' life cycle are closely interlinked and provide an insurance and consumption value.

The optimization problem (1) is solved in five steps that are explained in detail in Appendix C. The following section describes the parameter choice for the benchmark model before we present simulation results.

4 Calibration of the benchmark model

The model's time period is one year, agents start life at age 20 ($j = 1$), are forced to retire at age 65 ($j_r = 45$) and can live at maximum up to age 100 ($J = 80$). Survival probabilities for households are taken from the 2012/14 Life Tables for Germany reported in Statistisches Bundesamt (2016). In our model LTC shocks refer to the highest LTC grade. The cohort share of LTC patients with the highest grade increases between age 70 and age 90+ from 1.8 percent to 32.3 percent, see Statistisches Bundesamt (2017). In order to match these fractions of LTC patients among older cohorts, the probability to become a LTC patient in a certain year is rising from 0.05% at age 65 up to 6% at age 100. LTC households experience a reduction in their life expectancy. According to Unger et al. (2011) on average someone in good health at age 65 can expect to live 18.3 more years in good health (or with low grade care) and 1.27 years in (high grade) long-term care. Consequently, we increase the survival probabilities for those households in good health ($\psi_j(0)$) and reduce them by about 15 percent for those households who have received a LTC shock. Table 2 shows that our model roughly matches the targets. The model's reported overall life expectancy at age 65 of 19.2 years is roughly in line with the respective life expectancy reported in Statistisches Bundesamt (2016).

Table 2: Calibration of long-term care parameters

	Long-term care shares in age groups (in %)						Life expectancy at age 65	
	65-69	70-74	75-79	80-84	85-89	90+	without care	with care
Model	0.1	1.4	4.8	7.6	14.1	34.7	17.94	1.21
Data*	0.0	1.8	3.8	8.6	17.5	32.3	18.34	1.27

*Source: Statistisches Bundesamt (2017); Unger et al. (2011).

The remaining baseline parameters are provided in Table 3. The preference parameters are selected in order to (at least roughly) match the build-up of financial assets during the life cycle as well as the overall homeownership rates and mortgage fraction in the data. Consequently, the consumption share parameter is specified at $\alpha = 0.6$ while the time discount factor is $\beta = 0.94$. The shift parameter for housing utility after a long-term care shock or the move into rental housing is set at $\chi = 0.6$ similar to Nakajima and Telyukova (2013). Hu (2005) assumes a value of 0.8 when renting is compared to ownership. The literature typically assumes a γ value between 0.1 and 1.0, we follow Cocco (2005) or Yao and Zhang (2005) and set the intertemporal elasticity of substitution (IES) to $\gamma = 0.2$. Since our benchmark calibration should reflect the regular CES utility function, the relative risk aversion (RRA) parameter is set to $\nu = 5$. This combination will be analyzed in the sensitivity analysis. Finally, we apply the specification of De Nardi (2003) for the bequest function and specify a bequest parameter $b = -1.25$ and a bequest utility shift parameter $q = 5.0$ in order to have a realistic old-age wealth level.

Table 3: Baseline parameter values

Symbol	Definition	Value
	Preferences	
α	Ordinary consumption share	0.60
χ	Owner preference	0.60
β	Time discount factor	0.94
γ	Intertemporal elasticity of substitution (IES)	0.20
ν	Relative risk aversion (RRA)	5.00
b	Utility weight on bequest	-1.25
q	Shifter of bequest utility	5.00
	Productivity	
$e_j(\theta)$	Productivity of agent at age j	[1]
ρ	AR(1) correlation	[1]
σ_ϵ^2	Transitory variance	[1]
σ_ζ^2	White noise variance	0.0738
	Financial market	
μ_h	Expected house price return	0.02
σ_υ^2	House price variance	0.055^2
σ_ϑ^2	Stock market variance	0.157^2
$\bar{F}$	Stock market transaction cost	$0.10 \cdot \bar{y}$
r_f	Risk free interest rate	0.02
μ_r	Risk premium	0.04
	Correlation between	
ϱ_1	... stock returns and labor income	0.00
ϱ_2	... stock returns and house prices	0.00
ϱ_3	... labor income and house prices	0.00
ϖ_m	Mortgage premium	0.01
	Housing market	
h_{min}	Minimum house size	$5.5 \cdot \bar{y}$
δ_h	Depreciation rate	0.015
ξ	Loan-to-value ratio	0.70
ϖ_h	Rental surcharge	0.01
	Transaction cost	
ϕ_1	... of selling price	0.06
ϕ_2	... of buying price	0.12
φ	... free fraction	0.20
	Government	
κ_1	Pension replacement rate	0.50
κ_2	LTC co-payment fraction	0.25
τ^p	Pension contribution rate	0.20
τ^c	LTC contribution rate	0.01

[1] Taken from Fehr et al. (2013).

With respect to the labor productivity parameters we follow Fehr et al. (2013) and distinguish three skill levels that reflect high-, middle- and low-skilled households in Germany. The latter study provides the skill-specific deterministic age-profiles, as well as the correlation and variance terms. The skill-independent white noise component σ_ζ^2 as well as the interest rate shocks are taken from Cocco, Gomes and Maenhout (2005). The same study also provides the risk-free interest rate of r_f and an equity premium of μ_r. As already discussed before, house price risk in Germany is lower than in Anglo-saxon countries. Consequently, our standard deviation of 0.055 is lower than the respective 0.062 in Cocco (2005). Finally, our benchmark simulation assumes a mortgage premium ϖ_m of one percent and abstracts from any correlations between labor productivity, stock market returns and house prices.

When households want to become owners, they need to invest at least 5.5 times the average annual income. This figure is higher than in Hu (2005) or Yang (2009), but reflects the German situation where houses are typically more expensive due to specific safety and environmental regulations. Reasonable values for down payment in Germany are between 20 and 30 percent of the value of the house. However, Voigtländer (2016) expects a likely increase so that we fix the loan-to-value ratio $\xi = 0.7$. Voigtländer (2016) also computes the taxation and registry cost for housing purchases in Germany to $4.6 - 8\%$ property values. Including cost for real estate agents makes us set $\phi_2 = 0.12$. Transaction cost when selling the house are considerably smaller so that we specify $\phi_1 = 0.06$ which is roughly in line with the literature. We also assume that transaction cost only arise when the house size changes by more than 20 per cent, see Yang (2009) who specifies a slightly lower fraction. Following Cocco (2005), we set the depreciation rate of houses at $\delta_h = 0.015$. Finally, the wedge ϖ_h on the rental market is set to one percent reflecting the highly developed rental market in Germany, see Kindermann and Kohls (2018).

Finally, the replacement rate of the pension system is set at $\kappa_1 = 0.5$ and the co-payment fraction of LTC cost is set at $\kappa_2 = 0.25$. Furthermore we assume that total LTC cost per year in the highest grade amount to $m = 1.5\bar{y}$. Consequently, private co-payments of LTC cost in the benchmark model amount to roughly 75 percent of average pension benefits. This is a rather conservative value for κ_2 since we have already indicated above that average private cost for long-term care in the highest LTC grade may rise up to a level of an average pension. Given the replacement and co-payment rates we compute from the budget constraints of the respective insurance system the contribution rates τ^p and τ^c. The latter amount to 20 and 1 percent, respectively, which is fairly realistic for Germany.

Table 4 reports how the model solution matches some calibration targets. Roughly 45 percent of households live in their own house, the resulting real estate wealth is about 85 percent of their total net wealth while about 8 percent of their own house is financed by a mortgage. Finally, roughly 38 percent of homeowners are participating in the stock market while only 11 percent of renters own stocks. Overall, the main financial indicators from the model solution match the wealth structure in the German data set quite well.

Our model also does a good job in matching the life cycle profiles. Figure 3 shows the path for homeownership and the house value (relative to average income). In Figure 1 above, the

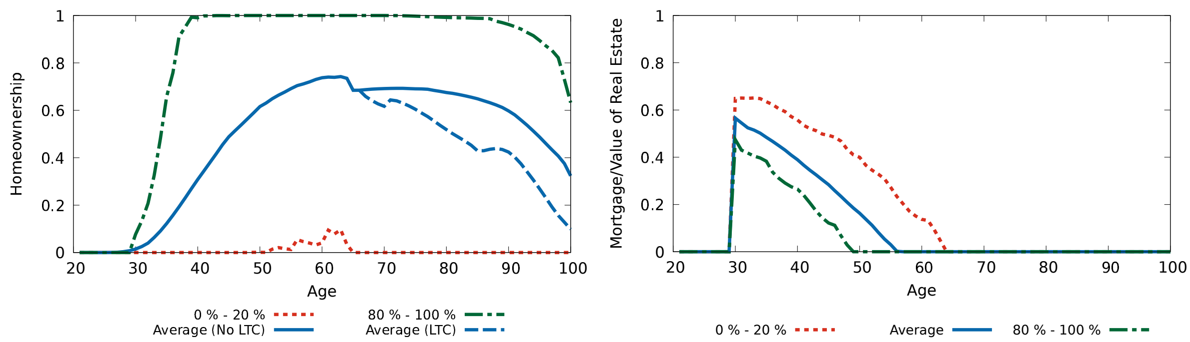
Table 4: Calibration targets and model solution (in %)

	Homeowner		Renter	
	Model	Data*	Model	Data*
Net wealth/Av. annual income	994	1122	182	91
Fraction	45	44	55	55
Stock market participation rates	38	32	11	17
Portfolio share of...				
Financial Assets	22	23	100	91
bonds	11	18	81	84
stocks	11	5	19	16
Real estate	85	85	0	0
Mortgage	8	14	0	0
Other real assets	0	5	0	19
Other debt	0	1	0	10

*Source: Own calculations derived from HFCS Data in Table 8.

average homeownership rate increased to 60% at age 55, then remained fairly stable for 20 years before it slightly decreased afterwards. While homeownership reached almost 100 % in the top wealth quintile after age 55, hardly any homeownership exists in the bottom quintile. The left part of Figure 3 documents that our model roughly matches these figures. Households save during early ages in order to buy a house after age 30. Then the average homeownership rate rises up to roughly 70 percent at age 65 when they retire. Afterwards healthy households try to keep their home until death. Those who have a long-term care shock, however, will sell their home much earlier. This distinct behavior of healthy and non-healthy individuals already indicates the insurance property of home equity. The right panel of Figure 3 shows

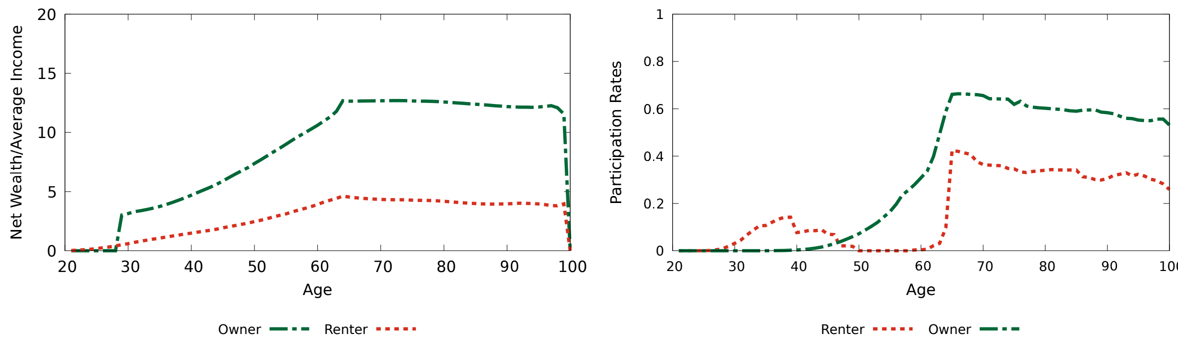
Figure 3: Homeownership and mortgages - Baseline



the mortgage fractions over the life cycle for different wealth quintiles of homeowners. The lowest quintile is clearly bounded by the maximum loan-to-value ratio and also pays back the mortgage almost until age 65. Wealthier households need much lower fractions of their house value as a mortgage and repay much faster. In the top quintile repayments are already finished at age 48.

Figure 4 reveals that in our setup households typically accumulate assets until retirement. On average, wealth at retirement age in the model is about fourteen times average income which is also shown in Figure 2 where we report the wealth profiles of homeowners and renters separately. After retirement wealth remains fairly stable due to the bequest motive. Renters in our model have much lower wealth, but the profile has the same shape. The right panel shows the

Figure 4: Net wealth and stock market participation rates - Baseline



participation rates in the stock market for homeowners and renters. Clearly, homeowners have higher participation rates than renters but especially in retirement they are much higher than in the data. Partially this is due to the model restriction that homeowners cannot invest in shares as long as they have mortgages. The sharp increase of participation rates around retirement is due to the fixed cost of stock market participation. The higher the investment, the lower are the relative transaction cost. The stock market participation of younger renters vanishes due to a composition effect when former renters with high wealth become homeowners around age 40 to 50.

5 Why do households become homeowners?

In this section we discuss the different motivations for homeownership in our model. The main cost of homeownership are the transaction cost which arise when buying and selling the house. These transaction cost are significant and kept constant throughout the paper. In addition, the minimum house size (which is also kept constant in the following) may also restrict low income households to become homeowners. On the other hand, there are four main benefits from homeownership in our model:[5]

[5] An additional indirect benefit may arise from the fact that real estate can be used to reduce the risk exposure in the portfolio. In our set up this benefit turns out to be negligible.

(a) Households have a preference for homeownership compared to renting which is reflected by χ in the utility function.

(b) The rental market is imperfect indicated by the wedge ϖ_h which increases the rental rate r_h.

(c) House prices are assumed to increase on average by μ_h percent each period.

(d) Homeowners can use the mortgage to smooth consumption intertemporally as long as the loan-to-value ratio ξ is positive.

In order to quantify the impact of these benefits on homeownership we first remove them in Table 5 and then introduce them successively again. As we show in the first line the elimination of

Table 5: Determinants of homeownership

Parameter choice				Model results (in %)		
μ_h	ξ	ϖ_h	χ	Net wealth/ av. income	Homeownership	Participation rates
0.00	0.00	0.00	1.00	–	0	–
0.02				1379	3	77
	0.70			1286	7	51
		0.01	1.00	1004	33	37
		0.00	0.60	996	41	36
		0.01	0.60	994	45	38

homeownership benefits induces all households to become renters.[6] The next line introduces a positive growth rate in house prices so that about 3 percent of very wealthy households become homeowners. Not surprisingly, a very high fraction of these homeowners also participates in the stock market. Opening the possiblity of improved intertemporal consumption smoothing via mortgages in the next line does only slightly increase the fraction of homeowners to 7 percent of households. Of course, this small impact of mortgages is also due to the fact that there is still hardly any benefit in homeowning. However, now stock market participation falls significantly for homeowners. This is due to the fact that as long as homeowners have not fully repaid their mortgages, they cannot participate on the stock market. The wedge in the rental market and the preference for homeownership have the strongest impact on homeownership. However, it is hardly possible to split up the impact of each parameter separately.

It seems that the utility premium of 40 percent on homeownership has a stronger impact (i.e. 34 percent against 26 percent increase in homeownership) than the rental market wedge of 1 percent if we introduce them separately. As one would expect, average wealth levels decrease as well as the stock market participation. Overall our model seems to confirm the recent study

[6] This result also holds with zero transaction cost despite the fact that homeownership might reduce risk exposure.

by Kindermann and Kohls (2018) who stress the importance of rental market wedges in order to explain the homeownership rates in Europe. However, our focus is the impact of the social security system to which we now turn.

6 Homeownership and social security

Our paper intends to isolate the insurance properties of homeownership and analyze the special relation with government provided social security. In order to quantify the impact of social security on homeownership and risk management, we eliminate in this section either the long-term care insurance or the pay-as-you-go financed pension system. In both cases the respective contribution rate falls to zero.

In the first simulation we assume that the co-payment rate for LTC cost rises to 100 percent (i.e. $\kappa_2 = 1.0$). Consequently, the elderly now not only face the risk of reduced longevity and an ownership preference shock, they also have to finance much higher cost. Figure 5 shows that now homeownership increases significantly during retirement. Of course, households now save more when young in order to balance the increased expected LTC cost in retirement. Net wealth almost doubles relative to average income after the reform, see Table 6. Due to higher savings they reach the minimum house size much earlier and can become homeowners at younger ages. When they get older they keep their house in order to balance the LTC shocks. Overall the homeownership rate increases from 45 to 53 percent.

Figure 5: Homeownership without LTC insurance

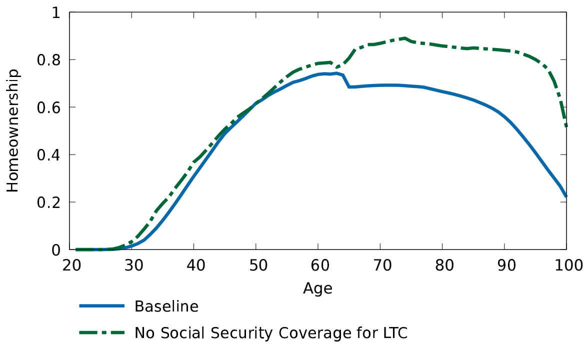
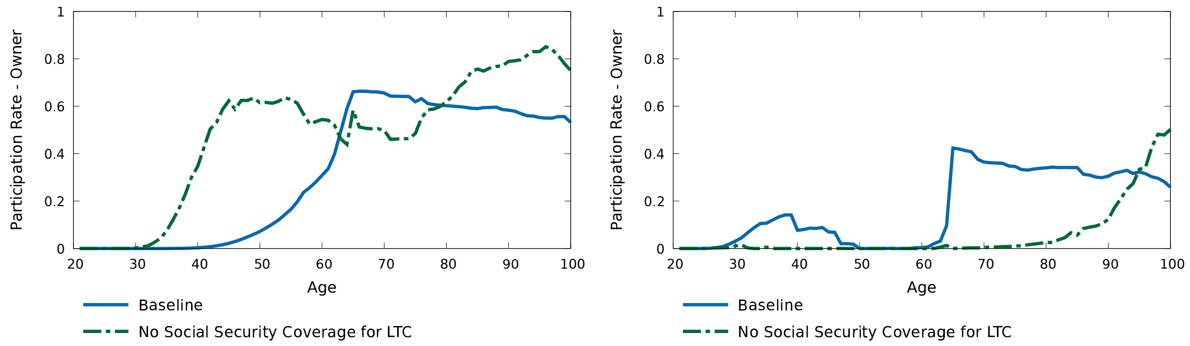


Figure 6 and Table 6 reveal an interesting asymmetric reaction of homeowners and renters with respect to stock market participation. While homeowners finance their houses with less mortgages, they increase their stock market participation already significantly during working periods. Since they have higher savings, (fixed) stock market transaction cost bite less so that they increase stock market participation during retirement. Renters, however, hardly change their stock market participation during employment years but reduce it significantly during retirement. Of course, they now face higher risks from LTC cost so that they need to reduce their financial risk in retirement.[7]

Figure 6: Stock market participation without LTC insurance



Consequently, our model clearly indicates the substitution between LTC insurance provision and homeownership. In countries like Germany, low homeownership rates might be (at least partially) due to the provision of rather generous public LTC insurance systems. Vice versa, the demand for private LTC insurance will be low in countries with high homeownership rates, even if these countries do not offer generous public support. This conclusion was already highlighted by Davidoff (2009, 2010), but our model captures this link even without resorting to reverse mortgages.

Next we analyze the interaction between homeownership and the pension system. Chen (2010) already shows that homeownership rises strongly when the paygo pension system is privatized. The key mechanism there is the fall in interest rates due to the rise in savings which boosts housing demand. In our partial equilibrium setup, bond and stock returns are not affected by the pension reform. Nevertheless, Figure 7 shows a significant increase of homeownership at almost all ages. Table 6 shows that on average homeownership increases from 45 to 62 percent compared to the benchmark. Again, we see the asymmetric behavior of homeowners and renters with respect to their stock market investments. While homeowners increase their stock market investments, renters reduce it significantly.

Figure 8 shows how stock market participation of homeowners and renters is affected over the life cycle. While homeowners in the left panel mainly increase their financial risk exposure before retirement (and hardly change it afterwards), renters dramatically reduce their financial risk exposure during retirement. Again, homeowners can hedge against longevity risks better than renters who need to adjust their financial portfolio.

7 Of course, there is also a selection effect since the group of homeowners has increased and the group of renters has decreased. Since renters have a lower stock market participation compared to owners, the pure selection effect should dampen the increase in stock market participation of owners.

Figure 7: Homeownership with private pensions

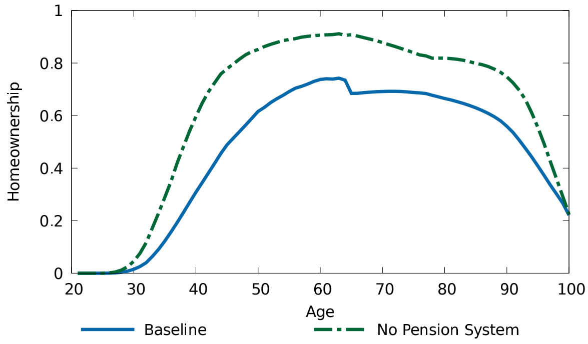
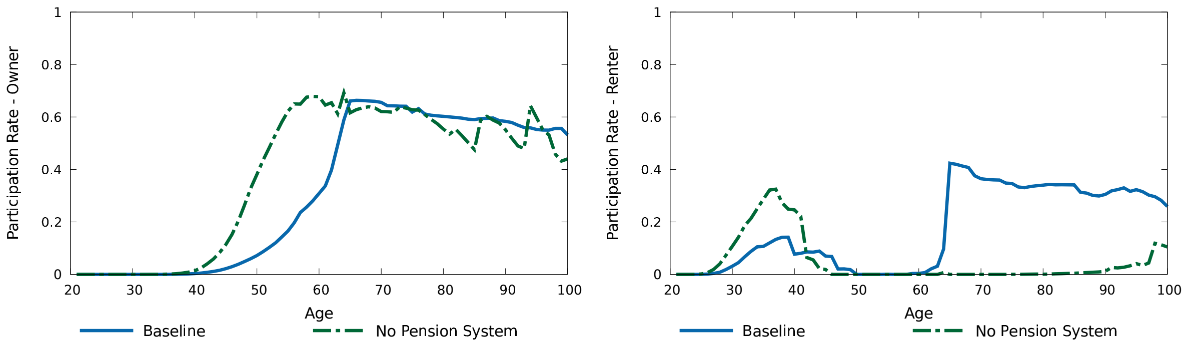


Table 6: Saving and risk management without social security (in %)

	No LTC insurance		Pension privatization	
	Homeowner	Renter	Homeowner	Renter
Net wealth/av. annual income	1921	330	1411	330
Fractions	53	47	62	38
Stock market participation	56	3	47	3
Portfolio share				
Financial assets	44	100	33	100
bonds	28	99	18	90
stocks	16	1	15	10
Real estate	56	0	70	0
Mortgage	0	0	4	0

Figure 8: Stock market participation with private pensions



Consequently, we derive quite similar results as Chen (2010), but the adjustment mechanism is quite different in our model. When households increase their private savings to substitute for paygo pension benefits in old age, they build up more risky investments at younger ages. In order to balance the risk exposure they buy houses which are less risky. When they sell their houses again at late ages, the proceeds are invested in less risky bonds in order to finance retirement. Consequently, the pension system affects both homeownership rates and portfolio choice dramatically in our model.

Figures 5 and 7 also show very stable homeownership rates after retirement. This is very much in line with Nakajima and Telyukova (2013) who argue that homeowners dissave much slower than renters, since households prefer to stay in their house as long as possible.

7 Sensitivity analysis

The sensitivity analysis in this section focuses on the impact of risk exposure and risk taking on homeownership and investment choice. Table 7 repeats in the first line the baseline indices which were already discussed above.

Table 7: Sensitivity analysis of homeowner's financial choice (in %)

	Homeownership rate	Net wealth/ av. income	Real estate/ Net wealth	Mortgage fraction	Stock market participation	Stocks/ Net wealth
Baseline	45	994	85	8	38	11
$\nu = 10.0$	45	1300	71	1	39	10
$\sigma_v^2 = 0.062^2$	44	1016	83	7	40	12
$\varrho_1 = 1.0$	43	994	86	8	32	9
$\varrho_1 = -1.0$	46	1005	83	7	44	12
$\varrho_2 = 1.0$	44	963	88	8	4	1
$\varrho_2 = -1.0$	45	982	84	8	60	15
$\varrho_3 = 1.0$	41	1049	81	5	42	12
$\varrho_3 = -1.0$	48	922	86	8	32	10

When household risk aversion is increased from 5.0 to 10.0 then individuals will accumulate more wealth. This wealth is particularly held in financial assets instead of real estate in order to ensure liquidity at very high ages when individuals are subject to long-term care risk. Homeowners will hence pay back their mortgages more quickly than in the baseline scenario. If we increase the volatility of house prices then real estate becomes less attractive in the portfolio. Homeowners reduce their housing investment and substitute towards stock market investments. The higher stock-market participation is resulting from the fact that the relative cost of stock-market participation is decreasing with the absolute amount of wealth in stocks.

If risk during employment increases due to a positive correlation between labor and capital income, the portfolio structure will be tilt towards bonds in order to reduce the risk exposure in savings. Consequently, households hardly change their real estate exposure and financing. However, investment in stocks is decreased relative to the benchmark as shown in the last two columns. Exactly the opposite reaction can be observed if the correlation between labor and capital income turns negative. A positive (negative) correlation between stock returns and house prices also increases (decreases) financial risk exposure. Again, homeownership is hardly affected but now stock market investment is significantly reduced (increased). Finally, the correlation between labor income risk and house price risk has the strongest effect on homeownership. In case of a positive correlation the latter is significantly reduced and financial resources are shifted towards the stock market. The opposite happens in the case of a negative correlation.

8 Extensions and future research

The main idea of this study is to analyze the interplay between homeownership, social security and portfolio choice. For this reason we build a life-cycle model which features risky investment opportunities and tenure choice as well as interlinks the long-term care cost with the utility from housing consumption. We are able to roughly replicate a realistic life cycle ownership pattern for Germany. In our setup, rental market imperfections have a strong impact on homeownership, but tenure choice is also significantly affected by long-term care and longevity risk. According to our calculations, the existing public insurance systems in Germany reduce the homeownership rate by roughly 15-20 percentage points. This main result is fairly robust with respect to alternative risk exposures in the present set-up. The figure therefore highlights the importance of the insurance property of homeownership. The clear policy message from the paper is therefore that housing subsidies may be justified also by insurance arguments.

A quite natural extension of the model is to allow for some specific reverse mortgage (RM) options and analyze the resulting welfare consequences. There is currently a growing interest in RM products and their efficiency in financing retirement consumption. For example, Hanewald et al. (2015) develop a stylized three period model for a retired homeowner who faces longevity, long-term care, house price and interest rate risk. They compare reverse mortgages and home reversion plans with respect to the optimal choice for the release of home equity either with or without government provided LTC insurance. While the availability of both products increase individual welfare, they find that the RM product offers a higher benefit. The already mentioned study by Nakajima and Telyukova (2017) extends the approach of Nakajima and Telyukova (2019) by considering an RM option. Their rich structural model allows to identify the determinants of RM demand, to explain why the RM market is currently so thin and how current RM contracts could be modified in order to make them more attractive. Their study also finds significant welfare gains for homeowners when they are given access to fair priced RM contracts.

A second interesting line of research would be to model the long-term care risk in more detail and include a choice between home care and nursing home care. Homeowners might have better options to receive home care than renters which would explain why the move less frequently to a nursing home, see Rowendahl and Thomese (2013). Kopecky and Koreshkova (2014) have recently modeled the nursing home choice in the U.S. but they did not consider the preceding tenure choice problem. In Germany the choice between home care and nursing home care is even more distorted because households receive transfers from the long-term care insurance if they stay at home.

A final important extension of our model concerns the consequences of the differentiated tax treatment of owner occupied and rented houses. Up to now we abstracted from this important issue mainly because we wanted to analyze housing investment from a portfolio choice selection perspective. In our partial equilibrium model homeownership reduces the risk exposure of households in equity markets. The analysis of taxation issues, however, requires a general equilibrium approach with overlapping generations. Such a set-up typically abstracts from aggregate investment risk and considers instead idiosyncratic labor income risk. Recent contributions in this direction by Chambers et al. (2009), Floetotto et al. (2016) or Sommer and Sullivan (2018) study the impact of the U.S. tax system on individual tenure choice and welfare. Other papers by Chen (2010) and Chun (2015) analyze the interplay between tenure choice and the pension systems in the U.S. and Australia. Recently, Kaas et al. (2019) implemented such a general equilibrium approach also for Germany. They analyzed the role of social housing, transfer taxes and the tax treatment of mortgage interest in explaining the low ownership rates.

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Appendix A: HFCS data without sample selection

Table 8: Average income and wealth of the German HFCS sample (in €)

	Homeowner	Renter	Total
Annual labor income	36.737	22.690	28.920
Net wealth	417.019	51.222	213.458
Business wealth	55.366	3.901	26.726
Financial assets	82.047	31.571	53.958
low risk assets	61.565	24.618	41.006
high risk assets	20.483	6.954	12.952
Real estate (HMR)	231.222	0	102.550
Real estate (Other)	84.404	14.809	45.675
Mortgage (HMR)	36.228	0	16.068
Mortgage (Other)	11.021	2.485	6.271
Other real assets	14.566	6.396	10.019
Other debt	3.337	2.971	3.133
Observations (unweighted)	2.621	1.840	4.461
Observations (weighted)	17.595.062	22.076.938	39.672.000
Fractions (in %)	44	56	100
Stock market participation rates (in %)	34	22	27

Source: Own calculations based on second wave of HFCS, unrestricted sample.

Appendix B: Aggregation of HFCS data in Table 1

We consider bonds, deposits and money owed to other households as low risk assets. On the other hand we consider non self-employment private businesses, publicly traded shares, managed accounts and other assets such as futures and options as high risk assets. Mutual funds are treated as high risk assets if they are particularly invested in stocks, otherwise only one-third of the money held in the mutual fund is accounted for as a high risk asset. We treat voluntary pensions and life insurances similarly, however we do not observe detailed information over the underlying portfolio in the data as it is the case for mutual funds. As a consequence we make the simplifying assumption that voluntary pensions and life insurances are invested more conservatively than mutual funds and set the share that is primarily invested in stocks to be only half of the respective share of mutual funds. The remaining voluntary pensions and life insurances are treated as low risk assets. Real estate includes the household main residence as well as other real estate, mortgages include similarly mortgages on the household main residence and on other real estate. In contrast to mortgages, other debt refers to rather short-run debt.

Appendix C: Detailed decision process in the model

At any state $z = (j, X, s, \theta, \eta, h)$, the household has to decide how to split up resources X into ordinary consumption $c(z)$ and total wealth $a^+(z)$. Next total wealth has to be divided into financial assets $a_f^+ = (1 - \omega_h^+)a^+ - tr(h, h^+)$ and future real estate $h^+ = \frac{\omega_h^+ a^+}{1-\xi}$. Finally, the household has to decide whether to invest on the stock market or not and (in case of positive investment) how to split positive financial wealth into stocks $\omega^+(a_f^+ - \xi h^+)$ and bonds $(1 - \omega^+)(a_f^+ - \xi h^+)$. Note that the current renter is identified whenever $h = 0$ while $h^+ = 0$ for the future renter. The corresponding optimization problem can be solved in five steps:

1. *Equity exposure in liquid wealth:* Given a specific state $\tilde{z} = (j, s, \theta, \eta, h)$, and a combination of future financial assets a_f^+ and future house h^+, future owners (i.e. where $h^+ \geq h_{min}$) and future renters (i.e. where $h^+ = 0$) solve

$$Q(\tilde{z}, a_f^+, h^+) = \max_{0 \leq \omega^+ \leq 1} \left[\psi_{j+1}(s) E \left[V(z^+)^{1-\nu} \right]^{\frac{1-\frac{1}{\gamma}}{1-\nu}} + (1 - \psi_{j+1}(s)) b \left(1 + \frac{\hat{a}^+}{q}\right)^{1-\frac{1}{\gamma}} \right]^{\frac{1}{1-\frac{1}{\gamma}}}$$

subject to

$$\begin{aligned}
I^+ &= \begin{cases} 1 & \text{if } \omega^+ > 0 \\ 0 & \text{otherwise.} \end{cases} \\
X^+ &= R_p(\omega^+, \vartheta^+)(a_f^+ - \xi h^+) + y^+ + pen^+ + (1 - \delta_h) p^+ h^+ - \mathbf{1}_{s^+=1} \cdot \kappa_2 m^+ - I^+) \bar{F} \\
\hat{a}^+ &= a_f^+ - \xi h^+) + h^+
\end{aligned}$$

where

$$R_p(\omega^+, \vartheta^+) = \begin{cases} 1 + r_f + \omega(\tilde{z}, a_f^+, h^+)\,(\mu_r + \vartheta^+) & \text{for } a_f^+ - \xi h^+ > 0 \\ 1 + r_f + \varpi_m & \text{otherwise.} \end{cases}$$

The solution to this problem is $\omega^+ = \omega(\tilde{z}, a_f^+, h^+)$.

2. *Stock market participation decision:* Given the household has decided $\omega^+ > 0$ (so that $I^+ = 1$) we still need to compare the situation $I^+ = 0$ in order to decide about participation

$$Q(\tilde{z}, a_f^+, h^+) = \max[\tilde{Q}(\tilde{z}, a_f^+, h^+, I^+ = 0); \tilde{Q}(\tilde{z}, a_f^+, h^+, I^+ = 1)]$$

3. *Wealth exposure in real estate:* The household who wants to become a renter simply has to sell the house (in case of an owner) and pay the resulting transaction cost. Given that we already know the optimal equity exposure ω^+ as well as the value function $Q(\tilde{z}, a_f^+, 0)$ from step 2, we can define

$$S(\tilde{z}, a^+, o^+ = R) = Q(\tilde{z}, a_f^+, 0)$$

where we need to make sure that

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

with $tr(h, 0)$ defining the transaction cost of moving to a rented home. Note that all combinations where $a^+ < tr(h, 0)$ are not feasible!

The situation when the household wants to become (or remain) a homeowner is more complicated since we need to split total savings a^+ between future financial assets and housing. In addition, we need to make sure that the minimum house requirement is fulfilled and again that the transaction cost are taken into account. The sub-optimization problem is now

$$S(\tilde{z}, a^+, o^+ = O) = \max_{\underline{\omega}_h(a^+) \leq \omega_h^+ \leq 1} Q(\tilde{z}, a_f^+, h^+)$$

s.t.

$$a_f^+ = (1 - \omega_h^+)a^+ - tr(h, h^+) \geq 0.$$

Note that we can define an implicit minimum housing share $\underline{\omega}_h(a^+) = \frac{(1-\xi)h_{min}}{a^+}$. The solution to this problem gives us $\omega_h^+ = \omega_h(\tilde{z}, a^+)$.

4. *The consumption-savings decision:* Finally, given the state z (i.e. including resources X) and knowing how to split wealth into real estate and liquid assets, it is possible to set up the consumption savings problem for *current* homeowners and renters separately. The former own a positive housing stock $h \geq h_{min}$ that is consumed. The maximization problem then reads

$$\begin{aligned} W(z, o^+) &= \max_{c, a^+} \left\{ u(c, c_h)^{1-\frac{1}{\gamma}} + \beta S(\tilde{z}, a^+, o^+)^{1-\frac{1}{\gamma}} \right\}^{\frac{1}{1-\frac{1}{\gamma}}} \\ &\text{s.t.} \quad X = c + a^+. \end{aligned}$$

Current renters (i.e. where $h = 0$) have to decide how to split their resources between ordinary consumption, housing consumption and savings. They therefore maximize

$$\begin{aligned} W(z, o^+) &= \max_{c, c_h, a^+} \left\{ u(c, c_h)^{1-\frac{1}{\gamma}} + \beta S(\tilde{z}, a^+, o^+)^{1-\frac{1}{\gamma}} \right\}^{\frac{1}{1-\frac{1}{\gamma}}} \\ &\text{s.t. } X = c + r_h c_h + a^+ \end{aligned}$$

Substituting the first order conditions

$$\frac{c}{c_h} = \frac{\alpha}{1 - \alpha} r_h$$

into the above budget constraint we derive the optimal housing choice

$$c_h = \frac{(1 - \alpha)(X - a^+)}{r_h}.$$

The solution yields the consumption and rental housing demand as well as the savings functions $c(z, o^+), c_h(z, o^+)$ and $a^+(z, o^+)$, respectively.

5. *The housing tenure decision:* Finally substituting the consumption and housing demand $c(z, o^+), c_h(z, o^+)$ and savings functions $a^+(z, o^+)$ from the last step into the respective objective functions we can derive the values $W(z, o^+ = R)$ and $W(z, o^+ = O)$ for future renters and owners, respectively. The final value function is then simply derived from

$$V(z) = \max\,[W(z, o^+ = R), W(z, o^+ = O)].$$