Household Stock Market Participation and Exit in the US: The Role of Homeownership

Revised Draft Coming Soon

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Abstract

This paper argues that a large part of the stock market participation puzzle is driven by high stock market exit rates among participants: In the US, 20% of households who have stock hold no stocks two years later. Using survey data I show that stock market exit largely coincides with renting households becoming first-time owners. After estimating a life-cycle model of portfolio choice with housing and per-period participation costs, I show that it can quantitatively match the US participation rate over the entire life-cycle. The model matches the high exit rate of new homeowners, while tying up wealth in housing reduces the participation rate among middle-aged and retired households. The estimated model jointly matches the participation rate, homeownership rate, net worth and conditional portfolio weights over the life cycle. Housing reduces the unexplained participation gap between the model and the data by 71%, compared to a model without housing.

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1 Introduction

Only half of US households hold any stocks or mutual funds at any given time. Among current stock market participants, 20% exit the stock market and hold no stocks two years later. At the same time, the majority of US households own their primary residence.[1] Given the high equity premium, the low participation rate challenges both economic theory and retirement policy. In this paper, I ask to whether homeownership, and the frictions associated with housing, can explain the low stock market rate and simultaneously the high exit rate among participants.

I first document the high exit rate from stock markets among US households. At any age, the two-year exit rate is between 15-40%, while the entry rate ranges from 8-16%. This novel fact underscores that the low participation rate is not only about low entry rates, but potentially more about high exit rates. Second, I show that homeownership is associated with non-participation. All else equal, the stock market participation rate of owners is 6 percentage points lower than that of renters. Third, the participation dynamics differ by house tenure: the exit rate is substantially higher among renters and becoming a homeowner increases the probability of exit by 16 percentage points. Taken together, the facts suggest that a life-cycle model of stock market participation should take into account the joint participation-ownership decision.

Motivated by these stylized facts, I extend the workhorse life-cycle portfolio choice model in Cocco et al. (2005). The extended model adds a per-period participation cost and house-tenure decisions to a realistic life-cycle model, and can jointly account for the participation rate, homeownership rate, conditional portfolio weight on stocks, and net worth over the entire life cycle. To do so, the model requires high participation costs ($199 per year, in 1995 dollars) and high constant relative risk aversion parameter ($\gamma = 12.36$). My model also nests Fagereng et al. (2017) who study limited stock market participation in Norway but omit housing. To under-

[1] Author's calculation from the Panel Study of Income Dynamics, see section 2 for details.

stand the contribution of housing to the participation puzzle, I estimate the model with and without housing. Housing drives down participation mainly by decreasing homeowners' liquid wealth and that owners prefer to build home equity in order to move away from the mortgage borrowing constraint before investing in stocks. Secondly, since renters aspire to become homeowners, they have short investment time horizons which decrease the attractiveness of the stock market and drive down their participation rates. As in the data, the model shows that renters who become homeowners often liquidate their stock holdings to finance a down payment.

To test the validity of the model I perform three exercises. First, the model matches the entry and exit rates into the stock market over the life cycle, even though this moment is not targeted in the estimation. Second, the model generates lower participation rates among renters than homeowners, a key feature of the data. Third, Chetty et al. (2017) obtain causal estimates of the effects of home equity and mortgage debt on the portfolio weights of US households. Using the same empirical models on the model-simulated panel provides estimates that are similar, showing that the model not only matches aggregate moments but also the causal effects of housing on portfolio choices in the US.

To understand the interplay between homeownership, financial frictions and stock market participation I perform a policy experiment where the down payment increases. An increase in the down payment delays homeownership. By delaying homeownership, the participation rate of renters goes up, as they hold more liquid wealth. At the same time, this means that the fraction of middle-aged households with low liquid increases, decreasing the participation rate of middle-aged households. Finally, I study the relative importance of the three ex-ante sources of risk (income, house prices, and stock returns) households face in the model and find that income risk/inequality is the main source of wealth dispersion. Still, the calculation shows that house price risk at age 60 causes the 20th percentile of the wealth distribution to have 2/3 lower net worth than the 80th percentile.

1.1 Relation to the Existing Literature

The main contribution of this paper is to demonstrate

1. That high exit rates among participating households drive limited stock market participation.
2. That house tenure changes drive stock market exit.
3. That a model with owner-occupied housing and participation decisions can explain the stock market participation puzzle and the high exit rate.

I provide a general literature review before discussing the two papers that are closest to mine.

There is a large literature on the life-cycle profiles of portfolio choices in models with realistic income processes (e.g. Cocco et al. (2005); Chang et al. (2018); Wachter and Yogo (2010)). This literature generally focuses on the portfolio weights and ignore the participation decision. One strand of this literature, owing back to Vissing-Jørgensen (2002) focuses specifically on limited stock market participation (Cocco (2005); Calvet et al. (2007); Athreya et al. (2017); Catherine (2019), who respectively uses a one-time fixed cost, investor mistakes, costly human capital investment or correlations between stock returns and income as mechanisms to explain non-participation. While most of the literature omits housing, Cocco (2005) and Yao and Zhang (2005) are notable exceptions, but each paper bypass either extensive margin, house tenure or the participation decision, respectively. My paper contributes by showing that a satisfying theory of limited stock market participation should also explain the high exit rate and that illiquid housing does so.[2]

Some empirical papers have cast doubt on the theoretical findings from life-cycle models with housing and stock market portfolio decisions, but Chetty et al. (2017)

[2] Another paper, Briggs et al. (2020) use Swedish register data and show that households do not immediately enter the stock market even when winning large lotteries. This is hard to explain with reasonable one-time fixed cost or per-period costs. In line with my model, they find that renters have smaller treatment effects on participation.

reconciles theory with evidence and finds that home equity or property values have large effects on portfolio weights and participation decisions. Further, Beaubrun-Diant and Maury (2016) explicitly considers the joint tenure-participation decision and find large causal effects of homeownership on participation. My paper contributes by showing that housing is important for participation decisions, and in particular, for stock market exit.

Fagereng et al. (2017) use high quality Norwegian administrative data to document a dual re-balancing away from stocks around retirement: households first decrease portfolio weights as they age, and then gradually exit the stock market. After extending the workhorse model by Cocco et al. (2005) to include a per-period participation cost and stock market tail events, they show that an estimated version of the model can match the dual adjustment. This age-dependent interaction of a participation cost and tail events is novel and occurs because older households are more reliant on financial assets, and thus stock market crashes are more costly, and they hold lower portfolio shares than younger households. However, the model is unable to generate sufficiently limited stock market participation, with over 90% of middle-aged households participating versus the 55% participating in the data. My paper contributes by showing that the addition of owner-occupied housing into this framework can jointly explain the low participation rate over the entire life cycle, portfolio weights, and the high exit rate.

While Fagereng et al. (2017) omits housing, Vestman (2019) focuses on the large difference in the participation rate among renters and homeowners. Using Swedish data, he argues that housing seems relatively unimportant in explaining the participation decision among Swedish households but finds evidence for unobserved household fixed effects. He then builds a model where households face a one-time participation cost and a house tenure decision. To match a peak participation rate of 75%, he uses a stylized form of preference heterogeneity, where one type (which tends to own) is more patient, lower risk aversion, and lower participation costs than the other type (which tend to rent). This preference heterogeneity can match the participation gap between renters and owners, a non-trivial achievement since renters have more to gain from participation. Vestman's work is the first to study the house tenure decision together with the entry decision. However, the calibrated model counter-factually predicts 100% participation among retirees and overpredicts participation at all ages above 35. Moreover, a model without per-period participation costs cannot generate exit from stock markets.

Compared to these two papers, this paper contains several innovations. First, the model is taken to the US, where institutional differences make private savings more important for consumption after retirement. Second, the combination of housing and per-period cost allows the model to qualitatively and quantitatively match the participation rate and other moments over the life-cycle. To my knowledge, no existing models can generate sufficiently low peak participation rates while jointly matching households' wealth and portfolio weights on stocks over the life cycle. Per-period costs, combined with tail-events, also generate lower participation rates among renters, which per-period costs alone cannot do. The mechanism behind this result is similar to the dual adjustment in Fagereng et al. (2017): renters need sufficient financial wealth for a down payment and so are less likely to participate in the stock market than owners, all else equal. I compliment the work in Vestman (2019) by highlighting another mechanism (tail events and per-period costs together with borrowing constraints) that induces a participation gap between owners and renters. Further, homeowners with low home equity and low liquid wealth ('home poor') prefer to build home equity to stock investment, decreasing participation even among the middle-aged.

2 Data

The Panel Study of Income Dynamics (PSID) is a longitudinal household survey compiled by the University of Michigan since 1968. Since the PSID follows individuals and households over time we can study households participation and portfolio decisions preceding, during, and after house tenure changes. From 1999 detailed wealth information has been collected bi-yearly. The largest drawback of the PSID is that the household's financial portfolio allocations are poorly measured. To complement the PSID and obtain more accurate portfolio information I also use the Survey of Consumer Finances (SCF). The SCF is a cross-sectional survey of US households and is conducted every three years by the Federal Reserve Board. The main advantage of the SCF is that it includes more detailed balance sheet information so that we can construct more accurate portfolio weights. The SCF's main drawback is that it consists of repeated cross-sections instead of following individuals over time. Throughout this paper the sample includes only households aged 25 to 84. To define household age, education and gender I use the household head. In the PSID households from the Survey of Economic Opportunity and Latino Samples are excluded to obtain a representative sample of households.

2.1 Estimation of Life-Cycle Profiles

When calibrating and estimating life-cycle models one must take a stand on whether one should control for time effects or cohort effects (Ameriks and Zeldes, 2004), or use another strategy as in Fagereng et al. (2017). Since age, birth year, and calendar year are perfectly collinear one cannot control for all three. No consensus has been reached in the literature on which approach to use. The resulting patterns are, in general, largely similar, but with larger deviations for older households. Since house prices and stock returns have large year-to-year fluctuations with similar effects across age, I control for time effects and assume that cohort effects are zero.

Age is binned into five year intervals from $[25, 29], [30, 34], \ldots, [80, 84]$ to reduce small-sample noise. To give each year a similar weight in the regressions, the weights are normalized within a year to sum to one. I drop households that belong to the top 1% and bottom 1% of the wealth distribution within each age group. For all life-cycle statistics in this paper, I use weighted linear regression with a full set of age and year fixed effects.[3] I then find the predicted value for each age and each year and find the average predicted value across all years in the sample.

2.2 Life-Cycle Participation, Ownership and Exit

I now turn to study how the participation and homeownership rates evolve over the life cycle in the PSID and the SCF. The left panel of 1 uses the PSID and reveals that stock market participation is limited at all ages. It starts at 10% among the youngest households, increases gradually to 55% at age 65 before it decreases slightly during retirement. Moreover, homeownership increases quickly from 15% among the young to 70% for households aged 45, with a peak at 80% at age 67 before households start to liquidate housing in retirement. The right panel plots the same data from the SCF. Broadly speaking, the patterns are the same, although the participation rate in the SCF is higher for younger households.

2.3 Entry and Exit Over the Life-Cycle

To better understand what drives the low participation rate in stock markets, I now turn to participation dynamics among US households using data from the PSID. Figure 2, left panel, plots the entry and exit rates from stocks over the life cycle, controlling for time effects. We can see that the exit rate is 35% at age 25, and then gradually decreases towards retirement age, at which point the exit rate starts to increase. Similarly, we see that the entry rate largely displays the opposite pattern,

[3]As is well known, this class of models cannot easily match the upper tail of the wealth distribution.

Figure 1: Life Cycle Participation and Homeownership

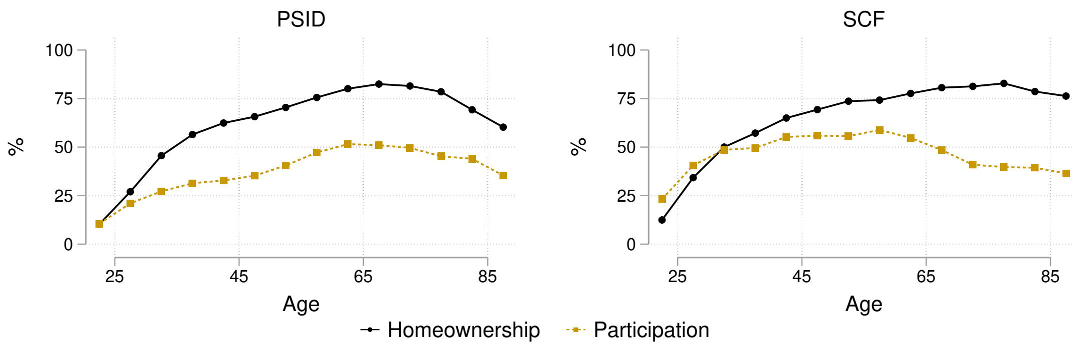
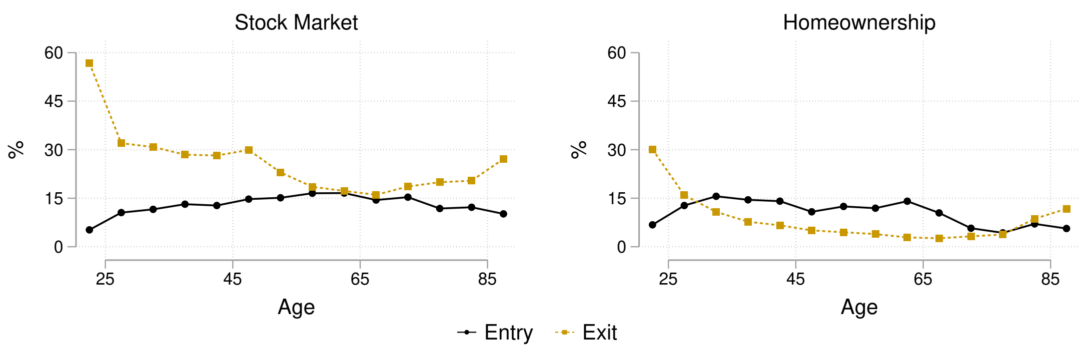


Figure 2: Life-Cycle Entry and Exit from Stock and Housing in the PSID

These figures plots the exit and entry rates in stocks and homeownership. The exit rate is defined as the fraction of households who own stocks (primary residence) in year t and do not in $t+2$, and are observed in both periods, and vice versa for the exit rates.



starting at 8% at age 25, gradually increasing until retirement age, and then weakly decreasing. The second panel plots the entry and exit into homeownership, and we can see that middle-aged renters rarely become owners and that about 10-15% of renters become homeowners while of working age. Once households retire, we see that the entry rate to ownership drops while the exit rate increases. We see that stock market participation is more dynamic than homeownership.

2.4 Regressions: Determinants of Participation and Exit

Why do some households enter and exit the stock market? I turn to linear regressions to shed light on the participation, entry, and exit decisions. Household stock market participation is related to homeownership using the following linear empirical model:

$$Participation_{it} = \beta \times Homeowner_{it} + \gamma X_{it} + \varepsilon_{it}, \tag{1}$$

where participation is measured as holding any amount of stocks in liquid accounts or IRA's or the alternative measure which excludes stock in IRA's. This specification mirrors the one used in Gianetti and Wang (2016), and who also use the PSID. The main set of controls include logged income and logged wealth, marriage status, education, lagged participation, logged age, and logged family size, in accordance with the existing literature (e.g. Guiso et al. (2008); Gianetti and Wang (2016)). Some variables are logged for ease of interpretation and to lessen the impact of outliers. The results are reported in Table 1. As Gianetti and Wang (2016) I use a linear probability model due to the large number of fixed effects and for ease of interpretations.

The first two columns regress participation (in any account), while columns 3-4 ignores participation in retirement accounts. Columns 2 and 4 include household fixed effects, to control for unobserved heterogeneity such as risk aversion. From column 2, we see that being a homeowner is associated with a 5.6 percentage point decrease in the probability of participation, indicating a strong substitution between stocks and housing. The effect is somewhat lower when ignoring stocks in retirement accounts. Other coefficients have the expected signs, with income and wealth increasing participation: a 10% increase in wealth increases the probability of participation by 5.0 percentage points when controlling for fixed effects. Controlling for fixed effects have minor impacts on the other control variables, except for the effect of lagged participation. This suggests that participation in one period does

Table 1: Determinants of Stock Market Participation

	(1) Participation	(2) Participation	(3) Participation (w/o IRA)	(4) Participation (w/o IRA)
Homeowner=1	-0.057***	-0.056***	-0.044***	-0.023***
	(0.004)	(0.006)	(0.003)	(0.005)
Log(Age)	-0.028***	0.171***	-0.010**	0.132**
	(0.004)	(0.043)	(0.004)	(0.049)
Married=1	0.027***	0.041***	0.009**	0.008
	(0.004)	(0.008)	(0.003)	(0.008)
Log(Family Size)	-0.044***	-0.013**	-0.025***	-0.005
	(0.003)	(0.005)	(0.002)	(0.005)
Log(Income)	0.033***	0.013***	0.014***	0.008***
	(0.002)	(0.002)	(0.001)	(0.002)
Log(Wealth)	0.055***	0.050***	0.032***	0.022***
	(0.001)	(0.001)	(0.001)	(0.001)
College=1	0.108***		0.078***	
	(0.004)		(0.004)	
Lagged Part.	0.432***	0.023***		
	(0.005)	(0.006)		
Lagged Part. (w/o IRA)			0.479***	-0.001
			(0.007)	(0.008)
Observations	74984	74984	58563	58563
Individual FE	N	Y	N	Y
Year and State FE	Y	Y	Y	Y
Within R^2	0.020	0.055	0.003	0.025

This table presents the relationship between household characteristics and stock market participation. Standard Errors in parentheses. Clustered at the family level. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

not lead to participation in later periods by itself, but that it is a combination of individual-specific characteristics and other financial observable variables that drive a household's participation decision.

Why is the exit rate so high? I report results from four different regressions, reported in table 2. The empirical model is the same as in equation (1) but with stock market exit as the dependent variable. The sample is thus limited to households who were observed participants in $t-2$. We see that controlling for other variables, homeowners are 4.3 percentage points more likely to exit stock markets. The impact of wealth is higher on exit than on participation: A 10% decrease in wealth increases the probability of exit by 8.3 percentage points, while it decreases the probability of participation by 'only' 5.5 percentage points. Marriage, family size, and income are only weakly related to the exit rate. Why is homeownership associated with stock market exit? Since the two first specifications include individual fixed effects the coefficient on homeownership must be interpreted with care. The estimate reflects the effect of homeownership only among households for whom we observe house tenure changes (renter→owner and owner→renter).

To decompose the effect of homeownership I limit the sample to households who were participating and renting in $t-2$. The results are reported in specifications (3) and (4) of table 2. I use the same set of control variables, but now measure the relationship between exit and becoming a homeowner. New homeowners have a 12-16 percentage points higher exit rate, relative to a mean exit rate of 21%. The relationship is higher when considering exit from non-retirement accounts, possibly as a result of their more liquid nature.[4] The effect of wealth is the same as when using the full participant sample. The effect of age, marriage status, family size, and income are all statistically non-significant.

Overall, the evidence in this section has three main implications. First, it suggests

[4] While retirement accounts are less liquid, they often have rules allowing a withdrawal in times of hardship or special circumstances. For example, first-time homeowners can withdraw penalty-free from an IRA to cover a down payment.

Table 2: The Determinants of Stock Market Exit

	Full Sample		Renters in $t-2$	
	(1)	(2)	(3)	(4)
	Exit	Exit (w/o IRA)	Exit	Exit (w/o IRA)
Homeowner=1	0.043**	0.030		
	(0.015)	(0.024)		
New Homeowner=1			0.124***	0.160***
			(0.029)	(0.045)
Employed=1	0.029**	0.038*		
	(0.010)	(0.017)		
Married=1	-0.047*	-0.009	0.001	-0.101
	(0.020)	(0.031)	(0.053)	(0.072)
Log(Age)	0.698***	0.986***	0.139	0.403
	(0.130)	(0.224)	(0.415)	(0.636)
Log(Family Size)	0.028*	0.023	0.083	0.154*
	(0.014)	(0.024)	(0.049)	(0.072)
Log(Income)	-0.017**	-0.013	-0.024	0.022
	(0.006)	(0.010)	(0.018)	(0.023)
Log(Wealth)	-0.083***	-0.077***	-0.074***	-0.064***
	(0.004)	(0.006)	(0.008)	(0.012)
Observations	20103	10485	3559	1751
Within R^2	0.076	0.089	0.145	0.211

This table present the relationship between household characteristics and exit from stock markets in a linear probability model. To be in the sample households must have owned stocks in year $t-2$. Standard errors in parentheses. Clustered at the family level. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

that the low participation rate is partially explained by the high exit rate. Second, I find that homeownership is a substitute for stock market participation. Third, homeownership is associated with stock market exit once other variables are held constant. These three facts taken combined suggest that a model with an endogenous house tenure decision combined with an endogenous entry/exit in stock markets may account for low stock market participation rates over the life cycle.

3 A Model of Participation and Homeownership

The previous sections establish novel facts about the life-cycle exit and participation decisions of US households. Existing models can account for the shape of the participation rate, but not for the joint patterns of homeownership, stock market participation, and the exit/entry in stock markets. In this section, I present a life-cycle model that explains these patterns. Before laying out the environment, technology, and preferences, I first provide a birds-eye of the model before describing the main two mechanisms through which housing reduces participation and increases exit.

To facilitate comparisons with the literature, I build on Fagereng et al. (2017), which in turn extends the workhorse model of Cocco et al. (2005). Relative to Fagereng et al. (2017), I add a housing market where households can choose to rent or own. The no-borrowing condition is also relaxed to allow for collateralized borrowing (mortgages). As in Fagereng et al. (2017), tail events and per-period participation account for the decreasing participation rate and portfolio weights among older households. Two main mechanisms improve the model's predictions.

First, housing decreases participation among younger and middle-aged households by tying up wealth in an illiquid asset. This effect is strengthened by the illiquidity of housing (through transaction costs): If a household recently bought a house, they have little liquid wealth. If they receive a bad income shock or a bad stock return shock, they may not be able to repay the mortgage payment in the next period and must downsize. Due to the sales cost, this is expensive.[5] This will also help generate more exit: Some wealthy households who own housing will receive bad income or stock return shocks, so that wealth drifts down. At some point, they become liquidity constrained, and so exit the stock market. Without housing, this only happens if households drift towards zero wealth, a very rare event both empirically and in the model.

[5] This mechanism relates to findings in Shore and Sinai (2010) and Chetty and Szeidl (2007), who show that illiquid housing increases risk aversion to 'large gambles'.

Second, As noted in Vestman (2019), renters will, all else equal, have more to gain by participation in stock markets. However, tail events reduce the renters' willingness to participate. Intuitively they face the trade-off of investing in stock markets to gain the equity premium to afford the down payment a little sooner. However, if a tail event happens, the dream of homeownership will be delayed if the intended downpayment was invested in stocks.

3.1 Households and Utility

Households enter the economy at age 25 and retire at age T^r. The probability of death between age a and $a+1$ is π_a, but households die with certainty at age 100. Households have time-separable preferences with discount factor β over consumption c_a and housing h_a, and the utility function is assumed to have a constant relative risk aversion form with a Cobb-Douglas aggregator:

$$U(c_a, h_a, \mathbf{o}) = \frac{\left(c_a^{\eta}(\chi_o h_a)^{(1-\eta)}\right)^{1-\gamma}}{1-\gamma}, \tag{2}$$

where the utility function is allowed to depend on house tenure through the parameter χ_o that equals unity if the household is renting and χ_1 if the household owns. The parameter γ measures risk aversion and η relates to the budget share of consumption expenditure. Households who do not survive between age a and $a+1$ derive warm glow utility from accidental bequest. A household that dies with x_{a+1} in networth receives $v(x_{a+1})$ utils, where

$$v(x_{1+1}) = \psi \frac{(\max\{x_{a+1}, 0\})^{1-\gamma}}{1-\gamma}. \tag{3}$$

The max operator is introduced for two reasons. First, in the US, households can die with negative net debt, but that debt is not passed on to inheritors. Second, with housing risk as introduced later, households can end up under water on the mortgage (market value less than their debt), and so net worth can be negative, but the CRRA utility function is only defined for strictly positive numbers.[6].

3.2 Market Structure and Stochastic Processes

3.2.1 Financial Markets

There are two financial assets, a risk-free one-year bond b_a and risky stocks s_a. The bond earns a constant interest rate r_f if positive, but debt (mortgage) has a mortgage premium of r^m. The risky asset has uncertain returns, defined as the sum of the risk-free rate, the risk premium r_p and a financial shock ε_t^s. The shock follows a normal distribution augmented with a small probability p_{tail} of stock market crashes:

$$r_t = r^f + r^p + \varepsilon_t^s, \text{ with } \varepsilon_t^s \sim \begin{cases} r_{tail} & \text{with probability } p_{tail}, \\ \mathcal{N}(0, \sigma_s^2) & \text{with probability } 1 - p_{tail}. \end{cases} \quad (4)$$

3.2.2 House Market

In the model house prices are linear in house quality h, and follow a stochastic process with drift μ and housing market uncertainty ε^h, as well as stock market correlation $\theta_h^s \varepsilon^s$:

$$R_{t+1}^h \equiv \frac{p_{t+1}}{p_t} = \exp(\mu + \varepsilon_{t+1}^h + \theta_h^s \varepsilon_{t+1}^s), \quad \sigma_t \sim \mathcal{N}(0, \sigma_h^2), \quad (5)$$

where p_a is the house price per square meter. The parameter θ_h^s pins down the correlation between the stock market and housing market. Further, the rental price is assumed to be a constant fraction f of the market value. To ease computations the rental market consists of a single unit of quality h_{rent}, and the owner-occupied markets has two sizes, h_{small}, h_{large}. House transactions are settled immediately, so a household that enters a period as a renter can immediately become an owner, and vice-versa.

[6] I actually therefore use $\max\{x_{a+1}, \epsilon\}$ where ε is a small number

3.2.3 Income

Income $w_{i,a}$ of individuals i at age a consists of one idiosyncratic transitory shock ε_i, an idiosyncratic persistent shock v_i, a deterministic life-cycle component f_a as well as the aggregate shocks:

$$\log(w_{i,a}) = f_a + v_{i,a} + \varepsilon_{i,a} + \theta_w^h \varepsilon_a^h, + \theta_w^s \varepsilon_a^s \quad a < T^R, \varepsilon_{i,a} \sim \mathcal{N}(0, \sigma_\varepsilon^2). \tag{6}$$

The persistent component $v_{i,a}$ follows a first-order autoregressive (AR(1)) process with normal innovations:

$$v_{i,a} = v_{i,a-1} + \nu_{i,a}, \quad \nu_{i,a} \sim \mathcal{N}(0, \sigma_\nu^2). \tag{7}$$

Retired households face no labor income risk. To capture social security and pension benefits retired households receive a fraction ϕ of their wage in the last period of working life:

$$w_{i,a} = \phi w_{i,T^r} \;\forall\; a \geq T^r.$$

Going forward the subscript i is omitted unless necessary.

3.2.4 Welfare System

Since house prices are growing at rate μ and subject to log-normal shocks, the house price is unbounded above. At the same time income is stationary, and so for very high price realizations some households may unable to afford a place to live. I therefore assume that the government runs a welfare system that guarantees that the minimum after-tax income w is 5% larger than the market price of rental housing.[7] If no such assumption is placed, the model must include either a reflecting barrier for house prices or explicitly model homelessness.

[7] In the simulations households receive this minimum income about XX%.

3.3 Borrowing Constraints and Law of Motion

The model is best understood from the household's budget constraints and the law of motion for wealth. Households have two sources of wealth: Financial wealth from stocks or bonds and owner-occupied real estate. Let x_a denote a household's wealth at age a.

3.3.1 Budget Constraints

In each period, the households choose how to spend their wealth on consumption c, bonds b, stocks s and housing services h. Stock market participation is costly, and households pay a real cost q in every period they hold stocks. Throughout the paper the notation $\mathbf{1_s}$ is shorthand for an indicator functions that equals one if households invests a strictly positive amount in stocks $\mathbf{1_s} \equiv \mathbf{1}_{s_{a+1}>0}$. If a household decides to rent it pays the rental price fph:

$$c_a + (s_{a+1} + \mathbf{1_s} q) + b_{a+1} + f p_a h_a = x_a. \tag{8}$$

Households that choose to own a house in the current period pay the market price of the house. Homeowners or renters who purchase a new house must pay a transaction and moving costs m proportional to the market value of the new home. Let $\mathbf{m}$ take the value m if the household moves in the current period or 0 else.

$$c_a + \mathbf{1}(s_{a+1} + q) + b_{a+1} + p_a h_a (1 + \mathbf{m}) = x_a. \tag{9}$$

3.3.2 Evolution of Cash-on-Hand

If the household chose to rent at the beginning of the period, the realized net worth in the next period is given by realized gains on bonds and stocks:

$$x_{a+1} = s_{a+1}(1 + r_{a+1}) + b_{a+1}(1 + r^f). \tag{10}$$

Homeowners' future wealth depends additionally on the next period market value of the house, net of deprecation:

$$x_{a+1} = s_{a+1}(1 + r_{a+1}) + b_{a+1}(1 + r^f) + p_{a+1}h_a(1 - \delta). \tag{11}$$

Since house prices are stochastic, from the budget constraints and the laws of motion we see that renters face house price risk in the cost of housing in the next period while homeowners face uncertainty in the evolution of wealth.

3.4 Recursive Formulation

All households have several choices: consumption c, portfolio choices between bonds b, stocks s, and housing h as well as the discrete ownership and participation decisions. Due to the discrete choices, the decision problems are easily separated into parts: First households choose whether to rent, buy a house or if they already own to stay. Second, households choose whether to participate in the stock market and given the two discrete choices they choose optimal consumption, savings, and portfolio weights. The discrete nature of the problem lends itself to solving the decision problem in parts, conditional on choosing to buy B, rent R or staying S in the house.

Since house transactions are immediate a homeowner who sells his house with wealth x_a is identical to a renter with wealth x_a. Denote a renter's value function by $V_a^R(x_a, v_a, p_a)$, the value function of households who buys a new house $V_a^B(x_a, v_a, p_a)$, and the value function of owners who stay by $V_a^S(x_a, v_a, p_a, h_a)$. For the rest of the paper I omit the age subscript on variables, and use primes to denote the $a+1$ subscript. A household of that owns at age a then chooses optimally between these tree alternatives:

$$V_a(x, v, p, h) = \max_{R,B,S}\{V_a^R, V_a^B, V_a^S\}. \tag{12}$$

A renter faces only the choices between renting and buying. It is worth mentioning that if one omits housing, for example by setting $h = 0$, that the model collapses exactly to the one in Fagereng et al. (2017), and thus also nests Cocco et al. (2005). See appendix C.2 for more.

3.4.1 Stayers' Decision Problem

I now present the decision problem of a stayer. The decision problem of renters and buyers are in appendix C.1. A household who enters the period with wealth x, has persistent human capital v, observes house prices p and owns a house of size h chooses consumption c, levels of stock investment s' and the net bond position b'. If he holds a positive amounts of stocks he pays the participation cost q:

$$
\begin{aligned}
V_a^S(x, v, p, h) &= \max_{c, b', s'} \{u(c, h) + \beta \mathbb{E}_a[\pi_a V_{a+1}(x', v', p', h) + (1 - \pi_a)(x')]\} \\
x + w &= c + \mathbf{1}(s' + q) + b' + ph \\
x' &= s'(1 + r') + b'(1 + r^f) + hp'(1 - \delta) \\
&\{c, s'\} \in [0, \infty)^2, b' \geq -(1 - d)ph \\
&\text{Processes for } w, r, p \text{ (eq. 6,4,5)}
\end{aligned}
\tag{13}
$$

4 Estimation

The model is estimated in two steps. In the first step I estimate prices and stochastic processes directly from the data or set them to the standard parameter values in the literature. In the second step I estimate the preference parameters, probability of stock market tail events and the participation cost by the method of simulated moments.

4.1 Externally Calibrated Parameter Values

I now list all parameters and their values when they are taken directly from the literature. All exogenously calibrated parameter values are listed in the top panel of table 3.

Table 3: Model Parameter Values

Parameter		Value	Source
Financial markets			
Risk free rate	r^f	0.02	Cocco et al. (2005)
Equity premium	r^p	0.04	Cocco et al. (2005)
Stock return std. deviation	σ_s	0.157	Cocco et al. (2005)
Tail event return	r_{tail}	-0.5	n/a
Mortgage premium	r^m	0.0169	Own calculation (sec. 4.1.1)
Correlation income & stocks	θ_w^s	0.0	Own calculation (sec. 4.1.2)
Correlation income & prices	θ_w^h	0.0	Own calculation (sec. 4.1.2)
Correlation stocks & prices	θ_h^s	0.12	Own calculation (sec. 4.1.2)
Labor Market			
Auto-correlation	ρ	0.95	Cooper and Zhu (2016), (sec. 4.2)
Transitory shocks std. dev.	σ_ε^2	0.08	Cooper and Zhu (2016), (sec. 4.2)
Persistent shocks std. dev.	σ_ν^2	0.018	Cooper and Zhu (2016), (sec. 4.2)
Start of retirement	T^R	69	PSID, section 4.2
Replacement ratio	ϕ_{ret}	0.758	PSID, section 4.2
Deterministic wage profile	f_a	fig. 9a	PSID, section 4.2
Housing Market			
House price drift	μ	0.015	Cocco (2005) (sec 4.1.1)
House price std. deviation	σ_h	0.093	Cocco (2005) (sec 4.1.1)
House price depreciation	δ	0.025	Harding et al. (2007)
Minimum down payment	d	0.15	Cocco (2005)
Transaction cost	mc	0.08	Cocco (2005)
Rent-to-house value	f	0.05	Davis et al. (2008)
Rental size	h_{rent}	4	PSID (sec 4.3)
Owner-occupied sizes	h_{small}, h_{large}	(5,8)	PSID (sec 4.3)
Simulation & Other			
Survival rates	π_a	fn.	2004 SSA Life Table
Wealth-Ownership joint distr.	n/a	fig 9b	PSID, (sec 4.3.2)

Note: The table lists the parameter values for the correlation parameter. These parameters gives a correlation of 0.0, 0.22 and 0.0 between stock market and labor market shocks, stock market and housing shocks, and housing and labor market shocks.

4.1.1 Return Processes

I take the parameters that govern the stock market returns from Cocco et al. (2005), and so the risk-free rate $r^f = 0.02$, the equity premium $r^p = 0.04$, and the standard deviation of stocks $\sigma_s = 0.157$. To find the mortgage premium I calculate the average spread between the average interest rate on 30-year fixed rate mortgages and 10-year treasury bills between 1971 and 2018, which yields $r^m = 0.0169$. Finally, I set the return in case of tail events to be $r_{tail} = -0.5$.[8] The probability of tail events is estimated jointly with the preference parameters.

4.1.2 Correlations of shocks

To calibrate the correlation between house prices, stock returns and wage shocks I use historical data: the seasonally adjusted monthly S&P/Case-Shiller House Price Index, monthly Wilshire 5000 Total Market Full Cap Index and yearly median weekly real earnings, respectively. To create yearly indexes I take the average value within each year. I then find the year-on-year percentage change of each index and calculate the correlation. This yields correlations of 0.017 between house prices and wages ($N = 31$), 0.215 between house prices and the stock market ($N = 31$) and 0.003 between wages and stocks ($N = 38$). Due to the low correlation between housing and wages as well as between wages and stocks I set $\theta_h^s = 0.0, \theta_w^h = 0$. I then set the value of $\theta_h^s = 0.12$ to generate a correlation of 0.215 between the percentage growth rate of prices and stock returns.

4.2 Income Process

To find the retirement age T^r I count disable households as retired, but omit households who retire before they turn 51. I then find that the average age at which households became permanently retired is 69, that is where no subsequent spells of

[8] Fagereng et al. (2017) estimate $p_{tail} = -0.485$ in Norway, but it is not clear how one estimates the typical return of rare events.

labor market participation is observed. To find the retirement income shifter ϕ_{ret} I take the average income of a household in the two preceding waves before retirement and divide by the average income in the three succeeding waves. The average ratio is 75.8% omitting the 1st and 99th percentiles.

Next, I find the common deterministic life-cycle component of income f_a by taking the sample of households aged 25-67 who are employed, looking for jobs, temporarily sick, or disabled and run OLS on log earnings with a full set of age and year dummies. I then find the average log earnings at each age equally weighting the years. I then fit a fifth-order polynomial to the resulting (non-logged) predicted earnings. The results are reported in figure 9a.

I take the parameters governing the stochastic component of labor income from the literature. Many papers (e.g. Cocco et al. (2005),Cooper and Zhu (2016)) estimate and solve the model for different education groups. However, in this paper I solve the model for the general population, ignoring heterogeneity in education. This is done for two reasons. First, for the purposes of this paper it is necessary to observe both stock market entry and exit, as well as transitions in homeownership. These are infrequent events, and so the sample is too small if limiting the sample to only use on education group. Second, the introduction of housing increases the computational burden significantly, and omitting heterogeneity in education keeps the problem tractable. I therefore set the persistence $\rho = 0.95$, variance of persistent shocks $\sigma_\nu^2 = 0.018$ and the variance of the transitory shock $\sigma_\varepsilon^2 = 0.08$. These parameter values lies squarely in the range considered in the literature (Carroll and Samwick, 1997; Cocco et al., 2005; Cooper and Zhu, 2016; De Nardi et al., 2019)

4.3 House Prices

I base the parameters governing the house price growth from Cocco (2005). He sets average price growth to be 1% and its standard deviation to be 0.062. To capture the development of house prices since 2000 I increase both the drift and standard deviation by 50%, to $\mu = 0.015, \sigma_h = 0.093$. I take depreciation $\delta = 0.025$ as estimated in Harding et al. (2007). Finally, I take the rental cost f to be 5% (Davis et al., 2008). Further, the median rental unit has 4 rooms. Finally I set the transaction cost mc and minimum downpayment d to be 8% and 15%, respectively, as in Cocco (2005). In section 6.2, I study the impact of different minimum downpayment requirements. The PSID records the number of rooms (excluding bathrooms) in both owner-occupied and rental housing. The 25th percentile of owner-occupied housing has 5 rooms while the 75th percentile has 8.

4.3.1 Remaining Parameters

I take the conditional survival probabilities from the 2004 Social Security Administration Life Table. For the simulations a crucial component is the initial distribution of wealth, ownership and productivity. I set the initial distribution of productivity v to be the stationary distribution of v. I estimate the joint distribution of initial wealth x_{25} and homeownership h_{25} non-parametrically from the data.

4.3.2 Initial Conditions

When simulating households, we need to simulate households initial wealth x, human capital v, price level p and homeownership. I draw human capital from the stationary distribution implied by the process in equation (7). I assume that the initial house price can take three values. The find the benchmark price I exclude house values below the first and above the top percentiles, or with 20 or more rooms. I then run a regression of house values on the number of rooms with year fixed-effects and without a constant. The estimated slope is $36,000 which I use as the benchmark initial price per room. Next, I run the same regression on a sample of 'coastal-urban states' (CA, NY, WA, MA) and another on the central Mid-West (WI, IO, MN, MI, IN, OH), which yields prices of $49,000 and $29,000 respectively. 70% of the economies use the national initial price while the remaining 30% are equally divided into the other two initial prices. For initial wealth and homeownership, I draw non-parametrically from the data. Let $v(x, h)$ denote the discretized PDF of net-worth and homeownership. All households who are owners are assumed to own a small house, and net worth is censored below by $-\$15, 0000$. I then group households who are 25 into 20 quantiles of wealth and whether they own or rent. The distribution is plotted in figure 9b. Within each wealth-bin, I use the mean wealth as a value for households drawn to be in that bin.

4.4 Simulation

In the model there are three sources of risk: idiosyncratic income risk, aggregate stock returns and aggregate house price fluctuations. To understand the relative importance of each channel I follow the simulation procedure in Dahlquist et al. (2018). First, I simulate the income shock realizations for 1250 individuals $\{v_{i,a}, \varepsilon_{ia,}\}_{a=25}^{Tr}$. I then simulate 16 realizations of stock returns $\{r_{j,a}\}_{a=25}^{100}$ and 40 house prices sequences $\{p_{k,a}\}_{a=25}^{100}$, which generates 640 different 'economies' $(j \times k)$. I then simulate the behavior of these 1250 individuals in the 640 economies, for a simulated panel with 800,000 individual×economy realizations. As the simulated outcomes are sensitive to aggregate outcomes, it is important to simulate multiple economies to avoid spurious results.

5 Estimation

I perform a structural estimation of the preference parameters of the model: risk aversion γ, discount factor β, participation cost q, housing expenditure share η, ownership preference χ_1, bequest parameters ψ_0, ψ_1 and the subjective probability of tail events p_{tail} by the Simulated Method of Moments (SMM). Denote the parameter vector by $\omega \in \mathbb{R}^8$. Given a candidate parameter vector ω, I solve the model and obtain simulated moments $m(\omega)$ and compare them to the the empirical moments

m. I search for a vector $\hat{\omega}$ that minimizes the weighted deviation:

$$\hat{\omega} = \arg\min_{\omega}\{[m(\omega) - m]'W[m(\omega) - m]\}, \tag{14}$$

where W denotes the weight matrix, chosen to be $1/m$ on the diagonal and zeros elsewhere, to normalize each moment. Details on the estimation procedure are in appendix D.3. The estimation targets the participation rate, homeownership rate, conditional portfolio weight on stocks and net worth over the life cycle, for households aged 25-79. A discussion of the estimation of the life cycle profiles is in appendix 2.1. I use the SCF to estimate the life cycle profile of portfolio weights among participants since the PSID does not include information on stock holdings within IRAs, see section 2 for more. The estimation is over-identified, with 6 parameters and 44 moments: four life-cycle moments in 11 age-bins ([25,29],[30,34],. . . ,[75,79]).

5.1 Estimation Results

Table 4 reports the estimated parameters and the most informative moments for each parameter, while figure 3 plots the simulated and true data moments ($m(\hat{\omega})$ and m). The plots reveal that the model largely fits the data quantitatively. We can see that the model fits the participation rate well. The model underpredicts portfolio weights for households over the age of 45 due to the large estimated risk aversion and high probability of tail events. The model matches wealth accumulation up to age 55 but generates a too hard cutoff around retirement. The model abstracts from several aspects of retirement and models it as an exogenous change at age 63. Finally, the model qualitatively matches the homeownership rate but overpredicts among middle-aged households. In the model, the high risk aversion and moderate-high discount factor make all households save substantial amounts to fund old-age consumption, ensuring that most households cross the endogenous rent/own wealth threshold.

The model struggles to explain behavior among middle-aged households. Since

Figure 3: Estimation With Housing- Targeted Life Cycle Moments

These figures plots the targeted life-cycle moments in the simulated ($m(\hat{\omega})$, dashed orange line) and empirical (m, solid black line) data. The estimation procedure minimizes the weighted squared distance between the lines.

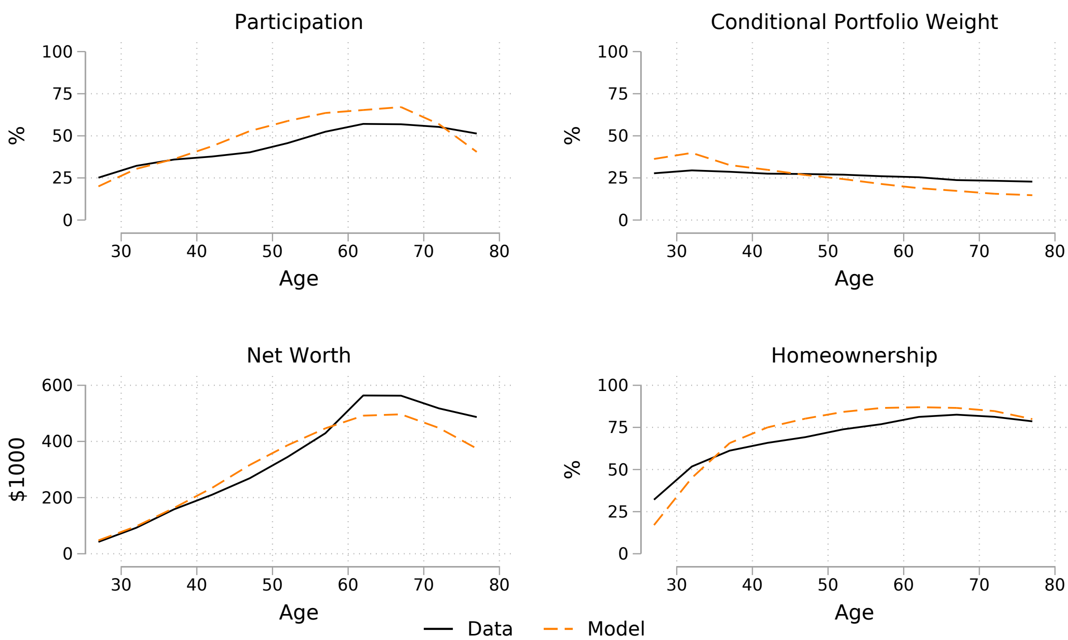


Table 4: Estimation Results

	Parameter	Housing	No Housing	Identifying Moments
q	Participation cost	0.124	0.441	Participation
β	Discount Factor	0.937	0.907	Net Worth, Participation
γ	Risk Aversion	4.518	4.111	Portfolio W., Net Worth
p_{tail}	Tail Events	0.041	0.044	Portfolio W., Participation
χ_1	Owner Preference	1.16	–	Homeownership
ψ	Bequest Motive	706.57	171.74	Net Worth
	# of Moments	44	33	
	Obj. Function	119.23	187.03	
	Part. Error	17.62	60.50	

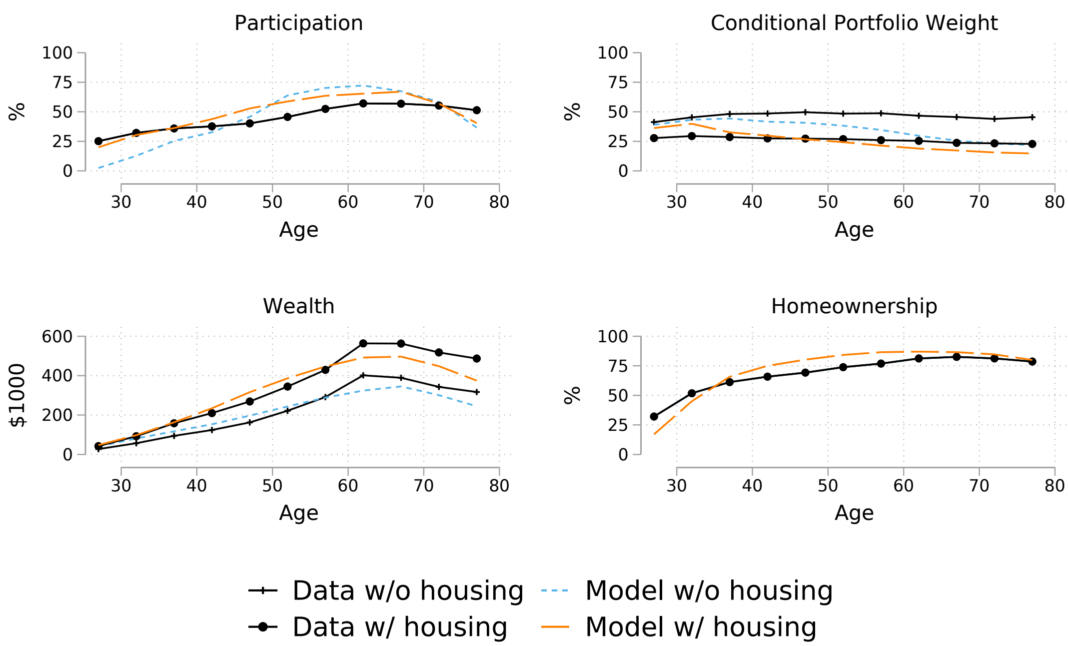
Identifying moments are listed in approximate order of importance, see Figure 12 and section D.3.2 for more. Standard errors in next draft.

stock market participation is largely driven by wealth, and the participation cost is constant across the life-cycle, the model must trade of increasing participation among the young by increasing β or decreasing the participation cost q or decrease participation among the middle-aged by decreasing β or increasing q. The only other mechanism is housing: since 'house-poor' homeowners are unlikely to participate in the stock market, the estimation increases the homeownership rate among the middle-aged to decrease their participation. The result is that more middle-aged households have low home-equity and prioritize building more home equity before participating in the stock market.

Finally, Table 4 lists the point estimates and the main identifying moments. The third column also reports the parameter estimates from a model without housing (see section 5.2). The participation cost is estimated to be 0.124, which can be interpreted as \$124 in 1995 dollars. The model estimates a discount factor of 0.937, a risk aversion of 4.52, a probability of tail events of 4.1%, which all are lower than the estimates in Fagereng et al. (2017) but comparable to those in Catherine (2019). The ownership preference premium is quite low 1.16 relative to other life-cycle papers (e.g., Corbae and Quintin, 2015; Chang, 2020). Two model mechanisms drive down the estimate preference shifter: First, the largest rental unit is the small

Figure 4: Estimation Without Housing - Targeted Life Cycle Moments

These figures plots the targeted life-cycle moments in the simulated data in the model with and without housing, as well as the empirical moments.



house size, so wealthy houses who want to equate the marginal benefit/marginal cost of consumption and housing must be homeowners once they are sufficiently wealthy. Second, with stochastic prices and constant rental price ratios, renting is risky, and becoming a homeowner provides insurance against cost of living expenses.

5.2 Model Improvement with Housing

While the estimated model does well at matching the observed life-cycle outcomes, it is instructive to see what happens when housing is omitted. I redefine net worth to financial wealth to keep the model consistent with the data.[9] The portfolio weight is similarly redefined to stocks over financial wealth, instead of over net worth. In

[9]When estimating the life-cycle moment, I follow the procedure described in 2.1, but I recoded financial wealth to missing for households in the top/bottom 1% of financial wealth, before dropping households in the top/bottom 1%.

addition, I remove the minimum income floor as in Fagereng et al. (2017). Since the model omits housing, the parameters χ_1 and η are redundant. The estimation thus mirrors the estimation in Fagereng et al. (2017) in all aspects, except that the estimation targets US data. Figure 4 plots the estimated life-cycle patterns, and Table 4 lists the estimated coefficients.

Comparing the estimated outcomes, it is clear that the model with housing matches the participation rate significantly better, even though it targets an additional moment. The peak participation rate is too high without housing, while the participation rates for young and old households are too low. The model is able to largely match net worth, but still with too strong withdrawal after retirement. Figure **??** plots the percentage deviation for both models and illustrates that both models are largely able to match the data for middle-aged households, but the largest improvement for the model without housing is among younger households. This is intuitive: The transition from renting to owning happens for young and middle-aged households. Further, the model and results in Fagereng et al. (2017) show that the model without housing can qualitatively match the dual adjustment of old households (exit and increased portfolio weights among participants). The housing market in this paper omits several factors that are important for older and retired households, such as reverse mortgages and increased depreciation, which could improve the model's ability to match data among older households.

Finally, from table 4, we see that the participation cost increases to 0.441 from 0.124 while the discount factor decreases to 0.907 from 0.937. At the same time, risk aversion falls slightly to 4.111 and tail events become slightly more frequent at 4.4% from 4.1%. The main takeaways are: First, a model with housing can quantitatively match the participation rate over the life cycle with a low participation cost ($124), relative to a model without housing. Second, the sum of the squared deviation between the model and empirical participation rates decreases by 71% from 60.5 to 17.62 when housing is included. Third, the model fit, as calculated by the sum of squared percentage deviations, decreases by 40% by including housing, even though it only introduces one new estimated parameter for 11 new moments (homeownership over the life-cycle).

5.3 Non-Targeted Moments

I now turn to discuss the models performance on matching non-targeted moments.

5.3.1 Stock Market Entry and Exit

This paper proposes a new channel (entry and exit) to explain limited stock market participation. Figure 5 plots the simulated and true two-year entry/exit rates over the life-cycle. The model does remarkably well at matching the qualitative and quantitative patterns with hump-shaped entry and u-shaped exit. In the model, almost all renters who become owners sell their stocks, leading to a too high simulated exit rate initially. However, without housing, we see that the model generates too little exit in middle age. Without housing, the only reason participating households exit is that their wealth drifts down below the participation threshold. However, at middle age, the threshold is low and most households have accumulated significant savings making this event unlikely.

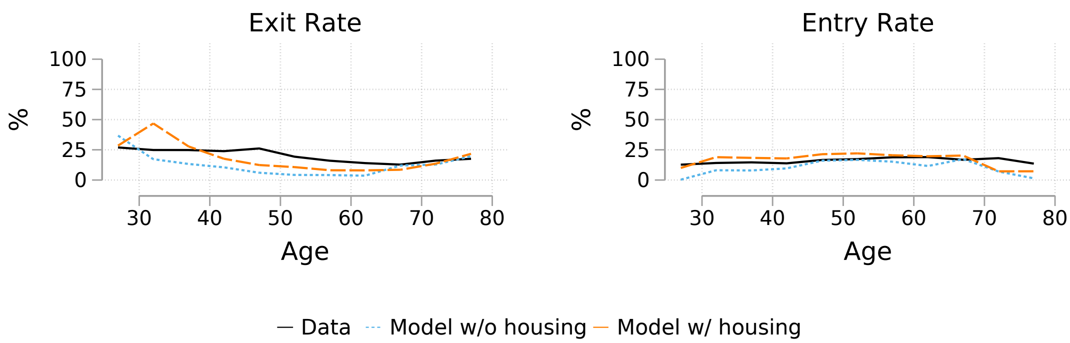
5.3.2 Micro-Level Behavior

The model matches aggregate behavior well. To verify that the individual-level simulated behavior is correct I now use the simulated panel to estimate the causal effects of property values on the participation decision. Chetty et al. (2017) (Section D) estimate

$$\Delta part_i = \alpha + \beta_1 \Delta PropertyValue_i + \beta_2 \Delta TotalWealth_i + \gamma \Delta X_{it} + \Delta\varepsilon_i, \tag{15}$$

Figure 5: Entry and Exit from Stock Markets - Data and Simulation

These figures plot the two-year entry/exit rates in stock markets in the data (solid line) and the model (dashed line).



where $\Delta x_i \equiv x_{i,t+1} - x_{i,t-1}$ for an individual who purchased a house in period t. The purpose of this regression is to control for selection while answering: "Do households who buy more expensive houses reduce their stock holdings by a larger amount from the year before to the year after home purchase?". To deal with the endogeneity in the size of a house one purchases, they instrument for property values using state house price indices. When I estimate equation (8) on the simulated panel, I follow their procedure as close as possible. For more details on their estimation I refer to section C in Chetty et al. (2017), while a detailed discussion of my replication using simulated data is in appendix E.1 and table 8 compares the estimation samples.

Table 5 include the result in Table 5 from Chetty et al. (2017) on participation, as well as the same regression in the model. Chetty et al. find that an increase in the property value of \$100,000 in 1990 dollars, keeping home equity and mortgage debt constant, decreases the probability of participation by 12 percentage points. The same increase in total wealth increases the portfolio weight by 5.88 percentage points. Overall, the estimates from the simulated panel are reported in the column (2) of Table 5 and match the effects found in Chetty et al. (2017) well. From these overall results, I conclude that the model not only matches average life-cycle moments well but also captures on an individual level the impacts of property values and total

Table 5: Replicating Chetty et al. (2017)

ΔParticipation	Chetty et al (2017)	Model Simulations
Δ Property Value	-12.14	-24.92
($\times$ \$100K)	(2.56)	(1.2)
Δ Total Wealth	6.10	7.3
($\times$ \$100K)	(0.96)	(1.58)
Observations	6912	60207

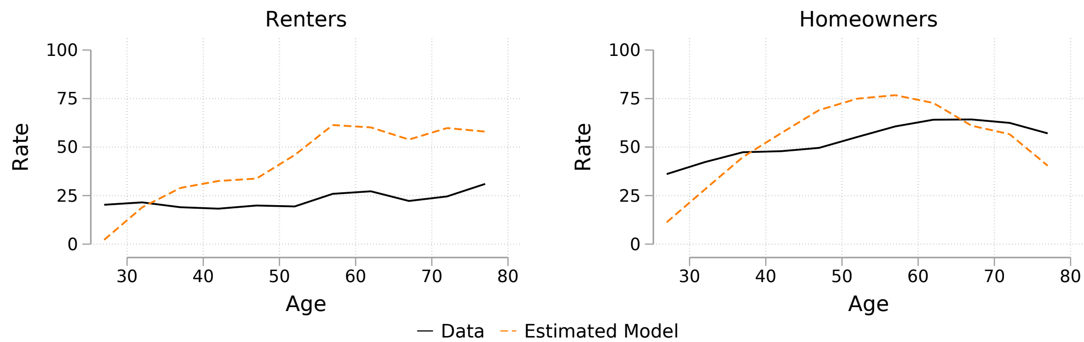
Note: Standard errors in parentheses. The results for specifications 1 is from column 5 in Table VI in Chetty et al. (2017). All specifications use a two-stage least squares estimator where the state price index instruments for the property value. The set of control variables is the same as in Chetty et al. (2017) except that the simulated model has no year fixed effects, and use the persistent human capital shock v as a proxy for education.

wealth on US households portfolio decisions.

5.3.3 The Owner-Renter Participation Gap

A major contribution in Vestman (2019) is to build a model that can rationalize the participation gap between renters and participants. In Vestman's model, the main mechanism is preference heterogeneity (higher risk-aversion, lower discount factors, and higher participation) cost for the renter-type, while the model in this paper has no ex-ante heterogeneity. I plot the participation rates by house tenure in figure 6. At first glance, we see that the model overpredicts participation among renters and underpredicts participation among young owners. The largest deviation from the data is that virtually all renters after age 40 participate. First, the estimated model predicts virtually 100% homeownership after age 50, so the high participation rate is driven by the very few renters that exist. These old renters are, in effect, 'gambling for resurrection' to afford housing. Second, the model gets the right qualitative pattern: participation rates among the renters is hump-shaped from aged 25-45, and again from 45-80. Second, the participation rate among young homeowners is virtually 0%: Due to the high risk aversion and mortgage premium r^b young home-poor households prefer building home equity to stock market participation.

Figure 6: Participation By Homeownership - Data and Simulation



6 Model Mechanisms

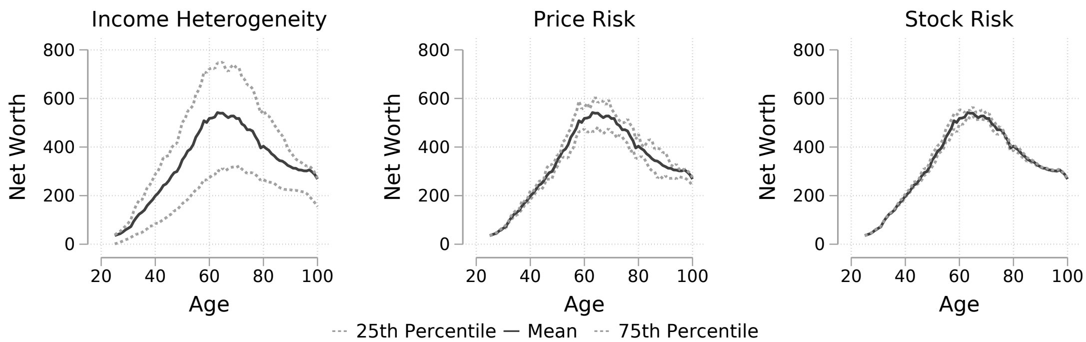
6.1 Risk Decomposition

Figure 7 plots the ex-ante income heterogeneity, price risk, and stock risk a household faces in the economy. The panels show the wealth distribution an individual faces after integrating out the other two sources of risk. As described in section 4.4, the simulated panels consist of the same individuals facing different aggregate shocks (economies). The first plot (income heterogeneity) is constructed as follows. I average each individual i's wealth at each age a across the economies to find the ex-ante expected wealth profile of each household. For each age, I then sort on wealth and plot the 20th percentile, mean and 80th percentile of wealth. This plot can thus be interpreted as the effect of income heterogeneity on wealth inequality. The second plot is constructed similarly, but by summing each a, p combination across all individuals and stock realizations to find the ex-ante effects of house price risk, and the third panel by summing each a, r combination to find the stock market risk.

Income risk is by far the largest source of risk to households. At age 60, 20% of households will have net worth below \$100,000, while 20% have net worth above \$350,000. House price has almost no impact on the wealth of young households for two reasons. First, most households start out as renters, so there is no first-order

Figure 7: Risk Decomposition

The figures shows the impact of income inequality, house price risk and stock return risk. The left panel shows how wealth accumulation vary over individuals based on their income risk, after integrating out house price and stock return risk. The middle panel shows how average net worth vary over the 30 house price economies. The right shows the the same over the 16 stock return economies. The sorting at any age is independent of the sorting at other ages.



effect on wealth, and when house prices increase, renters respond by saving more in order to obtain housing. Only when the majority of households have obtained housing do the prices move the wealth distribution, and we can see that house price risk is largest at retirement, at age 65, where 20% of households have net worth below \$200,000, and 20% have net worth above \$300,000. Finally, we see that stock market risk is not important for the dispersion in wealth. The main reason is for the low impact is that stock returns are transitory, and furthermore, households re-optimize every year. If stock returns are low in a given year, households' net worth decreases, and since households' optimal portfolio weight is decreasing in net worth, the response is to increase the portfolio weight leading to larger gains from the equity premium. Finally, the average participation rate is about 50%, and so the stock risk is irrelevant for half of the population.

6.2 Changing the Down Payment Requirement

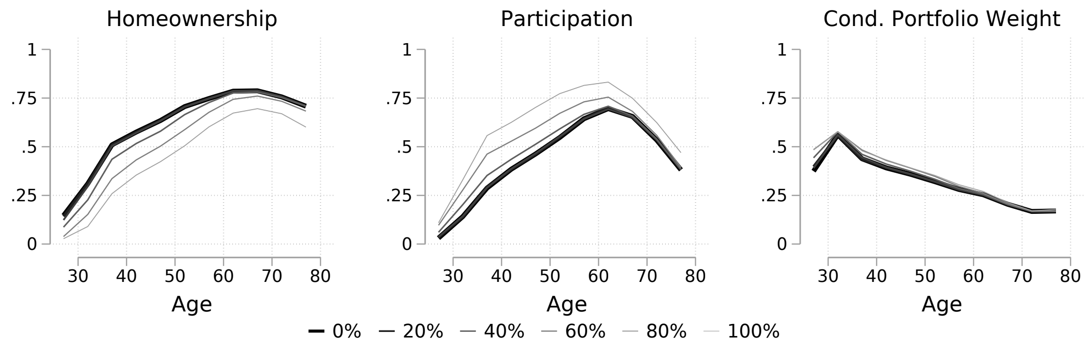
For young households who want to become homeowners, a key constraint is the down payment constraint. One of the main mechanisms in this model is that down payments generate non-monotone participation decisions in wealth. To shed light on how the down payment affect households' portfolio decisions, I solve and simulate the model under minimum down payment requirements ranging from 0-100% using the estimated parameters. The simulated homeownership, participation, and conditional portfolio weights are plotted in Figure 8. Since the model has no market clearing or price adjustment and so any price effects and equilibrium effects that could arise from a change in the down payment are ignored.

Homeownership is decreasing in the down payment, and higher requirements progressively delay homeownership. However, the participation rate among the young is increasing in tightening borrowing constraints. The reason is two-fold. First, the participation among renters is increasing since a) their investment time horizon is longer, and b) they have more wealth and savings. Second, homeowners are also more likely to participate since they now have lower leverage and debt, which allows them to participate in the stock market sooner. The conditional portfolio weight responds little to changes in the down payment. However, we see that with higher down payments, we have higher participation, which effectively means that the mean participant has lower wealth, which increases the average portfolio weight.

Finally, figure 10 also plots the effects for the entry and exit rates as well as net-worth. Higher downpayments increase the entry rate over the entire life-cycle because of later entry to ownership for young and middle-aged and that downsizing now increases liquid wealth more for older households. The exit rate is lower only for younger households, indicating that renters now stay in the market for longer, and less new owners exit the stock market. Net worth is not affected by downpayments when prices are constant, so these effects are driven purely by the effects of the borrowing constraint on the portfolio choices.

Figure 8: Effects of the Minimum Down Payment

These figures plot the effect of increasing the size of the minimum downpayment. Darker, thicker lines have lower minimum downpayment (d) requirements.



7 Conclusion

This paper improves our understanding of the causes of the low stock market participation rate over the entire life cycle in the US. New salient empirical results highlight the high exit rate (about 20%) from stock markets as a reason for the low participation rate among young and middle-aged households and the relative importance of homeownership in driving exit decisions. Based on the empirical results, it develops a quantitative life-cycle portfolio choice model that can match the four main components of households' portfolios over the life-cycle: the participation rate, homeownership rate, conditional portfolio weight, and net worth. To do so, the model requires a low participation cost and high risk aversion, relative to a model without housing.

Adding housing to the benchmark models (e.g., Fagereng et al., 2017; Cocco, 2005) improves the model fit for participation over the entire life cycle. The main mechanisms are that 'home poor' homeowners delay stock investment in order to build sufficient home equity. A model with a one-time cost and housing (e.g. Vestman (2019); Cocco (2005)) eventually predicts 100% participation among middle-aged and/or retirees. This paper shows that a model with housing and per-period costs can match the participation rate over the entire life-cycle. The combination of per-period costs and house-tenure allows the model to not only match targeted moments but it also qualitatively matches the entry and exit rates over the life cycle. Additional to matching targeted and non-targeted life-cycle moments, regressions on the simulated households recover the causal impacts of home equity and property values found in Chetty et al. (2017).

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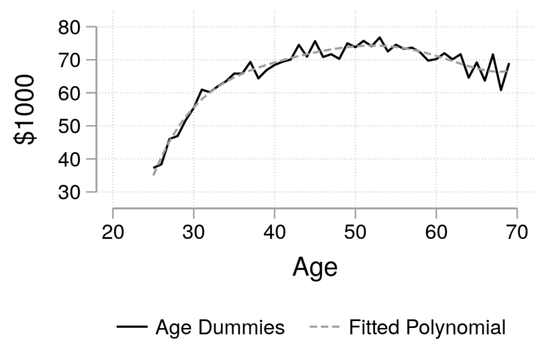
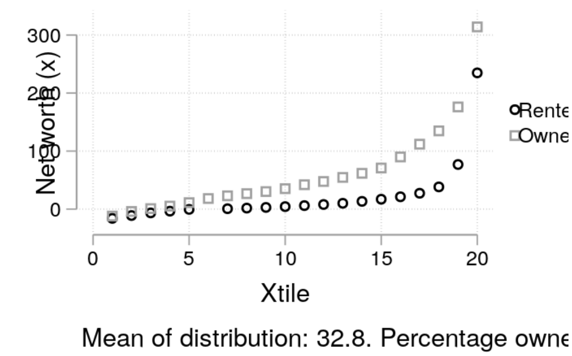
A Supplementary Figures and Tables

Figure 9: Life Cycle Participation, Homeownership, Entry and Exit

(a) Joint Wealth and Ownership Distribution



(b) Joint Wealth and Ownership Distribution



B Vestman's (2018) DiD

Table 7 replicates the Difference-in-Difference estimation in Vestman (2019). The main difference is that results in this paper are from the PSID, with a smaller sample and biannual data. For a detailed description of the identification strategy I refer to (Vestman, 2019, p. 21). From the results we learn that, in the US, there is weak evidence of long-term effects on the participation probability: renters that become homeowners have 4.4% and 11.3% percentage points lower probability of participating 4 and 6 years after purchase.

Table 6: Summary Statistics by Ownership in the PSID

	PSID		SCF	
	Renters	Homeowners	Renters	Homeowners
	mean	*mean*	*mean*	*mean*
Financial Portfolio				
Stock Participation	0.21	0.52	0.26	0.60
Exit	0.34	0.19	.	.
Entry	0.10	0.23	.	.
Weight on Stocks	.	.	0.06	0.12
Cond. Weight on Stocks	.	.	0.49	0.25
Financial Portfolio (w/o IRA)				
Stock Participation	0.12	0.32	0.15	0.30
Exit	0.40	0.29	.	.
Entry	0.05	0.12	.	.
Weight on Stocks	0.04	0.07	0.02	0.04
Cond. Weight on Stocks	0.14	0.16	0.31	0.15
Economic variables				
Income (thousands)	46.05	99.42	44.23	118.57
Wealth (thousands)	57.72	540.33	82.59	816.21
Stocks (thousands)	10.18	84.43	2.41	18.36
House Value (thousands)	0.00	244.60	−0.00	279.48
Home Equity (thousands)	0.18	156.31	−0.00	186.36
Other				
High School	0.55	0.52	0.56	0.51
College	0.23	0.33	0.20	0.34
Married	0.26	0.67	0.39	0.69
White	0.82	0.92	0.56	0.79
Age	43.69	54.39	42.42	53.61
Family Size	1.97	2.55	.	.

Note: Author's own calculation from the PSID, waves 1984-2015. All observation are equally weighted. Exit and entry is relative to the previous observation, i.e. a five year gap for waves 84, 89, 94, 99 and two year gap thereafter.

Figure 10: Effects of the Minimum Down Payment

These figures plot the effect of increasing the size of the minimum downpayment. Darker, thicker lines have lower minimum downpayment (d) requirements.

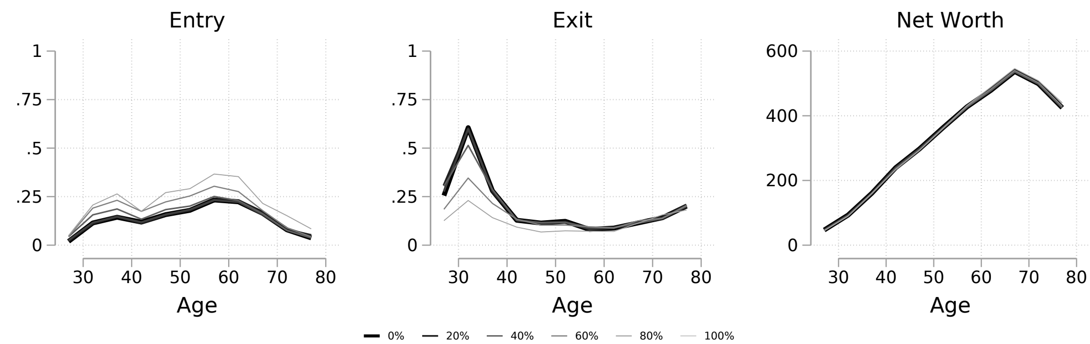


Table 7: Difference-in-Differences Estimation

	New Owners			New Renters		
	(1) Part.	(2) Portf. wgt	(3) C. Portf. wgt	(4) Part.	(5) Portf. wgt	(6) C. Portf. wgt
T-6	0.012	0.001	0.036	0.048	-0.058	-0.950
	(0.053)	(0.038)	(0.255)	(0.052)	(0.048)	(0.555)
T-4	-0.055	-0.053	-0.018	0.013	-0.001	-0.073
	(0.040)	(0.040)	(0.246)	(0.045)	(0.021)	(0.203)
T	0.054	-0.034	-0.130	-0.056	0.024	-0.072
	(0.032)	(0.025)	(0.101)	(0.039)	(0.030)	(0.229)
T+2	0.019	-0.013	-0.119	-0.106*	-0.004	-0.194
	(0.037)	(0.026)	(0.134)	(0.042)	(0.020)	(0.235)
T+4	-0.044	-0.004	0.050	-0.119*	-0.002	-0.224
	(0.042)	(0.026)	(0.171)	(0.046)	(0.019)	(0.194)
T+6	-0.113*	-0.041	0.040	-0.108	0.032	-0.156
	(0.048)	(0.029)	(0.214)	(0.061)	(0.022)	(0.207)
Observations	4573	4316	321	6257	5915	461
Within R^2	0.012	0.010	0.133	0.007	0.005	0.074

Clustered at the family level. Coefficient for $T-2$ is omitted (i.e. $=0$) as a normalization. Specification (3) and (6) conditions on being a participant. Standard Errors in parentheses. * $p <$ 0.05, ** $p < 0.01$, *** $p < 0.001$.

C More Model Details

C.1 Renters' and Buyers' Decision Problems

C.1.1 The renter's decision problem

Below I fully describe the decision problem facing an agent who doesn't own a house at the beginning of the period. The renter chooses optimal consumption, rental size, (positive) bond holdings and if he chooses to pay the fixed cost q, also how much to save in stocks:

$$\begin{aligned} V_a^R(x,v,p) &= \max_{c,b',s',h} \{u(c,h) + \beta_a \mathbb{E}_a[V_{a+1}(x',v',p',0)]\} \\ x + w &= c + \mathbf{1}(s'+q) + b' + fph \\ x' &= s'(1+r') + b'(1+r^f) \\ &\{c,b',s'\} \in [0,\infty)^3, h \in \{small, large\} \\ &\text{Processes for } w,r,p \text{ (eq. 6,4,5)} \end{aligned} \tag{16}$$

C.1.2 The buyer's decision problem

Compared to renters and stayers, buyers decide on how big of a house to own, don't pay rent, can borrow in the bond but also pay moving costs.

$$\begin{aligned} V_a^B(x,v,p) &= \max_{c,b',s',h'} \{u(c,h') + \beta_a \mathbb{E}_a[V_{a+1}(x',v',p',h')]\} \\ x + w &= c + \mathbf{1}(s'+q) + b' + ph'(1+mc) \\ x' &= s'(1+r_{a+1}) + b'(1+r^f) + hp'(1-\delta) \\ &\{c,s'\} \in [0,\infty)^2, b' \geq -(1-d)ph', h' \in \{small, large\} \\ &\text{Processes for } w,r,p \text{ (eq. 6,4,5)} \end{aligned} \tag{17}$$

C.2 Nesting models without housing

C.2.1 Nesting Fagereng, Gottlieb and Guiso (2017)

The model extends Fagereng et al. (2017) by including housing. To obtain their model one only must limit the economy to not include housing, i.e. setting $h \in \mathcal{H} = \{0\}$. Under this assumptions the house price p is redundant, as is the discrete choice between renting, staying and buying a new house. The household decision problem is then simplified into

$$
\begin{aligned}
V_a^{FGG}(x, v) &= \max_{c,b',s'} \{u(c) + \beta_a \mathbb{E}_a[V_{a+1}(x', v')]\} \\
x + w &= c + \mathbf{1}(s' + q) + b' \\
x' &= s'(1 + r') + b'(1 + r^f) \\
\{c, b', s'\} &\in [0, \infty)^3 \\
&\text{Processes for } w, r \text{ (eq. 6,4)}
\end{aligned}
\tag{18}
$$

C.2.2 Nesting Cocco, Gomes and Maenhout (2005)

To nest Cocco et al. (2005) only two further assumption is required; that the fixed cost is zero ($q = 0$) and the probability of a tail event is equal to zero ($p_{tail} = 0$). This removes one discrete choice (whether to participate), and mechanically implies 100% stock market participation.

$$
\begin{aligned}
V_a^{CGM}(x, v) &= \max_{c,b',s'} \{u(c) + \beta_a \mathbb{E}_a[V_{a+1}(x', v')]\} \\
x + w &= c + s' + b' \\
x' &= s'(1 + r') + b'(1 + r^f) \\
\{c, b', s'\} &\in [0, \infty)^3 \\
&\text{Processes for } w, r \text{ with } p_{tail} = 0 \text{ (eq. 6,4)}
\end{aligned}
\tag{19}
$$

D Numerical Details

D.1 Solution Algorithm

The problem is solved backwards, by first solving the value function of a retiree at age T, when death is certain. In the final period households liquidate all wealth for goods consumption and hold no housing wealth. This process is repeated backwards, until age $a = 25$. All stochastic elements are discretized following Rouwenhorst (1995). The persistent income shock v follows a three-state Markov chain process, and the transitory income shock is discretized to three states. The house price shock ε^h is discretized to five states. The stock market return shock is discretized to have six states (five normal returns and the tail return). The net worth x and price p grids are both unevenly spaced, with higher density for lower values. For values of x and p not on the grids I use linear interpolation.

D.2 Details on Moment Construction

I use the following procedure to estimate all the four life-cycle moments. I first group households into 5-year bins from 25-29 to 80-84. Next I drop all households who are in the top or bottom percentile of wealth within each age group. I then reweigh all sample weights to have constant sum of weights across years. I then run weighted linear regressions of the moment on the age dummies and year dummies. I then predict the value of the moment for each $age \times year$, and then find the average over years to obtain the life-cycle profile. When calculating the simulated moments there are no year effects so I simply find the average within each age group.

D.3 Structural Estimation

The estimation procedure is similar to the one in Daruich (2018):

1. Outside Estimation:I first set parameters that pin down the stochastic processes

and prices outside the model. These parameters are either estimated directly from the data or set to standard values in the literature. These parameters are listed in table 3.

2. Global Search: As there is no reason to think that the objective function will have a single local minimum, I use a global optimization procedure. First, I draw 10,000 parameter vectors ω from a six-dimensional hypercube (one dimension for each parameter) using a quasi-random low-discrepancy Sobol sequence. I then calculate the objective function for each parameter vector. The hope is that the parameter vector that minimizes the objective function approximates the global minimum.

3. I then perform a local search using a standard downhill simplex (Nelder-Mead), using as an initial guess the optimizer identified in the previous step. The convergence criteria is set to be that the percentage change between the objective function evaluated at the worst and best parameter vector in the simplex is less than 0.1%.

D.3.1 Setting the Global Search Intervals

First, to show that the global search covers a wide enough parameter space I do the following exercise:

1. First, calculate the objective function in (14) for each parameter vector.

2. Pick a parameter

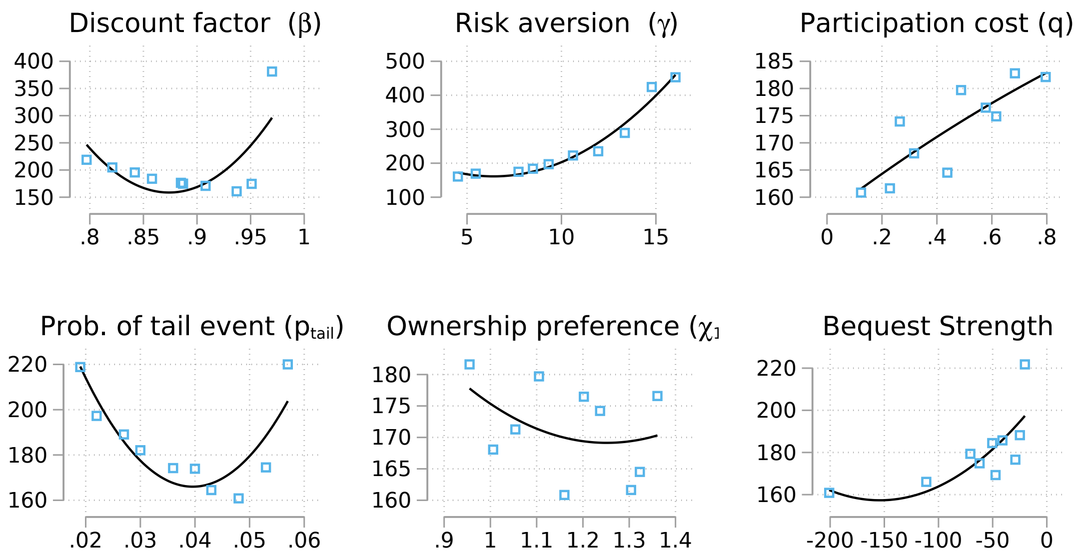
    (a) Store the lowest objective function from each quantile.

    (b) This gives an approximation of the lower envelope of the objective function for one parameter, keeping the distribution of other parameters constant

    (c) Plot the resulting data points and fit a curve through them

Figure 11: Approximate Lower Envelope of the SMM-Objective Function (14)

This figure displays the results of the algorithm described in section D.3.1. The vertical axis displays the objective function (14) that the SMM routine minimizes, while the horizontal axis denotes the parameter value for each given parameter.



3. Repeat for all parameters. Figure 11 plots the results

4. Check that the intervals that all parameters are drawn from is sufficiently wide, and that the endpoints are relatively far from the approximate minimum

Further, by comparing the level and slope of the fitted line we can infer the relative importance of a parameter for the objective function vis-a-vis other parameter. Further, we can see whether the function has multiple local minima in some parameters.

D.3.2 Identification of Parameters and Relevance of Moments

Next, we turn to check whether all moments respond to changes in at least one parameter (relevance), and whether each parameter affect at least one moment (identification). Again, the Sobol sequence approach allows us to easily perform these checks. The algorithm is as follows:

1. Pick a moment (e.g. wealth x at age 35)
   (a) Pick a parameter (e.g. γ)
      i. Divide the parameter in 50 quantiles
      ii. Calculate the 25th, 50th, 75th percentile for the moment for each quantile
      iii. Plot the percentiles for each parameter quantile
   (b) Repeat step 1a for each parameter
2. Repeat step 1 for some some moments (e.g. average wealth, participation rate, homeownership rate and average conditional portfolio weight on stocks at age 35, 55, 75)
3. A moment is identified if it responds to a change in at least one parameter
4. A parameter is relevant if it causes changes in at least one moment *and* the lower envelope in 11 is not flat.

Figure 12 shows that the conditional risky share at age 35 is pinned down by the probability of tail events p_{tail} and the risk aversion parameter γ, while the other parameters have no impact on this moment. The results in the last column ('identifying moments') in the structural estimation table 4 are inferred from repeating this exercise for all life-cycle moments at age 35, 55, and 75.

Next, we check that all parameters are relevant by plotting their impact on the various moments. Figure 13 shows that the homeownership preference is only relevant for the homeownership rate, but has no impact on the participation rate, the conditional portfolio weight or net wealth.

D.3.3 Local Search

After the global search I perform a local search from the best parameter vector ω. I display the results in figure 14.

Figure 12: Identification of the Conditional Portfolio Weight at Age 35

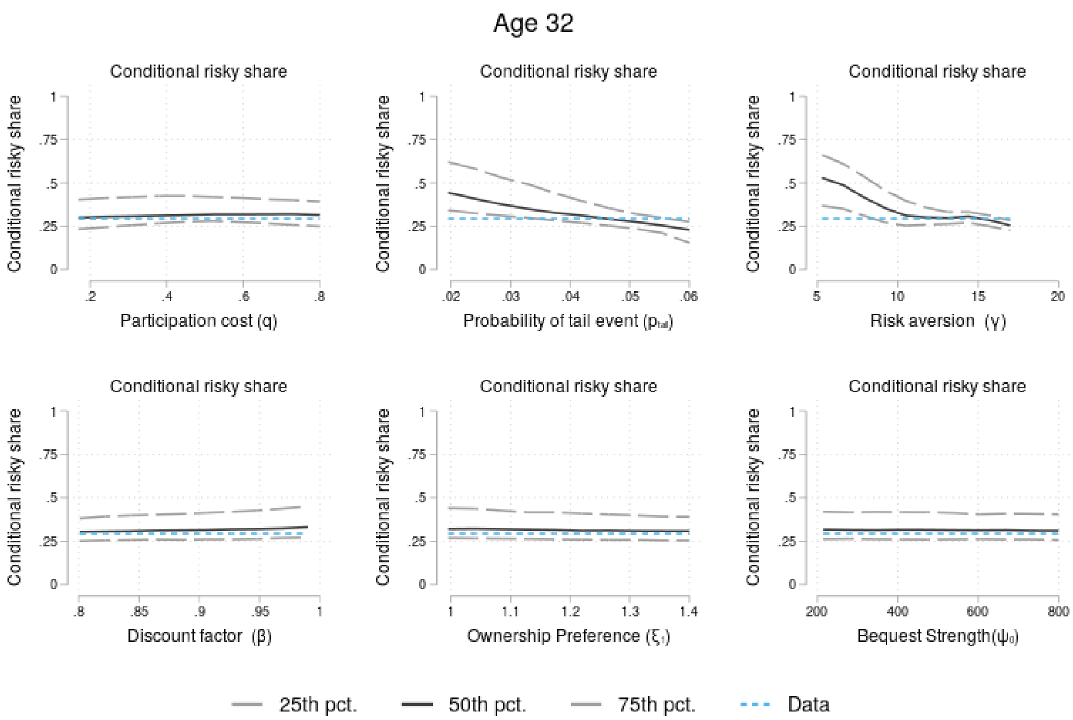


Figure 13: Relevance of the Homeownership preference shifter

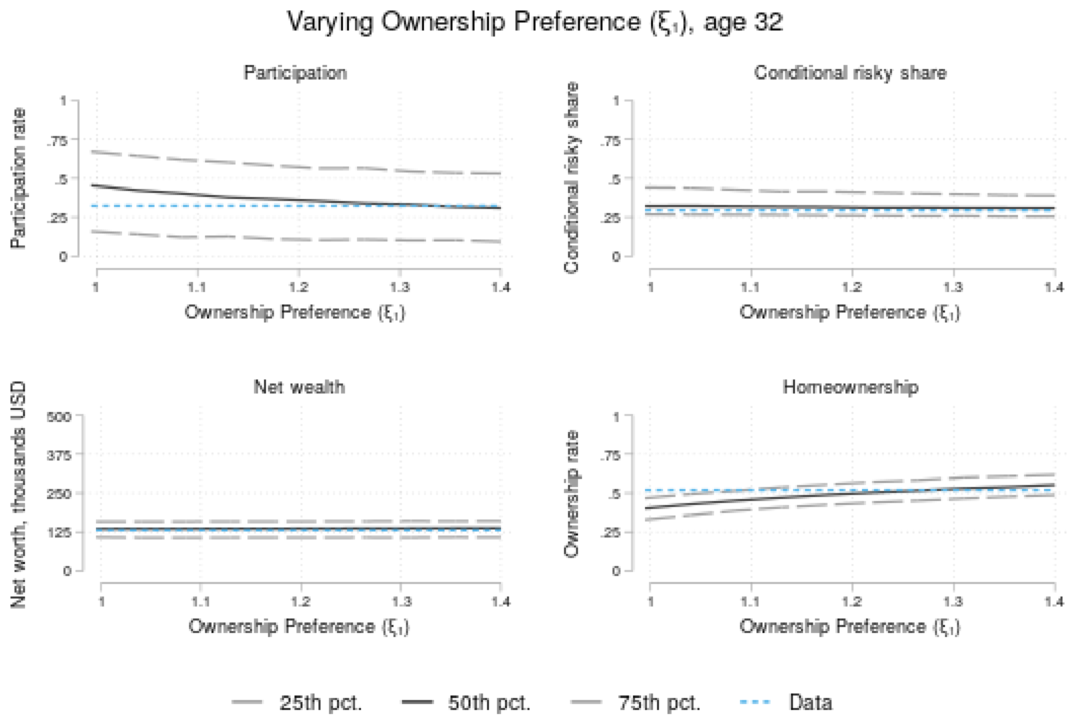


Figure 14: Results of Local Optimization

These figures show the evolution of the objective function and the estimated parameters in the third step of the estimation algorithm. The x-axes denote the number of iterations of the Nelder-Mead algorithm.

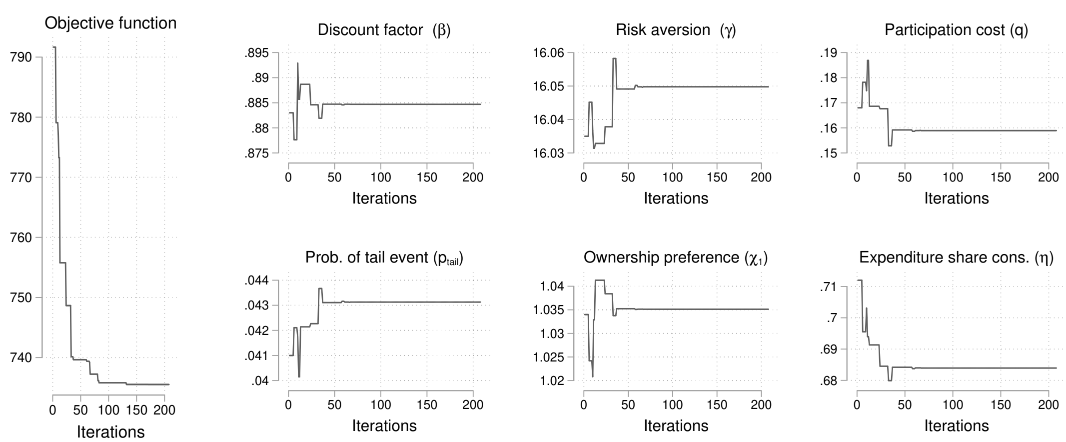


Table 8: Replicating Chetty et al. (2017)

	Chetty et al (2017)			Model Simulations		
	Mean	Median	Std. Dev.	Mean	Median	Std. Dev.
Age	43.53	40.00	13.70	44.21	42.00	13.11
Income	53.13	42.98	46.86	56.63	52.47	22.28
Property Value	133.87	109.83	96.23	156.66	141.94	52.74
Mortgage	79.24	70.75	62.07	30.96	34.48	23.36
Gross Wealth	139.89	70.87	200.63	175.67	131.16	118.04
Liquid Wealth	35.46	5.57	98.33	25.77	0.00	62.24
Home Equity	54.99	31.38	73.04	125.70	106.23	64.76
Participation Rate	36.31	0.00	48.09	17.52	0.00	38.01
Portfolio Weight	22.52	0.00	35.27	43.01	39.15	36.25
Observations	6912	6912	6912	59363		

Note: The descriptive statistics in the first two columsn are taken from table IIb in Chetty et al. (2017, p.1184). All variables in thousands 1990 US Dollars. Gross wealth in the simulation is defined as net worth plus mortgage ($x + b \times \mathbf{1}_{\{b<0\}}$) while liquid wealth is stocks plus bonds ($s + b \times \mathbf{1}_{\{b>0\}}$). The portfolio weight is defined as stocks over liquid wealth.

E Details on Post Estimation Procedures

E.1 Sample Construction for Chetty et al (2017)

I now describe in detail how I prepare the simulated sample in order to replicate the empirical participation regression in Chetty et al. (2017). Parantheses denote the value or method used in Chetty et al. (2017). I define an indicator function for when households buys a house (renting to owning as well as owning to a new owned house). I then renormalize all dollar variables to be in $100,000. I then keep all observations the year before, during and after a house transaction. The participation indicator is multiplied by 100 to make it into a percentage. I keep all households aged 25-79. I then run IV regressions of the participation decision on property values (instrumented by the house price at the time of purchase), gross wealth , and a full set of indicators for age, productivity v ('education') and economy ('state'), equation (15).

E.2 Comparing Samples