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Housing wealth across countries: the role of expectations, institutions and preferences

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Abstract

Homeownership rates and holdings of housing wealth differ immensely across countries. Using micro data from five economies, we estimate a life-cycle model with illiquid housing in which households face a discrete–continuous choice between renting and owning a house. We use the model to decompose the cross-country differences in the homeownership rate and the value of housing wealth into three groups of explanatory factors: house price expectations, the institutional set-up of the housing market and preferences. We find that all three groups of factors matter, although preferences less so. Differences in homeownership rates are strongly affected by (i) house price beliefs and (ii) the rental wedge, the difference between rents and housing maintenance costs, which reflects the quality of the rental market. Differences in the value of housing wealth are substantially driven by maintenance costs.

Keywords Housing, Homeownership, House Price Expectations, Housing Market Institutions, Cross-Country Comparisons

JEL codes D15, D31, D84, E21, G11, G51

Non-technical summary

The household main residence is the largest asset for most households and an important determinant of wealth inequality. Homeownership rates differ enormously across countries. For example, less than half of all households in Germany own their residence, while 80% of households in Spain are homeowners. These striking cross-country differences in homeownership persist over the whole life cycle, with the homeownership gap between Germany and Spain staying around 30 percentage points, not narrowing down with age. In addition, homeowners in different countries accumulate substantially different amounts of housing wealth.

We analyze how households accumulate housing wealth over the life cycle in a model with risky labor income and house prices, illiquid housing and a discrete–continuous choice between owning and renting a house. We estimate the model on micro data on age profiles of homeownership, housing wealth, rents and net wealth from a comprehensive set of five advanced economies: France, Germany, Italy, Spain, and the United States. The paper complements the existing work, which typically investigates cross-country differences in wealth using reduced-form regressions.

Our estimated model allows us to quantify three groups of explanatory factors for long-run, structural differences in housing wealth. First, in line with survey evidence, we allow for (persistent) differences in expectations of house prices across individuals within each country. Second, countries differ in the institutional set-up of the housing and rental market (maximum loan-value ratios, costs of renting, maintaining and selling a house). Third, preference parameters such as impatience and the share of housing expenditures are allowed to vary across households. Using micro and macro data, we also calibrate the remaining differences in house prices, incomes and demographics. Our model thus includes several features that are important for modeling housing: housing wealth is illiquid and subject to linear house selling costs, house size is continuous, house prices are risky, households face collateral constraints, and their beliefs about house prices differ.

Our model fits reasonably well empirical age profiles of homeownership rates and holdings of housing and total net wealth for each of the five countries. Through the lens of the estimated model, we then interpret the substantial differences in homeownership rates and housing wealth across the five countries. We propose a decomposition in which, moving from one country (e.g., Germany) to another (e.g., Spain), we switch one by one from the German parameter values to the Spanish ones, in each step recording the effect of the given factor on the housing wealth variable (homeownership or mean housing wealth–income ratio). We find that all three groups of factors above contribute to explaining the cross-country differences in homeownership and housing wealth, although preferences much less than house price beliefs and housing market institutions.

As for the extensive margin of housing wealth, differences in homeownership rates are strongly affected by two variables: (i) house price beliefs and (ii) the rental wedge, the difference between rents and maintenance costs, which reflects the quality of the rental market and the segmentation between rental and owner-occupied housing markets. These two factors are key for the decision whether to buy vs. rent a house: a higher rental wedge and higher expectations of house price growth make renting less appealing and increase the share of homeowners. Both elements contribute roughly equally to explaining the gaps in homeownership rates across countries and both of them matter throughout the life cycle.

Quantitatively, the two channels are powerful: small differences in long-run house price beliefs and the rental wedge result in large differences in homeownership rates. The rental wedge ranges from around 2% in France and the U.S., to 2.8% in Germany, 3.7% in Spain and almost 5% in Italy, reflecting a less efficient rental market. Our model implies that the 2 p.p. difference in rental wedges leads roughly to a 25–30 p.p. difference in homeownership rates between Germany vs. Italy. Mean long-run house price beliefs range between 0% in Italy and 2.8% in France, reflecting the historical growth in aggregate house prices. Across countries, a 1 p.p. difference in house price beliefs results roughly in a 15 p.p. difference in the homeownership rate. These considerations imply that small differences in long-run house price beliefs—well within the range documented in survey data—are a powerful driver of homeownership in a model, substantially affecting important economic decisions of households.

As for other factors, tighter collateral constraints and steeply growing labor incomes in Germany and the U.S. reduce the homeownership rate particularly for the youngest households, while the bequest motive affects the homeownership in particular among older households.

Regarding the intensive margin of housing wealth, differences in housing wealth of homeowners (as measured by the mean ratios of housing wealth to income) are mostly driven by maintenance costs, which in effect reduce homeowners' return on housing. Quantitatively, the estimated maintenance costs for Germany (2.6% of housing wealth) are roughly half those in Spain, France and the U.S. (around 5% or more), implying higher housing wealth in Germany by a multiple of 2–4 worth of annual incomes. Other factors that matter for the accumulation of housing wealth (although less than maintenance costs) are the housing preference, house price beliefs, and the rental wedge. We estimate that Germany and Italy have a lower share of housing utility (around 0.20) than the other countries (roughly 0.30), which is reflected in a positive contribution of the parameter to housing wealth outside of Germany. Roughly twice as large as in Germany, the rental wedge in Italy reduces housing wealth as marginal buyers purchase smaller houses. Higher house price growth beliefs increase the amount of housing wealth in Spain and the U.S. (compared to Germany) as existing homeowners upgrade to buy larger houses.

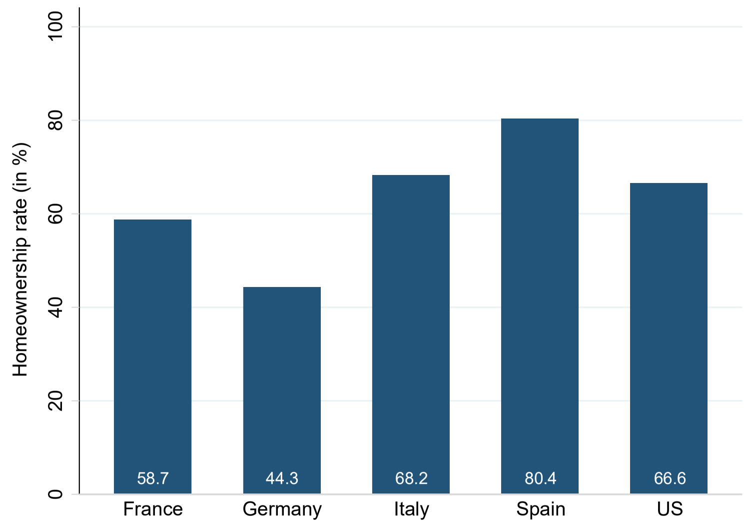
1 Introduction

Homeownership rates differ immensely across countries. For example, less than half of all households in Germany own their residence, while 80% of households in Spain are homeowners (Figure 1.a). These striking cross-country differences in homeownership persist over the whole life cycle, with the homeownership gap between Germany and Spain staying around 30 percentage points, not narrowing down with age (Figure 1.b). In addition, homeowners in different countries accumulate substantially different amounts of housing wealth (Figures 1.c and d).

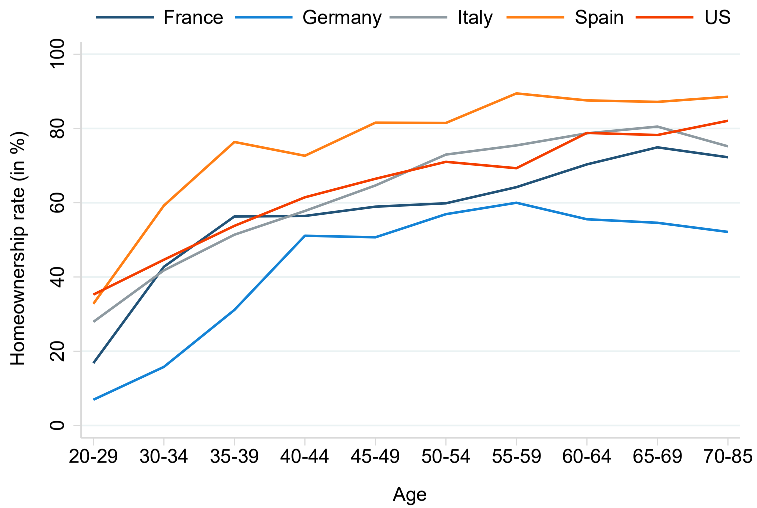
We study the accumulation of housing wealth in a 'canonical,' state-of-the-art life cycle model with risky labor income and house prices, illiquid housing and a discrete–continuous choice between owning and renting a house. Our estimated model allows us to quantify three groups of explanatory factors for long-run, structural differences in housing wealth. First, in line with survey evidence, we allow for (persistent) differences in expectations of house prices (Landvoigt, 2017, Armona et al., 2018, Kuchler et al., 2023). Second, countries differ in the institutional set-up of the housing and rental market (maximum loan–value ratios, costs of renting, maintaining and selling a house); see, e.g., Chiuri and Jappelli (2003), Chambers et al. (2009), Greenwald and Guren (2021) and Malmendier and Steiny Wellsjo (2024). Third, preference parameters such as impatience and the share of housing expenditures are allowed to vary across households (see, e.g., Krusell and Smith, 1998, Epper et al., 2020 and Calvet et al., 2024). Using micro and macro data, we also calibrate the remaining differences in house prices, incomes and demographics. Our model thus includes several features that are important for modeling housing: housing wealth is illiquid and subject to linear house selling costs, house size is continuous, house prices are risky, households face collateral constraints, and their beliefs about house prices differ.

We use the simulated method of moments to match the model to micro data on age profiles of homeownership, housing wealth, rents and net wealth from a comprehensive set of five advanced economies: France, Germany, Italy, Spain, and the United States. We discuss and document how those moments in the data identify estimates of house price beliefs, housing market institutions and preferences. Our model fits reasonably well

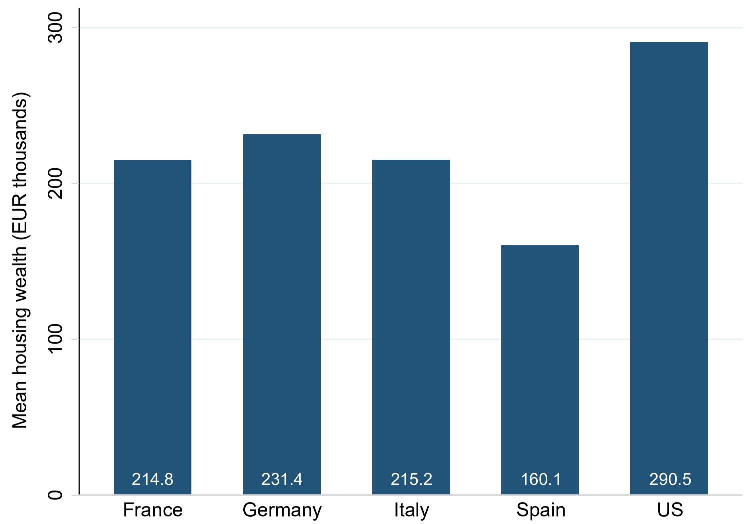
Figure 1 The Extensive and the Intensive Margins of Housing Wealth: Homeownership and the Value of Housing Wealth



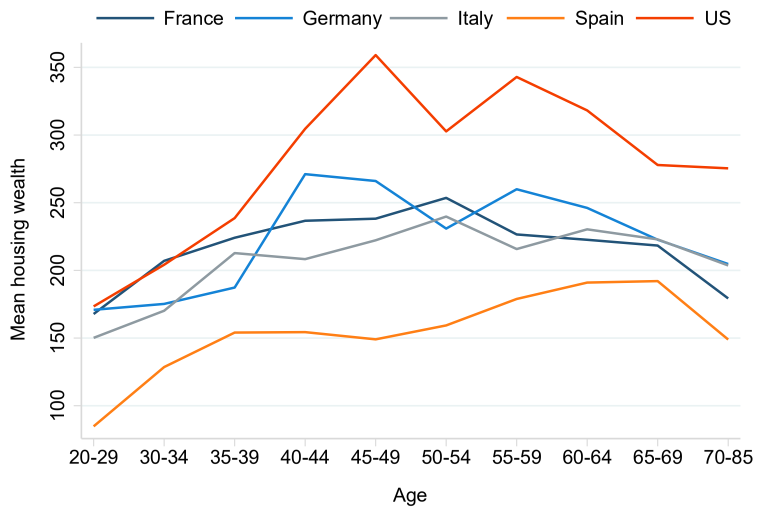
(a) Homeownership Rate



(b) Homeownership Rate by Age



(c) Mean Housing Wealth



(d) Mean Housing Wealth by Age

Source: Household Finance and Consumption Survey, wave 2014; Survey of Consumer Finances 2016.
Note: The upper panels show the homeownership rate across countries and over the life cycle. The lower panels show the mean housing wealth of homeowners (in thousands of EUR) across countries and over the life cycle. The homeownership rate is measured using the indicator of ownership of the household main residence.

empirical age profiles of homeownership rates and holdings of housing and total net wealth for each of the five countries.

Through the lens of the estimated model, we then interpret the substantial differences in homeownership rates and housing wealth across the five countries. We propose a decomposition in which, moving from one country (e.g., Germany) to another (e.g., Spain), we switch one by one from the German parameter values to the Spanish ones, in each step recording the effect of the given factor on the housing wealth variable (homeownership or mean housing wealth–income ratio).[1]

To our knowledge, this is the first paper that uses an estimated life-cycle model of housing to systematically document drivers of differences in the extensive and intensive margins of housing wealth across advanced economies. We find that all three groups of factors above contribute to explaining the cross-country differences in homeownership and housing wealth, although preferences much less than house price beliefs and housing market institutions.

As for the extensive margin of housing wealth, differences in homeownership rates are strongly affected by two variables: (i) house price beliefs and (ii) the rental wedge, the difference between rents and maintenance costs, which reflects the quality of the rental market and the segmentation between rental and owner-occupied housing markets. These two factors are key for the decision whether to buy vs. rent a house: a higher rental wedge and higher expectations of house price growth make renting less appealing and increase the share of homeowners. Both elements contribute roughly equally to explaining the gaps in homeownership rates across countries and both of them matter throughout the life cycle.

Quantitatively, the two channels are powerful: small differences in long-run house price beliefs and the rental wedge result in large differences in homeownership rates. The rental wedge ranges from around 2% in France and the U.S., to 2.8% in Germany, 3.7% in Spain and almost 5% in Italy, reflecting a less efficient rental market. Our model implies that the

[1]Our model is far from linear due to house selling cost and precautionary saving. To account for this fact, in the decomposition we permute over all possible paths in which parameters can switch. We then report the average contribution of each factor and the spread across the paths. These statistics are informative about the average effect of each factor as well as the range of likely effects.

2 p.p. difference in rental wedges leads roughly to a 25–30 p.p. difference in homeownership rates between Germany vs. Italy. Mean long-run house price beliefs range between 0% in Italy and 2.8% in France, reflecting the historical growth in aggregate house prices. Across countries, a 1 p.p. difference in house price beliefs results roughly in a 15 p.p. difference in the homeownership rate. These considerations imply that small differences in long-run house price beliefs—well within the range documented in survey data—are a powerful driver of homeownership in a model, substantially affecting important economic decisions of households. As for other factors, tighter collateral constraints and steeply growing labor incomes reduce the homeownership rate particularly for the youngest households, while the bequest motive affects the homeownership in particular among older households.

Regarding the intensive margin of housing wealth, differences in housing wealth of homeowners as measured by the mean ratios of housing wealth to income, are mostly driven by maintenance costs, which in effect reduce homeowners' return on housing wealth. Quantitatively, the estimated maintenance costs for Germany (2.6% of housing wealth) are roughly half those in Spain (4.9%), France (6%) and the U.S. (7%), implying higher housing wealth in Germany by a multiple of 2–4 worth of annual incomes. Other factors that matter for the accumulation of housing wealth (although less than maintenance costs) are the housing preference, the rental wedge and house price beliefs. We estimate that Germany has a lower share of housing consumption (of 0.186) than the other countries (ranging between 0.210 and 0.307), which is reflected in a positive contribution of the parameter to housing wealth. Roughly twice as large as in Germany, the rental wedge in Italy reduces housing wealth as marginal buyers purchase smaller houses. Higher house price growth beliefs increase the amount of housing wealth in Spain and the U.S. (compared to Germany) as existing homeowners upgrade to buy larger houses. The strength of the effects of the various factors on housing wealth rises with age, reflecting the gradual accumulation of the stock of housing wealth over the life cycle (relative to the flow of income).

Our paper also contributes to the existing literature with a solution method for models with illiquid housing, a variant of the discrete–continuous endogenous grid method (Carroll, 2006 and Iskhakov et al., 2017), which we implement so that it is fast and robust enough to estimate a realistic quantitative life cycle model across countries with widely ranging distributions of housing wealth. Different from Iskhakov et al. (2017), our solution method does not require adding taste shocks, given the presence of income and house price shocks, which naturally smooth out some kinks in the value function.

The paper is structured as follows. The next section relates our setup and findings to the literature. Section 3 presents and discusses the model. We then describe the model estimation and identification strategy in section 4 before documenting the structural estimates in section 5. Section 6 contains our key results on decompositions for homeownership rates and housing wealth. Section 7 provides supporting evidence from surveys of expectations and data on housing market institutions to document that our structural estimates are reasonable. Section 8 concludes. The appendices provide further details on the model, computational techniques and empirical results.

2 Modeling Housing—Literature Review

The bulk of the work investigating cross-country differences in wealth is reduced-form. Most structural work on housing analyzes one or two countries or a role of a particular factor for the homeownership or accumulation of housing wealth (e.g., collateral constraints, transaction costs, quality of the rental market or financial innovations). In contrast, our paper models various factors jointly and quantifies their contributions to differences in housing wealth in a 'horse race' within a single encompassing model estimated for the five countries. In addition to structural work on housing, our paper is also related to recent work measuring and modeling house price beliefs, housing market institutions and preference heterogeneity.

Structural Modeling of Housing. Our model is based on the setup pioneered by Yao and Zhang (2005), Li et al. (2016), Bajari et al. (2013) and others, who solve and estimate a standard model of housing demand with adjustment costs. Compared to Li et al. (2016), our model includes heterogeneity in preferences and beliefs.

Existing calibrated or estimated models of housing were applied to analyze quantitatively various trends in the data, mostly focusing on the homeownership rate in the U.S. (different from our interest in quantifying long-run drivers of housing wealth). For example, Chambers et al. (2009) estimate that mortgage innovation (rather than demographics) accounted for about two thirds of the increase in the U.S. homeownership rate between 1965 and 2005. Attanasio et al. (2012) model individual demand for housing over the life cycle focusing on the effects of income, house prices and transaction costs. Analyzing the increasing homeownership rate in the U.S., Halket and Vasudev (2014) quantify the contribution of financial constraints, housing illiquidities and house price risk to homeownership and mobility over the life cycle. Focusing on the U.S. housing boom of the 2000s, Landvoigt (2017) investigates whether housing choices of households can be explained by a rational model with reasonable expectations about future house prices. Paz-Pardo (2024) estimates that riskier and more unequal earnings contributed substantially to the decline in the homeownership rate among younger U.S. households (despite improvements in financial conditions).

A few recent papers focus on structural models of housing wealth across countries. Huber et al. (2024) analyze how the efficiency of rental housing markets affects homeownership and wealth inequality. While rental market efficiency (i.e., the rental wedge) can explain the different homeownership rates across countries, wealth inequality is mainly driven by mortgage market characteristics (interest rate spreads between mortgage and deposit rates, loan-to-value requirements). Compared to their model, we allow in our setup for differences in beliefs and preferences and estimate our model (to match the levels of homeownership and housing wealth). Hintermaier and Koeniger (2024) study how differences in household finance affect the transmission of monetary policy to consumption. Kaas et al. (2021) model in detail three housing institutions in Germany relevant for the comparison with the U.S.: social housing sector, high transfer taxes when buying real estate (transaction costs) and no tax deductions for mortgage interest payments by owner-occupiers.[2]

Compared to our setup, the existing life cycle models are often calibrated, not estimated,

[2] The transfer tax in Kaas et al. (2021) is in line with our sale costs; however, we focus on explaining differences in housing wealth across more countries. They find that reducing transaction costs to the U.S. level (by 4.7 p.p.) would shift homeownership in Germany up by 6 to 14 p.p. over working life. (The effect in our model is much smaller, more in line with the estimates of Halket and Vasudev, 2014.)

do not include risky house prices, or capture house size on a discrete grid of a few values (not as a continuous variable).

House Price Beliefs. A booming literature has measured and analyzed empirical facts about subjective house price expectations of households (see, e.g., Adelino et al., 2018, Ben-David et al., 2024, Kuchler and Zafar, 2019 and the review of Kuchler et al., 2023). In general, this work finds pervasive differences in house price expectations across households with only a small part of the heterogeneity explained by observables.

Importantly for our results on the extent of differences in house price beliefs, Giglio et al. (2021) estimate heterogeneous and persistent *individual* fixed effects in beliefs. Similar to our modeling assumption, heterogeneity in beliefs is not well explained by observable respondent characteristics such as gender, age or wealth. In addition, they find a robust relationship between beliefs and portfolio allocations (documenting that beliefs matter for economic actions). Similarly, Liu and Palmer (2021) document that survey-based house price beliefs matter for real estate investment decisions (and more so when subjective past house price growth is used as an additional predictor of behavior even conditional on stated expectations).

Separate work uses structural models to analyze how various ways to process information and form beliefs about house prices matter for accumulation of housing and financial wealth (see, e.g., Bailey et al., 2018, Kaplan et al., 2020, Malmendier and Steiny Wellsjo, 2024, Kindermann et al., 2021 and others). Similar to Landvoigt (2017), we estimate house price beliefs from moments of housing and total wealth (although his focus is on short run beliefs during the U.S. housing boom of the 2000s, while ours is on long run beliefs).

Housing Market Institutions. A large literature has recognized that differences in housing market institutions across countries affect accumulation of wealth (including housing wealth) and the response of the economy to shocks and policies; see Davis and Van Nieuwerburgh (2015) and Piazzesi and Schneider (2016) for reviews. Our calibrations and estimates below build on the work measuring the flexibility of the housing market institutions (e.g., Cardarelli et al., 2008 and Andrews et al., 2011) in terms of collateral constraints (down payment requirements), housing transaction costs and the quality of rental housing markets. Using structural models, Greenwald and Guren (2021) estimate the degree of segmentation between rental and owner-occupied housing markets in the U.S. and show that the highly frictional markets imply a large effect of credit shocks on house prices but a small effect on the homeownership rate. Landvoigt et al. (2015) and Piazzesi et al. (2020) analyze the effects of collateral constraints and search activity on the cross section of house prices in a framework with many housing markets segmented by quality.

Our paper complements the reduced-form empirical work that has estimated the role of housing market institutions in household-level and aggregate data. For example, Chiuri and Jappelli (2003) find in household-level data that a wider availability of mortgage finance, as measured with down payment ratios, affects the age profile of homeownership, especially at the young end. We use a structural model to document a similar pattern: tighter collateral constraints reduce homeownership of young households (see section 6 below). Section 7.2 below provides further evidence on measures of quality of rental markets across countries.

In aggregate time-series data across countries, it has been documented that monetary policy stimulates consumption, residential investment and house prices more strongly in countries with a larger flexibility and development of mortgage markets (Calza et al., 2013 and Corsetti et al., 2021).

Preference Heterogeneity: Impatience. Many empirical papers document substantial differences in estimates of the discount factor across households; see Frederick et al. (2002) for a review. Epper et al. (2020) estimate that time discounting reported in incentivized experiments is correlated in a stable way with individuals' positions in the distribution of wealth: more patient households accumulate more wealth.

Some modeling work found it useful to allow for heterogeneity in impatience, to capture the extent of heterogeneity in wealth, financial assets and the marginal propensity to consume found in the data (Krusell and Smith, 1998, Carroll et al., 2017, Krueger et al., 2016, Calvet et al., 2024, Aguiar et al., 2024).

3 A 'Canonical' Life Cycle Model of Housing

Our model concerns a realistic life cycle of a household agent who derives (geometrically discounted) utility flows from its housing and non-housing consumption; upon death, the agent receives a "warm glow" terminal payout based on the amount of wealth he bequeaths. Each period, the household makes a discrete housing status decision—whether to rent, stay in the currently owned house, or move to purchase another house—and then continuous decisions about how much to consume (versus save) and the size of home to purchase or rent. Budget constraints and value functions depend on the housing status.

Housing is an illiquid asset: selling a house is subject to transaction costs proportional to the value of the house. The household's end-of-period financial position is subject to a collateral constraint based on the house he owns: he can hold negative non-housing wealth, but only up to a percentage of the house value. Housing also serves as a risky asset, as house prices follow a geometric random walk with drift. For tractability, we treat housing debt as completely liquid, absorbed into the non-housing financial asset.

At the start of each period, the household faces three shocks: a permanent shock to labor income (permanent productivity), a purely transitory shock to labor income (including unemployment), and a shock to the value the house he owns (if any). Forward looking agents account for these future risks when making optimizing decisions about consumption and housing in the present. For details of our solution method, see Appendix A.[3]

3.1 Model Statement

We begin by specifying the model primitives. We then demonstrate that the model permits a normalization (by permanent income and the housing price) that reduces the dimensionality of the state space (in each period) from four to two continuous dimensions.

[3] Our model is based on the influential work of Yao and Zhang (2005), Li and Yao (2007) and others.

Finally, we discuss how we extend the literature by allowing for differences in impatience and beliefs.

3.1.1 Model Sequence

In time period t, when household i is headed by someone j_{it} years old, the household head's state (at the moment when he makes its decisions for the period) is characterized by four real values: liquid market resources M_{it}, the size of the house that he already owns $\overline{H}_{it}$, its permanent income level P_{it}, and the price level of housing relative to non-housing goods π_t. An agent that does not own a house (because he rented at time $t-1$, or because this is the very first model period) has $\overline{H}_{it} = 0$.

The sequence of events in each discrete period t can be summarized as follows:

1. The living household agent experiences and observes a permanent income shock ψ_{it}, a transitory income shock θ_{it} and a shock to the value of his house η_t.

2. The agent receives capital income from his retained financial assets A_{t-1} and non-capital (labor) income Y_{it}.

3. The agent makes a discrete decision d_{it} about whether to rent a home ($d_{it} = 0$), stay in the currently owned house ($d_{it} = 1$), or move to a new house ($d_{it} = 2$).

4. The agent makes a continuous decision about how much to consume C_{it} and the size of house to live in H_{it}; the constraints of this decision depend on his discrete choice and his state variables.

5. The agent pays for his consumption and housing choice (depending on his discrete choice), leaving him with A_{it} in retained financial assets.

6. The agent transitions to the next period, experiencing a mortality shock; a surviving household ages to $j_{it+1} = j_{it} + 1$ years old.

3.1.2 Household Preferences

We assume that agents have CRRA preferences (with coefficient ρ) over a Cobb–Douglas aggregation of consumption C_{it} and housing H_{it}, with a weight of ω on housing:

$$U(C_{it}, H_{it}) = \frac{(C_{it}^{1-\omega} H_{it}^{\omega})^{1-\rho}}{1-\rho}. \tag{1}$$

Note that from the perspective of current period utility flows, the agent is indifferent to whether he rents or owns the house—only the *size* of the house is relevant. The household agent discounts future (expected) utility flows at a rate of β per period.

If the owner household dies at the end of period t, he receives a terminal "warm glow" of utility based on his final net worth (discussed below), which also has a CRRA form with scaling factor L, representing bequest motive intensity:

$$B(\widehat{W}_{it}) = L\,\frac{\widehat{W}_{it}^{1-\rho}}{1-\rho}. \tag{2}$$

A household with age j_{it} dies at the end of the period with probability D_j and survives to the next period with complementary probability $1-\mathsf{D}_j$. We assume that there is some maximum age J beyond which the agents cannot live, so $\mathsf{D}_J = 1$.

3.1.3 Exogenous Dynamics

The household's non-capital income Y_{it} follows a standard permanent–transitory process, with an age-dependent expected permanent income growth factor of Γ_j (which includes an aggregate income component):

$$Y_{it} = \theta_{it} P_{it}, \qquad P_{it} = \Gamma_j \psi_{it} P_{it-1}. \tag{3}$$

We assume that the (mean one) permanent income shocks ψ_{it} are drawn iid and distributed lognormally. The transitory income shocks θ_{it} are likewise lognormally distributed, but with a point mass at $\underline{\theta}$ (representing unemployment benefits).

The price of housing relative to consumption π_t is also stochastic and follows a geometric random walk with drift (by factor G):

$$\pi_t = G\eta_t\pi_{t-1}. \tag{4}$$

The house price shock η_t is mean one and lognormally distributed, and assumed to be shared across all households i in period t.[4]

3.1.4 Choices and Budget

As noted above, the agent's decision-time state is characterized by $(M_{it}, \overline{H}_{it}, P_{it}, \pi_t)$, and he makes a discrete choice $d_{it} \in \{0, 1, 2\}$ followed by a continuous choice over C_{it} and H_{it}. When making his continuous choice, the agent must obey a collateral constraint on his end-of-period financial position, characterized by his end-of-period liquid wealth A_{it} and the size of house that he owns $\widehat{H}_{it}$ (which is zero for renters):

$$A_{it} + (1-\delta)\pi_t \widehat{H}_{it} \geq 0, \qquad \widehat{H}_{it} \equiv \mathbf{1}(d_{it} > 0) H_{it}. \tag{5}$$

That is, a household can end a period with negative financial assets, but he can only borrow proportionally to the value of its owned house. The parameter δ can be (roughly) interpreted as the required fraction of a home's value that must be provided as a down payment; its additive complement is the fraction of a home's value that can be used as loan collateral. Renters must hold non-negative end-of-period assets A_{it}.

If the household chooses to rent ($d_{it} = 0$) or to purchase a house ($d_{it} = 2$), any currently owned house is sold for its market value $\pi_t \overline{H}_{it}$; the agent pays proportional transaction cost ϕ, representing moving costs, selling cost, and transfer taxes. This leaves him with a single "net worth" level of:

$$W_{it} = M_{it} + (1-\phi)\pi_t \overline{H}_{it}. \tag{6}$$

This value does not exist and is not relevant for an agent that chooses to remain in his already-owned home ($d_{it} = 1$).

Renter. We assume that the intensive margin of rental housing is purely transitory: the household can freely choose the size of his rented home each period, abstracting from any moving or search costs. Rent is charged according to the market value of the home, by proportion $\widehat{\alpha}$. Hence an agent who chooses to rent a home in period t will retain

[4]Note that in our estimation, households can have different *subjective expectations* about the average growth rate of housing relative to other goods. For notational simplicity, we only specify this feature below in equation (17).

end-of-period financial assets of:

$$A_{it} = W_{it} - C_{it} - \widehat{\alpha}\pi_t H_{it} \text{ if } d_{it} = 0. \tag{7}$$

Total rental cost $\widehat{\alpha}$ represents the sum of maintenance cost proportion λ (discussed below) and a "rental wedge" parameter α, representing frictional costs or inefficiencies in the rental market.[5]

Stayer. A household agent that chooses to remain in his currently owned home can freely choose his consumption level C_{it} (subject to the constraint in (5)), but his choice of house size is strictly limited to that of the one he owns: $H_{it} = \overline{H}_{it}$ if $d_{it} = 1$. Such a household must pay *maintenance costs* (including property taxes) on his owned home at proportion λ of the house's value, so that end-of-period liquid assets will be:

$$A_{it} = M_{it} - C_{it} - \lambda\pi_t H_{it} \text{ if } d_{it} = 1. \tag{8}$$

Mover. After selling his previously owned house (if any), an agent who chooses to move to a new owned home can freely choose his level of consumption C_{it} and the size of house that he purchases H_{it} (again subject to the collateral constraint in (5)). However, he must pay maintenance costs on his newly purchased home, based on its value, hence his end-of-period liquid assets will be:

$$A_{it} = W_{it} - C_{it} - \lambda\pi_t H_{it} \text{ if } d_{it} = 2. \tag{9}$$

Note that (after selling his prior house) the mover's simultaneous decision on C_{it} and H_{it} is equivalent to a sequential decision on H_{it} only, followed by the stayer's decision over C_{it} given H_{it}.

Next period's liquid market resources and housing are determined as follows:

$$M_{it+1} = RA_{it} + Y_{it+1} \qquad \text{and} \qquad \overline{H}_{it+1} = \widehat{H}_{it}. \tag{10}$$

If the agent dies, we assume that his estate is liquidated without transaction costs, resulting in a final net worth amounting to:

$$\widehat{W}_{it} = (A_{it} + \pi_t \widehat{H}_{it}). \tag{11}$$

[5] We structurally estimate the parameter α, while the rental cost $\widehat{\alpha} = \lambda + \alpha$ is the "household-facing" parameter.

3.1.5 Recursive Formulation and Normalization

At the terminal age J, when the household agent will surely die at the end of the period, the agent's maximum value of being in any state is given by:

$$\mathrm{V}_J(M_{it}, \overline{H}_{it}, P_{it}, \pi_t) = \max_{C,H,d} U(C,H) + B(\widehat{W}_{it}) \qquad \text{s.t. (1)–(11).} \tag{12}$$

At any non-terminal age $j_{it} < J$, the agent's maximum value of being in any state (assuming he acts optimally in all future periods) can be expressed as:

$$\mathrm{V}_j(M_{it}, \overline{H}_{it}, P_{it}, \pi_t) = \max_{C,H,d} U(C,H) + (1-\mathsf{D}_j)\beta\mathbb{E}_t\left[\mathrm{V}_{j+1}(M_{it+1}, \overline{H}_{it+1}, P_{it+1}, \pi_{t+1})\right] + \mathsf{D}_j B(\widehat{W}_{it})$$

$$\text{s.t. (1)–(11), for } j \in \{j_0, \cdots, J-1\}. \tag{13}$$

Following Li and Yao (2007), we simplify the problem by normalizing out the price state variables. Particularly, all money-metric variables are divided through by the agent's current permanent income level P_{it}, while the housing variables are first multiplied by the housing price level π_t and then divided by permanent income. We denote normalized variables by using lowercase:

$$m_{it} \equiv M_{it}/P_{it}, \qquad c_{it} \equiv C_{it}/P_{it}, \qquad a_{it} \equiv A_{it}/P_{it}, \qquad w_{it} \equiv W_{it}/P_{it}, \quad y_{it} \equiv Y_{it}/P_{it} = \theta_{it},$$

$$\overline{h}_{it} \equiv \overline{H}_{it}\pi_t/P_{it}, \qquad h_{it} \equiv H_{it}\pi_t/P_{it}, \qquad \widehat{h}_{it} \equiv \widehat{H}_{it}\pi_t/P_{it}, \qquad \widehat{w}_{it} \equiv a_{it} + \widehat{h}_{it}. \tag{14}$$

The value function itself is normalized by the composite factor $(P_{it}/\pi_t^{\omega})^{1-\rho}$, so it can be expressed as:

$$\mathrm{v}_j(m_{it}, \overline{h}_{it}) \equiv \mathrm{V}_j(M_{it}, \overline{H}_{it}, P_{it}, \pi_t)\Big/(P_{it}/\pi_t^{\omega})^{1-\rho}. \tag{15}$$

With these substitutions, the normalized problem can be compactly written as:

$$\begin{aligned}
\mathrm{v}_j\Big(m_{it}, \overline{h}_{it}\Big) &= \max_{c,h,d} U(c,h) + (1-\mathsf{D}_j)\beta\,\mathbb{E}_t\left[\mathrm{v}_{j+1}\Big(m_{it+1}, \overline{h}_{it+1}\Big)\left(\frac{\Gamma_{j+1}\psi_{it+1}}{(G\eta_{t+1})^{\omega}}\right)^{1-\rho}\right] + \mathsf{D}_j B(\widehat{w}_{it}) \\
&\text{s.t.} \qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad (16)\\
a_{it} &= \begin{cases} m_{it} + (1-\phi)\overline{h}_{it} - c - \widehat{\alpha}h & \text{if } d=0 \quad \text{Renter} \\ m_{it} - c - \lambda h, \qquad h = \overline{h}_{it} & \text{if } d=1 \quad \text{Stayer} \\ m_{it} + (1-\phi)\overline{h}_{it} - c - (1+\lambda)h & \text{if } d=2 \quad \text{Mover} \end{cases}, \\
\widehat{h}_{it} &= \mathbf{1}(d>0)h, \\
0 &\leq a_{it} + (1-\delta)\widehat{h}_{it},
\end{aligned}$$

$$
\begin{aligned}
m_{it+1} &= \frac{R}{\Gamma_{j+1}\psi_{it+1}} a_{it} + \theta_{it+1}, \\
\overline{h}_{it+1} &= \frac{G\eta_{t+1}}{\Gamma_{j+1}\psi_{it+1}} \widehat{h}_{it}.
\end{aligned}
$$

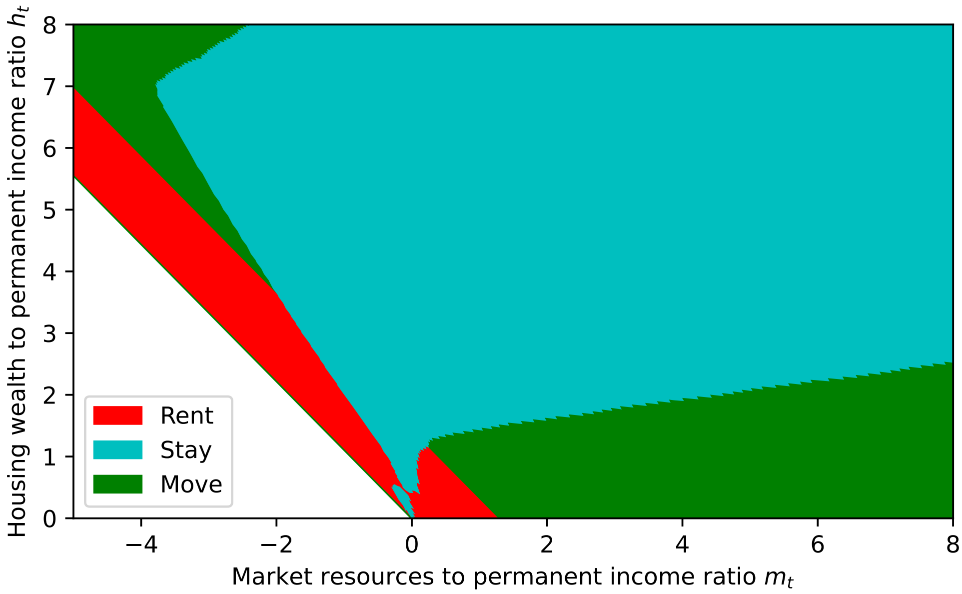
For any given parameterization, the normalized model can be solved recursively backward from the terminal age J to the earliest age in the model, j_0. Within each period, we separately solve the problems of the renter, the stayer, and the mover, computing a value function for each (Appendix A.7). The overall value function for the period is the upper envelope over the three discrete-choice-conditional value functions. The renter's problem is simplified by the fact that housing is also a consumption good in this context; with a Cobb–Douglas aggregator, the agent wants to use a *constant fraction* of his expenditure on housing, effectively reducing the control space to a single variable. Moreover, as noted above, the choice problem for an agent that stays in the same house he already owns is univariate (consumption choice only), and the mover's problem can be treated as a sequential choice of house size (with only one continuous state) followed by the stayer's consumption problem.

We numerically solve the model using the endogenous grid method (EGM) first presented in Carroll (2006), employing a variation on the extension to discrete–continuous models discussed in Iskhakov et al. (2017). Our solution method is fast and robust enough so that we can estimate the model across five countries, which is important for adequately fitting the housing wealth variables and explaining the cross-country differences with the various factors (expectations, institutions, and preferences). See Appendix B for computational details.

3.2 Discussion of the Model

Our model is constructed to account for the key features of homeownership and housing wealth. Housing can either be owned or rented, and is modeled as a continuous variable whose adjustment is subject to transaction costs, proportional to the value of the house. These costs generate a region of inaction, so that homeowners adjust their house size only occasionally. Homeowners benefit from capital gains on housing wealth and are subject to the collateral constraint, which tightens when house prices drop (from a shock to π_t).

Figure 2 Optimal Housing Status as Function of Liquid Market Resources m and Housing Wealth h — An Example



Note: The figure shows an example of the optimal housing status as a function of liquid market resources m and housing wealth h (expressed as ratios of permanent income). The colors denote the optimal housing status: **Red**: Renter, **Cyan**: Stayer, **Green**: Mover ("Go"). The choice is evaluated for a non-college educated individual at age of 48 years for $\beta = 0.9206$ and expected house price growth of $\widehat{G} = 1.0069$.

The optimal housing status depends on liquid market resources and housing wealth, shown by example in Figure 2. When households hold market resources and housing wealth that are roughly balanced, they stay in the current house (the cyan region of inaction, "stay area"). When their market resources are too high or too low relative to the housing wealth, they move (upgrade or downgrade their house). When liquid market resources are low, households rent (red) and some of them save to accumulate wealth for a down payment.[6]

The size of the region of inaction (cyan) depends on preferences and house price beliefs. More patient households have a smaller stay area because they are more willing to pay the near term costs of moving. More patient households also have a smaller rent area because housing delivers a higher return than market resources. Similarly, households

[6] At *very* low levels of liquid wealth, close to the collateral constraint, the agent will sell their current house and downgrade to a smaller one, rather than rent (the narrow green band to the left of the red band). Mathematically, households so close to the borrowing constraint prefer to own a very small home rather than to rent because it represents an additional asset they own in $t + 1$. Likewise, an agent who does not own any home and finds themselves with *extremely* low assets will buy a *very* small home rather than rent. When the model is simulated, agents never visit these regions of the state space.

more optimistic about house prices also have a smaller rent area. Compared to more pessimistic households, the stay area of more optimistic households is shifted upward as they are willing to hold a larger house (rather than down-size) because they believe staying in the house increases their wealth. In addition, the stay area of more optimistic households is reduced from below as households with low housing wealth are more willing to move, upgrade and benefit from the expected house price increases. The width of the "stay area" also scales with frictional transaction costs ϕ: as transaction costs go to zero, the region of inaction shrinks to nothing as households can costlessly move each period (as if they were model renters).

Our model is different from the models that study durable consumption (e.g., Carroll and Dunn, 1997 and Berger and Vavra, 2015) or portfolio choice between liquid and (generic) illiquid assets (e.g., Kaplan and Violante, 2014 and Bayer et al., 2019). Those models do not focus on the discrete choice between renting and owning a house and adjusting its size; instead, they study the choice between adjusting or not the stock of durable goods or illiquid assets. Also, they do not target the life cycle profile of the homeownership rate and housing wealth, typically do not account for risky house prices and heterogeneous expectations, and are usually calibrated, not estimated.

When estimating the model, we allow for a (modest) degree of heterogeneity in impatience and house price expectations. Specifically, we assume that the economy consists of households with varying degrees of impatience and expected mean growth rate of house prices. Beliefs about (average) house price growth $\widehat{G}$ are uniformly distributed across households indexed by i, with center $\overline{G}$ and half-width $\widetilde{G}$:

$$\widehat{G}_i = \overline{G} + \widetilde{G}\epsilon_{i1}, \qquad \epsilon_{i1} \sim \text{Uniform}[-1, 1]. \tag{17}$$

To allow correlation between the time discount factor and house price growth beliefs, we specify the (log) time preference rate ϑ as uniformly distributed *conditional* on that individual's house price beliefs. This heterogeneity can be expressed as:

$$\beta_i = \Big(1 + \exp(\vartheta_i)\Big)^{-1}, \qquad \vartheta_i = \overline{\vartheta} + \widetilde{\vartheta}\epsilon_{i2} + \kappa\epsilon_{i1}, \qquad \epsilon_{i2} \sim \text{Uniform}[-1, 1]. \tag{18}$$

Here, κ represents the extent of correlation between house beliefs and patience: A negative value of κ implies that households optimistic about house prices (higher $\widehat{G}_i$) are more patient (higher β_i). This specification ensures that every individual's discount factor $\beta_i < 1$, no matter the distributional parameters. Note that house price beliefs in our model are long-run beliefs about G, with a horizon of the entire remaining lifetime. For the estimation and counterfactual exercises, we discretize permanent heterogeneity with 15 nodes for $\widehat{G}_i$ and 3 nodes for β_i (for each $\widehat{G}_i$), with two education levels; this yields 90 distinct "types" of agents for each country.

Our specification imposes that households permanently differ in their impatience and house price beliefs. This parameterization is in line with the existing work that allows for preference heterogeneity and estimates its extent based on the data on wealth inequality, reaction of spending to income shocks and the structure of household portfolios (see, e.g., Krusell and Smith, 1998, Carroll et al., 2017, Krueger et al., 2016 and De Nardi and Fella, 2017 for heterogeneity in impatience, and Alan et al., 2018, Calvet et al., 2024 and Aguiar et al., 2024 for heterogeneity in risk aversion). In addition, substantial survey evidence documents that expectations of asset prices, including house prices, vary across households. Importantly for our specification of heterogeneity in beliefs $\widehat{G}$ in (17), in which households permanently differ in their expectations, Giglio et al. (2021) estimate heterogeneous and persistent individual fixed effects in beliefs and find that this heterogeneity in beliefs is not well explained by observable respondent characteristics such as gender, age, and wealth. We confirm these results for house price beliefs of European households in section 7.1 below.

4 Estimation and Identification

This section describes how we estimate the model using household-level data on wealth from the five countries and shows how the empirical moments identify structural parameters. In the first stage, some parameters are calibrated using country-level aggregate or micro data. In the second stage, we estimate the remaining parameters by matching moments simulated from the model to those reported in the data.

4.1 Calibration

We begin with an overview of the calibration of parameters, including income processes, age profiles of income and wealth, house prices, and housing market institutions. The model is calibrated, solved, and simulated at an annual frequency; for structural estimation we generate moments for five-year age brackets. We estimate the model country-by-country on cross-country comparable micro data from the 2014 wave of the Household Finance and Consumption Survey for France, Germany, Italy and Spain and the 2016 wave of the U.S. Survey of Consumer Finances.

Table 1 presents the calibration of key statistics of our model using various aggregate and micro data sources. Starting with the coefficient of relative risk aversion, we fix its value at $\rho = 2$ in all countries. We measure survival probabilities $1 - \mathsf{D}_j$ using data from the Human Mortality Database of the University of California, Berkeley for women, to reflect the idea that households plan using the longer expected horizon.

Income Profiles and Processes. For the four European countries, the income profiles and processes were calibrated using cross-sectional and panel (longitudinal) micro data from the 2009–2019 EU Statistics on Income and Living Conditions (EU SILC) and the German SOEP dataset; for the U.S., we use income profiles based on the 1997–2017 PSID data. Similar to other work (e.g., Cocco et al., 2005 and Calvet et al., 2024), we estimate income profiles for groups of households depending on their education: (i) households in which the head does not have a college degree and (ii) those with a college degree. The net unemployment replacement rates and net pension replacement rates were calibrated using OECD data (from Social and Welfare Statistics and Pensions at a Glance, respectively). All households are born at the age of 20 (with the initial time period $j_0 = 0$), retire at the age of 65 (i.e., $T = 45$) and the maximum age is 120 (i.e., $J = 100$). As in Cocco et al. (2005), labor income profiles were estimated by regressing net disposable income on the third order polynomial of age (see Appendix C for details).

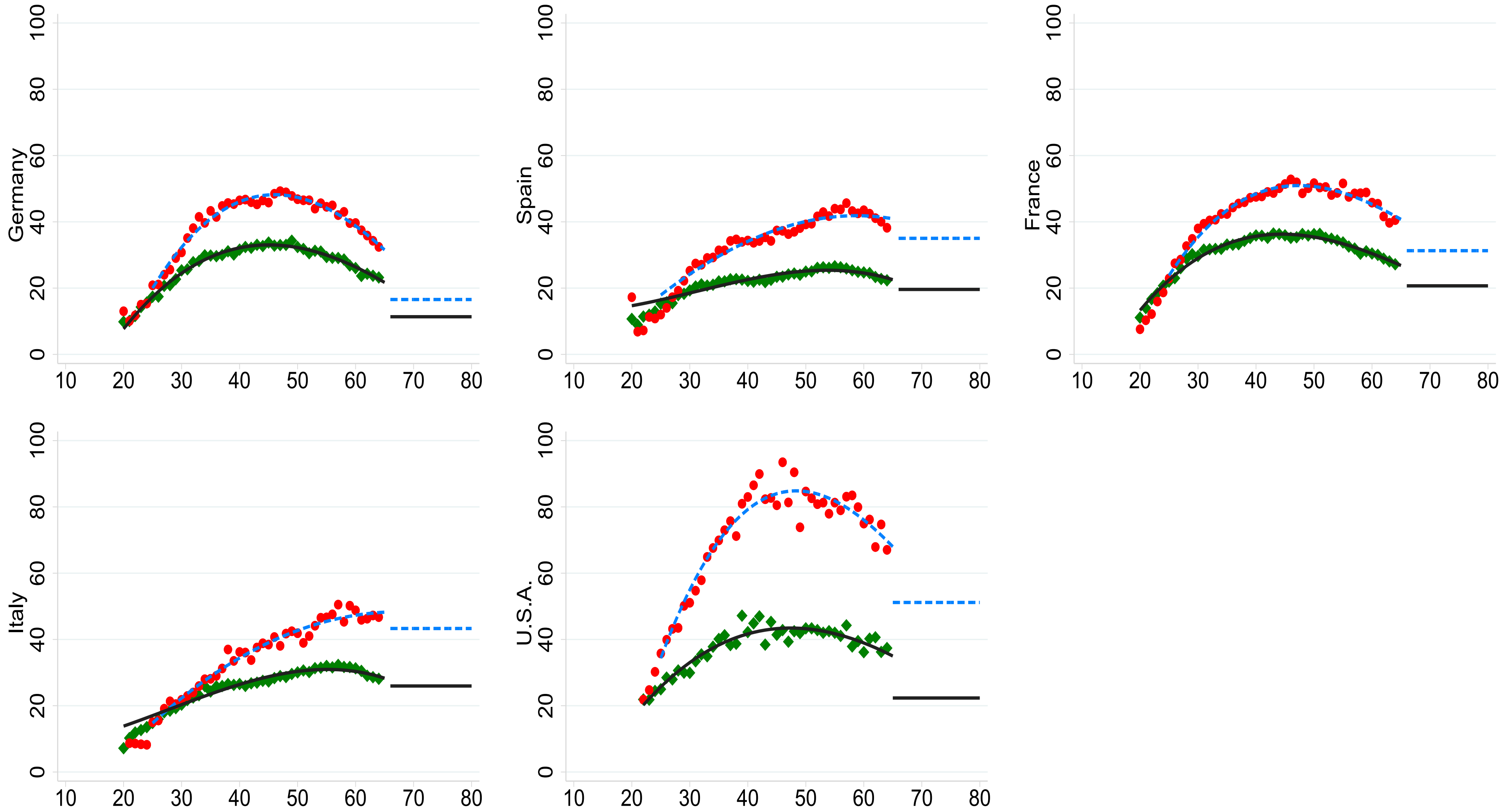
Income profiles differ substantially across the five countries (Figure 3). In the first group of countries (Germany, France and the U.S.) the profiles are strongly hump-shaped, peaking around the ages of 40–50 years. In contrast, in Italy and Spain, incomes keep

Table 1 Calibration of Parameters

Symbol	Description	Value: Germany	Spain	France	Italy	U.S.A.	Source
Preferences							
ρ	CRRA coefficient	2	2	2	2	2	
House prices							
G	Mean growth of house prices	1.004	1.020	1.028	1.000	1.021	Aggregate data, 1995–2020
$\text{std}(\eta)$	Std dev of growth of house prices	0.031	0.075	0.049	0.037	0.064	Aggregate data, 1995–2020
Income processes							
	Share of college graduates	0.311	0.287	0.274	0.134	0.350	HFCN (2016), Table 1.3
Household head without a college degree							
$\text{std}(\psi)$	Std dev of permanent income shock	0.138	0.152	0.134	0.148	0.143	Appendix C
$\text{std}(\theta)$	Std dev of transitory income shock	0.117	0.115	0.111	0.124	0.221	Appendix C
Household head with a college degree							
$\text{std}(\psi)$	Std dev of permanent income shock	0.146	0.148	0.137	0.150	0.143	Appendix C
$\text{std}(\theta)$	Std dev of transitory income shock	0.118	0.097	0.105	0.122	0.205	Appendix C
$\underline{\theta}$	Unemployment probability	0.050	0.050	0.050	0.050	0.050	
μ_U	Net unemployment replacement rate	0.59	0.78	0.68	0.74	0.59	OECD, 2020
τ	Net Pension replacement rate	0.50	0.85	0.75	0.90	0.505	OECD, 2018
T	Mandatory retirement period	45	45	45	45	45	Corresponds to 65 years of age
J	Maximum life cycle period	65	65	65	65	65	Corresponds to 85 years of age
$1-\mathsf{D}$	Survival probability						Human Mortality Database
	Aggr income growth (included in Γ_j)	1.0036	$(1-0.0033)$	1.0009	$(1-0.0077)$	1.0068	Aggregate data, 1995–2019, Fred
Housing market institutions							
δ	Down payment requirement	0.35	0.25	0.20	0.40	0.20	EDW; ECB (2019), Chart 6
ϕ	Cost of selling house (roundtrip)	0.100	0.110	0.130	0.120	0.0783	OECD (2012), Li and Yao (2007)
r	Risk-free interest rate	0.03	0.03	0.03	0.03	0.03	Aggregate data

Note: OECD 2018 refers to data from 2018 from the publication "Pensions at a Glance 2021: OECD and G20 Indicators," OECD Publishing, Paris. OECD 2020 refers to the publication "Benefits and Wages: Net Replacement Rates in Unemployment (edition 2020)," OECD Social and Welfare Statistics (database). Fred refers to the Federal Reserve Economic Data of the Federal Reserve Bank of Saint Louis.

Figure 3 Median Non-Asset Disposable Income by Age



Source: EU Statistics on Income and Living Conditions, cross section, 2009–2019; Panel Study of Income Dynamics, 2009–2017 (biennial).
Note: The figure shows the median income levels (red dots and green diamonds) and smoothed income profiles (black solid and blue dashed curves) in EUR thousands calculated for two education levels, below college and college and above, as described in Appendix C. U.S. values were converted using the exchange rate of 2016.

rising until later in life or even until retirement age. In addition, in all countries, incomes irrespective of educational attainment start around the same level for young people, but incomes of college educated households rise steeply, so that roughly after the age of 30 they substantially exceed incomes of households without a college degree. The gap between the incomes of the two groups continues to widen almost until retirement.

We estimate the standard deviations of permanent and transitory income shocks using the Carroll and Samwick (1997) method on the panel component of the (annual) income data in the EU Statistics on Income and Living Conditions, 2009–2019, the German SOEP 2009–2019 and the (biennial) U.S. PSID, 1997–2017 (see Appendix C). The standard deviations of both shocks are around 0.10 to 0.15, in line with the literature (which is mostly based on U.S. data; e.g., Carroll and Samwick, 1997, the special volume Review of Economic Dynamics, 2010, and Carroll et al., 2014, Table 1 for an overview of estimates in European data).

Wealth Profiles. The empirical moments of age profiles of the seven variables that we use in the SMM estimation below were calculated using micro data from the 2014 wave of the Household Finance and Consumption Survey (for France, Germany, Italy and Spain) and the 2016 wave of the U.S. Survey of Consumer Finances: (i) homeownership rate, (ii) average housing wealth–income ratio of homeowners, (iii) average rent–income ratio of renters, and (iv)–(vii) average and median net wealth–income ratios of homeowners and renters (see Figures 14–17). The net sample sizes range between 4,500 households in Germany and 12,000 households in France. The moments were calculated using the corresponding wealth and income components (and applying household weights). The homeownership rate was calculated based on a dummy variable indicating households' ownership of the main residence. Housing wealth of homeowners reflects the value of the household main residence (and does not include the value of other real estate). Rent–income ratios reflect rent payments of renters as a share household income. Net wealth is the sum of housing wealth and financial wealth, net of total debt.[7]

[7] As this paper focuses on capturing the extensive and intensive margins of housing wealth, we normalized the mean and the median aggregate net wealth–income ratios to be the same across the five countries, which strongly reduces the cross-country variation in estimated mean discount factors $\overline{\beta}$.

The seven moment groups tend to rise with age (except mean rent-to-permanent-income ratio, which is fairly constant), reflecting accumulation of wealth and its components over the life cycle; there is relatively little de-cumulation during retirement. The increases in homeownership rate at younger ages vary across countries, although the gaps between countries tend to persist throughout the life cycle, with the share of homeowners in Germany substantially lower than in Spain, the U.S. and Italy (Figure 1.b). The mean (gross) housing wealth–income ratios of homeowners tend to rise from around 4 to around 6, considerably boosted by the fall of income in retirement. Substantial differences persist across countries, with low levels in the U.S. and high levels in Italy, Spain and France. Mean rent–income ratios range roughly between 0.15 and 0.35, with high levels in France and the U.S.

Figures 14–17 show mean and median ratios of net wealth to income for homeowners and renters. All series tend to rise more steeply than housing wealth–income ratios, reflecting the repayment of (mortgage) debt and accumulation of financial wealth. For homeowners, ratios increase from around 2 to more than 10 for the mean and from around 2 to roughly 8 for the median.[8] For renters, the ratios of net wealth are much lower, ranging typically between 1 and 3 for the mean and well below 1 for the median, and tend to rise only modestly.

House Prices. Rather than structurally estimate mean house price beliefs $\overline{G}$, we instead match it to actual, long-run average growth rate of real house prices in aggregate data, 1995–2020 for the five countries. This choice, analogous to Landvoigt (2017), ensures that the average (long-run) expectations are rational (unbiased), and not unrelated to actual house prices. This feature is appealing also in light of the evidence that house price expectations fully revert toward the unconditional mean of actual house price growth within several years (Li et al., 2023).

The calibration uses aggregate time series on house prices (adjusted for inflation), 1995–2020, from the OECD Analytical House Price Database (Figure 24). The values are: 0%

Net wealth–income ratios were topcoded at 50 for households younger than 65 years and at 200 for the remaining households. We dropped from the sample households with very low annual incomes (less than EUR 3,000).

[8] The net wealth–income ratios for homeowners in Italy at young ages are higher than in the other countries.

for Italy, 0.4% for Germany, 2.0% for Spain, 2.1% for the U.S. and 2.8% for France. The standard deviations of the house price shocks η are calibrated using aggregate house price data and range between 0.031 in Germany and 0.075 in Spain.

Housing Market Institutions. Our calibrations build on the work measuring housing market institutions (following Cardarelli et al., 2008 and Andrews et al., 2011). Specifically, we calibrated the down payment requirement δ primarily using data from Gaudencio et al. (2019), chart 6, p. 15. The statistics on down payment ratios were constructed using the European DataWarehouse (EDW), `https://www.eurodw.eu/`, which collects loan-level data on loans underlying asset-backed securities, including residential mortgage-backed securities. The dataset provides arguably the best available information on loan standards, collected consistently across euro area countries. We calibrate down payment requirements to range between 0.40 for Italy and 0.20 for the U.S. These values reflect similar calibrations in the literature, e.g., Cardarelli et al. (2008). Costs of selling a house were calibrated based on OECD (2012), chapter 2 and Li and Yao (2007). They range between 7.8% in the U.S. and 13% in France. Finally, we set the interest rate r at 3%, accounting for the fact that it reflects both return on saving and interest on mortgages; this value broadly corresponds to real interest rates on mortgages after 1995 (see Table 3 below).

4.2 Structural Estimation

We estimate the remaining model parameters with the simulated moments method (SMM). Specifically, we estimate structural parameters ξ consisting of (i) the spread of house price beliefs $\widetilde{G}$; (ii) housing market parameters, including the rental wedge α and the costs of maintaining a house λ; and (iii) preference parameters, including mean and spread of the (log) time preference rate $\overline{\vartheta}$ and $\widetilde{\vartheta}$, the share of housing in the utility function ω, the magnitude of the bequest motive L, and the interaction between the discount factor and mean house price beliefs κ:

$$\xi \equiv \Big\{ \underbrace{\widetilde{G},}_{\substack{\text{House price}\\ \text{beliefs}}} \quad \underbrace{\alpha, \lambda,}_{\substack{\text{Housing market}\\ \text{institutions}}} \quad \underbrace{\overline{\vartheta}, \widetilde{\vartheta}, \omega, L, \kappa}_{\text{Preferences}} \Big\}.$$

Let $x = \{x_1, \ldots, x_N\}$ be the actual empirical data, $m(x)$ be moments based on these data, $\widetilde{x} = \{\widetilde{x}_1, \ldots, \widetilde{x}_S\}$ be S simulations of data from the model and $\widehat{m}(\widetilde{x}|\xi) = 1/S \sum_{s=1}^{S} m(\widetilde{x}_s|\xi)$ be the counterpart moments simulated from the model (averaged across simulations). The estimation minimizes the weighted distance between moments in the data $m(x)$ and those simulated from the model $\widehat{m}(\widetilde{x}|\xi)$:

$$\widehat{\xi} = \arg\min\,(f(\xi)) \quad \text{with} \quad f(\xi) = \Big(m(x) - \widehat{m}(\widetilde{x}|\xi)\Big)' \Omega^{-1} \Big(m(x) - \widehat{m}(\widetilde{x}|\xi)\Big).$$

For the weighting matrix Ω, we use a diagonal matrix with the inverse variances of the empirical moments, thus putting more weight on the moments for which the data is "more confident". The SMM estimator is then efficient and asymptotically normal:

$$\sqrt{N}(\widehat{\xi}_N - \xi_0) \rightarrow_d \mathcal{N}(0, \Sigma),$$

with the covariance matrix $\widehat{\Sigma} = (\widehat{D}\,\widehat{\Omega}^{-1}\widehat{D'})^{-1}$, for which:

$$\widehat{D'} = \left.\frac{\partial \widehat{m}(\widetilde{x}|\xi)}{\partial \xi'}\right|_{\xi=\widehat{\xi}}.$$

4.3 Identification

To estimate the model for each country, we choose as empirical moments m the following age profiles, using ten age brackets: homeownership rate, average rent–income ratio, average (gross) housing wealth–income ratio of homeowners, and both average and median net wealth–income ratios for homeowners and renters. These moments reflect the distribution of the extensive and the intensive margin of housing and net wealth over the life cycle. The moments are standard in similar work estimating life cycle models with housing, e.g., Li et al. (2016), Bajari et al. (2013) and Landvoigt (2017). The empirical moments $m(x)$ identify the parameters $\xi = \left\{\widetilde{G}, \alpha, \lambda, \overline{\vartheta}, \widetilde{\vartheta}, \omega, L, \kappa\right\}$ as illustrated in Figure 4 motivated by Andrews et al. (2017), which shows how the fitted moments change with a small positive and negative change in the corresponding parameter. As usual for a structural model, each parameter affects almost all simulated moments. Structural identification thus depends on *differential* dependence of moments on parameters, whether qualitatively or in magnitude. The identification arguments presented here do not mean that the parameters do not affect other simulated moments, but rather that we focus on the *strongest* or *unique* effects that differentiate the parameters.

With seven moment groups and ten age brackets per group, our objective function would have 70 moments for the eight parameters to be estimated. However, we omitted four moments from this set and only use the remaining 66; the omitted moments are all for the top age bracket. For all countries and any parameter set that reasonably matches the other moments, the simulated homeownership rate approaches or reaches 100% for the highest age bracket (70+). The jump happens because of a "prudence" effect: when income risk goes to zero, model agents are much more willing to own rather than rent, confident that they will never experience a financial shock that would require them to move. This phenomenon poses problems for the estimation.[9]

Turning to our identification arguments, the overall *level* of homeownership (across ages) identifies the rental wedge parameter α (panel a).[10] A homeowner pays a λ fraction of their home's value in maintenance costs, while a renter pays $\widehat{\alpha} = \lambda + \alpha$ fraction of their unit's value, so that the rental wedge represents the cost *beyond* ownership (representing inefficiency in the rental market, *inter alia*). Thus a higher value of α makes renting less appealing and increases the share of homeowners. Given the costless adjustment of housing for renters, the weight of housing ω in utility is pinned down by the empirical rent–income ratio (panel b). That is, our model predicts that agents will use a constant fraction of their spending on rent, and this fraction is strictly determined by ω.[11]

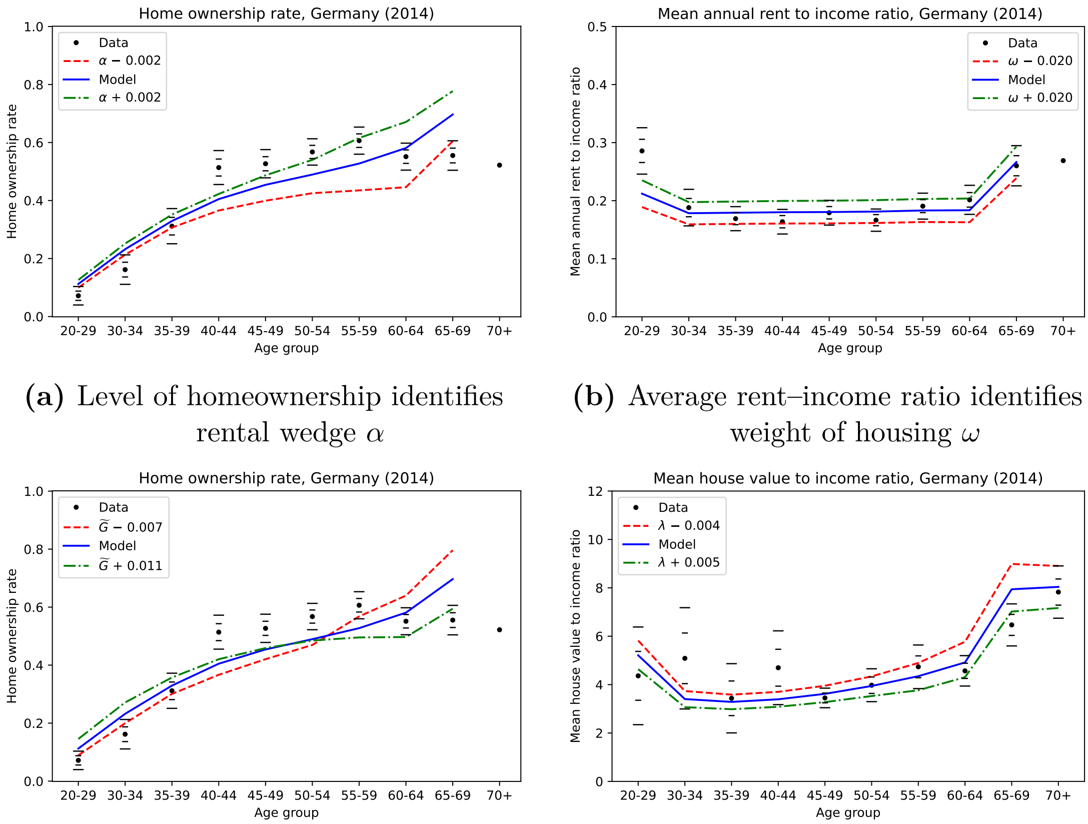
Next, the spread of house price beliefs $\widetilde{G}$ is identified by the *slope or shape* of the homeownership profile (panel c). All else equal, someone being more optimistic about

[9]There are two problems. First, for countries whose actual homeownership rate at older ages is far below 100% (e.g. Germany), the minimizer expends considerable effort to try to rectify this badly matched moment. That is, the objective function is *quadratic* in the gap between simulated and empirical moments, so the estimator wants to avoid "big errors". In doing so, it has to move *other* simulated moments away from their empirical counterparts, leading to an overall poor fit driven by one moment. Second, for countries whose actual homeownership rate is near 100% at older ages (e.g. Spain), the simulated homeownership rate at 70+ reaches or becomes extremely close to 100%. When homeownership is actually 100%, the mean and median net worth to income ratio for renters *does not exist*, nor does the mean rent to income ratio. When the homeownership rate is just barely below 100%, those moments depend on an exceedingly small number of simulated agents, who might choose to rent because of a very unlikely sequence of shocks. To maintain symmetry across all estimated countries, we assign zero weight to the homeownership rate at age 70+, and likewise exclude the moments for renters in this age bracket.

[10]Recall that we do not estimate the mean of beliefs about house price growth. In addition to wanting our model agents' beliefs to be disciplined by reality (on average), it turns out that the level of expected house price growth is difficult to disentangle from the rental wedge. That is, they have nearly identical effects on *all* simulated moments.

[11]Housing utility weight ω drives other moments as well, particularly the mean house value to income ratio, but it is the *only* parameter that substantially affects the rent to income ratio, hence this moment group is what pins down ω.

Figure 4 Identification of Parameters



(a) Level of homeownership identifies rental wedge α

(b) Average rent–income ratio identifies weight of housing ω

(c) Slope of homeownership identifies spread of beliefs $\widetilde{G}$

(d) Average housing wealth of owners identifies maintenance costs λ

Source: Household Finance and Consumption Survey, wave 2014.
Note: The blue solid line shows the fitted values. The red dashed and green dash-dotted lines show how a small negative and positive change in a parameter affect the relevant fitted moment. The dots denote data; the brackets around them denote one and two standard error bands. The figures illustrate the moments for the case of Germany.

future house price growth makes them more likely to prefer homeowning over renting—and to purchase a home earlier in their lifecycle in order to benefit from high returns for longer. People who are very optimistic about future house price growth purchase their house at a young age, while those who are somewhat less optimistic buy their house later in life. This means that if the dispersion of house price beliefs is wider, the homeownership profile rises less steeply as some people buy a house early while others delay until later in life. Conversely, low dispersion in house price growth beliefs would cause the model to predict a sharp uptake of homeownership in a narrow range of ages.

The maintenance cost parameter λ is identified by the level of housing wealth of homeowners (panel d). It is a flow, per-period cost that affects how attractive it is to hold housing wealth relative to liquid wealth. In effect, maintenance costs reduce homeowners' return on housing wealth, hence the more expensive it is to maintain the house, the smaller a house the homeowners buy relative to their income. Recall that the center (mean) of house price beliefs $\overline{G}$ is calibrated to recent historical data for each country. If we did not use aggregate time-series data on house prices to identify the mean house price beliefs, the two parameters $\overline{G}$ and λ would not be separately identified from the available moments.[12]

The strength of the bequest motive L is identified by the shape of the net wealth profiles for homeowners and renters late in life (Figure 11 in Appendix D). Households whose wealth declines less quickly are interpreted to have a stronger bequest motive.

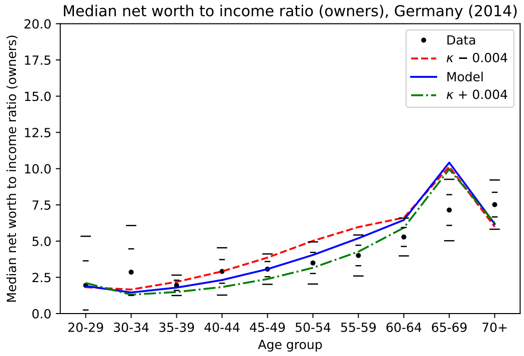
The shape and relative levels of the four wealth-to-income profiles (mean and median for homeowners and renters separately) identify the remaining preference parameters. As typical in consumption–saving models, an agent's (log) time preference rate ϑ is a strong determinant of the rate at which they accumulate assets over their working life: more patient households (lower ϑ) put more weight on the future, making them more willing to defer utility flows into the future. The relationship between ϑ and wealth accumulation is highly convex, with increases in patience associated with progressively more wealth accumulation. Hence the center $\overline{\vartheta}$ and spread $\widetilde{\vartheta}$ of (log) time preference rates are identified by the slope of wealth accumulation and the difference between mean and median (within homeowners and renters, but especially the former; Figures 12 and 13 in Appendix D).

Likewise, the interaction (correlation) between house price beliefs and time preferences κ is identified by the difference in wealth accumulation between owners and renters (Figure 5). That is, a positive value of κ means that optimistic households (who will tend to be owners) are also impatient (higher ϑ), so they will accumulate less wealth; a

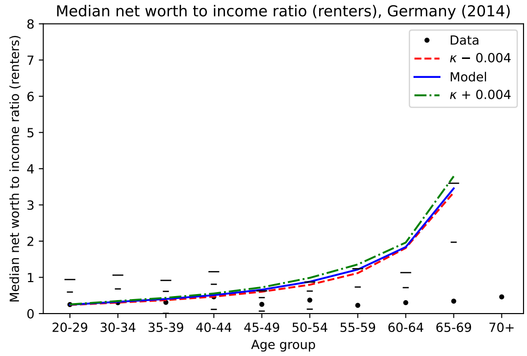
[12] If we instead calibrated λ from some outside source, then the mean of house price growth beliefs $\overline{G}$ would be identified by the housing wealth profile.

To save on free parameters, we do not include a preference for homeowning over renting. Note that, hypothetically, preference for owning would have a different effect than optimism about house prices because the former relates to housing consumption of the (physical) house H_{it} while optimism relates to accumulation of the value of housing wealth $\pi_t H_{it}$ for investment. From a structural identification perspective, the rent–income ratio is determined by housing preference share ω, and is not affected by house price beliefs. So while both housing preference and house price beliefs affect the house value–income ratio, only preferences affect rent–income ratio.

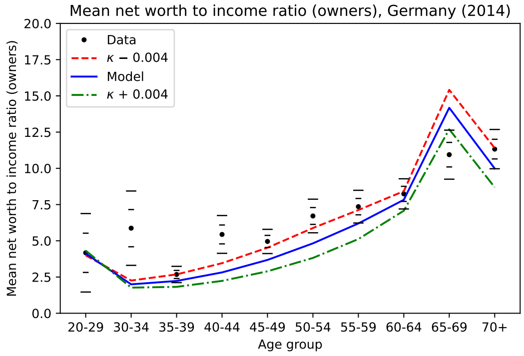
Figure 5 Identification of the Correlation between House Price Beliefs and Time Preferences κ



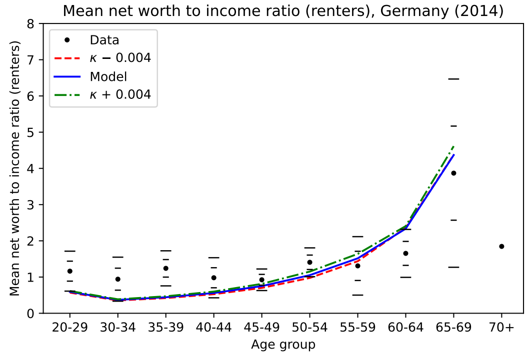
(a) Median net wealth–income ratio of owners



(b) Median net wealth–income ratio of renters



(c) Mean net wealth–income ratio of owners



(d) Mean net wealth–income ratio of renters

Source: Household Finance and Consumption Survey, wave 2014.
Note: The blue solid line shows the fitted values. The red dashed and green dash-dotted lines show how a small negative and positive change in a parameter affect the relevant fitted moment. The dots denote data; the brackets around them denote one and two standard error bands. The figures illustrate the moments for the case of Germany.

negative κ pushes owners to hold more total wealth than renters.[13] A more negative value of κ increases net wealth of owners and reduces net wealth of renters.

5 Structural Estimates

This section presents the structural estimates and documents that the model fits well the key moments of housing wealth.

[13] In our data, renters hold very little wealth, a fairly well-known fact. This relationship is in line with survey evidence on expectations (discussed in section 7.1).

5.1 Estimates of Expectations, Institutions and Preferences

Table 2 shows the structural estimates $\xi = \left\{\widetilde{G}, \alpha, \lambda, \overline{\vartheta}, \widetilde{\vartheta}, \omega, L, \kappa\right\}$ of three groups of parameters : (i) house price beliefs, (ii) housing market institutions and (iii) preferences.

The dispersion in house price expectations $\widetilde{G}$ is estimated to range between 0.7% in France and 3.9% for Spain; see Figure 6. These values are in line with the dispersion of long-run house price expectations of households documented in survey data; see section 7.1 below.

The estimates of maintenance costs λ, which include property taxes and depreciation, range between roughly 2% in Italy and Germany and 6–8.5% in France and the U.S. As we documented above, maintenance costs are identified by the housing wealth to income ratio of homeowners. For countries with relatively high expectations of house price growth (France and the U.S.) and not particularly high housing wealth, the estimation implies substantial maintenance costs, which limit the accumulation of housing wealth.

To cross-check our estimates with external sources, Table 3 below provides a summary of estimates across countries based on the existing studies. Estimates of maintenance costs are quite rare. For the U.S., Poterba and Sinai (2008) calibrate maintenance costs at 3.5% (including property taxes of 1.04%). Net of property taxes, Li and Yao (2007) calibrate maintenance costs at 3%, while Li et al. (2016) estimate them at 1.7%. For European countries, the European Commission Housing Taxation Database (Grünberger et al., 2023) adopts the value of Poterba and Sinai (2008) of 3.5% (including the depreciation of 1% and property taxes of 1%).

Table 2 Structural Estimates

Symbol	Description	Value: Germany	Spain	France	Italy	U.S.A.
House price beliefs						
$\overline{G}-1$	Mean of house price growth beliefs (percent)	0.4	2.0	2.8	0.0	2.1
	(calibrated)	(—)	(—)	(—)	(—)	(—)
$\widetilde{G}$	Spread of house price growth beliefs (percent)	2.73	3.69	0.77	4.28	4.27
		(0.27)	(0.07)	(0.10)	(0.08)	(0.58)
$\overline{G}\mp\widetilde{G}$	Range of house price belief types	[0.98, 1.03]	[0.98, 1.06]	[1.02, 1.04]	[0.96, 1.04]	[0.98, 1.05]
Housing market institutions						
λ	Owned housing maintenance cost (percent)	2.58	4.85	6.03	1.69	8.55
		(0.18)	(0.17)	(0.12)	(0.05)	(0.31)
α	Rental wedge (percent)	2.82	3.74	1.67	4.91	2.30
		(0.08)	(0.09)	(0.03)	(0.04)	(0.13)
$\widehat{\alpha}=\lambda+\alpha$	Implied total rental cost (percent)	5.40	8.59	7.70	6.60	10.85
Preferences						
$\overline{\vartheta}$	Mean of log intertemporal discount rate	−1.511	−2.530	−2.614	−2.456	−1.834
		(0.077)	(0.040)	(0.025)	(0.010)	(0.110)
$\widetilde{\vartheta}$	Spread of log intertemporal discount rate	0.705	0.891	1.136	0.212	0.992
		(0.256)	(0.106)	(0.073)	(0.055)	(0.365)
$\overline{\beta}=\frac{1}{1+\exp(\overline{\vartheta})}$	Discount factor implied by $\overline{\vartheta}$	0.819	0.926	0.932	0.921	0.862
	Range of discount factor types at $\overline{G}^{\star}$	[0.69, 0.90]	[0.84, 0.97]	[0.81, 0.98]	[0.90, 0.94]	[0.70, 0.94]
ω	Share of housing in utility function	0.186	0.291	0.307	0.210	0.296
		(0.004)	(0.009)	(0.004)	(0.001)	(0.006)
L	Bequest motive magnitude	79.45	70.39	3.90	46.87	39.96
		(14.45)	(7.57)	(0.62)	(0.89)	(7.64)
κ	Interaction factor between discount rate	−1.85e−2	−1.58e−2	−0.86e−2	−2.08e−2	−2.64e−2
	and house price growth beliefs	(0.13e−2)	(0.10e−2)	(0.08e−2)	(0.04e−2)	(0.18e−2)
$\min f(\xi)$	Optimal value of the objective function	283.59	379.38	1268.83	400.58	285.95

Note: Numbers in parentheses show standard errors calculated using the delta method. $\star$: The range is calculated as: $1/\left(1+\exp\left(\overline{\vartheta}\pm\widetilde{\vartheta}\right)\right)$. See Figure 6 for the joint distribution of $(\beta,\widehat{G})$ household types.

Table 3 Comparison of Our Structural Estimates with External Data, Percent

Symbol	Description	Germany Structrl	Germany External	Spain Structrl	Spain External	France Structrl	France External	Italy Structrl	Italy External	U.S.A. Structrl	U.S.A. External
Components of the user cost of owning $r+\lambda-\overline{G}$											
$\overline{G}-1$	House price growth[1]	0.4	0.4	2.0	2.0	2.8	2.8	0.0	0.0	2.1	2.1
λ	Maintenance costs[2]	2.58	3.5	4.85	3.5	6.03	3.5	1.69	3.5	8.55	3.5
	Property tax[3]		Yes		Yes		Yes		Yes		Yes
r	Interest rate[4]	3	2.5	3	2.9	3	2.9	3	2.2	3	3.9
	Tax deductions for mortgages[5]		No		No		No		Yes		Yes
$r+\lambda-\overline{G}$	User cost of owning[6]	5.18	5.6	5.85	4.4	6.23	3.6	4.69	5.7	9.45	5.3
Components of the user cost of renting $\widehat{\alpha}\equiv\alpha+\lambda$											
α	Rental wedge[7]	2.82		3.74		1.67		4.91		2.30	
	Rental controls[8]		Yes		No		Yes		Mid		No
	Tenant security[9]		Mid/Yes		Yes		Yes		Yes		No
$\widehat{\alpha}$	Total rental cost[10]	5.40	4.6	8.59	2.2	7.70	3.3	6.60	3.7	10.85	4.7

Note: This table compares our structural or calibrated estimates from Table 2 (columns 'Structrl') with values reported in external sources (data and literature; columns 'External'). The value are shown in percent (of housing wealth, except for the interest rate and house price growth). Some indicators are qualitative.

[1] External data source: Aggregate data, 1995–2020, OECD Analytical House Price Database; see Table 2; values are calibrated.
[2] Maintenance costs include property taxes of 1% and depreciation of 1%. External data source: Poterba and Sinai (2008) for the U.S.A. and Grünberger et al. (2023) for other countries.
[3] External data source: Poterba and Sinai (2008) for the U.S.A. and Grünberger et al. (2023) for other countries, give values of property taxes of around 1%.
[4] External data source: Mortgage interest rates net of inflation, 1995–2020, Grünberger et al. (2023) and, for the U.S., Federal Reserve Economic Data (FRED), Federal Reserve Bank of Saint Louis, 30-Year Fixed Rate Mortgage.
[5] External data source: Kholodilin et al. (2023) and Grünberger et al. (2023).
[6] External data source: Based on values from external data for the three components in the rows above: $r+\lambda-\overline{G}$. Himmelberg et al. (2005) estimates for the U.S. user costs of 3.3–7.1% (see also Poterba and Sinai, 2008).
[7] External data source: Aggregate data, 1995–2020, OECD Analytical House Price Database; see Table 2.
[8] External data source: Weber (2017), Rent laws index.
[9] External data source: Weber (2017), Tenure security laws index and Andrews et al. (2011), Table 20.
[10] External data source: Jordà et al. (2019), housing rental yield, `housing_rent_yd`, average 1995–2020.

Recalling that we set the interest rate $r = 3$ percent, the user cost of owner-occupied housing, the sum of interest rate and maintenance costs net of expected capital gains on housing wealth: $r + \lambda - \widehat{G}$ (Poterba, 1984, Poterba and Sinai, 2008), implied by these values ranges around 5% in Italy and Germany, around 6% in Spain and France, and around 9.5% in the U.S. These values match Himmelberg et al. (2005)'s estimates of user costs across 46 metropolitan areas in the U.S. (with available data), which range between 3.3 and 7.1% (see Poterba and Sinai, 2008 for similar estimates in household level data). Table 3 shows that the user cost of owning across countries, implied by the values for the three components from the literature is comparable.

In a hypothetical frictionless benchmark, the lack of arbitrage ensures that the user cost of owner-occupied housing equals the total rental cost: $r + \lambda - \widehat{G} = \widehat{\alpha}$ (see, e.g., Dougherty and Order, 1982, Poterba, 1984 and many others). In reality, owner-occupied housing is subject to large transaction costs and binding collateral constraints, and rental and owner-occupied housing markets are highly segmented. This means that the user cost of owner-occupied housing may differ considerably from the rental cost. Indeed, our estimates document that this is the case and that the rental wedge $\alpha = \widehat{\alpha} - \lambda$ tends to exceed its frictionless benchmark $r - \widehat{G}$.

The rental wedge α varies substantially across countries, ranging from around 2% in France and the U.S., to 2.8% in Germany, 3.7% in Spain and almost 5% in Italy. A higher wedge reflects a lower quality of rental housing and a higher segmentation between rental and owner-occupied housing markets, making housing for renting harder to substitute with housing for owning: a higher wedge makes renting less appealing and increases the share of homeowners.[14] Our structural estimates of the rental wedge correspond to the measures of the quality and segmentation of the rental markets in a separate literature

[14] In Greenwald and Guren (2021)'s general equilibrium model, the segmentation between rental and owner-occupied housing markets determines the slope of the housing "tenure supply" curve, the menu of house price–rent ratios at which landlords are willing to supply different amounts of rented housing to the owner-occupied market. When it is difficult to convert between renter-occupied and owner-occupied housing, the tenure supply curve is steeper, implying that housing demand shocks (e.g., due to changing credit availability) strongly affect the price–rent ratio and only slightly the homeownership rate. In such setup with substantial segmentation the rental wedge can be high.

In the setup with segmented housing markets, the size of the rental wedge can be driven by various supply side factors, e.g., quality of institutional features of housing markets or preference for renting and owning housing. Different from e.g., Foote et al. (2020), our focus here is on the long-run differences in homeownership rates and we do not analyze higher frequency (e.g., business-cycle) changes.

(Huber et al., 2024, Andrews et al., 2011, Greenwald and Guren, 2021, Malmendier and Steiny Wellsjo, 2024; see also section 7.2 below).[15]

Our estimates of the total rental cost implied by maintenance costs and the rental wedge, $\widehat{\alpha} = \lambda + \alpha$, range between 5.4% (of the house value) in Germany and 10.9% in the U.S. These values tend to be higher than the historical evidence from aggregate time series on rent–price ratios of Jordà et al. (2019) of around 3–5% (see Table 3). These aggregate data may for our purposes under-estimate the relevant rent–price ratios, especially in countries with frictional rental markets (such as Italy), where aggregate rents are based on rental housing, which is of lower quality than owner-occupied housing. For the U.S., Li and Yao (2007) calibrate rental cost at 7.5% and Li et al. (2016) estimate them at 4.9% (consisting of maintenance costs of 1.7% and the rental premium of 3.2%).

Similar to house price beliefs, we assume that the (log) time preference rate ϑ is uniformly distributed (conditional on the individual's house price beliefs) over an interval that we estimate. The parameters $\overline{\vartheta}$ and $\widetilde{\vartheta}$ are pinned down by the distribution of net wealth (mean and median for renters and homeowners). To limit the differences in discount factors across countries, we normalize the mean net wealth in each country to coincide (at the value of its mean across countries). The implied median discount factors $\overline{\beta} = \left(1 + \exp(\overline{\vartheta})\right)^{-1}$ lie at around 0.82–0.93, values in line with many estimates in the literature. The dispersion $\widetilde{\vartheta}$ conditional on expected house price beliefs is quite small (Figure 6), typically less than 0.05 (somewhat higher for pessimistic households in Germany).

The estimated share ω of housing expenditures on total consumption ranges between 0.184 in Germany and 0.308 in France. These values correspond quite well to the share of spending on housing measured in national accounts and micro data on consumption expenditures (see, e.g., Andrews et al., 2011, Figure 1).

The bequest magnitude L ranges between $L = 3.9$ for France and 70 to 79 in Spain and Germany. These differences translate into similar marginal propensities to consume of the "moment of dying consumption," defined as $L^{-1/\rho}$. That is, the warm glow bequest motive

[15] Huber et al. (2024) model the rental wedge as the fraction of rental units that gets lost in the renting process due to tighter rental market regulation. While we model the rental wedge differently from them, our interpretation of it as a proxy summarizing the various institutional features that make rental markets less efficient is similar to theirs.

can be algebraically rearranged to represent having one last dose of consumption equal to $W \times L^{-1/\rho}$ when the household dies. Given our calibration of the CRRA coefficient of $\rho = 2$, that object is not sensitive to L at its higher levels (ranging between 0.112 for Italy and 0.158 for the U.S. For the U.S., Li et al. (2016) estimate the bequest strength to generate a terminal MPC of about $7.56^{-1} = 0.132$.[16]

We estimate a strong negative relationship between the discount rate and the mean expected growth of house prices, κ (Figure 6).[17] This means that more patient households are more optimistic about house prices and want to accumulate housing wealth. In contrast, less patient people, who accumulate less total wealth, are pessimistic about house prices and rent housing rather than buying it. Renters are thus both impatient and pessimistic about house prices and, consequently, prefer consuming to accumulating net wealth and do not want to buy a house either.

The negative relationship between the discount rate and optimism about house prices is in line with additional evidence. First, a key fact in the data is that renters accumulate much less net wealth than homeowners (partly perhaps because illiquid housing serves as a commitment for the accumulation of wealth as in Kovacs et al., 2021): While renters typically hold around one annual income worth in net wealth (or even less), homeowners own wealth worth around 4–10× their income. Second, survey data on expectations document that high-economic status households (who tend to be more patient) are more optimistic, see, e.g., Das et al. (2020). The positive relationship between patience and wealth accumulation has also been documented in Epper et al. (2020).

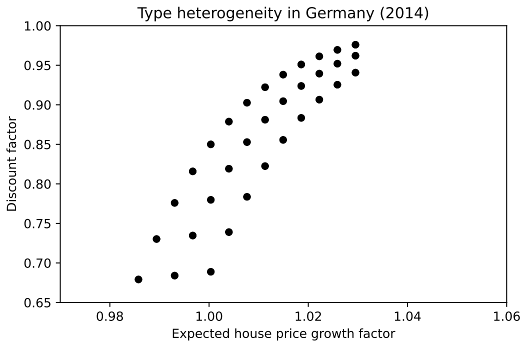
5.2 Model Fit

The model fits the data reasonably well. The overall fit as reflected in the minimum value of the objective function $f(\widehat{\xi})$ ranges between 280 and 1270 (see Table 2), with the latter

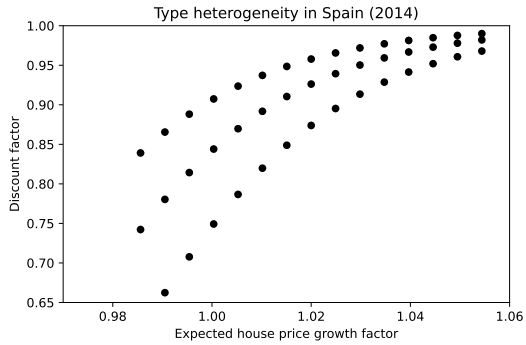
[16] Angelini et al. (2014) and Nakajima and Telyukova (2016) document cross-country difference in housing and saving behavior of retirees. The decumulation of wealth late in life is affected by other factors not included in our model, e.g., out-of-pocket medical expenses, capital gains taxation or pension systems.
Inheritance taxes across the five countries range roughly between 1% in the U.S. and 15% in Spain; see Drometer et al. (2018). Including an inheritance tax proportional to the final net worth $\widehat{W}$ would result in a corresponding increase in the estimated bequest motive L.

[17] We impose a nonlinear (logistic) transformation to make sure that the discount factor lies below 1. The relationship was estimated for 15 types by house price expectations times 3 household types by discount factor (conditional on house price expectations). With two education levels, there are 90 total "types" of households in our model.

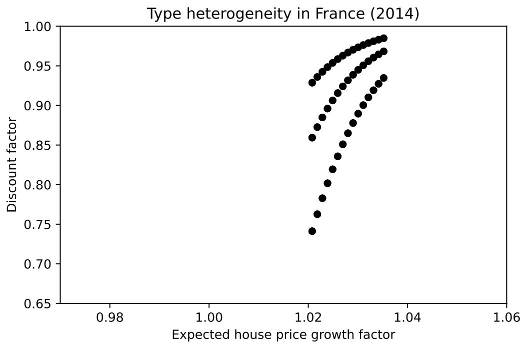
Figure 6 Estimated Relationship Between the Discount Factor and House Price Expectations



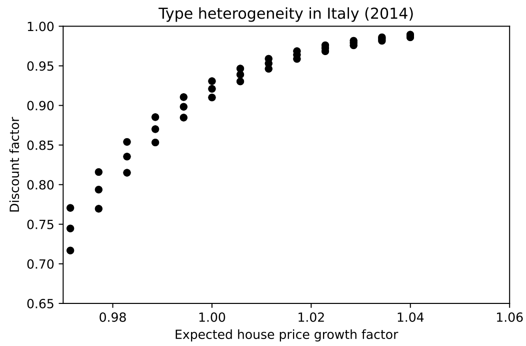
(a) Germany



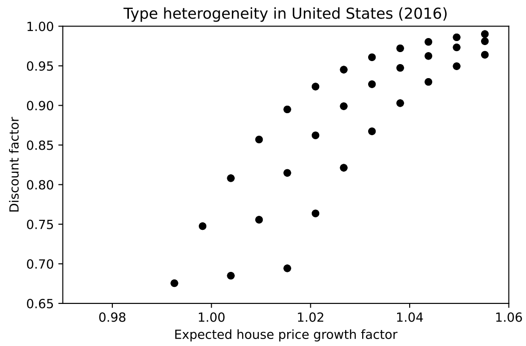
(b) Spain



(c) France



(d) Italy



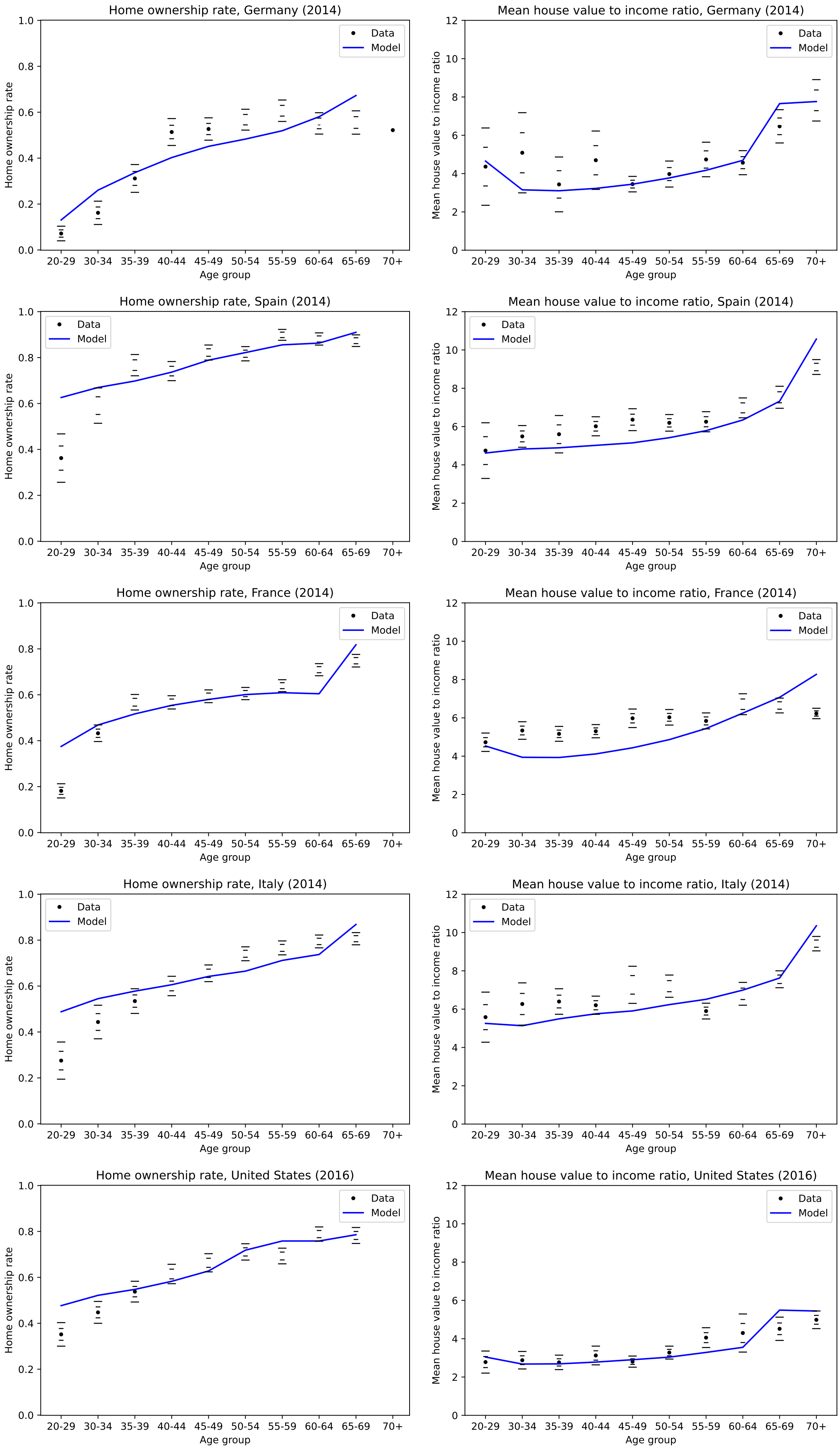
(e) United States

Note: The figure shows the estimated relationship between the discount factor β and the expected house price growth $\widehat{G}$. The relationship was estimated for 45 household types by discount factor and house price expectations, imposing a logistic transformation, which ensures that the discount factor lies below 1 for all households. The same 45 combinations of β and $\widehat{G}$ are used for each of the two education groups.

value for France driven by larger sample and lower variances of the moments (rather than a worse fit by visual inspection).

Given our interest in housing, let us focus on the homeownership rates and holdings of housing wealth (shown in the Figure 7; Figures 14–18 in Appendix D display all seven

Figure 7 Fit of Moments: Homeownership Rates and Housing Wealth–Income Ratios



moments). The model captures quite well the shape of the age profile of the homeownership over the life cycle. For some countries (Spain, Italy) the model overestimates homeownership for younger households.[18] As for the holdings of housing wealth relative to income, the model also generally does a good job at fitting the level. For some countries though (France), it is not able to match the flat profile and implies an increase over the life cycle, driven by the the positive trend in house prices. The model generally fits reasonably well the moments for rents and net wealth (see Appendix D).

6 Decomposing Cross-Country Differences in Housing Wealth

This section presents our key result: a decomposition that quantifies the impact of house price beliefs, housing market institutions and preferences on housing wealth. We investigate how differences across countries in estimated parameters (and other objects, such as income profiles) contribute to the substantial differences across countries in the fitted moments for the extensive and intensive margins of housing wealth: homeownership rates and the value of housing wealth of homeowners.

6.1 The Decomposition

We now describe a decomposition for the example of the difference in fitted homeownership rates between Germany and Spain: $\widehat{m}(\tilde{x}|\widehat{\xi}^{DE}) \longrightarrow \widehat{m}(\tilde{x}|\widehat{\xi}^{ES})$, where $\widehat{m}(\tilde{x}|\widehat{\xi}^{c})$ denotes the homeownership rate in country c (Germany or Spain) fitted by our model. We decompose the contributions of the various factors as follows. Starting from the parameter values for Germany, we switch one by one each element of $\widehat{\xi}^{DE}$ to its Spanish value, so that we eventually end up at parameter values for Spain $\widehat{\xi}^{ES}$ and the corresponding fitted

[18] Homeownership rates at the beginning of the life cycle differ across countries due to co-habitation of young adult household members with older generations. Grevenbrock et al. (2023) show in an overlapping generations model that the preference of young people to live with their parents can rationalize these differences for the case of Germany vs. Italy. We do not include similar preferences in our model as co-habitation accounts for almost no differences in homeownership rates of young households across Germany, France and the U.S.

Average household size varies little across the five countries, between 2.0 and 2.5 people per household, and has been documented not to matter much for wealth levels (Household Finance and Consumption Network, 2013) and wealth inequality (Bover, 2010 and Cowell et al., 2018).

homeownership values $\widehat{m}(\tilde{x}|\widehat{\xi}^{ES})$.[19] Thus, for each parameter we investigate how much moving from German parameters to the Spanish counterparts affects homeownership.

Our model turns out to be substantially non-linear due to house selling cost and precautionary saving. This implies that the effect on homeownership of each parameter depends on the order in which it switches from its German to its Spanish value. To address this fact we estimate the decomposition for all possible orderings of parameters. We then report the mean effect (averaged across the orderings) for each parameter.

Specifically, we focus on ten factors that matter the most: the rental wedge (rents minus maintenance costs), house price beliefs (mean and spread), the collateral constraint, discount factor (mean and spread), housing preference ω, variance of actual house prices, maintenance costs, house selling cost, labor income, the bequest motive, and an eleventh category for all other factors. With eleven factors, there are $2^{11} = 2048$ permutations between the two countries; for each factor, we average the $2048/2 = 1024$ moment series differences when that factor is changed. In addition to the mean effect of each factor, we also report what we label as "90 percent range," which depicts the dispersion between the 5th and 95th percentile of the effect across the orderings (Figures 19–22). The width of this range indicates how nonlinear the model is; for an additive model the ordering of the factors would not matter and the range would have zero width.

6.2 The Extensive Margin of Housing Wealth: Homeownership Rates

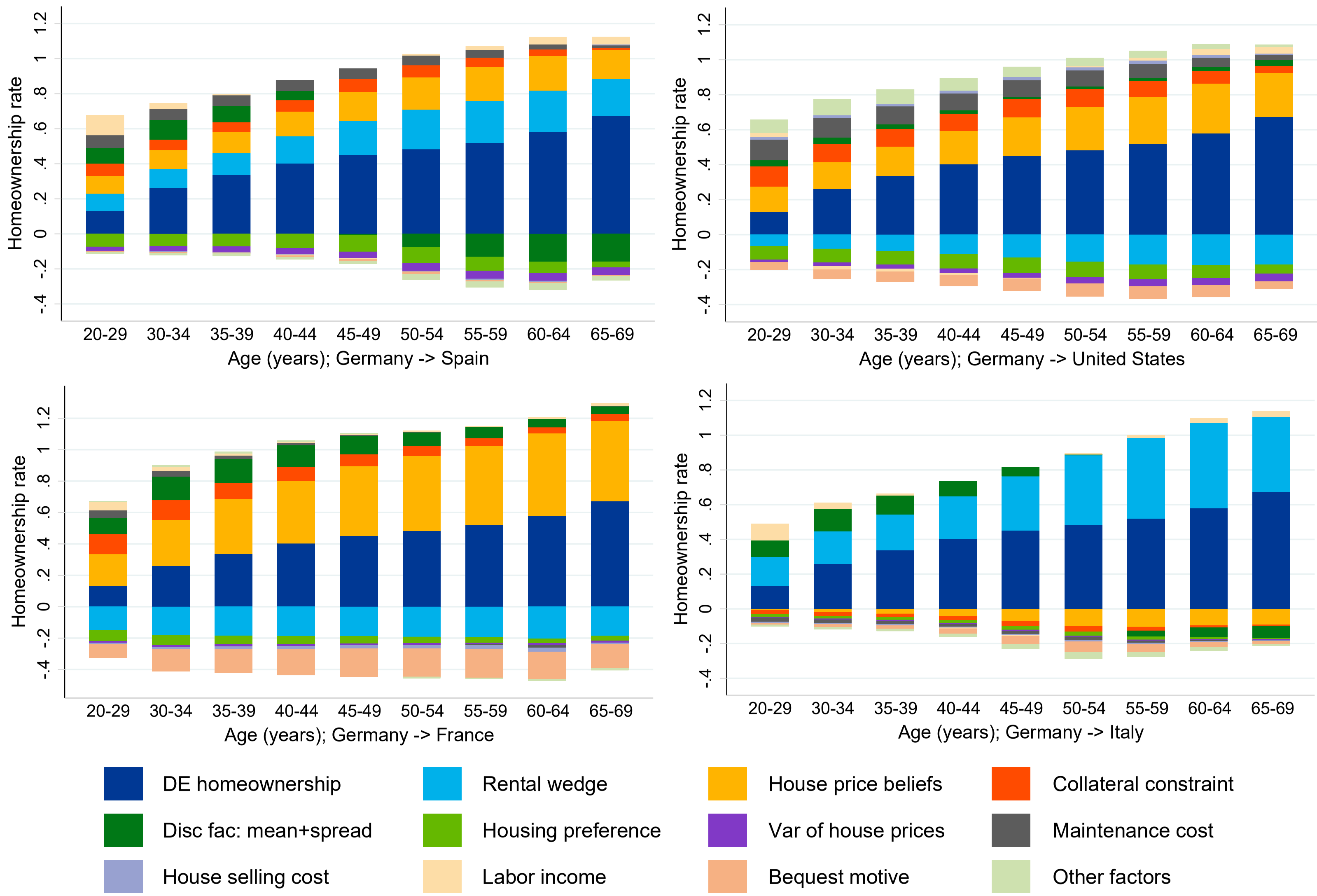
Let us start with the case of the extensive margin of housing wealth, the homeownership rate; Figure 8 reports how the various factors contribute to explaining the gaps between Germany and the other four countries.[20] Throughout the life cycle, differences in homeownership rates are strongly affected by two variables: (i) house price beliefs and (ii) the rental wedge, the difference between rents and maintenance costs.

Quantitatively, these two variables matter roughly the same (with some differences across countries, depending on the relevant differences in parameters and homeownership gaps across the pairs of countries). Average house price growth beliefs range between 0%

[19] This is a small abuse of notation, as the counterfactual experiments permute both estimated parameters $\widehat{\xi}$ and those calibrated outside the model (see section 4.1), e.g. proportional moving costs ϕ.

[20] We choose Germany as the 'base' country because of its very low homeownership rate.

Figure 8 Decomposition of Homeownership Rates



Note: The dark blue bars show the fitted homeownership rate in the base country (Germany). The other bars reflect the impact of various factors on homeownership, averaged across the permutations of factors. The sum of all bars results in the homeownership rate in the second country (Spain, the U.S., France or Italy). "Other factors" include mortality, realized house price growth, and interest rate.

in Italy and 2.8% in France, with 0.4% in Germany and around 2% in Spain and the U.S. (see the aggregate house prices in Figure 24). Figure 8 documents that a 1 p.p. difference in house price beliefs results roughly in a 15 p.p. difference in the homeownership rate. The rental wedge in France and the U.S. amounts to around 2%, 2.8% in Germany, 3.7% in Spain and almost 5% in Italy, reflecting a less efficient rental market. Roughly speaking, the 2 p.p. difference in rental wedges implies a 25–30 p.p. difference in homeownership rates between Germany vs. Italy (keeping in mind that the model is non-linear).

The rental wedge and house price beliefs (expected capital gains on housing wealth) are key factors for the decision whether to rent or own a house. Households compare the expected user cost of owning, the total mortgage financing costs and maintenance net of capital gains on housing wealth $r + \lambda - \widehat{G}$, to the cost of renting $\widehat{\alpha} \equiv \lambda + \alpha$, or $(r - \widehat{G})$, to the rental wedge α. In a frictionless model, the rental wedge and house price beliefs would equally strongly affect the homeownership rate.[21] It turns out that in our setup with transaction costs, collateral constraints and nonlinearities, the effect of the rental wedge and house price beliefs is also roughly the same: a 1 p.p. change in either of them implies a 15 p.p. effect on homeownership.

These considerations imply that small differences in long-run house price beliefs—smaller than those documented in survey data—are a powerful driver of homeownership in a lifecycle model. In the same vein, small differences in the rental wedge result in large differences in homeownership rates.

As for other factors, collateral constraints and (to some extent) differences in the bequest motive and labor income processes also affect the homeownership rate, especially at younger ages. Tighter collateral constraints reduce the homeownership rate of young households: A higher down payment requirement by 15 p.p. (in Germany) lowers the homeownership of households younger than 30 years by 6 p.p. (compared, e.g., to Spain, the U.S. or France). Similarly, a weaker bequest motive lowers the homeownership rate in France, the U.S. and Italy.[22] The steep labor income profile in Germany decreases

[21] In a setup with transaction costs, the expected user cost of owner-occupied housing should also account for the frequency of adjusting the house and expected transaction costs conditional on adjusting.

[22] In contrast to collateral constraints and the bequest motive, the effects of house price beliefs and rental wedge tend to rise with age.

the homeownership rate among the youngest households by around 10 p.p., compared to Spain and Italy.

6.3 The Intensive Margin of Housing: Housing Wealth

As for the intensive margin of housing, differences in housing wealth of homeowners, as measured with the mean ratios of housing wealth to income, are mostly driven by maintenance costs, which in effect reduce homeowners' return on housing wealth (Figure 9). Quantitatively, the estimated maintenance costs for Germany (2.6%) are less than a half the size of those in Spain (4.9%), France (6.0%) and the U.S. (8.6%) and larger than in Italy (1.7%). Compared to Germany, these values imply lower holdings of housing wealth in Spain, France and the U.S.—by roughly a multiple of 2–4 worth of annual incomes—and somewhat higher housing wealth in Italy.

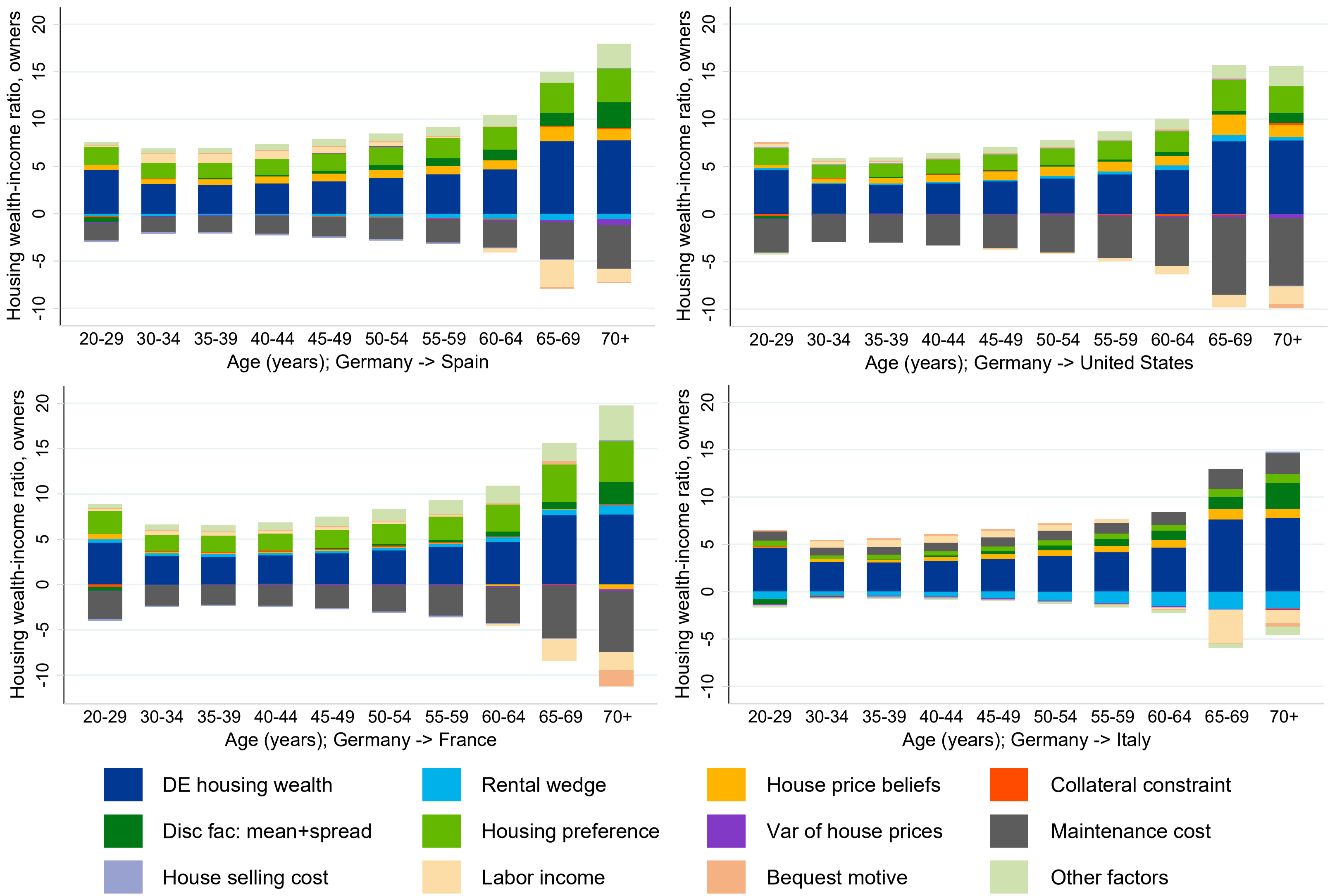
Our decompositions are informative about how property taxes and taxation of mortgage payments affect accumulation of housing wealth. Lower property taxes reduce maintenance costs λ and encourage accumulation of housing wealth (the intensive margin). In contrast, tax deductions of mortgage payments for primary residence (which are present in many countries; see Table 3) affect the effective interest rate r, reduce the user cost of owning and stimulate homeownership (the extensive margin).

Other factors that matter less for the accumulation of housing wealth are: preference parameters (especially the utility share of housing ω and bequest motive L), house price beliefs, and the rental wedge. We estimate that Germany and Italy have a lower share of housing utility ω (around 0.20) than the other countries (roughly 0.30), which is reflected in a positive contribution of the parameter to housing wealth outside of Germany.

A higher rental wedge in Italy reduces the accumulation of housing wealth due to a selection effect: Increasing the rental wedge makes additional people switch from renting to homeowning, but the marginal buyers purchase smaller houses and thus reduce the average housing wealth.

Higher house price growth beliefs in Spain and the U.S. than in Germany tend to increase the amount of housing wealth. A selection effect analogous to that for the rental wedge is at work, somewhat lowering housing wealth in Spain and and the U.S. as new

Figure 9 Decomposition of the Mean Gross Housing Wealth–Income Ratios of Homeowners



Note: The dark blue bars show the fitted mean housing wealth–income ratio of homeowners in the base country (Germany). The other bars reflect the impact of various factors on the housing wealth–income ratio, averaged across the permutations of factors. The sum of all bars results in the housing wealth–income ratio in the second country (Spain, the U.S., France or Italy). "Other factors" include mortality, realized house price growth, and interest rate.

homeowners tend to buy smaller than average houses. However, this effect is outweighed by an increase in housing wealth among existing homeowners, who buy larger houses, resulting in a positive overall contribution of higher house price beliefs. The strength of the effects on housing wealth rises with age, reflecting the gradual accumulation of the stock of housing wealth over the life cycle (relative to the flow of income).

As we estimate the model country by country, our decompositions provide an upper bound on how large differences in preferences across countries are needed to explain differences in homeownership and housing wealth. It turns out that very little preference heterogeneity is needed to explain the gaps in homeownership, around 5 p.p. or less.

Figures 19–22 show the mean effects together with what we label as "90 percent range," which depict the dispersion across the various permutations. While the width of these intervals indicates that the model is quite far from linear, we still find that the effects of the various factors are substantially different from zero, across most permutations.

7 Comparison of Estimates with External Evidence

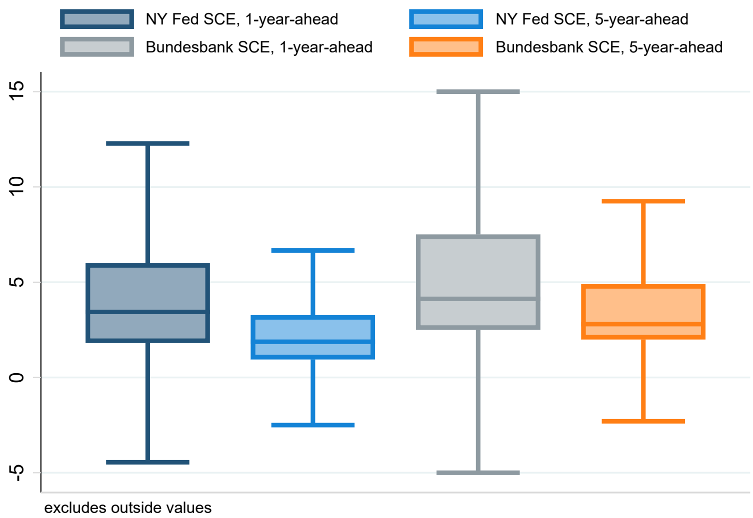
This section provides supporting external evidence from surveys of expectations and data on housing market institutions to cross-check that our structural estimates of the spread in house price beliefs $\widetilde{G}$ and the rental wedge α are reasonable.

7.1 Evidence from Survey-Based House Price Expectations

We estimated the spread in house price beliefs $\widetilde{G}$ using the moments for the slope of the age profile of homeownership in micro data from wealth surveys. Separately, a burgeoning literature has been documenting pervasive heterogeneity in measures of subjective expectations of households elicited in surveys (Adelino et al., 2018, Ben-David et al., 2024, Kuchler and Zafar, 2019, Das et al., 2020, Kuchler et al., 2023 and others).

So far, the literature on self-reported expectations has, however, predominantly focused on documenting stylized facts in the data. Instead, our structural model estimates how much heterogeneity in house price expectations is needed to improve the fit of a model with

Figure 10 Dispersion of 1-Year and 5-Year Ahead House Price Growth Expectations



Source: New York Fed Survey of Consumer Expectations, 2014–2019; Bundesbank Survey on Consumer Expectations, 2019.
Note: The figure shows the dispersion of household expectations at the 1-year and annualized 5-year horizons for the U.S. and Germany in percent. The box plot shows the lower adjacent value, the 25th percentile, the median, the 75th percentile and the upper adjacent value. The adjacent values are the 25th percentile $-$ 1.5$\times$interquartile range and the 75th percentile + 1.5$\times$interquartile range.

housing, and our decomposition below quantifies the effect of beliefs on homeownership and housing wealth.

Dispersion of households' subjective expectations of house price growth for the 1-year-ahead horizon exceeds that for the 5-year-ahead horizon; the interquartile range for the former is around 5%, while for the latter around 3% (Figure 10). In our setup (of section 3) and for our purpose (explaining long-run difference in homeownership and housing wealth), long-run house price beliefs (over the remaining lifetime) matter much more than short-run beliefs (over the next year), which are much less important for investment in housing given the substantial house selling cost. Data from the U.S. and Germany document that for the 5-year horizon, the interquartile range is roughly around 3 percent, in line with our estimates of the spread $\widetilde{G}$ in Table 2.[23]

These facts qualitatively mirror a similar finding of Li et al. (2023) for professional

[23] Most available household surveys measure house price expectations only at the short horizon, 1 year ahead. The two surveys shown in Figure 10 are to our knowledge the only ones that report household expectations at the 5-year horizon (and horizons longer than 1 year).

Table 4 Decomposition of the Variation in Average House Price Beliefs: Individual and Time Fixed Effects

	R^2 (percent) of panel regression			
Country	Time FE	Individual FE	Time + individual FE	Observations
Germany	1.5	41.9	43.0	2,342
France	0.4	32.9	33.2	2,397
Italy	0.7	37.2	37.8	2,539
Spain	1.7	37.3	38.4	2,399
United States	0.7	42.3	42.7	953

Note: Source: ECB Consumer Expectations Survey, waves April 2020–September 2023—42 monthly waves; U.S. Survey of Consumer Expectations, Federal Reserve Bank of New York, January 2020–February 2023. The table reports R^2 from the regressions of average house price beliefs on time fixed effects (column 2), on individual fixed effects (column 3) and on both time and individual fixed effects (column 4). Column 4 (rightmost) reports the average number of households across waves. The structure of the table follows Giglio et al. (2021), Table 6. The sample is restricted to households for whom at least 8 observations are available.

forecasters that dispersion in short-run forecasts is higher than in long-run forecasts. Li et al. (2023) also report that long-horizon (4-year-ahead) house price expectations are fully mean-reverting toward the realized long-run unconditional house price growth. This fact suggests that for households, the 5-year-ahead house price expectations shown in Figure 10 are a useful data benchmark for comparison of our model-based estimates of the dispersion of house price beliefs $\widetilde{G}$. In addition, Li et al. (2023) estimate a model of learning in which large differences across forecasters in the priors about the long-run mean house price growth are needed to match the disagreement documented in the data.

The interquartile range for the 1-year horizon is roughly 5%, reflecting the higher volatility of short-run expectations and their sensitivity to contemporaneous and recent house price changes (see Armona et al., 2018 and others). The interquartile range of the 1-year-ahead forecasts does not vary much across the four European countries and is roughly stable at around 5% (Figure 23 in Appendix D).

Our specification of heterogeneity in beliefs $\widehat{G}$ in equation (17) above imposes that households permanently differ in their optimism/pessimism about house prices. This fact is in line with survey evidence of Giglio et al. (2021), who estimate that a large fraction of differences in beliefs of wealthy U.S. investors is explained by individual fixed effects and very little by time fixed effects. We document that an analogous finding holds for house price beliefs of households in the five countries we analyze (Table 4). In addition, separate evidence also based on the CES confirms the well-known fact of Giglio et al. (2021), Kuchler et al. (2023) and others that differences in beliefs across households are not well explained by observable respondent characteristics such as gender, age, and income (Table 6 in Appendix D).

7.2 Evidence on the Quality of Rental Markets

Our structural estimates of the rental wedge α, the difference between rents and maintenance costs, correspond to the measures of the quality of the rental and housing market institutions and the segmentation of housing markets in separate empirical literature. Extensive work has collected indicators of various aspects of these institutions across countries: tax benefits of homeownership (tax relief on mortgages used to finance owner-occupied housing), rent controls, tenant protection (measures of tenant–landlord regulations, tenure security and ease of tenant eviction), availability of social housing, legal formalism and others; see Cardarelli et al. (2008), Andrews et al. (2011), Cuerpo et al. (2014), Weber (2017), Kaas et al. (2021), Kholodilin et al. (2023) and others.

Our estimates of the rental wedge imply that rental markets in France and the U.S. (with the rental wedge of around 2%) are more efficient than in Germany (2.8%), Spain (3.7%) and in particular in Italy (where the wedge is 4.9%).

Andrews et al. (2011) and Weber (2017) provide a detailed summary and quantitative measures of the various features of rental and housing markets across advanced economies. First, countries differ in the tax treatment of debt financing of the owner-occupied housing. The tax relief is more generous in the U.S. than in Spain, France and especially Italy (Andrews et al., 2011, Figure 17). In Germany, and more recently in France and Spain, interest paid on mortgages for own-use properties has not been tax-deductible (Kholodilin et al., 2023 and Table 3 above).

Second, regulations that cover rental market and tenant–landlord relationships vary substantially across countries. Rent controls in the private rental market in France and especially Germany are stricter than in Italy and especially Spain and the U.S. (Andrews et al., 2011, Figure 19 and Weber, 2017). Tenant–landlord regulations (including the ease of tenant eviction, tenure security and deposit requirements) provide more protection for tenants in France, Italy, Spain and Germany than in the U.S. (Andrews et al., 2011, Figure 20 and Weber, 2017).[24]

In addition, the degree of procedural formalism of the legal system (which is related to the length of dispute resolution and enforceability of contracts) matters for the size of the rental market. Legal formalism in Spain and Italy exceeds that in France and Germany and is low in the U.S. (Djankov et al., 2003).

Separate work on the U.S. by Greenwald and Guren (2021) estimates a substantial degree of segmentation between rental and owner-occupied housing markets. The fact that these two types of housing markets are highly frictional—close to fully segmented—implies that shocks such as changes in credit standards have a large effect on house prices and the price–rent ratios, but a small and statistically insignificant effect on the homeownership rate (see Landvoigt et al., 2015 for related results). For European countries, Koeniger et al. (2022) estimate that the transmission of interest rate changes to housing tenure transitions (renter to homeowner and vice versa) is weaker in Italy than in Germany and Switzerland—consistent with the fact that the rental wedge in Italy is large.

8 Conclusions

To our knowledge, this is the first paper that uses an estimated life cycle model of housing to systematically quantify drivers of differences in the extensive and intensive margins of housing wealth across advanced economies. We find that house price beliefs and housing market institutions matter substantially and household preferences less so. More specifically, differences in homeownership rates are strongly affected by (i) house price beliefs and (ii) the rental wedge, the difference between rents and maintenance costs, which reflects the quality of the rental market and segmentation of the housing markets. These two factors are key for the decision whether to buy vs. rent a house, reflecting the

[24] The share of social rental dwellings on all dwellings in the five countries we investigate is below 5%, except for France, where it amounts to 14%, and has been declining (OECD, 2020).

user costs of the two options. Differences in the value of housing wealth are substantially driven by maintenance costs, which reduce the return on housing wealth.

This paper focuses on the long-run, structural differences in housing across countries and could be extended in several ways. Our setup could be used to analyze how various economies respond to shocks and economic policies at higher, business-cycle frequencies. Our partial equilibrium model could also be embedded in a general equilibrium framework to analyze feedbacks between direct and indirect effects of shocks. It could be studied in more detail what supply-side or demand-side factors affect the rental wedge, for example, the history of institutions, cultural factors and experiences of memorable inflation rates and housing returns. Future work could also zoom in on population groups, for example middle class or young households, and study how their homeownership status and accumulation of wealth are affected by shocks and housing market institutions.

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Appendices

A The Model in Detail and the Solution Method

This appendix describes in detail the model with risky income and illiquid risky housing. The model concerns an agent who derives a utility flow in discrete time period t characterized by CRRA preferences over a Cobb–Douglas aggregation of the size of the house he lives in H_t and his level of consumption C_t. At the beginning of each period, the agent faces shocks to his income and the price of housing relative to consumption. After observing these shocks, he first makes a choice among renting a house, living in the house he already owns, or purchasing a different house. He then immediately chooses his level of consumption and housing, subject to constraints that depend on his ownership choice. In general, an agent's end-of-period position is subject to a collateral constraint based on the house he owns.

A.1 Beginning a Period, Discrete Choice and Preferences

Agent i enters age j in absolute time period t with A_{it-1} in net financial position (liquid assets less mortgage balance), owns a house of size $\widehat{H}_{it-t} \equiv \mathbf{1}(d_{it-1} > 0) \times H_{it-1}$ from the previous period,[25] and has a permanent income level of P_{it-1}; the relative price of housing was π_{t-1}. The agent is immediately hit with period t shocks to his income and the relative price of housing:

$$M_{it} = RA_{it-1} + Y_{it}, \qquad Y_{it} = \theta_{it} P_{it}, \qquad P_{it} = \Gamma_j \psi_{it} P_{it-1}, \qquad \pi_t = G\eta_t \pi_{t-1}, \tag{19}$$
$$\overline{H}_{it} = \widehat{H}_{it-1}, \qquad \theta_{it} \sim F_{\theta j}, \qquad \psi_{it} \sim F_{\psi j}, \qquad \eta_t \sim F_\eta.$$

This leaves him with market resources M_{it} and owning a house of size $\overline{H}_{it}$, with new levels of permanent income and the relative price of housing.[26]

At this moment, the agent makes a choice among the three values of the housing status: $d_{it} \in \{0 \text{ (Rent)}, 1 \text{ (Stay)}, 2 \text{ (Move)}\}$. If the agent does *not* choose to stay in the house he currently owns, he must sell this house and pay transactions costs ϕ proportional to the house value. This will leave him with a net worth position of:

$$W_{it} = M_{it} + (1-\phi)\pi_t \overline{H}_{it}. \tag{20}$$

If the agent *does* stay in the house he currently owns, $H_{it} = \overline{H}_{it}$, then he does not pay the transaction costs and his state variables are his market resources M_{it} and his house size $H_{it} = \overline{H}_{it}$.

Agents derive utility flow according to utility function $U(C,H)$:

$$U(C,H) = \frac{(H^\omega C^{1-\omega})^{1-\rho}}{1-\rho}. \tag{21}$$

The agent is an expected lifetime utility maximizer who geometrically discounts future flows at a factor of β per period. The agent dies stochastically at the end of each age j with probability D_j;

[25] If the agent rented in period $t-1$, or this is the very first period, then $\widehat{H}_{it-1} = 0$. Thus the housing stock variable always exists, but is irrelevant in some circumstances.

[26] Note that there is no subscript i on the price of housing (or its shock), as this is assumed to be shared across all agents, rather than drawn idiosyncratically. Likewise, there is no age subscript j on this process.

death yields a final "warm glow" based on net worth given by:

$$B(\widehat{W}) = L\,\frac{\widehat{W}^{1-\rho}}{1-\rho}, \qquad \widehat{W} = A_{it} + \pi_t \widehat{H}_{it}. \tag{22}$$

Budget constraints and choice-conditional value functions depend on the three values of the housing status: rent, stay, move.

A.2 The Renter's Problem

After making the decision to *rent*, $d_{it} = 0$, the agent's state is characterized by his net worth W_{it}, his permanent income level P_{it}, and the relative price of housing π_t. He can choose to rent a house of any size H_{it} he can afford, paying a fraction of its current market value $\widehat{\alpha}$. The agent will own no house at the end of the period, so he is constrained to end the period with non-negative assets (having no house to use as collateral). The renter's problem is thus to choose consumption C_{it} and rental house size H_{it} subject to:

$$A_{it} = W_{it} - C_{it} - \widehat{\alpha}\pi_t H_{it}, \qquad A_{it} \geq 0, \qquad \widehat{H}_{it} = 0, \qquad \widehat{\alpha} \equiv \lambda + \alpha. \tag{23}$$

A.3 The Stayer's Problem

After making the decision to *stay*, $d_{it} = 1$, the agent's state is characterized by his market resources M_{it}, the size of the house he currently owns $\overline{H}_{it}$, his permanent income level P_{it}, and the relative price of housing π_t. His choice of the size of house to live in is trivial, but he must pay maintenance costs proportional to his house's value λ. The stayer's problem is thus to choose consumption C_{it} and house size H_{it} subject to:

$$A_{it} = M_{it} - C_{it} - \lambda\pi_t H_{it}, \qquad A_{it} + (1-\delta)\pi_t \widehat{H}_{it} \geq 0, \qquad \widehat{H}_{it} = H_{it} = \overline{H}_{it}. \tag{24}$$

An agent who owns a house may have negative end-of-period assets, but cannot borrow more than a $(1-\delta)$ proportion of his house value.[27]

A.4 The Mover's Problem

After making the decision to *move*, $d_{it} = 2$, the agent's state is characterized by his net worth W_{it}, his permanent income level P_{it}, and the relative price of housing π_t. The mover's problem is to choose consumption and house size subject to the collateral constraint. He must pay maintenance costs on the house he moves into this period. The mover's problem is thus to choose consumption C_{it} and house size H_{it} subject to:

$$A_{it} = W_{it} - C_{it} - \lambda H_{it}\pi_t, \qquad A_{it} + (1-\delta)\pi_t \widehat{H}_{it} \geq 0, \qquad \widehat{H}_{it} = H_{it}. \tag{25}$$

A.5 Recursive Formulation

The agent's problem is characterized by the preference parameters $\{\beta, \rho, \omega, L\}$ and market parameters $\{R, \alpha, \phi, \lambda, \delta, G, F_\eta\}$, as well as the income and mortality processes $\{\Gamma_j, F_{j\theta}, F_{j\psi}, \mathsf{D}_j\}$ for $j \in \{j_0, \cdots, J\}$, where j_0 is the age at model entry and J is such that $\mathsf{D}_J = 1$. The problem

[27] Note that the renter is also subject to the same collateral constraint, because $\widehat{H}_{it} = 0$ for him.

can be phrased recursively, defining $\mathrm{V}_j(\cdot)$ as the value function at age j at the time the ownership choice is made. In all situations, definitions and transitions (19), (21), (22) hold.

The renter's problem can be written as:

$$\check{\mathrm{V}}_j(W_{it}; P_{it}, \pi_t) = \max_{C_{it}, H_{it}} U(C_{it}, H_{it}) + (1-\mathsf{D}_j)\beta\mathbb{E}\left[\mathrm{V}_{j+1}(M_{it+1}, \overline{H}_{it+1}; P_{it+1}, \pi_{t+1})\right] + \mathsf{D}_j B(\widehat{W}_{it}) \text{ s.t. } (23). \tag{26}$$

The stayer's problem can be written as:

$$\overline{\mathrm{V}}_j(M_{it}, \overline{H}_{it}; P_{it}, \pi_t) = \max_{C_{it}, H_{it}} U(C_{it}, H_{it}) + (1-\mathsf{D}_j)\beta\mathbb{E}\left[\mathrm{V}_{j+1}(M_{it+1}, \overline{H}_{it+1}; P_{it+1}, \pi_{t+1})\right] + \mathsf{D}_j B(\widehat{W}_{it}) \text{ s.t. } (24). \tag{27}$$

The mover's problem can be written as:

$$\widehat{\mathrm{V}}_j(W_{it}; P_{it}, \pi_t) = \max_{C_{it}, H_{it}} U(C_{it}, H_{it}) + (1-\mathsf{D}_j)\beta\mathbb{E}\left[\mathrm{V}_{j+1}(M_{it+1}, \overline{H}_{it+1}; P_{it+1}, \pi_{t+1})\right] + \mathsf{D}_j B(\widehat{W}_{it}) \text{ s.t. } (25). \tag{28}$$

The agent's problem when he makes his ownership decision is thus:

$$\mathrm{V}_j(M_{it}, \overline{H}_{it}; P_{it}, \pi_t) = \max\left\{\check{\mathrm{V}}_j(W_{it}; P_{it}, \pi_t),\ \overline{\mathrm{V}}_j(M_{it}, \overline{H}_{it}; P_{it}, \pi_t),\ \widehat{\mathrm{V}}_j(W_{it}; P_{it}, \pi_t)\right\} \text{ s.t. } (20). \tag{29}$$

Note that the right-hand side of each sub-problem[28] is identical but for the transition constraints in each situation. The problem has been written so that the agent "chooses" the size of house to live in each period, even if this choice is from a singleton set when staying. Likewise, housing stock at the beginning of $t+1$ is trivially $\overline{H}_{it+1} = 0$ when renting, but this is explicitly captured in (23). This formulation allows us to characterize the continuation payoff as based only on end-of-period assets A_{it} and size of house owned $\widehat{H}_{it}$, no matter what discrete ownership choice was made. Along with a clever normalization with respect to prices, this enables us to use a variation on the endogenous grid method to efficiently solve the model.

A.6 Normalization by Price Variables P_t and π_t

Following Li and Yao (2007), the model can be normalized with respect to *both* price levels (P_{it} and π_t), eliminating them as state variables. Generally, variables measured in real money units are normalized by P_{it}, housing variables are normalized by P_{it}/π_t, and variables measured in utility are normalized by $(P_{it}/\pi_t^{\omega})^{1-\rho}$:

$$\begin{gathered} a_{it} \equiv A_{it}/P_{it}, \quad c_{it} \equiv C_{it}/P_{it}, \quad y_{it} \equiv Y_{it}/P_{it} = \theta_{it}, \quad m_{it} \equiv M_{it}/P_{it}, \quad w_{it} \equiv W_{it}/P_{it}, \\ \widehat{h}_{it} \equiv \widehat{H}_{it}\pi_t/P_{it}, \quad h_{it} \equiv H_{it}\pi_t/P_{it}, \quad \overline{h}_{it} \equiv \overline{H}_{it}\pi_t/P_{it}, \quad \mathrm{v}_j(\cdot) \equiv \mathrm{V}_j(\cdot)/(P_{it}/\pi_t^{\omega})^{1-\rho}. \end{gathered} \tag{30}$$

Substituting (30) into (19) and (20) and simplifying yields a new set of transition dynamics:

$$\begin{gathered} m_{it} = Ra_{it-1}/(\Gamma_j\psi_{it}) + \theta_{it}, \quad \overline{h}_{it} = (G\eta_t)\widehat{h}_{it-1}/(\Gamma_j\psi_{it}), \quad w_{it} = m_{it} + (1-\phi)\overline{h}_{it}, \\ \widehat{w}_{it} = a_{it} + \widehat{h}_{it}, \quad \theta_{it} \sim F_{\theta j}, \quad \psi_{it} \sim F_{\psi j}, \quad \eta_t \sim F_{\eta}. \end{gathered} \tag{31}$$

[28]As a mnemonic device, the *breve* on $\check{\mathrm{V}}$ means that the agent only briefly lives in the rental, the bar on $\overline{\mathrm{V}}$ represents staying put in the same house, and the hat on $\widehat{\mathrm{V}}$ stands for choosing a new roof to live under.

We can now divide (26), (27), and (28) by $(P_{it}/\pi_t^{\omega})^{1-\rho}$ to yield the normalized forms of the three subproblems. The renter's normalized problem is:

$$\check{\mathrm{v}}_j(w_{it}) = \max_{c_{it},h_{it}} U(c_{it},h_{it}) + (1-\mathsf{D}_j)\beta\mathbb{E}\left[\left(\frac{\Gamma_{j+1}\psi_{it+1}}{(G\eta_{t+1})^{\omega}}\right)^{1-\rho} \mathrm{v}_{j+1}(m_{it+1},\overline{h}_{it+1})\right] + \mathsf{D}_j B(\widehat{w}_{it}) \text{ s.t.}$$
$$a_{it} = w_{it} - c_{it} - \widehat{\alpha}h_{it}, \qquad a_{it} \geq 0, \qquad \widehat{h}_{it} = 0. \tag{32}$$

The stayer's normalized problem is:

$$\overline{\mathrm{v}}_j(m_{it},\overline{h}_{it}) = \max_{c_{it},h_{it}} U(c_{it},h_{it}) + (1-\mathsf{D}_j)\beta\mathbb{E}\left[\left(\frac{\Gamma_{j+1}\psi_{it+1}}{(G\eta_{t+1})^{\omega}}\right)^{1-\rho} \mathrm{v}_{j+1}(m_{it+1},\overline{h}_{it+1})\right] + \mathsf{D}_j B(\widehat{w}_{it}) \text{ s.t.}$$
$$a_{it} = m_{it} - c_{it} - \lambda h_{it}, \qquad a_{it} + (1-\delta)\widehat{h}_{it} \geq 0, \qquad \widehat{h}_{it} = h_{it} = \overline{h}_{it}. \tag{33}$$

The mover's normalized problem is:

$$\widehat{\mathrm{v}}_j(w_{it}) = \max_{c_{it},h_{it}} U(c_{it},h_{it}) + (1-\mathsf{D}_j)\beta\mathbb{E}\left[\left(\frac{\Gamma_{j+1}\psi_{it+1}}{(G\eta_{t+1})^{\omega}}\right)^{1-\rho} \mathrm{v}_{j+1}(m_{it+1},\overline{h}_{it+1})\right] + \mathsf{D}_j B(\widehat{w}_{it}) \text{ s.t.}$$
$$a_{it} = w_{it} - c_{it} - (1+\lambda)h_{it}, \qquad a_{it} + (1-\delta)\widehat{h}_{it} \geq 0, \qquad \widehat{h}_{it} = h_{it}. \tag{34}$$

The discrete ownership choice normalized problem is:

$$\mathrm{v}_j(m_{it},\overline{h}_{it}) = \max\left\{\check{\mathrm{v}}_j(\underbrace{m_{it} + (1-\phi)\overline{h}_{it}}_{w_{it}}),\, \overline{\mathrm{v}}_j(m_{it},\overline{h}_{it}),\, \widehat{\mathrm{v}}_j(\underbrace{m_{it} + (1-\phi)\overline{h}_{it}}_{w_{it}})\right\}. \tag{35}$$

To further simplify the problem and motivate the numeric solution, we can define end-of-period (marginal) value functions, based on end-of-period assets and housing stock:

$$\begin{aligned}
\mathfrak{v}_j(a_{it},\widehat{h}_{it}) &\equiv (1-\mathsf{D}_j)\beta\mathbb{E}\left[\left(\frac{\Gamma_{j+1}\psi_{it+1}}{(G\eta_{t+1})^{\omega}}\right)^{1-\rho} \mathrm{v}_{j+1}\Big(m_{it+1},\overline{h}_{it+1}\Big)\right] + \mathsf{D}_j B(a_{it}+\widehat{h}_{it}),\\
\mathfrak{v}^a_j(a_{it},\widehat{h}_{it}) &\equiv (1-\mathsf{D}_j)R\beta\mathbb{E}\left[\frac{(\Gamma_{j+1}\psi_{it+1})^{-\rho}}{(G\eta_{t+1})^{\omega(1-\rho)}} \mathrm{v}^m_{j+1}\Big(m_{it+1},\overline{h}_{it+1}\Big)\right] + \mathsf{D}_j B'(a_{it}+\widehat{h}_{it}),\\
\mathfrak{v}^h_j(a_{it},\widehat{h}_{it}) &\equiv (1-\mathsf{D}_j)\beta\mathbb{E}\left[\frac{(\Gamma_{j+1}\psi_{it+1})^{-\rho}}{(G\eta_{t+1})^{\omega(1-\rho)-1}} \mathrm{v}^h_{j+1}\Big(m_{it+1},\overline{h}_{it+1}\Big)\right] + \mathsf{D}_j B'(a_{it}+\widehat{h}_{it}),
\end{aligned}$$

$$m_{it+1} = Ra_{it}/(\Gamma_{j+1}\psi_{it+1}) + \theta_{it+1}, \qquad \overline{h}_{it+1} = \frac{G\eta_{t+1}}{\Gamma_{j+1}\psi_{it+1}}\widehat{h}_{it}. \tag{36}$$

A.7 First Order Conditions and Model Solution

In this subsection, we present a characterization of the agent's optimal choices via their first order conditions (FOCs) for each discrete choice. Because of the presence of non-concavities in the value function (at the manifolds where choice-conditional value functions cross, as well as potential "secondary non-concavities"), the FOCs are *necessary* but not *sufficient* to characterize the optimal policy function. In this appendix, we temporarily ignore this complication and discuss the FOCs *as if* they were necessary and sufficient. Computational details for how we handle multiple candidate solutions (etc) are presented in Appendix B.

A.7.1 The Renter's Problem

The renter's problem can be easily solved if we notice that housing is merely a consumption good for the renter, as he makes the choice of house size for exactly one period with no penalty. We can thus define $x_{it} = h_{it}^{\omega} c_{it}^{1-\omega}$, the composite good. Using the well known solution to the Cobb–Douglas form, an ω proportion of spending $c_{it} + \widehat{\alpha} h_{it}$ will be on housing and a $1 - \omega$ proportion will be on consumption. Thus a unit of x can be purchased at price φ when acting optimally, and the renter's problem is:

$$\check{\mathrm{v}}_j(w_{it}) = \max_{x_{it}} u(x_{it}) + \mathfrak{v}_j(a_{it}, 0) \text{ s.t. } a_{it} = w_{it} - \varphi x_{it}, \qquad u(x) = x^{1-\rho}/(1-\rho). \tag{37}$$

This problem has one first order condition, with respect to x_{it}:

$$x_{it}^{-\rho} - \varphi \mathfrak{v}_j^a(a_{it}, 0) = 0 \Longrightarrow x_{it} = \Big(\varphi \mathfrak{v}_j^a(a_{it}, 0)\Big)^{-1/\rho} \Longrightarrow w_{it} = a_{it} + \varphi x_{it}. \tag{38}$$

In this way, we can find the endogenous gridpoint w_{it} associated with any end-of-period assets a_{it}. The composition of x_{it} is dictated by the Cobb–Douglas solution:

$$c_{it} = \left(\frac{1-\omega}{\omega/\widehat{\alpha}}\right)^{\omega} x_{it}, \qquad h_{it} = \frac{\omega}{1-\omega}\left(\frac{1-\omega}{\omega/\widehat{\alpha}}\right)^{\omega} x_{it}, \qquad \varphi = \frac{1}{1-\omega}\left(\frac{1-\omega}{\omega/\widehat{\alpha}}\right)^{\omega}. \tag{39}$$

With a simple application of the envelope theorem, marginal value of wealth is:

$$\check{\mathrm{v}}_j'(w_{it}) = \mathfrak{v}_j^a(w_{it} - \varphi x_{it}, 0) = \mathfrak{v}_j^a(a_{it}, 0) \ \text{ when } \ a_{it} > 0. \tag{40}$$

More generally, $\check{\mathrm{v}}_j'(w_{it}) = U^c(c_{it}, h_{it})$ holds everywhere, even when $a_{it} = 0$. Note that in the presence the warm glow bequest motive (with no shifter), the marginal value of end-of-period assets approaches infinity as $a_{it} \to 0$. Hence as long as death is possible, $\mathsf{D}_j > 0$, a renter will *never* end the period with zero assets, and the liquidity constraint never binds for them.

A.7.2 The Stayer's Problem

The stayer's problem—given that $h_t = \overline{h}_t$—can be written in simplified form as:

$$\overline{\mathrm{v}}_j(m_{it}, \overline{h}_{it}) = \max_{c_{it}} \overline{h}_{it}^{\omega(1-\rho)} \widetilde{U}(c_{it}) + \mathfrak{v}_j(a_{it}, \overline{h}_{it}) \text{ s.t. } a_{it} = m_{it} - c_{it} - \lambda \overline{h}_{it}, \quad \widetilde{U}(c) = \frac{c^{1-(\rho+\omega-\omega\rho)}}{1-\rho}. \tag{41}$$

This problem has one first order condition, with respect to c_{it}:

$$\frac{1-(\rho+\omega-\omega\rho)}{1-\rho} \overline{h}_{it}^{\omega(1-\rho)} c_{it}^{-(\rho+\omega-\omega\rho)} - \mathfrak{v}_j^a(a_{it}, \overline{h}_{it}) = 0, \tag{42}$$

which implies that:

$$c_{it} = \left(\frac{1-\rho}{1-(\rho+\omega-\omega\rho)} \overline{h}_{it}^{-\omega(1-\rho)} \mathfrak{v}_j^a(a_{it}, \overline{h}_{it})\right)^{-1/(\rho+\omega-\omega\rho)} \equiv \mathfrak{c}_j(a_{it}, \overline{h}_{it}), \qquad m_{it} = a_{it} + c_{it} + \lambda \overline{h}_{it}. \tag{43}$$

Thus we can find the endogenous $(m_{it}, \overline{h}_{it})$ gridpoint for any end-of-period state $(a_{it}, \overline{h}_{it})$. Using the envelope theorem we can calculate marginal value with respect to market resources or the housing stock:

$$\overline{\mathrm{v}}_j^m(m_{it},\overline{h}_{it}) = \mathfrak{v}_j^a(a_{it},\overline{h}_{it}), \qquad \overline{\mathrm{v}}_j^h(m_{it},\overline{h}_{it}) = U^h(c_{it},\overline{h}_{it}) + \mathfrak{v}_j^h(a_{it},\overline{h}_{it}) - \lambda\mathfrak{v}_j^a(a_{it},\overline{h}_{it}). \tag{44}$$

As for the renter, the envelope condition only holds when the liquidity constraint is non-binding, but the more general form of marginal value is also true for the stayer: $\overline{\mathrm{v}}_j^m(m_{it},\overline{h}_{it}) = U^c(c_{it},\overline{h}_{it})$.

A.7.3 The Mover's Problem

The mover's problem is a bit more complex, but can be written in simplified form as:

$$\widehat{\mathrm{v}}_j(w_{it}) = \max_{c_{it},h_{it}} U(c_{it},h_{it}) + \mathfrak{v}_j(a_{it},h_{it}) \text{ s.t. } a_{it} = w_{it} - c_{it} - (1+\lambda)h_{it}. \tag{45}$$

This problem has two first order conditions, with respect to c_{it} and h_{it}:

$$U^c(c_{it},h_{it}) - \mathfrak{v}_j^a(a_{it},h_{it}) = 0, \qquad U^h(c_{it},h_{it}) - (1+\lambda)\mathfrak{v}_j^a(a_{it},h_{it}) + \mathfrak{v}_j^h(a_{it},h_{it}) = 0. \tag{46}$$

For any end-of-period state (a_{it},h_{it}), we can solve for the value of c_{it} that solves the first order condition for consumption identically to the stayer's problem: $c_{it} = \mathfrak{c}_j(a_{it},h_{it})$. Substituting this into the first order condition for h_{it}, we get a unified first order condition:

$$U^h(\mathfrak{c}_j(a_{it},h_{it}),h_{it}) - (1+\lambda)\mathfrak{v}_j^a(a_{it},h_{it}) + \mathfrak{v}_j^h(a_{it},h_{it}) \equiv \mathfrak{H}_j(a_{it},h_{it}) = 0. \tag{47}$$

Solving this equation requires the use of a numeric rootfinding operation to find the value(s) of a_{it} that satisfy $\mathfrak{H}_j(a_{it},h_{it}) = 0$ for a given value of h_{it}. Once a root has been found, the accompanying endogenous wealth gridpoint is:

$$w_{it} = a_{it} + \mathfrak{c}_j(a_{it},h_{it}) + (1+\lambda)h_{it}. \tag{48}$$

Alternatively, we can think of the mover's problem as being a choice of allocating their wealth w_{it} between liquid market resources m_{it} and their housing wealth h_{it}, trading them off one for one, and *then* experiencing the stayer's problem in their new state. That is, optimal consumption for someone living in a house with state (m_{it},h_{it}) does not depend on whether the house is newly purchased or continuously occupied. Under this approach, the mover's housing-only problem is:

$$\widehat{\mathrm{v}}_j(w_{it}) = \max_{h_{it}} \overline{\mathrm{v}}_j(\underbrace{w_{it}-h_{it}}_{m_{it}},h_{it}). \tag{49}$$

This form has one intraperiod FOC, to equate the marginal value of liquid and illiquid wealth:

$$-\overline{\mathrm{v}}_j^m(w_{it}-h_{it},h_{it}) + \overline{\mathrm{v}}_j^h(w_{it}-h_{it},h_{it}) = 0 \implies \overline{\mathrm{v}}_j^m(w_{it}-h_{it},h_{it}) = \overline{\mathrm{v}}_j^h(w_{it}-h_{it},h_{it}). \tag{50}$$

As with (47) above, solving the mover's intraperiod FOC requires a numeric rootfinding method, yielding candidate solutions that must be compared to find the true optimum.

No matter which form of the problem is considered, the envelope theorem tells us that the marginal value of wealth of the mover is simply:

$$\widehat{\mathrm{v}}_j'(w_{it}) = \mathfrak{v}_j^a(a_{it},h_{it}) = U^c(c_{it},\overline{h}_{it}). \tag{51}$$

B Computation

This appendix provides details of the computational methods used to solve the agent's decision problem and represent the policy and (marginal) value functions. We begin with a presentation of the state space grids and numeric integration methods used to compute future expectations, then discuss transformations used to represent the policy and (marginal) value functions, as well as the lower bound with respect to liquid wealth. The succeeding subsections then address solving each of the three sub-problems, following the mathematical treatment in Appendix A. Finally, we discuss our method for handling multiple candidate solutions that arise from using the endogenous grid method with non-concavities in the value function.

B.1 Making State Grids

As with nearly all structural models, ours cannot be solved exactly at every point in the state space. Instead, we specify finite grids in each state dimension, numerically solve the model at those points, and interpolate the functions in between. This subsection presents our methods for constructing state space grids.

The choice of optimal consumption is solved using (a variation of) the endogenous grid method (EGM), so our "money" grid is primarily chosen for end-of-period assets. More precisely, we make a grid of normalized assets-above-minimum, which is then shifted appropriately to account for the relevant minimum. Specifically, for each age j we define the discrete set $\mathbb{A}_j$ as exponentially spaced between $a = 0$ and some upper bound, with 72 gridpoints. Denoting T the period of retirement, before retirement, for $j < T$, we set the highest gridpoint to $a = 24$; for $j \geq T$ we use $a = 48$ (because of the jump in *normalized* assets at retirement). For solving the mover's intraperiod problem, we also specify the grids $\mathbb{W}_j$ of liquid wealth values as versions of $\mathbb{A}_j$ that are thrice as dense. That is, two additional gridpoints are added *between* each pair of consecutive gridpoints in $\mathbb{A}_j$ (linearly spaced) to make $\mathbb{W}_j$; these have $72 \times 3 - 2 = 214$ gridpoints each.

Constructing the grid of house size values (or end-of-period housing values) is somewhat more complicated. When developing the model, our most difficult complications arose from extrapolating the policy and (marginal) value functions above the upper bound of the housing grid, potentially because of non-concavities that occur near this upper boundary (causing extrapolation to behave unexpectedly). To ensure stability of the solution method when estimating the model, it was necessary to minimize extrapolation by choosing the housing grid in $t+1$ to go high enough compared to the values used in t. With house prices expected to grow on average, house price shocks, and almost 100 periods, the highest value in the house price grid becomes quite large.

We use the following procedure to generate the housing grid for each age j:

1. Set the initial $h_{\max} = \max(\mathbb{A}_{j_0})/(\delta + \lambda)$, representing the largest house size that someone with the highest assets in the assets grid at the initial age would be able to purchase (if they consumed zero).

2. Set the "scaling factor" proportional to the growth rate of house prices G and its standard deviation σ_η: $S = G + \sigma_\eta/3$, but bounded by $[1.0, 1.08]$.

3. Specify the "log density factor" as $D = 10$, and set $j = j_0$ (the minimum age).

4. Set the number of main gridpoints for this age to $N = \lfloor D \log(h_{max}) \rfloor$.

5. Construct the main housing grid for age j as exponentially spaced between 0 and $h_{\max}$, with N points.

6. Construct the auxiliary grid as triple-exponential-nesting spaced between 0.005 and 90% of the second lowest main gridpoint, with 5 points.

7. Combine and sort the main and auxiliary grids, discarding duplicates; this is $\mathbb{H}_j$.

8. Scale up the maximum housing gridpoint for the next age: $h_{\max} := Sh_{\max}$. If and only if $j = T$, also scale it by the inverse permanent income growth factor: $h_{\max} := \Gamma_j h_{\max}$.

9. Unless $j = J$, increment age j and then go to step (4).

Step (6) adds a few more gridpoints near zero, where we found that optimal behavior becomes unusual. To correctly account for the worst outcomes occurring, our (marginal) value functions must correctly handle extreme cases where both liquid and illiquid wealth are close to zero, as well as when the agent is living in an absurdly small house relative to his income.

B.2 Computing Expectations

Our model includes three continuous shocks: permanent income shock ψ, transitory income shock θ, and house price shocks η. Conveniently, we specified these shocks as *independent* from each other, so they can be numerically integrated sequentially rather than jointly. When developing the code, we tried several different numeric integration methods, but present here only the one on which our published results rely.[29]

Suppose the problem has been solved back through age $j+1$, so we have value function $v_{j+1}(m_{it+1}, h_{it+1})$ and the marginal value functions $\mathrm{v}^m_{j+1}(\cdot)$ and $\mathrm{v}^h_{j+1}(\cdot)$ for decision-time in the next period. Our goal is to produce end-of-period (marginal) value functions $\mathfrak{v}_j(a_{it}, \widehat{h}_{it})$ over retained liquid assets a_{it} and the relative size of owned house $\widehat{h}_{it}$. As an intermediate step, we will first construct a value function for the (imaginary) moment in time *after* income shocks have realized but the house price shock has not. Specifically, define:

$$\mathbb{V}_{j+1}(m_{it+1}, \widehat{h}_{it}/(\Gamma_{j+1}\psi_{it+1})) = \mathbb{E}_\eta\left[(G\eta_{t+1})^{-\omega(1-\rho)}\mathrm{v}_{j+1}(m_{it+1}, \overline{h}_{it+1})\right], \tag{52}$$

$$\overline{h}_{it+1} = (G\eta_{t+1})\widehat{h}_{it}/(\Gamma_{j+1}\psi_{it+1}).$$

Likewise, the marginal value functions for this snapshot in time are:

$$\mathbb{V}^m_{j+1}(m_{it+1}, \widehat{h}_{it}/(\Gamma_j\psi_{it+1})) = \mathbb{E}_\eta\left[(G\eta_{t+1})^{-\omega(1-\rho)}\mathrm{v}^m_{j+1}(m_{it+1}, \overline{h}_{it+1})\right], \tag{53}$$

$$\mathbb{V}^h_{j+1}(m_{it+1}, \widehat{h}_{it}/(\Gamma_{j+1}\psi_{it+1})) = \mathbb{E}_\eta\left[(G\eta)^{-\omega(1-\rho)+1}\mathrm{v}^h_{j+1}(m_{it+1}, \overline{h}_{it+1})\right].$$

Note that ψ_{it+1} is known at this time, but does not need to be tracked separately; all relevant information is summarized by $\widehat{h}_{it}/(\Gamma_{j+1}\psi_{it+1})$.

To execute these expectations, we use an equiprobable discretization of the lognormal distribution F_η: the kth quadrature node of the approximation represents the (exact) expectation of η conditional on it being in the kth quintile. For each housing value in $\mathbb{H}_j$, we use a grid of market

[29] All of the methods produced nearly identical results, as they are merely different approximations of the same underlying math. However, they differed in their stability and consistency when solving many types of agents across many parameter sets.

resources corresponding to $\mathbb{A}_j$ offset by the minimum allowable m_{it} conditional on h_{it} (see below). With the expectations computed on those gridpoints, we then construct interpolated (marginal) value functions for this intermediate step, using the method described in the subsection below.

Rolling back one instant of time, we can then compute expectations over income shocks. It is possible to break this step into two components (first integrating out transitory shocks, then integrating permanent shocks), and we experimented with this, but here present the "combined income integration" approach. Under our new notation:

$$\mathfrak{v}_j(a_{it},\widehat{h}_{it}) = \beta(1-\mathsf{D}_j)\mathbb{E}_{\psi,\theta}\left[(\Gamma_{j+1}\psi_{it+1})^{1-\rho}\mathbb{V}_{j+1}(Ra_{it}/(\Gamma_{j+1}\psi_{it+1})+\theta_{it+1},\widehat{h}_{it}/(\Gamma_{j+1}\psi_{it+1}))\right]+\mathsf{D}_jB(a_{it}+\widehat{h}_{it}). \tag{54}$$

The marginal value of end-of-period liquid assets is:

$$\mathfrak{v}^a_j(a_{it},\widehat{h}_{it})=R\beta(1-\mathsf{D}_j)\mathbb{E}_{\psi,\theta}\left[(\Gamma_{j+1}\psi_{it+1})^{-\rho}\mathbb{V}^m_{j+1}(Ra_{it}/(\Gamma_{j+1}\psi_{it+1})+\theta_{it+1},\widehat{h}_{it}/(\Gamma_{j+1}\psi_{it+1}))\right]+\mathsf{D}_jB'(a_{it}+\widehat{h}_{it}). \tag{55}$$

And the marginal value of end-of-period owned housing stock is:

$$\mathfrak{v}^h_j(a_{it},\widehat{h}_{it}) = \beta(1-\mathsf{D}_j)\mathbb{E}_{\psi,\theta}\left[(\Gamma_{j+1}\psi_{it+1})^{-\rho}\mathbb{V}^h_{j+1}(Ra_{it}/(\Gamma_{j+1}\psi_{it+1})+\theta_{it+1},\widehat{h}_{it}/(\Gamma_{j+1}\psi_{it+1}))\right]+\mathsf{D}_jB'(a_{it}+\widehat{h}_{it}). \tag{56}$$

For these expectations, we use a joint discretization of (ψ,θ). As with housing price shocks η, we make a five-point equiprobable discretization of ψ_{it+1}. The *continuous* component of θ_{it+1} also has five equiprobable support points, with an adjustment for unemployment (adding an additional quadrature node and downweighting the probability of each of the other five nodes). The joint discretization is simply the cross product of the two independent discretizations, and we use this to compute the expectations above on a 2D grid of $\mathbb{A}_j \times \mathbb{H}_j$, adjusting a_{it} by its minimum conditional on $\overline{h}_{it}$ (see below). We then construct interpolating functions using the methods described in the next subsection.

B.3 Representing Functions

The (marginal) value functions are highly concave (convex), as the value function represents the expected sum of many CRRA utility terms, themselves concave functions (and the agent tries to smooth marginal utility across periods). Approximating such functions with linear splines would thus be highly inaccurate and generate unusual and unwanted features in the policy functions. To avoid this problem, we transform levels of the value function through the inverse utility function, and then construct linear interpolations on this "pseudo-inverse" value. That is, for any version of the value function:

$$\widetilde{\mathrm{v}}(\cdot) = u^{-1}(\mathrm{v}(\cdot)) = ((1-\rho)\mathrm{v}(\cdot))^{1/1-\rho}. \tag{57}$$

The pseudo-inverse value function is much more linear than the value function, as it has been "decurved" through the inverse of the function that generally characterizes its shape. It usually looks a lot *like* a consumption function (qualitatively speaking) and in some modeling contexts can be shown to have nice mathematical properties with respect to its limits. Such results are not available here, but we nonetheless find this transformation very useful. The value function itself is represented in code as the composition of the CRRA utility function with the pseudo-inverse value function.

The marginal value function with respect to liquid and illiquid wealth is highly convex, so we apply a similar transformation when representing such functions. Unsurprisingly, we apply the inverse marginal utility function to marginal values before interpolating them. For any version of a marginal value function with respect to x:

$$\tilde{\mathrm{v}}^{x}(\cdot) = (u')^{-1}(\mathrm{v}^{x}(\cdot)) = \mathrm{v}^{x}(\cdot)^{-1/\rho}. \tag{58}$$

After making an interpolant of the pseudo-inverse marginal values, the marginal value function in code is then represented as the composition of the marginal utility function and the pseudo-inverse marginal value function.

This transformation works very well with respect to liquid assets (whether market resources m_{it} or end-of-period assets a_{it}), but hits a snag with illiquid housing wealth h_{it}: there is no guarantee that the marginal value of housing is positive everywhere! At *most* places in the state space, and especially in the states that agents visit frequently (because they are near the optimal path when typical shocks occur), the marginal value of housing wealth is positive, as expected. However, consider the case of a stayer who has $m_{it} = (1 - \delta - \lambda)h_{it} + \epsilon$ for small $\epsilon > 0$. This person has *just barely* enough market resources to satisfy the collateral constraint after paying maintenance costs, forcing their consumption to be no more than ϵ. If this person were to have a marginal bit more housing stock, they would be able to consume a bit more (by borrowing against their increased house value), but would also have to pay marginally more maintenance costs in this period *and* until they sell the house.

Because selling a house is subject to proportional transaction costs, the agent can't freely transform his new bit of housing wealth into liquid wealth. While it is rare and only happens extremely close to the lower boundary of the stayer's state space, it is possible for the marginal value of illiquid housing to be negative. If this occurred, the inverse marginal value function would break when it tried to compute a fractional power of a negative number. To guard against this rare instance, for segments of the marginal value function where either end point has a negative marginal value, the transformation is not applied. Instead, we linearly interpolate those splines and "fuse" the two sections together.

When constructing 2D interpolants, we generally represent them as a "linear interpolation over 1D interpolators", adjusted for a lower bound in the liquid wealth dimension that depends on the value of illiquid assets. That is, we make interpolants *across liquid assets* within each $h \in \mathbb{H}_j$ (one for each), and then make an interpolator *across* illiquid housing stock values. When evaluated at a query point, the function searches for the appropriate bounding h values, evaluates the linear interpolant for both endpoints, and then weights them linearly according to their proportional distance between the bounds. This operation is always performed on *adjusted* liquid wealth, representing "liquid wealth above minimum possible"; because liquid wealth is unbounded above, this means there is no possibility that the code will try to evaluate a linear interpolant below the minimum *for its level of housing stock* (see below).

When considering the value function as a whole, from the perspective of the moment when the discrete choice is made, we evaluate it as a true upper envelope among the three options. That is, whenever $\mathrm{v}_j(m_{it}, \widehat{h}_{it})$ is queried in the code, all three choice-conditional value functions are evaluated, and the maximum is returned. Likewise, when either marginal value function for this moment of time is queried, the three choice-conditional value functions are also evaluated; the index of the best one is used to determine which choice-conditional marginal value function should be used for this query point.

B.4 Lower Bounds of Liquid Wealth

The lower bound on liquid wealth depends on the context. For the renter and mover, they (temporarily) only have liquid wealth, and the lower bound is simply zero. At the very end of a period, the borrowing constraint says that someone can only borrow a $(1-\delta)$ fraction against the value of their owned home, so $a_{it} \geq (1-\delta)\widehat{h}_{it}$. However, this is not the only constraint they face. The forward-looking agent knows that they must arrive in period $t+1$ in a legal state– one from which it is possible to make *some* choice that yields non-infinitely negative utility and satisfies constraints in $t+1$. The agent must obey a *natural* borrowing constraint that depends on the *worst possible shocks* occurring at the start of $t+1$. Most of the time, the natural borrowing constraint does not bind, because the artificial collateral constraint is more restrictive.[30] But with a sufficiently lax collateral constraint and low enough house price growth, it can happen.

As expressed in the body of the paper, the minimum (infimum) values of all three shocks are *zero*, as lognormal distributions have support on the positive real line. In that case, agents in our model would never borrow against their house *at all*, as they know that there is a positive probability of an arbitrarily bad shock that would force their house value arbitrarily close to zero and require them to sell it to satisfy the period-by-period collateral constraint. Rather than implement that absurd case, we instead treat the "worst case" shocks as the lowest value that they take on in our discretizations. An alternative approach would be to specify that the shocks never go past (say) 3 standard deviations below the mean and put a tiny "truncating point mass" there. This would make the natural borrowing constraint bind more often, but would not change our results by much.

Denoting the minimum shocks with an underline and next period's minimum allowable liquid market resources as $\underline{m}_{j+1}(\overline{h}_{it+1})$, the natural borrowing constraint is:

$$\begin{aligned}
\underline{m}_{j+1}(\widehat{h}_{it+1}) \leq m_{it+1} \;\Big|\; a_{it}, \underline{\psi}_{j+1}, \underline{\theta}_{j+1}, \underline{\eta} = Ra_{it}/(\Gamma_{j+1}\underline{\psi}_{j+1}) + \underline{\theta}_{j+1} \Longrightarrow \qquad (59)\\
\underline{m}_{j+1}((G\underline{\eta})\widehat{h}_{it}/(\Gamma_{j+1}\underline{\psi}_{j+1})) \leq Ra_{it}/(\Gamma_{j+1}\underline{\psi}_{j+1}) + \underline{\theta}_{j+1} \Longrightarrow \\
a_{it} \geq \left[\left(\underline{m}_{j+1}((G\underline{\eta})\widehat{h}_{it}/(\Gamma_{j+1}\underline{\psi}_{j+1})) - \underline{\theta}_{j+1}\right) \cdot \Gamma_{j+1}\underline{\psi}_{j+1}\right] \Big/ R.
\end{aligned}$$

The actual minimum value of end-of-period assets conditional on end-of-period housing stock is the *greater* (more restrictive) of the natural and artificial borrowing constraints.

The minimum allowable liquid market resources for a stayer is very closely related to the minimum allowable end-of-period liquid assets. Someone who owns their house must pay maintenance costs proportional to its value, but can consume as little as zero (in the limit). Hence the lower bound of market resources for a stayer conditional on their housing stock is simply minimum end-of-period assets plus $\lambda\widehat{h}_{it}$.

At the time the discrete decision is made over renting, staying, or moving, the minimum allowable market resources (as a function of housing stock) is the *least* restrictive among the three possibilities. That is, as long as the agent can make *some* legal choice in this period, they are in a legal state. For renting and moving, the agent can make a legal choice as long as their total wealth (after selling any previously owned home) is non-negative: $w_{it} = m_{it}+(1-\phi)\overline{h}_{it} \geq 0$. Because moving costs are in the range of 7–14% for our countries of interest, this is always less restrictive than the minimum market resources for staying in the currently owned house. However, hypothetically, very high values of ϕ (perhaps representing an extreme tax policy

[30] In fact, it was never relevant when *estimating* the model, only coming up when counterfactually simulating hypothetical "hybrid" countries.

that severely penalizes real estate transactions) could force this solvency constraint to be more restrictive, and our code accounts for this bizarre possibility.

B.5 Solving the Renter's Problem

Numerically solving the renter's problem is relatively straightforward and closely follows the math in Appendix A.7.1. Suppose we have computed future expectations as described in Appendix B.2. Using the same grid of end-of-period assets $\mathbb{A}_j$, we apply (38) to end-of-period marginal value of assets, yielding pairs of (w_{it}, x_{it}) solution points. We then use (39) to split x_{it} into its components c_{it} and h_{it}, and construct linear spline interpolants for the renter's consumption function and rental house function. The renter's marginal value function can be found by applying the envelope condition in (40), then using the pseudo-inverse transformation described above before interpolating. The renter's value at each endogenous gridpoint is calculated using (32), noting that the latter two terms of the RHS are end-of-period value for the corresponding a_{it}. The renter's value function is constructed by our normal method.

B.6 Solving the Stayer's Problem

Solving the stayer's problem is very similar to solving the renter's problem, except that there are many values of housing stock h_{it}. Beginning with the computed grid of end-of-period marginal value of liquid assets, we apply (43) to generate the corresponding optimal consumption c_{it} and hence the market resources values m_{it} from which this choice must have been made. The consumption function is constructed as described in Appendix B.2, applying the appropriate shifter for the minimum allowable market resources by housing wealth as described in Appendix B.3. The stayer's consumption function is then composed with the marginal utility function to yield the stayer's marginal value of market resources function, as in (44).

The stayer's value function is constructed similarly, using the "pseudo-inverse" transformation described in Appendix B.2 and applying the value function definition in (33); as before, we already have end-of-period value computed for the relevant $(a_{it}, \overline{h}_{it})$ pairs. The marginal value of housing wealth for the stayer is simply a transformation of end-of-period marginal values, as in the final part of (44), combining the marginal utility of more housing this period, the marginal value of owning more housing at the end of the period, and holding less liquid assets due to needing to pay marginally more maintenance costs.

B.7 Solving the Mover's Problem

There are manyways to solve the mover's problem, and we tried several of them. Ultimately, the method we present here was the most consistent and stable. We treat the mover's problem as an intraperiod asset allocation choice: they have already liquidated any prior home, and must divide their total wealth w_{it} between liquid market resources m_{it} and illiquid housing h_{it}. After making this choice, they will choose consumption according to the stayer's solution for that (m_{it}, h_{it}), found using EGM. For the mover's intraperiod allocation, we take a more brute force approach.

We will find the optimal allocation of liquid and illiquid assets for each level of $w_{it} \in \mathbb{W}_j$, the dense grid of total of wealth. The procedure below is performed (mostly) in parallel for all w_{it} simultaneously, but we describe it for a single w_{it} value for clarity.

1. Find the maximum allowable h_{it} to consider as the smaller of $w_{it}/(\delta + \lambda)$ and $\max \mathbb{H}_j$ – the largest allowable house and the largest house size in the state grid.

2. Make a *temporary* grid of h_{it}, linearly spaced between 0 and that maximum (minus ϵ on both ends), with the same number of points as $\mathbb{H}_j$.

3. Calculate the complementary grid of $m_{it} = w_{it} - h_{it}$.

4. Evaluate the LHS of (50) on the grids of m_{it} and h_{it}, the difference between marginal values of liquid and illiquid assets; call this z_{it} for convenience.

5. Candidate solutions to the intraperiod FOC are bounded by consecutive values of z_{it} with alternate signs. In fact, we want the upper z_{it} to be non-positive and the lower z_{it} to be non-negative, indicating a local maximum; the opposite case is a local minimum. Call these "candidate segments".

6. For each candidate segment, assume z is linear in between and compute the proportional distance where the FOC would be satisfied as $q = -z_0/(z_1 - z_0)$.

7. For each candidate segment, find candidate $h_{it} = (1 - q)z_0 + qz_1$, and candidate $m_{it} = w_{it} - h_{it}$.

8. For each candidate, find c_{it} using the stayer's consumption function evaluated at (m_{it}, h_{it}), then compute the value of this choice as $U(c_{it}, h_{it}) + \mathfrak{v}_j(m_{it} - c_{it} - \lambda h_{it}, h_{it})$.

9. Choose the best candidate for this w_{it} as the one with the best value.

After repeating across all $w_{it} \in \mathbb{W}_j$, we have a collection of points on the mover's optimal solution. The mover's housing function and consumption function can be constructed as linear spline interpolants. The marginal value for the mover is calculated as the marginal utility of consumption, which is then used to construct the mover's marginal utility function using our normal method. The selection of the best candidate solution already yielded levels of the mover's value for each w_{it} in the grid, so the pseudo-inverse transformation can be applied and the value function constructed normally.

B.8 Handling Multiple Candidate Solutions

The mover's problem manually handled multiple candidate solutions by explicitly searching over the allocation of liquid and illiquid assets, finding candidate solutions (via the intraperiod FOC), and then choosing the best one. However, the renter and stayer problems described a fairly straightforward EGM procedure, but this method will sometimes yield a non-monotone sequence of m_{it} (for the stayer, conditional on h_{it}) or w_{it} (for the renter)– the mapping from a_{it} to liquid market resources "doubles back" on itself. In this subsection, we describe our method for handling these multiple candidate solutions to the consumption–saving problem.

Suppose that in the EGM step, we find that the mapping from a_{it} to m_{it} or w_{it} is non-monotone. We follow these steps to generate a proper policy and (marginal) value function:

1. Specify a dense grid of m_{it} values that is bounded by the lowest and highest endogenous gridpoints from the EGM step. The grid has $10\times$ the number of points as the EGM grid, and is exponentially spaced.

2. Specify identically sized empty vectors to hold the solutions for the control variable (c_{it} or x_{it}) and pseudo-inverse value function $u^{-1}(\text{v})$.[31] Both vectors begin with all zeros, representing zero consumption and infinitely bad value.

3. Loop over segments of the endogenous grid, indexed by k. Designate $\underline{m} = m_k$ and $\overline{m} = m_{k+1}$, the top and bottom of this segment. If $m_{k+1} \leq m_k$, skip this k because points on it cannot be part of the optimal solution.

4. Designate $\underline{\text{v}} = \widetilde{\text{v}}_k$ and $\overline{\text{v}} = \widetilde{\text{v}}_{k+1}$, the corresponding pseudo-inverse values for this segment of the endogenous grid.

5. For all nodes of the (exogenous) dense grid of state space points, calculate linear weight $\gamma = (m - \underline{m})/(\overline{m} - \underline{m})$. Designate as "valid" all nodes such that $\gamma \in [0, 1]$, indicating that they are within the bounds of this segment of the endogenous grid.[32]

6. For each valid exogenous gridpoint, compute candidate pseudo-inverse value as $\check{\text{v}} = (1 - \gamma)\underline{\text{v}} + \gamma\overline{\text{v}}$.

7. Compare each $\check{\text{v}}$ to the corresponding value currently in the grid initialized in step (2). If it is greater, designate that candidate solution as "accepted".

8. For each exogenous gridpoint whose solution was accepted, put $\check{\text{v}}$ into the pseudo-inverse value grid. Also fill in the control variable grid with $(1 - \gamma)\underline{c} + \gamma\overline{c}$ for such gridpoints, defining $\underline{c}$ and $\overline{c}$ similarly to their counterparts.

9. Unless this is the last segment of the endogenous gridpoint, go back to step (3), incrementing k to the next segment.

This procedure generates valid grids of states, controls, and (pseudo-inverse) value that can be used to construct the policy and (marginal) value functions by the regular methods. Marginal value can be obtained by calculating end-of-period a_{it} for each exogenous gridpoint and applying the usual envelope condition.

B.9 Simulation

Simulating the model is relatively straightforward and follows the math presented in the paper and Appendix A. For each of the 90 agent types, we simulate 3,000 agents from age 22 until death, for a total (initial) population of 270,000. Random shocks for each person–time pair are kept constant across parameter sets.

C Estimation of Income Processes

This appendix describes the estimation of income profiles and variances of permanent and transitory income shocks.

[31] Without loss of generality, we will refer only to m_{it} and c_{it} from here on, letting it stand for either state or control variable depending on the context.

[32] In the code, we use $[-\epsilon, 1 + \epsilon]$, permitting exogenous gridpoints just barely outside of the segment. We found that this was necessary due to numeric discrepancies.

C.1 Income Measure

The income variable is net household disposable income excluding income from rental of a property or land and interest, dividends, profit from capital investments in unincorporated business. Using the EU SILC variable names,

$$\text{net disposable income} = \text{HY020} - \text{HY040N} - \text{HY090N}, \tag{60}$$

where:

- Total disposable household income HY020 = HY010 – HY120G – HY130G – HY140G
- Total household gross income HY010 = HY040G + HY050G + HY060G + HY070G + HY080G + HY090G + HY110G + [for all household members](PY010G + PY021G + PY050G + PY080G + PY090G + PY100G + PY110G + PY120G + PY130G + PY140G), where:
  - Income from rental of a property or land (HY040G),
  - Family/children related allowances (HY050G),
  - Social exclusion not elsewhere classified (HY060G),
  - Housing allowances (HY070G),
  - Regular inter-household cash transfers received (HY080G),
  - Interests, dividends, profit from capital investments in unincorporated business (HY090G),
  - Income received by people aged under 16 (HY110G)),
  - Gross employee cash or near cash income (PY010G),
  - Company car (PY021G),
  - Gross cash benefits or losses from self-employment (including royalties) (PY050G),
  - Pensions received from individual private plans (other than those covered under ESSPROS) (PY080G),
  - Unemployment benefits (PY090G),
  - Old-age benefits (PY100G),
  - Survivor benefits (PY110G),
  - Sickness benefits (PY120G),
  - Disability benefits (PY130G),
  - Education-related allowances (PY140G).
- Regular taxes on wealth (HY120G),
- Regular inter-household cash transfer paid (HY130G),
- Tax on income and social insurance contributions (HY140G),
- Income from rental of a property or land (net) (HY040N),
- Interest, dividends, profit from capital investments in unincorporated business (net) (HY090N).

Income is deflated with the HICP price index.

C.2 Age Profiles: Sample and Regression Specification

For the four European countries, we use EU SILC annual cross-sectional data from years 2009–2019. For the U.S., we use biennial data from the Panel Study on Income Dynamics, 1997–2017 as processed in the Appendix of Paz-Pardo (2024).

Households younger than 16 years and older than 65 years were excluded. The sample size in our sample is about 13,000 persons per year for Germany, about 12,000 for Spain, about 10,000 for France, 18,000–20,000 for Italy and 8,000 per year for the U.S. We winsorize income by country and education level (low and high) for the top and bottom 1 percent. For individuals aged 65 years and less, we regress the median income on the third order polynomial of age. (For retirees, we assume constant income given by the retirement replacement rate and the pre-retirement income.) This specification follows Cocco et al. (2005) and many others.

The estimated income profiles are shown in Figure 3.

C.3 Variances of Permanent and Transitory Income Shocks

We estimate the parameters of the permanent–transitory income process following Carroll and Samwick (1997).

We use three income panels, depending on the country. For France, Italy and Spain we use EU SILC annual panel (longitudinal) data from years 2009–2019; see Borst and Wirth (2022). For Germany we use the EU-SILC-like panel of the SOEP, 2009–2019; see Bartels et al. (2023). For the U.S. we use the biennial data from the PSID, 1997–2017. We measure household net disposable income as defined in (60) above for the two education groups (with and without college).

We restrict our sample to employed household heads aged 20–65 years, following Cocco et al. (2005) and others. We deflate the income levels with the HICP and winsorize income levels and growth rates at the 5th and 95th percentiles. Across the three countries, the EU SILC panel sample size ranges roughly between 4,000 and 8,000 households per year, with a rotating sample in which each household is interviewed at most for 4 consecutive years. The sample for Germany is about 12,000 households per year, for the U.S. 8,000 households per year.

Following Carroll and Samwick (1997), we first remove the predictable component from income by collecting the residuals $\log Y^*_{it}$ from the regression of income on demographics (gender, age, marital status, occupation, economic status, employment status, type of contract). We construct the d-year growth rates for $d = 1, \ldots, h$, up to $h = 3$ years:

$$r^d_{it} = \log Y^*_{it+d} - \log Y^*_{it},$$

whose variance is a combination of variances of the underlying permanent and transitory shocks:

$$\mathrm{var}(r^d_{it}) = d \times \mathrm{var}(\psi_{it}) + 2 \times \mathrm{var}(\theta_{it}). \tag{61}$$

We estimate $\mathrm{var}(\psi)$ and $\mathrm{var}(\theta)$ by regressing $\mathrm{var}(r^d_{it})$ on the constant and the corresponding horizon d, controlling for household-specific fixed effects.

For household heads without a college degree, variances of the permanent shocks $\mathrm{var}(\psi)$ range between roughly 0.018 and 0.023 and variances of the transitory shocks range between 0.012 and 0.049 (Table 5). For household heads with college degree, variances of the permanent shocks $\mathrm{var}(\psi)$ range between roughly 0.019 and 0.023 and variances of the transitory shocks range between 0.009 and 0.042. These values imply standard deviations of around 0.14 for permanent shocks and around 0.10 for transitory shocks (although somewhat higher for the transitory shock for the U.S.), which are in line with the literature (Carroll and Samwick, 1997, Heathcote et al., 2010 and many others).

Table 5 Estimates of Variances of Permanent and Transitory Income Shocks

		Value				
Symbol	Description	Germany†	Spain‡	France‡	Italy‡	U.S.A.§
Household head without a college degree						
var(ψ)	Variance of permanent income shock	0.0189***	0.0230***	0.0180***	0.0219***	0.0204***
	Standard error	(0.0003)	(0.0007)	(0.0004)	(0.0004)	(0.0007)
var(θ)	Variance of transitory income shock	0.0136***	0.0132***	0.0124***	0.0153***	0.0488***
	Standard error	(0.0003)	(0.0006)	(0.0004)	(0.0004)	(0.0013)
R^2		0.336	0.558	0.463	0.537	0.337
N	Number of observations	133,405	23,749	49,929	59,157	40,087
std(ψ)	Implied std dev of permanent income shock	0.1376	0.1517	0.1342	0.1480	0.1429
std(θ)	Implied std dev of transitory income shock	0.1167	0.1147	0.1111	0.1235	0.2209
Household head with a college degree						
var(ψ)	Variance of permanent income shock	0.0212***	0.0220***	0.0187***	0.0226***	0.0205***
	Standard error	(0.0005)	(0.0004)	(0.0005)	(0.0007)	(0.0010)
var(θ)	Variance of transitory income shock	0.0139***	0.0094***	0.0111***	0.0149***	0.0420***
	Standard error	(0.0005)	(0.0003)	(0.0004)	(0.0007)	(0.0011)
R^2		0.352	0.572	0.486	0.556	0.358
N	Number of observations	58,251	21,707	37,677	21,260	54,174
std(ψ)	Implied std dev of permanent income shock	0.1456	0.1483	0.1367	0.1503	0.1432
std(θ)	Implied std dev of transitory income shock	0.1177	0.0970	0.1051	0.1221	0.2250

Note: Source: †: Sozio-oekonomisches Panel (SOEP)/EU-SILC-like panel, 2009–2019; ‡: EU Statistics on Income and Living Conditions (EU SILC), 2009–2019; §: PSID 1997–2017, biennial. The table reports estimates and statistics from equation (61). The implied standard deviations are calculated as the square root of the variances. Low values of income levels and growth rates were winsorized at 5 percent.

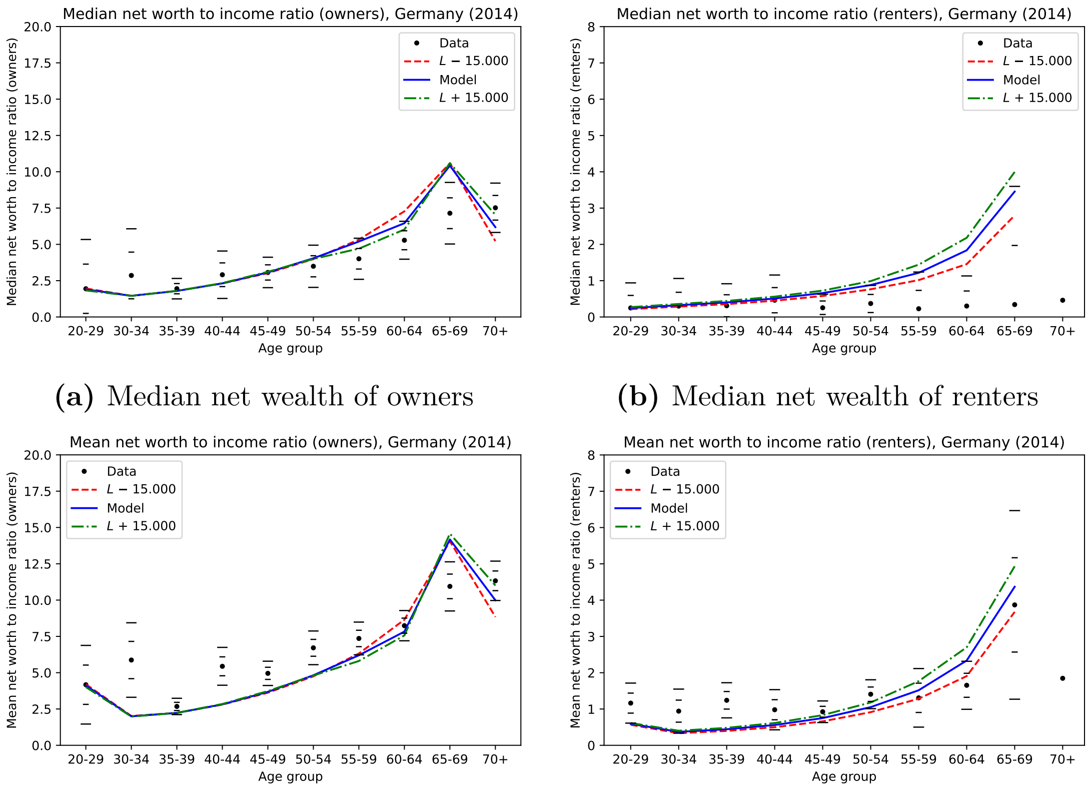
D Additional Tables and Figures

Table 6 Correlates of Individual House Price Beliefs

	Average house price beliefs		
	(1)	(2)	(3)
35–49 years		0.191*	0.185*
		(0.0840)	(0.0837)
50+ years		0.303***	0.307***
		(0.0839)	(0.0840)
Upper secondary education		−0.420***	−0.219
		(0.117)	(0.119)
Tertiary education		−0.472***	−0.329**
		(0.108)	(0.109)
2nd income quintile		−0.465***	−0.479***
		(0.115)	(0.115)
3rd income quintile		−0.459***	−0.463***
		(0.111)	(0.111)
4th income quintile		−0.455***	−0.500***
		(0.108)	(0.108)
5th income quintile		−0.496***	−0.520***
		(0.107)	(0.107)
Constant	0.744***	1.325***	1.431***
	(0.102)	(0.164)	(0.175)
Survey month fixed effects	Yes	Yes	Yes
Country fixed effects			Yes
Number of observations N	544,517	544,517	544,517
R^2	0.00618	0.00726	0.00941

Note: Source: ECB Consumer Expectations Survey, waves April 2020–September 2023; 42 monthly waves. The table reports estimates and R^2 from the regressions of average house price beliefs on demographic variables and fixed effects. The structure of the table follows Kuchler et al. (2023), Table 1 (which is based on the U.S. Survey of Consumer Expectations from the Federal Reserve Bank of New York). The numbers in the parentheses show standard errors; the stars denote statistical significance.

Figure 11 Identification of the Strength of Bequest L

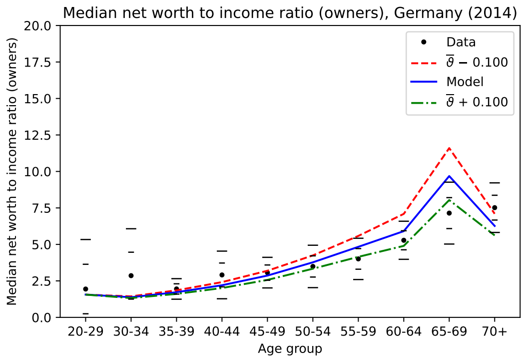


(a) Median net wealth of owners **(b)** Median net wealth of renters

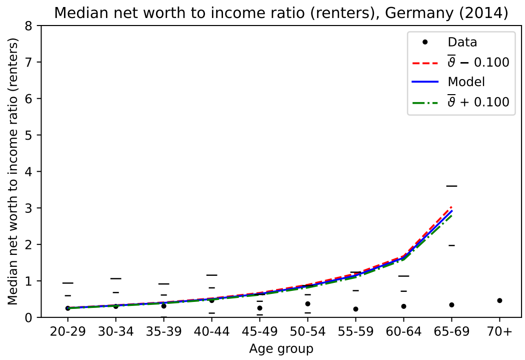
(c) Mean net wealth of owners **(d)** Mean net wealth of renters

Source: Household Finance and Consumption Survey, wave 2014; Survey of Consumer Finances, 2016.
Note: The blue solid line shows the fitted values. The red dashed and green dash-dotted lines show how a small negative and positive change in a parameter affect the relevant fitted moment. The dots denote data; the brackets around them denote one and two standard error bands. The figures illustrate the moments for the case of Germany.

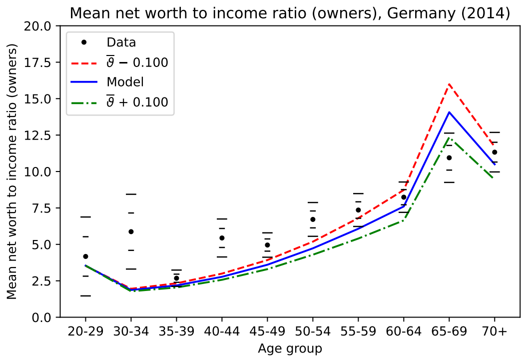
Figure 12 Identification of the Mean Discount Rate $\overline{\vartheta}$



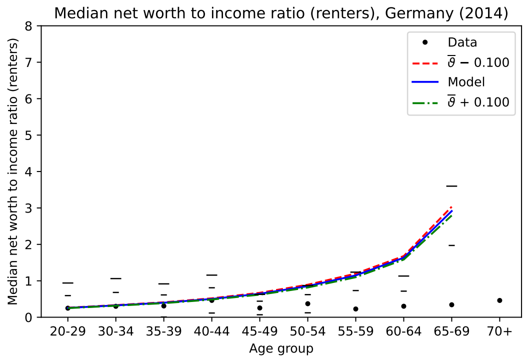
(a) Median net wealth–income ratio of owners



(b) Median net wealth–income ratio of renters



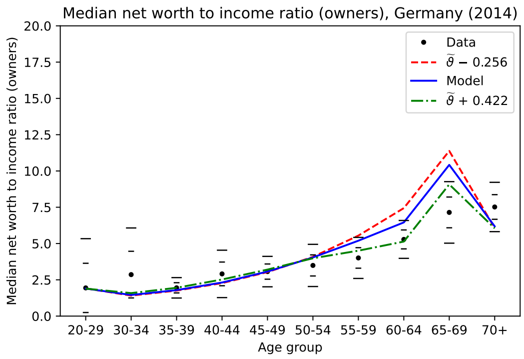
(c) Mean net wealth–income ratio of owners



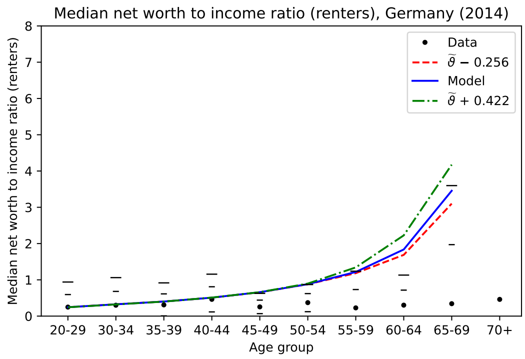
(d) Mean net wealth–income ratio of renters

Source: Household Finance and Consumption Survey, wave 2014.
Note: The blue solid line shows the fitted values. The red dashed and green dash-dotted lines show how a small negative and positive change in a parameter affect the relevant fitted moment. The dots denote data; the brackets around them denote one and two standard error bands. The figures illustrate the moments for the case of Germany.

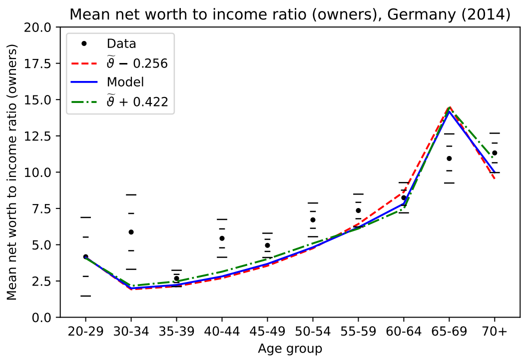
Figure 13 Identification of the Spread of the Discount Rate $\widetilde{\vartheta}$



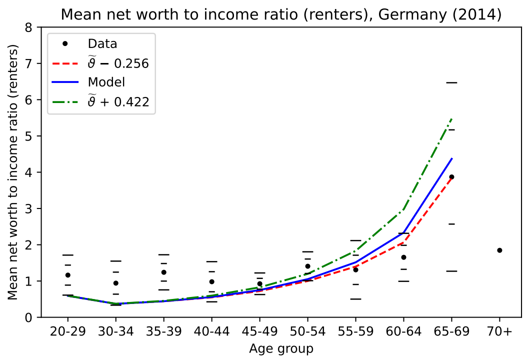
(a) Median net wealth–income ratio of owners



(b) Median net wealth–income ratio of renters



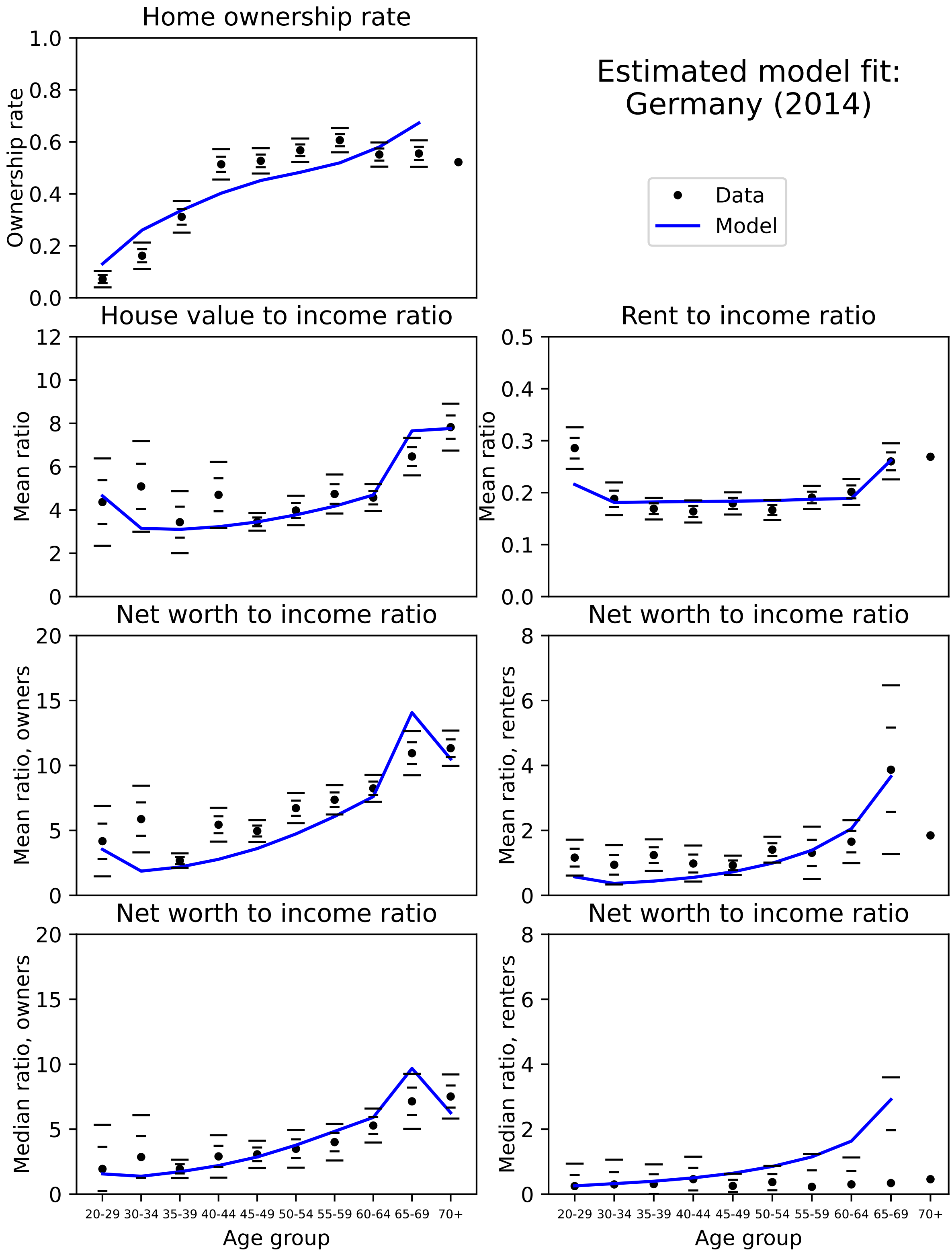
(c) Mean net wealth–income ratio of owners



(d) Mean net wealth–income ratio of renters

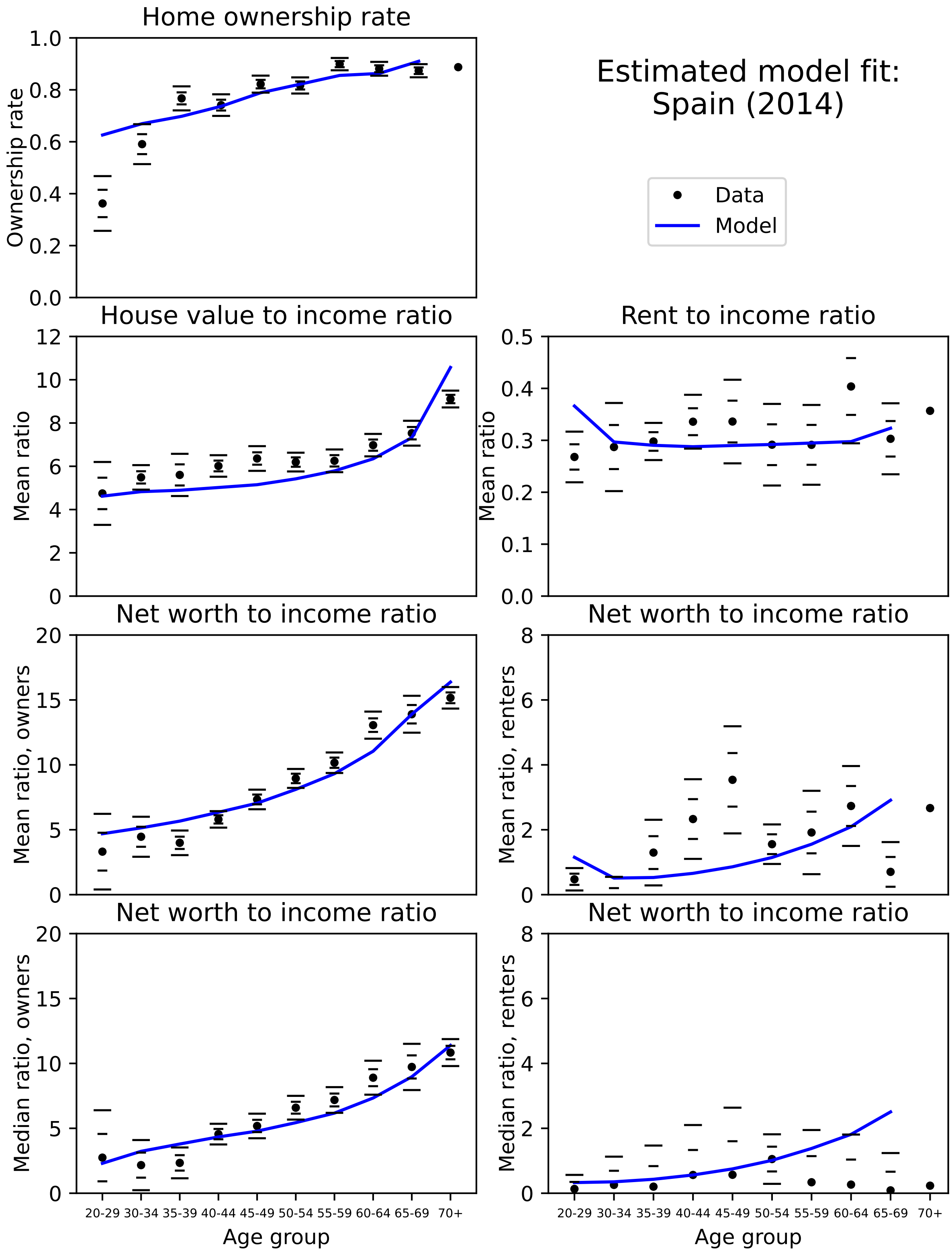
Source: Household Finance and Consumption Survey, wave 2014.
Note: The blue solid line shows the fitted values. The red dashed and green dash-dotted lines show how a small negative and positive change in a parameter affect the relevant fitted moment. The dots denote data; the brackets around them denote one and two standard error bands. The figures illustrate the moments for the case of Germany.

Figure 14 Fit of Moments—Germany



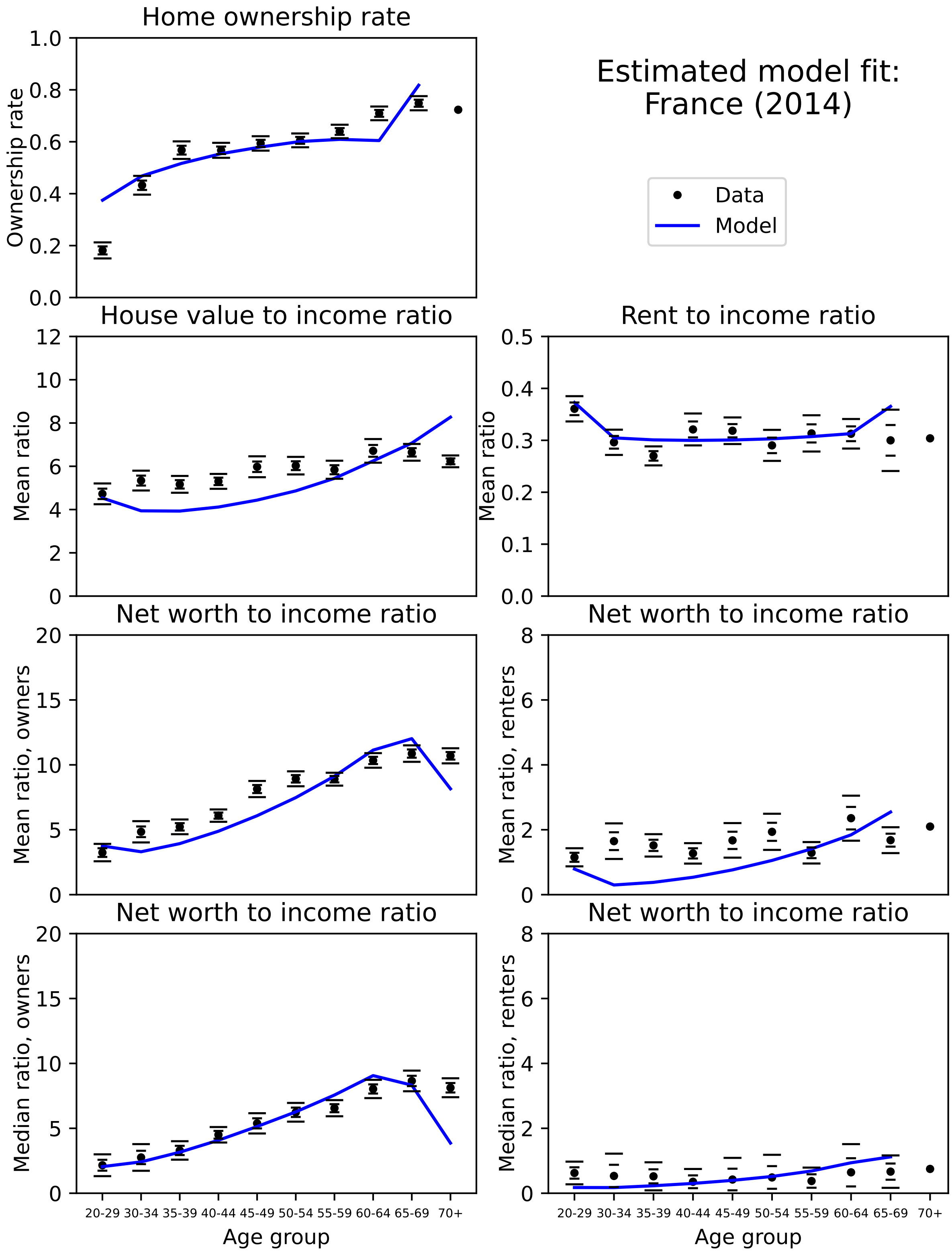
Source: Household Finance and Consumption Survey, wave 2014.
Note: The dots denote data; the brackets around them denote one and two standard error bands. The blue line shows the moments fitted by the model.

Figure 15 Fit of Moments—Spain



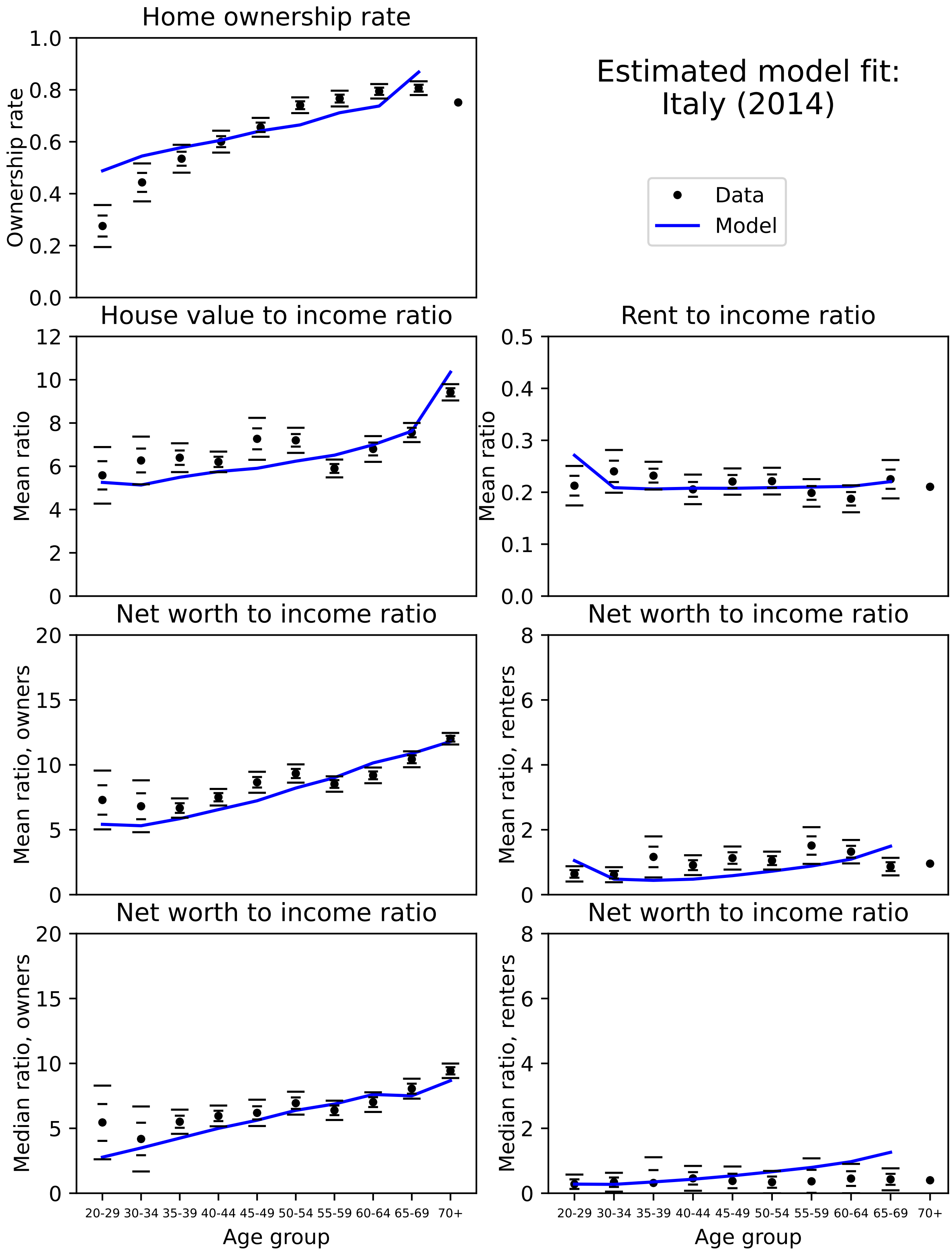
Source: Household Finance and Consumption Survey, wave 2014.
Note: The dots denote data; the brackets around them denote one and two standard error bands. The blue line shows the moments fitted by the model.

Figure 16 Fit of Moments—France



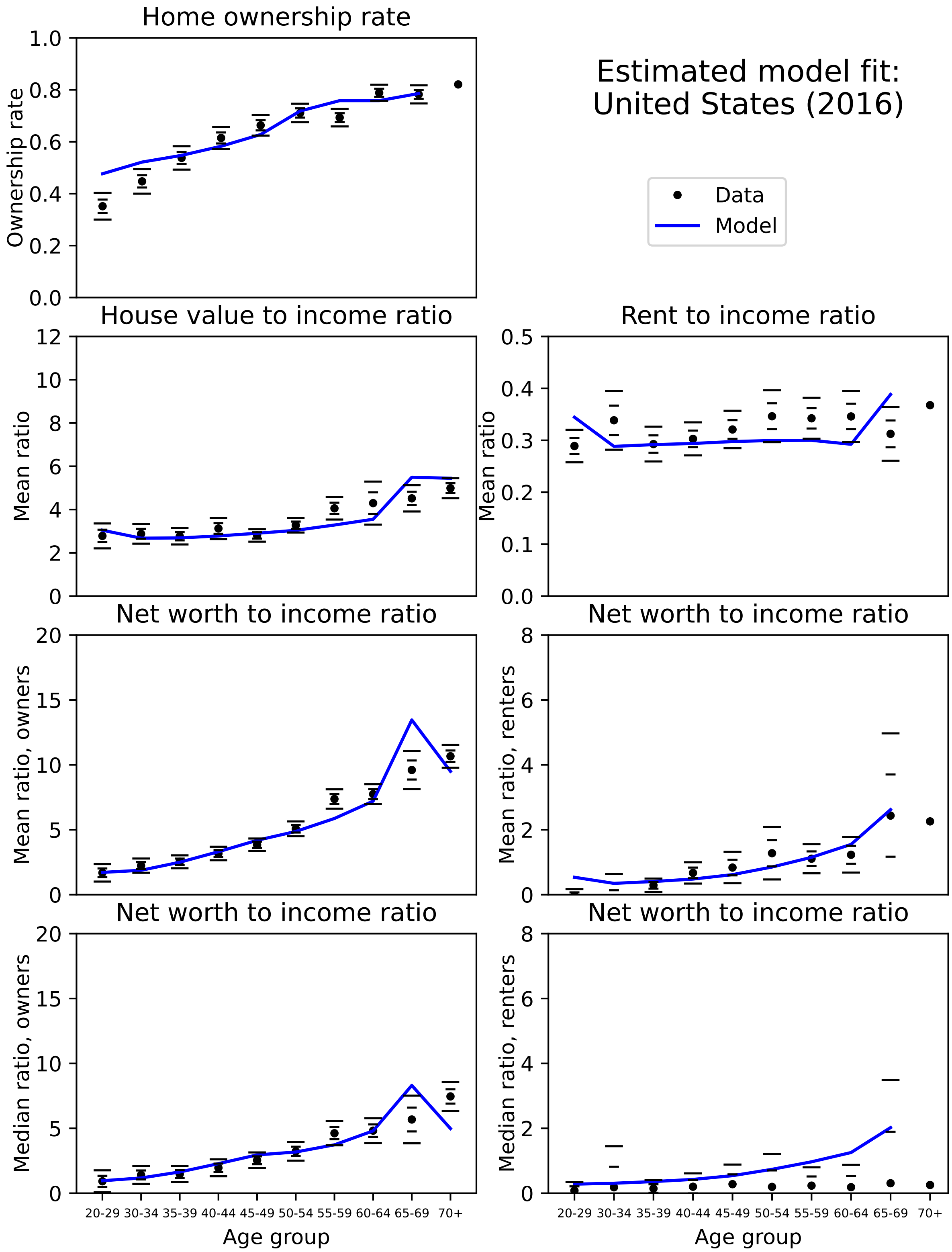
Source: Household Finance and Consumption Survey, wave 2014.
Note: The dots denote data; the brackets around them denote one and two standard error bands. The blue line shows the moments fitted by the model.

Figure 17 Fit of Moments—Italy



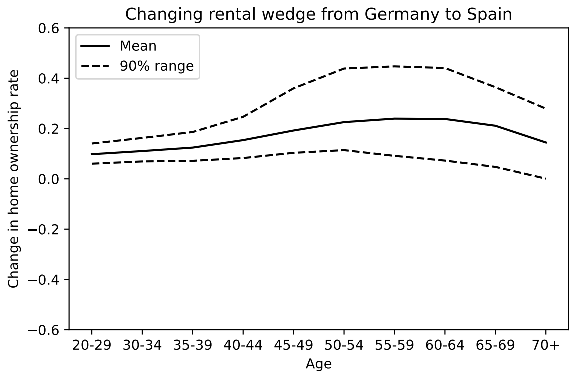
Source: Household Finance and Consumption Survey, wave 2014.
Note: The dots denote data; the brackets around them denote one and two standard error bands. The blue line shows the moments fitted by the model.

Figure 18 Fit of Moments—United States

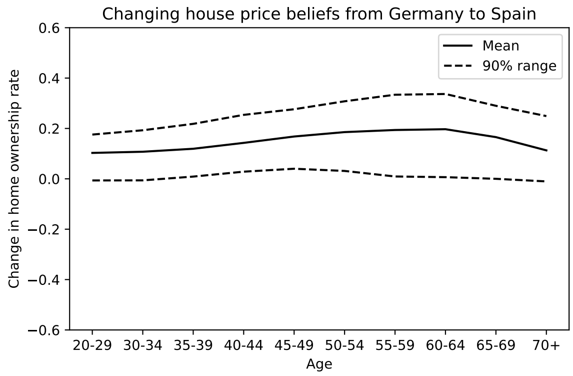


Source: Survey of Consumer Finances, 2016.
Note: The dots denote data; the brackets around them denote one and two standard error bands. The blue line shows the moments fitted by the model.

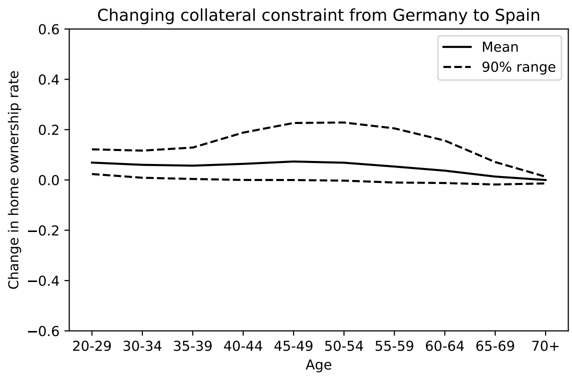
Figure 19 Decomposition of Homeownership Rates: Germany → Spain I.



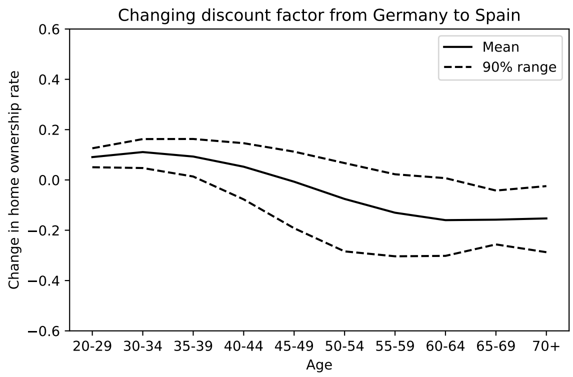
(a) Rental Wedge



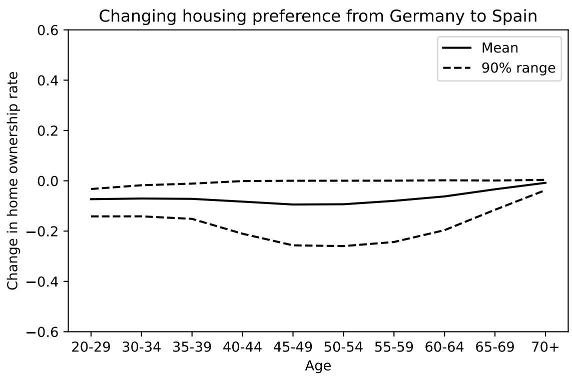
(b) House Price Beliefs



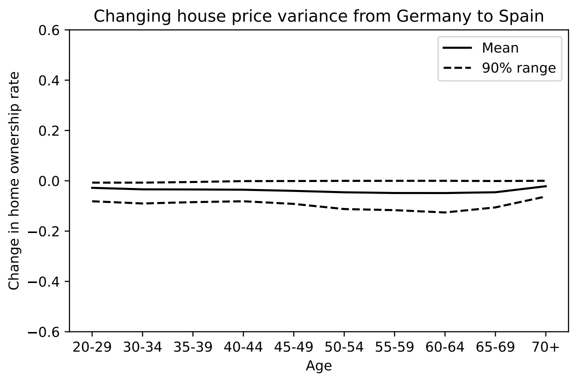
(c) Collateral Constraint



(d) Discount Factor Mean and Spread



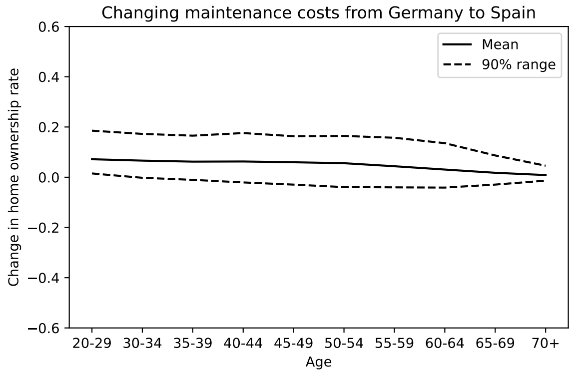
(e) Housing Preference



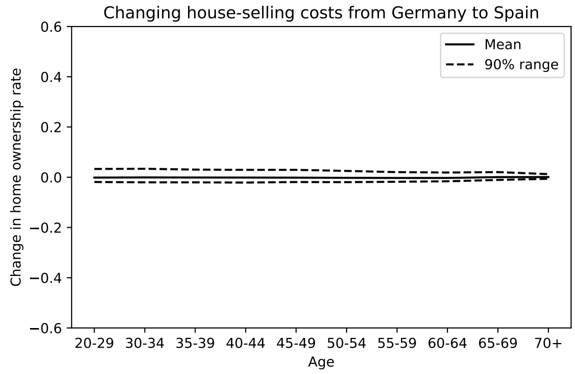
(f) Variance of House Prices

Note: The solid line shows the mean effect of various factors on the homeownership rate, averaged across the orderings of the factors for an example of the decomposition between Germany and Spain. The dashed lines show the spread across the decompositions, reflecting the 90 percent range across the orderings.

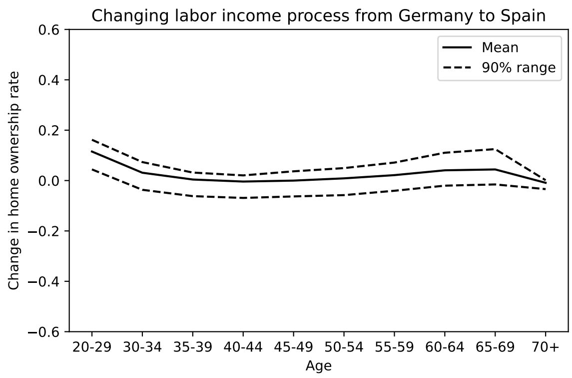
Figure 20 Decomposition of Homeownership Rates: Germany → Spain II.



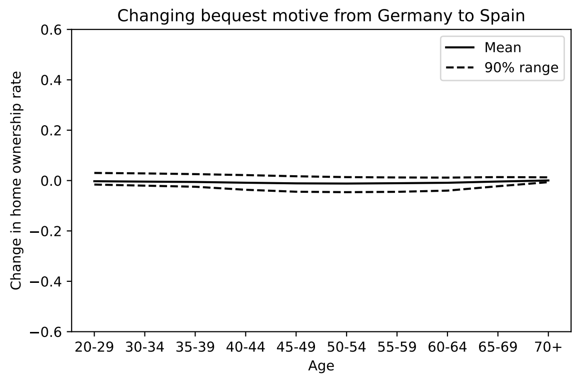
(a) Maintenance Cost



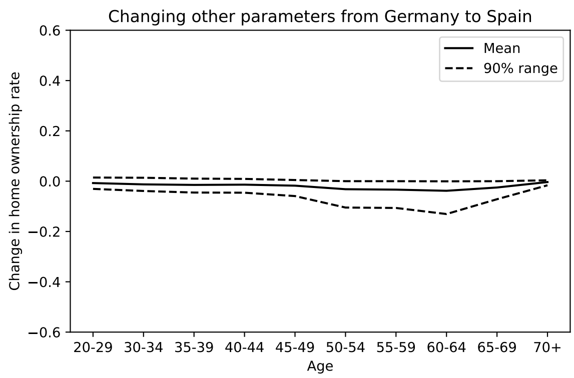
(b) House Selling Cost



(c) Labor Income Process



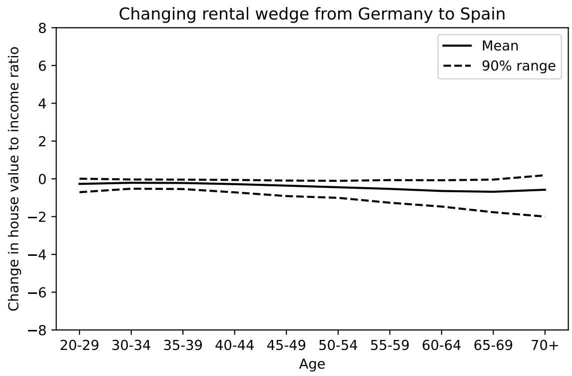
(d) Bequest Motive



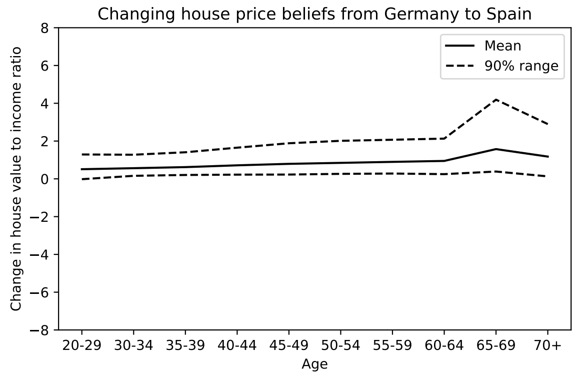
(e) All Other Factors

Note: The solid line shows the mean effect of various factors on the homeownership rate, averaged across the orderings of the factors for an example of the decomposition between Germany and Spain. The dashed lines show the spread across the decompositions, reflecting the 90 percent range across the orderings. "All other factors" include mortality, transaction costs, realized house price growth and interest rate.

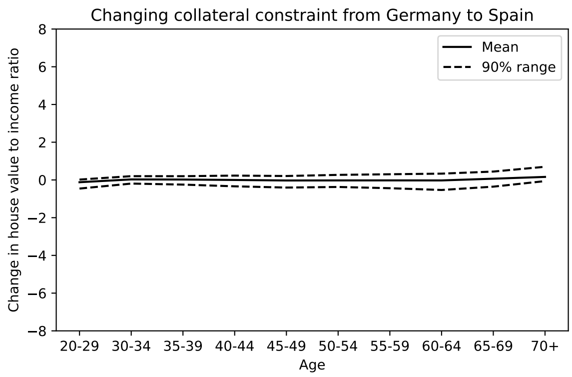
Figure 21 Decomposition of Mean Housing Wealth: Germany → Spain I.



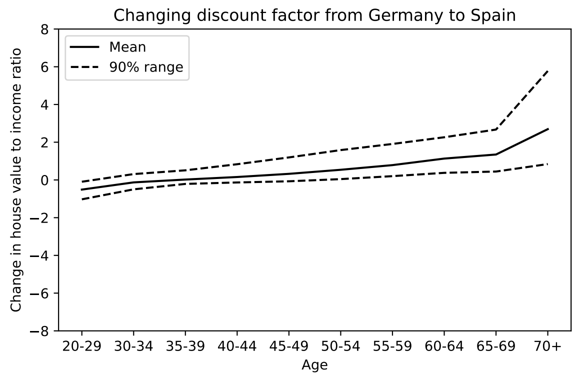
(a) Rental Wedge



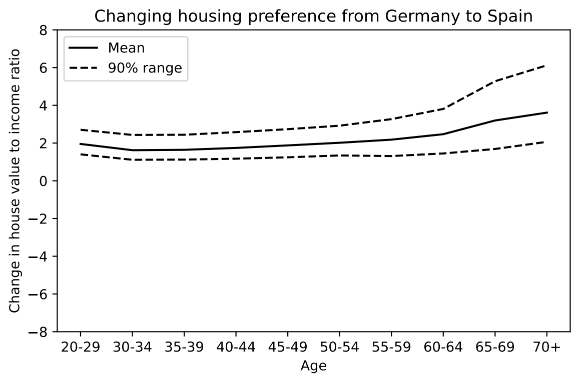
(b) House Price Beliefs



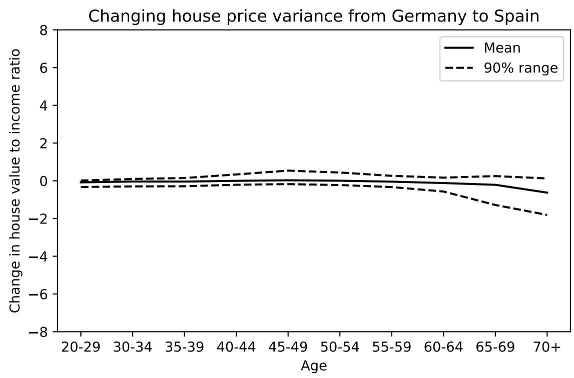
(c) Collateral Constraint



(d) Discount Factor Mean and Spread



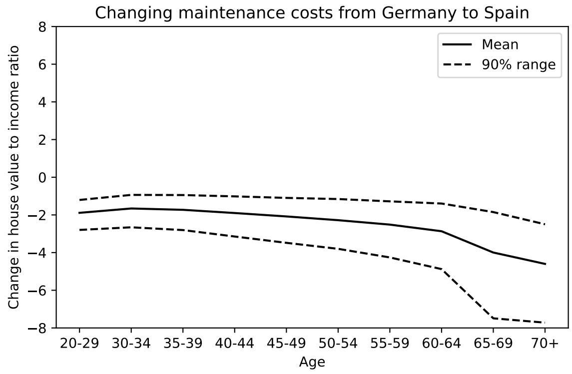
(e) Housing Preference



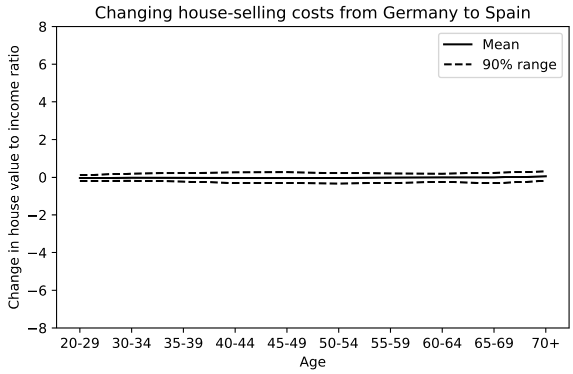
(f) Variance of House Prices

Note: The solid line shows the mean effect of various factors on the homeownership rate, averaged across the orderings of the factors for an example of the decomposition between Germany and Spain. The dashed lines show the spread across the decompositions, reflecting the 90 percent range across the orderings.

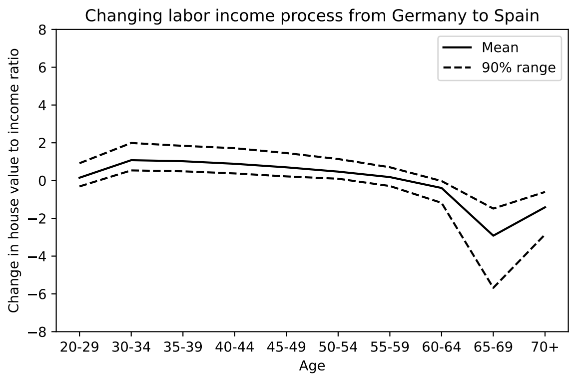
Figure 22 Decomposition of Mean Housing Wealth: Germany → Spain II.



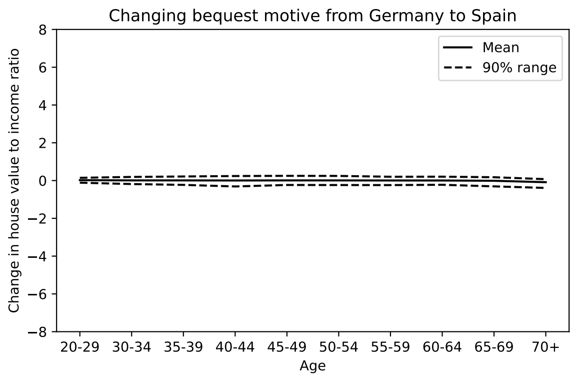
(a) Maintenance Cost



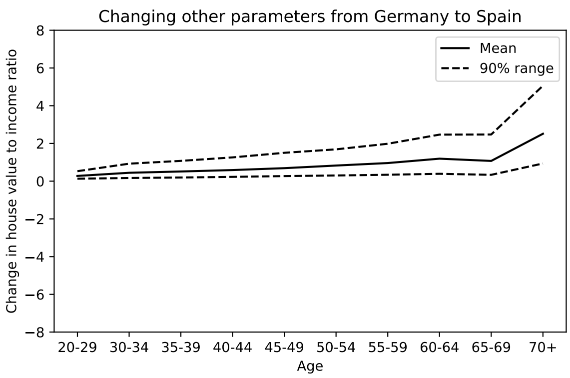
(b) House Selling Cost



(c) Labor Income Process



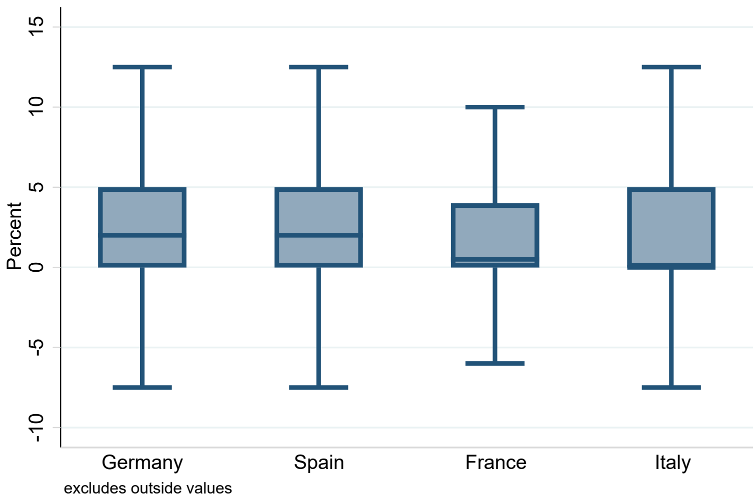
(d) Bequest Motive



(e) All Other Factors

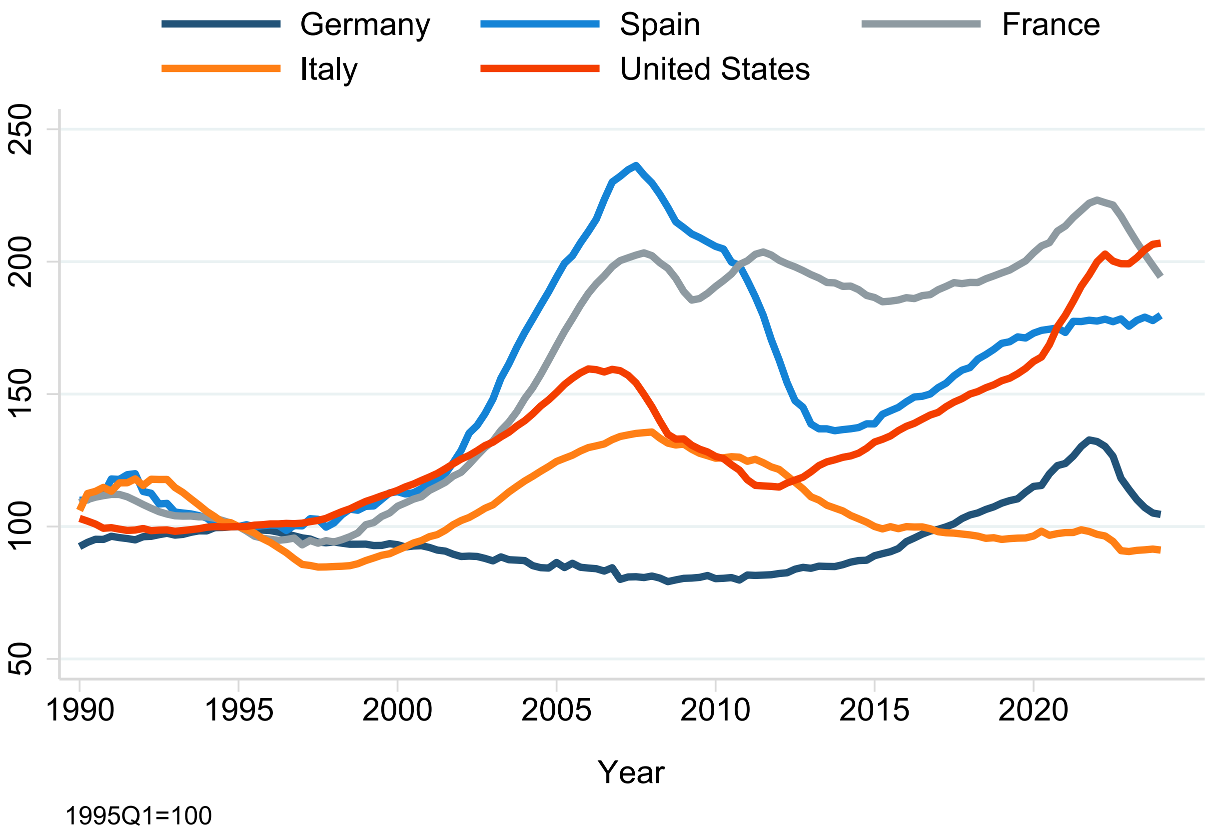
Note: The solid line shows the mean effect of various factors on the homeownership rate, averaged across the orderings of the factors for an example of the decomposition between Germany and Spain. The dashed lines show the spread across the decompositions, reflecting the 90 percent range across the orderings. "All other factors" include mortality, transaction costs, realized house price growth and interest rate.

Figure 23 Dispersion of 1-Year Ahead House Price Growth Expectations



Source: ECB Consumer Expectations Survey, April 2020–May 2023.
Note: The figure shows the dispersion of household expectations at the 1-year horizon for Germany, Spain, France and Italy in percent. The box plot shows the lower adjacent value, the 25th percentile, the median, the 75th percentile and the upper adjacent value. The adjacent values are the 25th percentile − 1.5×interquartile range and the 75th percentile + 1.5×interquartile range.

Figure 24 Real House Prices



Source: OECD Analytical House Price Database, 1990–2023.

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The views presented in this paper are those of the authors, and do not necessarily reflect those of the European Central Bank or the European Commission. This paper uses data from the Eurosystem Household Finance and Consumption Survey.

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