ISSN 1755-5361

University of Essex

Department of Economics

Discussion Paper Series

No. 712 April 2012

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Abstract

In a Bewley model with endogenous price volatility, home ownership and mobility across locations and jobs, we assess the contribution of financial constraints, housing illiquidities and house price risk to home ownership over the life cycle. The model can explain the rise in home ownership and fall in mobility over the life cycle. While some households rent due to borrowing constraints in the mortgage market, factors that effect propensities to save and move, such as risky house values and transactions costs, are more important determinants of the ownership rate.

Keywords: Home Ownership, Incomplete Markets, Illiquid Assets, Financial Constraints

JEL Classification: C62, E21, J61, R21.

1 Introduction

What accounts for the steep, upward life-cycle profile of home ownership in the United States? There are several popular explanations: borrowing constraints in the mortgage market that prevent young households from purchasing housing; the illiquidity of owner-occupied housing that makes rental housing preferable for young, mobile households; and changes in the hedging motives of households when housing is risky.

Each explanation has found supporting evidence in the data. Young households are more mobile than older households: they are more likely to move to a new home (figure 4), to move to a new U.S. state and to move for self-reported "job reasons" (figure 6). Similarly, young renters are

*We thank for valuable comments Andy Atkeson, Andrew Caplin, Douglas Gale, Greg Kaplan, Matthias Kredler, John Leahy, Dino Palazzo, Morten Ravn, Thomas Sargent, Gianluca Violante and seminar participants at the Society for Economic Dynamics conference, Wisconsin Real Estate Mini-conference, NYU Stern, NY Federal Reserve, Federal Reserve Board, Ente Einaudi and the University of Copenhagen. Jonathan Halket thanks the ESRC for funding under grant number PTA-026-27-2395.

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more mobile than young owners (figure 5). Young households are also poorer, with lower wealth and income, on average, than middle-aged households (figure 8).

There are many studies that find, individually, financial market constraints, changes in mobility (due to either changes in demographics, and career concerns) and risk to be significant factors affecting the ownership choice decision. There is a large literature on credit constraints and its impact on ownership choice. We quote Linneman et al. [1997], Haurin et al. [1996] and Zorn [1989] as representative of this strand. Papers that focus on demographics or career concerns implicitly concern housing transaction costs, since changes in the former primarily affect the ownership decision through a household's expected duration of stay. Clark and Onaka [1993] and Quigley and Weinberg [1977] find that changes is family size significantly affect housing consumption and the ownership choice of households. Cameron and Tracy [1997] emphasizes the effect of career concerns on the mobility and ownership choice decisions of younger households.

There are at least several theories on the interplay between risk and home ownership. Davidoff [2006] finds that households buy smaller homes when their income is more correlated with regional house prices, indicating that renting may partial insure households against changes in their income (since part of their income is correlated with local house prices and rents). Two potential reasons why owning may provide insurance have been mooted. Sinai and Souleles [2005] explores how changes in a household's expected duration may affect its willingness to hedge against changes in rental prices by owning. In their model, increases in expected duration of stay in a new home increase the likelihood that a household owns because changes in the spot price of housing instantaneously change rental prices, *a fortiori*, but an owner-occupier only capitalizes the resultant change in the value of their housing stock when it sells in the future. Banks et al. [2010] and Ortalo-Magne and Rady [2006] propose and find supporting evidence that households use home ownership to insure themselves if there is a housing ladder (i.e. large houses are only available on the owner-occupied market).

In this paper, we build a life cycle model that can explain the observed rise in home ownership over the life cycle while also matching the fall in mobility and the rise in wealth over the life cycle. The model, which features risky house values and borrowing constraints, encompasses the above, popular explanations for home ownership. We are thus able to assess how important savings motives (life cycle, precautionary and down payment accrual), hedging/insurance motives and mobility concerns are to explaining why some working-age households rent while others own.

We find that while borrowing constraints in the mortgage market (henceforth, we refer to these constraints as "the down payment constraint") deter some households from owning, the inability to borrow against future earnings together with the illiquidities in the owner-occupied housing market are the most important reasons why many young households rent. In other words, households largely become home owners when they anticipate moving less often and when they want to start saving more. The ability to use a house to borrow against future income through negative amortization is relatively more attractive to young households than simple lower down payment requirements. We find little evidence that home ownership is a special source of insurance for households.

Models of home ownership choices over the life cycle in general equilibrium (e.g. Gervais [2002], Chambers et al. [2009b]) study incomplete markets settings in the tradition of Aiyagari [1994] and Bewley [1984]. We build on these models by allowing for volatility in house prices, changes in family sizes and choice of location. These additions are key to generating the observed patterns of household mobility, without which there is no way to measure the importance of housing illiquidity. Moreover volatility in prices is obviously necessary for generating hedging motives.

To generate volatility and mobility, we situate a Bewley-type model of earnings shocks in incomplete markets in a Lucas and Prescott [1971]-like island model of housing and labor markets. Exogenous stochastic variation in the quality of the local labor market will create endogenous household mobility and movements in house prices and rents. We calibrate the model to U.S. data from before the recent housing boom and bust. We find that the relative value to the household of owning versus renting depends primarily on their relative user costs, the household's expected horizon of stay in the house, the riskiness of housing equity and the transaction costs of buying and selling a house. Households that expect to move soon, either for family or career (earnings related) reasons, rent to avoid paying the high transaction costs for buying and selling a house. Furthermore, because housing is risky, home owners optimally accrue equity in it and thus wealth. Young households, which comprise most of the renters in the U.S., mostly do not wish to save and are relatively mobile and so do not own.

In the estimated model's equilibrium, younger households have a lower expected duration than older households in their current home for four reasons. First, from a career perspective, the benefits of moving to a location that offers a higher salary are greater when the household is younger. Second, young households expect their wages to increase dramatically in the future, but are unable to borrow against future income and smooth housing consumption over their life cycle. So young households expect to move into larger houses in the future. Third, expected future earnings comprise a larger part of a young household's total wealth and are subject to large, permanent shocks. Households that receive such shocks to their total wealth are likely to adjust their housing consumption. So, young households expect to move in the (potentially near) future in response to future permanent earnings shocks. Last, relative to middle-aged households, younger households are also smaller but growing in size and thus inhabit smaller houses, making it cheaper to move given the transaction costs.

Our contribution is on two fronts. On the quantitative front, we evaluate consumer behavior in the presence of housing and location choice using the baseline model. Despite the many reasons to study home ownership[1], there is little consensus on which determinants of the relative value of owning versus renting offered are quantitatively meaningful. That is, while explanations like borrowing constraints are known to explain why some households choose to rent, we do not know whether it can explain why most renters choose to rent. We provide a dynamic, stochastic, general equilibrium model which can measure the relative importance of several prominent theories.

In the consumer durables tradition of Grossman and Laroque [1990], Yao and Zhang [2005], Li and Yao [2007], our model is rigged so that the household's value function is homothetic. Homothecity makes the household's problem computationally tractable but at a cost. For one, we are limited to using constant proportional income taxation and transaction costs, among other modeling choices. For another, homothecity limits the scope for heterogeneity in discrete choices; the "state-space" for household's discrete choices is effectively one dimension smaller, which is the reason it is computationally attractive but can potentially make it harder for the model to generate sufficient within-age heterogeneity in home ownership choices. For instance, instead of wealth and income separately influencing home ownership decisions, it is the wealth-to-income ratio that helps determine it. We calibrate the model to fit macroeconomic moments and moments from panel and cross-sectional data. Despite the challenges posed by homothecity, our model is successful in replicating several key aspects of the home ownership and mobility profiles over the life cycle.

We conduct a series of counterfactual experiments to evaluate the relative impact of various factors in the ownership choice decision. We find that households that are financing constrained are as likely to adjust along the intensive margin versus extensive margin, as in Ortalo-Magne and Rady [2006]; about as many first-time home buyers in the model choose to delay owning rather than buy a smaller house when forced to make a down payment (23.6 and 27.8 percentage points, respectively, in the general equilibrium counterfactual with no down payment requirement). Lower down payment requirements lead to only small changes in the home ownership rate; consistent with the findings in Chambers et al. [2009a], which models the mortgage market in greater detail than here.

Moreover households also can also adjust along a margin novel to the literature: when down payment requirements are high, they can choose to live in a location with lower house prices. As such, we find that lowering the required down payment increases the dispersion across locations of house prices. The intuition is as follows: households weigh the tradeoff of living in high productivity locations with the high cost of housing in those locations, leading to limited[2] positive

[1] Home ownership plays a key role in many studies of, among others, the response of consumption to changes in housing wealth (Case et al. [2005], Campbell and Cocco [2007]), household portfolios (Flavin and Yamashita [2002]), investment volatility (Fisher and Gervais [2007]), the regional mobility of households and the propensity to default (Ferreira et al. [2010], Sterk [2010]), and house price dynamics (Ortalo-Magne and Rady [2006]).

[2] "limited" in part due to the transaction costs of moving and in part due to wealth effects

assortive matching. Young households in particular sort strongly since they have relatively little wealth. Credit constraints limit sorting: the inability to borrow against future earnings reduces a wealth-poor but high ability household's desire to move to expensive locations. When constraints are partially relaxed, more young households want to live in productive locations pushing up the price of housing in those locations and decreasing the price in low productivity locations.

Changes in the cost of mobility have large effects on home ownership patterns. When the relative transaction costs of moving into rental and owner-occupied housing are equalized (in the baseline, owner-occupied housing is much more costly), housing consumption and prices go up. Home ownership also increases by about seven percentage points - roughly an order of magnitude larger than the increase that occurs with no down payment. More young households become home owners when there are changes in mobility costs rather than changes to down payment constraints. Home ownership choices are as much about "settling down" (i.e. lower expected future mobility) as "saving up" (i.e. being able to afford a down payment).

Young households would like to insure themselves against future labor earnings shocks; young households that save anything do so for precautionary reasons. By buying a house with a mortgage, a household is instead taking a leveraged position in an illiquid asset that is positively correlated with its labor earnings. So, home equity is less useful than liquid wealth for precautionary savings for young households - as Ejarque and Leth-Petersen [2009] finds. In our model with incomplete markets, *ceteris paribus*, owner-occupiers will optimally hold more wealth than renters, in part for insurance reasons. Reducing the riskiness of housing in a counterfactual economy leads to less savings, lower down payments, more home ownership and higher interest rates - consistent with the findings of Amior and Halket [2011] that less risky cities have higher home ownership rates and higher loan-to-value ratios at origination. Households are not less likely to own when rental prices are riskless, contrary to Sinai and Souleles [2005]. In other words, we find that many young households rent because owning a home means accruing home equity and thus financial wealth at a point in their life cycle where households would rather be borrowing against their future earnings - as in Chen [2010], which finds that more liquid savings accounts (i.e. reducing social security pensions) would increase home ownership. As a household's intertemporal marginal rate of substitution changes as it ages, so will its willingness to hold the extra precautionary savings that owning compels and thus its willingness to own.

On the qualitative front, we extend the literature by endogenously incorporating location choice, ownership and house price risk into a GE model of housing. Heterogeneous agent, incomplete-market models with non-constant prices typically feature infinite dimensional state variables in the agents' decision problems, and thus afford only approximate solutions (as in, for instance, Krusell and Smith Jr. [1998]). Our economy, which follows from a simpler setting in Halket [2011], has an exact stationary equilibrium in which the price of housing in a location in equilibrium is dependent only on the location's productivity. This allows us to characterize prices and allocations without having to keep track of distributions over households on every island.

With recent advances in computing, many dynamic OLG models incorporate housing. The issues addressed range from the ownership choice decision (Chambers et al. [2009b] and Diaz and Luengo-Prado [2008]), the evolution of consumer debt (Scoccianti [2008]), portfolio choice in the presence of housing (Cocco [2005], Yao and Zhang [2005]), and the consumption of durables over the life cycle (Fernandez-Villaverde and Krueger [2004], Gruber and Martin [2003]). Fernandez-Villaverde and Krueger [2004] argue that the hump-shaped pattern of durable consumption (of which housing is a large part) is due to incentives to accrue collateral. In our model, the hump-shape is due in part to borrowing constraints (and in part due to family size changes) and incentives to accrue wealth, not collateral. Han [2008] builds a model where homeowners may choose to accumulate more housing in order to hedge against housing risks. Under the assumption of separable utility, she provides conditions for when the hedging motive outweighs the household's normal disinclination to hold riskier assets (as in Rosen et al. [1984]). Our work expands on this contribution by adding the option of renting, and uses a general equilibrium framework without separable utility.

In a sense, our model is a natural merging of three strands of the literature: home ownership with stochastic prices; home ownership in life cycle, general equilibrium models; and spatial models of working and housing. Cocco [2005], Yao and Zhang [2005] and Diaz and Luengo-Prado [2008] each use partial equilibrium models where the price of housing is correlated with household labor income. Chambers et al. [2009b], Scoccianti [2008], Fernandez-Villaverde and Krueger [2004] and Gruber and Martin [2003] have GE models where the price of housing is constant. Van Nieuwerburgh and Weill [2010] uses an island model of renter-workers to examine the changes in the spatial distribution of house prices and wages in the U.S., while Sterk [2010] uses an island model of owner-workers to examine how falls in house prices can reduce mobility due to mortgage lock in. Ortalo-Magne and Prat [2010] prices houses that differ spatially in an OLG model where households choose their location at birth.

The rest of the paper is organized as follows: section 2 presents the model and section 3 discusses the calibration. Section 4 compares the model to the data. In section 5, we conduct counter factual experiments to assess the importance of family size, down payment constraints and career concerns in determining the ownership rate. Section 6 concludes. Appendix A contains the definition of the competitive equilibrium. Further appendices containing a proof of the equilibrium's existence and details on the calibration and computation are available online at the corresponding author's website.

2 Model

We consider an OLG island model of household consumption choice. There is a continuum of measure 1 of households and islands each in the economy. Households are indexed by $\iota \in [0,1]$ and islands are indexed by $\varepsilon \in \mathscr{E} \in [0,1]$.

Time is discrete and each period in the economy corresponds to one year in the data. Households are born at age $A = 21$ and live at most to age $T = 100$. In every period, the household survives to next period with probability, $\lambda : \mathscr{A} \to [0,1]$, which is a function of the age of the head, $a \in \mathscr{A} = \{A, A+1, ..., T\}$. We assume that $\lambda(a)$ is not only the probability for a particular individual of survival, but also the deterministic fraction of households that survive until age $a+1$ having already survived until age a. Each period, a measure $\mu_1 = (1 + \sum_{\kappa=A}^{T} \prod_{a=A}^{\kappa} \lambda(a))^{-1}$ is born; so the population of households in the economy is stationary.

2.1 Technology

There are two goods in the economy: a non-durable, globally available, consumption good and a durable housing good. The housing good is island specific and in fixed and equal supply on each island, $H(\varepsilon) = \overline{H} \quad \forall \varepsilon \in \mathscr{E}$. Housing is "putty" within an island; households choose housing $h \in \mathscr{H} \equiv [0, \overline{h}]$.

The consumption good is produced according to a Cobb-Douglas production function, where K is the aggregate capital stock and L is the stock of available efficiency labor units in the entire economy. A consumption good produced can be consumed in that period, converted into capital next period, K', spent on government consumption, used to maintain the housing stock or used up in transaction costs. Capital depreciates at rate δ. The aggregate resource constraint for the consumption good is:

$$C + G + K' - (1-\delta)K = L^{1-\alpha}K^{\alpha}$$

where C refers to consumption used for all purposes except investment in capital goods and government consumption, G.

2.2 Preferences

The household derives utility from housing and from the consumption good, which is the numeraire good. Preferences are time-separable where β is the time discount factor. The instantaneous utility function $u(\cdot,\cdot,\cdot)$ is a CRRA type with a Cobb-Douglas aggregator over housing and the consumption good [3]

$$u(c,h,f) = \frac{((\frac{c}{S(f)})^{1-\sigma}(\frac{h}{S(f)})^{\sigma})^{1-\gamma}}{(1-\gamma)}$$

where σ is the share of housing in the Cobb-Douglas aggregate and γ is the inverse of intertemporal elasticity of substitution.

The path for the family size adjustment factor[4], $S : F \to \mathbb{R}_{++}$, is a function of the household's family size in that period, $f \in F$. A household's family size follows a finite state Markov chain with age-dependent transition probabilities given by the matrices $\pi_f(f'|f,a)$. Any time a household under the age of 60 transitions from $f > 1$ to $f' = 1$, that household divorces, which forces it to move from the house that it chose last period. In the case of divorce, the household must move from its current house and pay the relevant moving and transaction costs[5].

2.3 Labor productivity and job offers

Each island has a productivity, indexed[6] by j, which follows a finite state Markov chain with state space $j \in \mathscr{J} \equiv \{1,...,\mathrm{J}\}$ and transition probabilities given by the matrix $\pi_J(j'|j)$. Let Π_J denote the unique invariant measure associated with π_J.

Similarly each household has an ability, indexed by i, which follows a Markov chain with state space $i \in \mathscr{I} \subset [-I,I]$ and transition probabilities given by the matrix $\pi_I(i'|i)$. The initial realization of a newborn household's ability is assumed to be drawn from the distribution Π_I for all households.

Households are endowed with one unit of time per period. If a household chooses to move in the current period, moving occupies θ_m units of time. All other time is supplied inelastically in the labor market. A household's effective labor supply in any period is the product of four elements that depend on whether the household moves, the household's age, the household's ability, and the productivity of the island on which it chooses to work:

$$l(a,f,i,j,1_m) = (1-1_m\theta_m)l_i(a,f,i)l_j(j)$$

[3]Piazzesi et al. [2007] finds an intratemporal elasticity of substitution between housing and consumption in the range of 1.04 to 1.25 using NIPA data. However, Davis and Ortalo-Magne [2011] finds that the expenditure share on housing is constant across time and U.S. Metropolitan Statistical Areas, consistent with the Cobb-Douglas specification.

[4]Attanasio et al. [1999], Gourinchas and Parker [2002], Cagetti [2003] each let family size affect a household's discount factor. In Gourinchas and Parker [2002]'s model, the life cycle profile for family size is deterministic and homogeneous across households of the same age. Attanasio et al. [1999], Cagetti [2003] let the profiles vary by education. Browning and Lusardi [1996] have a stochastic process for family size (see their paper for more references).

[5]We could also allow for some loss of wealth in the case of divorce. However this would not change the results materially.

[6]We will often say an "island has productivity j."

where $l_i : \mathscr{A} \times F \times \mathscr{I} \to \mathbb{R}_{++}$, $l_j : \mathscr{J} \to \mathbb{R}_{++}$ are known functions and 1_m is a dummy variable which equals 1 if the household moves in the current period and is 0 otherwise. $l_j(\cdot)$ is assumed without loss of generality to be an increasing function.

2.4 Assets and Prices

There exists a one-period, risk-free asset b which pays a net interest rate r. All firms and households may borrow or lend at this rate. Households choose asset holdings from the set $b' \in \mathscr{B} \equiv [\underline{b}, \overline{b}]$ subject to a collateral constraint.[7] Wages per unit of effective labor supply are w. There is a proportional income tax rate t_y. The tax is levied on a household's total net income from labor earnings. We denote the after tax wage rate as $\tilde{w}$.

2.5 Institutional structure of the housing market

Housing is distinct from both the consumption good and the risk-free asset in the following ways: housing enters the utility function, and at the same time is an asset. It is immovable and, for the households, indivisible. The transaction cost for households for buying a house is a proportion θ_h of the purchased house value.

Housing may be either rented or bought from a risk-neutral, competitive agency in the real estate industry. If rented, a household pays $q(j)$[8] per unit of housing h on island ε of productivity j. The household can buy and sell housing on island ε of productivity j at the price $p(j)$. In turn, every house sold by a household is bought by a real estate agency.

We assume that all houses require upkeep in consumption goods in an amount proportional to the house value as maintenance: $\delta_h p(j)h$. In addition, we assume that this keeps the house at a constant quality over time. Owner-occupiers and landlords must pay a property tax, t_p, on the value of the house (assessed each period).

A household cannot rent housing that it owns[9] but does not use and it can only consume housing on the island on which it works. A household cannot simultaneously consume owner-occupied and rental housing and cannot short-sell housing.

Housing is the sole form of collateral for households in the economy. We model this by giving households a home equity line of credit.[10] When purchasing a house, households can borrow up to $(1-d(a))$ of the value of the house, where $d(a)$ is the down payment constraint for a household of age a. Thereafter, as long as they continue to be home owners, households may borrow up to

[7] We set $\overline{b}$ and $\overline{h}$ so that they do not affect the equilibrium.

[8] In the online appendix, we show that prices and rents on an island are only functions of the island's productivity in equilibrium.

[9] See Chambers et al. [2008] for a model with household landlords.

[10] We also call this a mortgage throughout.

$(1-d(a))$ of the value of the house. They may also choose to roll over their debt after making an interest payment. So a household's borrowing constraint is:

$$b' \geq \min\{-(1-d(a))\tau' p(j)h', (1-1_m)b\},$$

where τ', ownership, is an indicator variable which equals one if the household chooses to own in the period. This borrowing constraint is different from the more typical one which restricts borrowing to be weakly less than some percentage of the house value ($b' \geq -(1-d)\tau' p(j)h'$). With risky house prices, for a household near the typical borrowing constraint, a fall in the value of a house results in a "call on the mortgage principal" - the household must reduce the amount borrowed. If house price volatility is large enough, the effective down payment constraint (the amount the household could borrow and still be able to repay in any state of the world next period) may be much tighter than the actual (d).

If the household chooses to sell its house, it must pay off all existing debt, though another loan can be taken out if another house is purchased. A household that does not have positive total cash-in-hand (housing wealth plus financial wealth plus current income) will not be able to pay off the mortgage it has (the debt it owes) on its house and will not choose to move in this period. We do not allow the household to choose to default (see Jeske and Krueger [2005], Jeske et al. [2011] for a models with mortgage default), but households can default implicitly by dying or becoming divorced with negative net worth.[11]

Buying a home does not allow households to borrow against future earnings (unless $d < 0$). In this respect, the lack of unsecured borrowing treats renters and owners equivalently.

Finally, we follow Gervais [2002] and assume that mortgage interest payments are tax-deductible for households.

2.6 Real Estate Industry

Households have to buy, sell or rent housing through real estate firms. These firms are risk-neutral and can borrow at the interest rate, r. The real estate industry is competitive, so the size and number of individual firms is indeterminate.

Differences in the tax treatment of owner-occupied versus rental housing create a wedge between the user costs of owning and renting. Real estate firms pay income tax on any rental earn-

[11] The household has negative net worth if $b \leq -\tau p(j)h(1-\theta_h)$. In this case, the household will leave the house with 0 wealth. We actually do allow for default in the computed model: a home owner can walk away from its house at any time. However it will then lose all of its assets and a proportion of its earnings that period. We set the proportion of lost earnings so that no one chooses to default in the calibrated economy. Without default and with Inada conditions on utility and no consumption floor imposed, extremely low probability events had an outsized effect on household choices.

ings (as in Gervais [2002]), maintenance, interest and property taxes, and potentially earn capital gains/losses from housing (which we assume that they carry forward). Since real estate is competitive, firms make zero profit on average. The zero-profit condition is:[12]

$$(1-t_y)q(j) = (\delta_h + t_p + \frac{r}{1+r})p(j) - \frac{1}{1+r}E(p(j') - p(j)|j),$$

where t_y is the income tax rate and $E(p(j') - p(j)|j)$ is the expected capital gain for a unit of housing on an island of productivity j.

2.7 Birth and Death and the Government's Budget Constraint

Newborn households are born with no housing and therefore their initial location is unimportant (since they will pay the moving costs regardless). Their birth family state is determined by drawing from a density $\Pi_F : F \to [0,1]$. When households are born, they draw their initial wealth from a distribution Π_b, which is a probability distribution on $\mathscr{B}$. The government collects taxes and any accidental bequests by dead households, after making whole the financial sector on any outstanding loans to dead households. Newborn households receive their initial wealth from the government.[13]The remander of tax receipts funds government spending G which yields no direct utility to households.

In summary, the benefits of renting are that there are no transaction costs and no downpayment is required. The benefits of owning are the tax benefits: the user cost of owner-occupied housing is lower, particularly if the household has a mortgage. In addition, due to the lack of complete markets, there may be insurance benefits from either owning or renting.

2.8 Timing

The timing within a period is as follows:

1. Some households die. A household of age a enters the period, observes its ability i, family size f, and its island's productivity j, and accidental bequests b (if it is newborn, $a = 1$). All of the dead households' housing stock is sold to the real estate agency. Households that get divorced sell their house.

[12] We allow households to move frictionlessly between rental houses of the same size on the same island, so that renters are indifferent between their current house and any other rental of the same size and location if their rents are equal.

[13] In the calibration section, we discuss how Π_b is chosen to match certain aspects of the data. In our counterfactuals, we assume that Π_b remains the same as in the baseline. We leave to further research a joint examination of housing policy, bequests and the wealth of young households.

2. The household chooses to locate/work on island ε' which has productivity $\tilde{j}$. If the household moves, the household sells any housing τh and chooses home size h' and how many consumption goods c to consume this period and its ownership choice (rent or own), τ', and next period's financial assets b'. If it chooses to stay in its current housing, the household only chooses c and b'.

3. Efficiency labor units and capital are supplied.

4. Factor payments are made, and consumption and housing services are consumed.

Information is public and all decisions are publicly observable.

2.9 Household's Problem

The household's problem can be split up into three parts[14]: the household's problem where it chooses whether to stay or move to a different location, and then a mover's problem and a stayer's problem. The state variables of the model economy are: i, the idiosyncratic ability of the household; j, the island productivity; τ, an indicator which equals one if the ownership chose to own last period; h, last period's housing consumption; b, the household's financial wealth; a, the age of the household; f, the household's family size; I_d, an indicator for whether the household has received a divorce shock; and ε, the island index.

The household's problem is to choose whether to stay in its current house or move to a new location, given its state and the value functions V^s and V^m (unless it has a divorce shock, in which case it must move):

$$V(a,f,i,j,\tau,h,b,I_d,\varepsilon) = (1-I_d)\max\{V^s(a,f,i,j,\tau,h,b,\varepsilon), \sup_{\tilde{j},\varepsilon'} V^m(a,f,i,\tilde{j},b^m,\varepsilon')\} + I_d \sup_{\tilde{j},\varepsilon'} V^m(a,1,i,\tilde{j},b^m,\varepsilon')$$

$$\text{s.t.} \qquad b^m = I_d \max\{0,(1+\tilde{r})b + p(j)h\tau\} + (1-I_d)((1+\tilde{r})b + p(j)h\tau)$$

$$\tilde{j} = \bar{j}(\varepsilon') \qquad \varepsilon' \in \mathscr{E}$$

$$\tilde{r} = \begin{cases} r & \text{if} \quad b \geq 0 \\ (1-t_y)r & \text{if} \quad b < 0 \end{cases}$$

b^m is the household's wealth that it takes into the moving sub-problem, after selling any housing it may own. If it receives a divorce shock, any net debt is assumed wiped out. $\bar{j}$ is a stochastic function which simple requires that a mover's choice of island productivity, $\tilde{j}$, be consistent with the productivity of the island it chooses to live on, ε'.

[14]For an "all-in-one" version of the household's problem, see the online appendix.

2.10 Mover's Problem

The problem of the mover is to choose consumption, house size and ownership, and savings, given its age, family size, ability, location's productivity, cash-in-hand, and location, subject to budget, borrowing, and non-negativity constraints:

$$V^m(a,f,i,\tilde{j},b^m,\varepsilon') = \sup_{c,h',\tau',b'} u(c,h',f) + \lambda(a)\beta E[V(a+1,f,i',j',\tau',h',b',I'_d,\varepsilon')]$$

$$\text{s.t.} \quad c + b' + h'((1-\tau')q(\tilde{j}) + \tau' p(\tilde{j})(\delta_h + t_p + 1 + \theta_h)) \leq b^m + \tilde{w}(1-\theta_m)l(a,f,i,\tilde{j})$$

$$b' \geq -(1-d(a))p(\tilde{j})\tau' h'$$

$$c \geq 0 \qquad h' \geq \mathscr{H} \qquad \tau' \in \{0,1\}$$

2.11 Stayer's Problem

The problem of the stayer is to choose consumption and savings, given its age, family size, ability, location productivity, ownership, house size, assets and location, subject to budget, borrowing and non-negativity constraints:

$$V^s(a,f,i,j,\tau,h,b,\varepsilon) = \sup_{c,b'} u(c,h,a) + \lambda(a)\beta E[V(a+1,f',i',j',\tau,h,b',I'_d,\varepsilon)]$$

s.t.

$$c + (p(j)\tau(\delta_h + t_p) + q(j)(1-\tau))h + b' \leq b(1+\tilde{r}) + \tilde{w}l(a,f,i,j)$$

$$b' \geq \min\{(1-d(a))\tau h p(j), b\}$$

$$c \geq 0$$

$$\tilde{r} = \begin{cases} r & \text{if} \quad b \geq 0 \\ (1-t_y)r & \text{if} \quad b < 0 \end{cases}$$

2.12 Stationary competitive equilibrium

Appendix A defines a stationary competitive equilibrium for the economy. Since our model has both discrete and continuous state variables the proof of existence of an equilibrium correspondingly differs from the one in Aiyagari [1994]. In particular, aggregates (e.g. the aggregate supply of capital through savings) are potentially correspondences and not functions of prices, and so may be discontinuous - a point discussed at length in Chatterjee et al. [2007]. The proof is in an online appendix and is an adaption of Halket [2011]. The equilibrium definition involves a selection of state-contingent action plans in areas of indifference using mixed allocations which serve as tie-breaking criteria. Since our economy is populated by a continuum of households, there is no aggregate uncertainty using a mixed allocation. Areas of indifference are non-existent in our computational solution and so mixed allocations play no role in our numerical results.

In equilibrium, island-specific house prices and rents are a deterministic function of the island-specific productivity, j. Objects such as the distribution of wealth (as in Krusell and Smith Jr. [1998]) on a particular island do not help forecast prices. This is due in part to the fact that households that choose to move in a given period are indifferent over islands with the same productivity. This would not have been the case if moving costs varied by distance (i.e. higher costs for moving to a different island than to moving within an island).

3 Calibration

3.1 Household life-cycle and preferences

The survival probability, $\lambda(a)$, is taken from the National Center for Health Statistics, United States Decennial Life Tables for 1989-1991. This table gives the mortality rate of the population as measured in the 1990 Census. We use the life table for the whole population from 1989. We set the retirement age to 66.

In the model, households evolve exogenously in terms of size and composition. We use the PSID to estimate the transition matrices for family size. See the online appendix for details.

3.2 Initial wealth distribution

We calibrate the wealth distribution of newborns using the distribution of wealth among 21-25 year olds in the Survey of Consumer Finances (SCF) waves from 1989-2001. We drop top-coded observations, households with negative wealth and students from the sample and use the sample weights provided by the SCF. We parametrize the initial wealth distribution as an exponential distribution. That gives us one parameter that we have to match.

$$f(b_0) = \lambda_w e^{-\lambda_w b_0}$$

where b_0 is the initial wealth, and λ_w is the parameter to estimate in the exponential distribution. We estimate λ_w by matching the mean of the initial wealth distribution.

$$\lambda_w = \frac{1}{\bar{b}_0}$$

This gives us $\lambda_w = 0.00589$. We convert the initial wealth distribution in the data to model terms by scaling by the ratio of average labor earnings at age 21 in the model to average labor earnings at age 21 in the data.

3.3 Technology

Following Cooley and Prescott [1995], we calibrate δ using the law of motion for the capital stock: $K' = K(1-\delta) + I$, where I is investment. In the steady state (adjusting for growth), the capital stock remains constant and investment is used only to replace depreciated capital: $\delta = \frac{I}{K}$, We calculate K from the *Historical-cost Stock of Private Non-Residential Fixed Assets* in the NIPA. I is calculated from the *Historical-cost Investment in Private Non-Residential Fixed Assets*. We use data from the period $1970-1993$[15]. δ is computed as the growth adjusted average of $\frac{I}{K}$ over this period. This gives us $\delta = 0.13$. We set the capital share of output, α, at 0.34.[16]

3.4 Housing

Analogous to capital depreciation, we calibrate housing depreciation using the law of motion of housing capital. In the model we assume that housing supply is fixed and that home owners pay a maintenance cost to replace depreciated housing capital. So, the (growth-adjusted) relationship between housing depreciation and housing investment is

$$\delta_h = \frac{I_h - \Delta(pH)}{pH}$$

For the value of housing, pH, we use non-farm owner-occupied housing from NIPA's *Historical-Cost Net Stock of Residual Fixed Assets* table. Investment in housing is computed using non-farm owner-occupied housing from NIPA's *Historical-cost Investment in Residential Fixed Assets.* This gives $\delta_h = 0.02$. These values from NIPA are the value of the structures and do not include the value of land.

These NIPA data focus on owner-occupiers, whereas there have been papers that stress the importance of moral hazard in renter-occupied housing. Campbell and Cocco [2007] and Henderson and Ioannides [1983] are two representatives of this literature. Further, Chambers et al. [2009b], for instance, finds a depreciation rate of owner-occupied housing of 3.4%, and a depreciation rate of tenant-occupied housing of 7.49% from their method-of-moments estimation process used to

[15]This period is chosen in part to remain consistent with our decision to look at the economy before the housing boom-bust period circa 2001-2011 and also due to changes in the PSID after 1993 that would complicate extending the sample period by just a few years.

[16]Heathcote et al. [2009] set the value of α at 0.33 after surveying the literature. Cooley and Prescott [1995] set $\alpha = 0.4$. Greenwood et al. [1995] set $\alpha = 0.29$, which is followed by Gervais [2002].

match, in part, data on home ownership rates. This suggests that the difference between the two depreciation rates could be significantly different. In order to examine this difference, we use the *Current-cost Net Stock of Residential Fixed Assets* and *Current-cost Depreciation of Residential Fixed Assets* tables in the NIPA. The rate of depreciation of non-farm owner-occupied housing is 0.0143, and for tenant-occupied housing the rate of depreciation is 0.0164. These numbers suggest that the two depreciation rates may in fact be quite similar. Since the model is homogeneous of degree 1, we are free to normalize the price of housing on islands with the lowest productivity and to arbitrarily set the housing stock on each island, $\bar{H}$.

We use data from the American Housing Survey (AHS) on household's loan-to-value ratios (LTV) at origination to guide the calibration of the down payment constraint.[17]

Figure 1 plots the density of LTVs at origination for owner-occupiers. It is easy to see that any absolute, exogenous borrowing constraint such as the one we have in our economy or the ones in, e.g., Gervais [2002], Chambers et al. [2009b], Chen [2010], Diaz and Luengo-Prado [2008], Fisher and Gervais [2011] is "reduced-form". We set the down payment constraint to 10 percent, $d(a < 65) = .1$. We do not allow retired households to take out new loans: $d(a \geq 65) = 1$. In the calibrated equilibrium, this is sufficient to ensure that no one at age T has any debt.

Martin [2003] finds that the average monetary cost involved in a housing transaction is $7-11\%$. We conservatively set the owner-occupied moving costs to $\theta_h = .08$. As the effects of lower down payment requirements and transaction costs are some of the main interests of this paper, we will also compute economies with alternative values for these parameters in the counterfactual section of the paper.

3.5 Taxes

There are two forms of taxes in the model economy - income tax, t_y, and property tax, t_p. Piketty and Saez [2007] uses public use micro-files of tax return data from the Internal Revenue Service, which have the advantage of being aggregated to the household level already. The income tax rate we choose, $t_y = 0.2$, is in the same range that they compute for the US economy[18].

[17] We follow Amior and Halket [2011] in constructing the data. The sample for the estimation of LTVs is owner occupiers, with mortgages, who purchased their home since 1975, and who took out a mortgage when they purchased their home. The last condition ensures that we measure the loan and price in the same year, to calculate LTV. All first and second mortgages at time of origination are used. The metropolitan survey covers 41 MSAs, and a further 6 MSAs (the largest) are included in the national survey. These surveys cover different MSAs in different waves, and we therefore rely on four different waves to put together a complete sample: the metropolitan surveys of 1998, 2002 and 2004, and the national survey of 2003. We index observations by year of purchase (rather than survey year), because we have information on the mortgage and home value (to calculate LTV) at the purchase year. Unfortunately, there is a large amount of measurement error in the loan and house price variables: over 6% of observations in our data have LTVs of over 1, with some reaching over 100,000. We exclude all observations with LTV greater than 1.

[18] See Table 1, page 6 in their paper

We use data from the Integrated Public Use Microdata Sample (IPUMS) 1990 5% sample for the amount of property tax paid and the estimated value of the house.[19] The weighted average of the ratio of the amount of property tax paid to the estimated value of the house is 0.01 so we set $t_p = 0.01$.

3.6 The productivity process

Labor earnings are given by $l(a, f, i, j)w$, where w is the wage per efficiency unit of labor, and $l(a, f, i, j)$ is the number of efficiency units of labor supplied by a household of age a, family size f, idiosyncratic ability i, and in a location of productivity j. We follow Storesletten et al. [2004] and develop a model of labor earnings over the life cycle. The basic structure of the model is that a household receives a base wage that is conditional on age, its idiosyncratic ability and location of the household. We assume that a location's productivity follows an AR(1) process and assume that shocks to ability contain a permanent component only so that ability follows a random walk[20]. Further, households are also born with a certain amount of ability, which we incorporate as a fixed effect in the model. See the online appendix for details. Lastly, we assume that single households earn only a proportion of their married counterparts.

Parameter	Description	Value
σ_f	Std. dev. of the fixed effect shock	0.5
σ_ι	Std. dev. of the persistent idiosyncratic shock	0.098
σ_j	Std. dev. of the regional productivity shock	0.026
ρ_i	Persistence of the idiosyncratic shock	1
ρ_j	Persistence of the regional shock	0.9839

Table 1: Productivity parameters

Table 1 shows the estimated parameter values. We discretize the location productivity AR(1) process following Tauchen [1986]. Due to computational constraints we pick a 5-point distribution. Since the persistent idiosyncratic shock is a unit root process, we discretize its innovations with a 3-point distribution.

3.7 Setting macroeconomic variables

The remaining variables are $r, w, \sigma, \beta, \gamma, \theta_m$. We normalize $w = 1$. We set $\gamma = 3$, within the typical range of 2 to 5 (e.g. Piazzesi et al. [2007], Diaz and Luengo-Prado [2008]).

[19]We remove top-coded variables from the sample, and consider only owner-occupiers. Sample observations are weighted using the household weights given in the data set.

[20]Though potentially important for the overall savings rate, we choose to not include a transitory component of income for computational reasons.

3.7.1 σ, β and macroeconomic moments

Finally, we pick σ, β, θ_m so that the simulated economy matches the data in three moments: the capital stock-output ratio ($\frac{K}{Y}$), the share of housing expenditures in income for households under 65 , and the average moving rates of renters under the age of 65. We choose to focus primarily on these younger households so that the choices of older household in our model do not greatly effect our parameter values. See the online appendix for more details on our matching process.

The capital stock, K, is calculated using the *Current-cost Stock of Net Fixed Assets* table from the NIPA. We set K to be equal to *non-residential private and government fixed assets.* Output, Y, is computed from the *Personal Consumption Expenditure* table in the NIPA. We calculate Y as personal consumption of non-durable goods + personal consumption of services + gross private domestic investment + government consumption expenditure and gross investment - housing services + services from durable consumption and find $\frac{K}{Y} = 2.00$.

Davis and Ortalo-Magne [2011] find a median expenditure share for working age households of .24 across MSAs in United States. The average moving rates for renters and owners with ages from 22 to 65 in our PSID sample is 22.3% and 9.7%, respectively.

The capital-output ratio also pins down the interest rate: $r = .04$. From our equilibrium, we get that $\beta = 1.00$, $\sigma = .25$, and $\theta_m = .03$. The expenditure share in the model is within the $\pm.02$ the confidence interval in Davis and Ortalo-Magne [2011].

Parameter	Value	Moment	Data	Model
β	1.00	$\frac{K}{Y}$	2.00	1.89
σ	.25	Expenditure share	.24	.25
θ_m	.04	Renter moving rate	22.3%	23.0%

Table 2: Parameters calibrated internally

4 Comparing the model to the data

What aspects of a house help explain why home ownership increases over the early part of the life cycle? We proceed in two steps to use the model to answer this question. In this section, we show that the model matches many patterns found in the data. Then in section 5, we use a series of partial and general equilibrium counterfactual experiments to see how home ownership choices would change if one or more aspects of the household's problem (e.g. removing the down payment constraint) were changed.

4.1 Ownership over the life cycle

Figure 2 shows the proportion of home ownership over the life cycle generated by the simulations and from the data. The model economy generates a pattern of ownership over the life cycle that is close to the actual economy. The overall home ownership rate for households under 65 in the simulated economy is 62.6%, close to the data's 72.5%[21] Home ownership in the model starts below the data and peaks above it but well below 100%.

Figure 3 plots home ownership by age and family size in the model and the data. To keep things simple we plot two profiles for each: a profile for households with fewer than three family members ("no kids") and one with at least three members. We see that in both the model and the data, the home ownership rate for larger families is higher than for smaller families, though again both simulated profiles start below and rise above their data counterparts.

4.2 Moving

The model also matches the moving rates over of the life cycle (figure 4). This pattern in the model arises because of two factors: firstly, renters are more mobile than owners and the proportion of owners increases over the life cycle; secondly, mobility falls conditional on ownership as lifetime earnings and family size uncertainty are resolved . The model is able to broadly match the data on the average mobility conditional on ownership (figure 5), as well as the rates of decline in mobility conditional on ownership.

In the model, we count "inter-state" movers as those households that move to an island of a different productivity from the one on which they start the period. In figure 6, the calibrated model and data both feature the same pattern of declining "state" moving rates over most of the working-life. The level of "inter-state" moving in the model is higher than the data; higher than the inter-state movers and job-related movers[22]. Many movers in the simulated economy also move to a new island when they move. In the model, the moving costs of moving "next door" (i.e. changing house size or tenure but not regional location) are the same as moving to a completely new location. If there are enough different islands to choose from, nearly every household can find a better "match" with an island that is different from the one that it comes into the period living on. So, conditional on choosing to move to a new house, the household is likely to move to a new island. Evidently, even with only five states for the island productivity process, l_j, the set of islands to choose from is comprehensive enough that many households can find a better match on a different island should they choose to move. Including a cost of moving to a new island would

[21]These figures use the population weights in the model.

[22]Relocation would probably be better analyzed at the MSA or district level, but the lack of publicly available data on those variables in the PSID precludes that possibility. The pattern of inter-state moving is closely related to the pattern of career-related moving; the correlation between the two is .6.

clearly help the model match the level of regional mobility seen in the data. However, including such a cost would mean that house prices on any island would be a function of the distribution of households (over the state space) on that island, seriously complicating the computational scale of the model.

That said, locations are an important component in explaining the declines in general mobility over the life cycle (both conditional and unconditional on tenure). The choice of location for households is a trade-off between higher earnings due to higher productivity and higher house prices and rental costs. Three factors play a significant role here. The steep slope of the base wage in the early part of life (base wage peaks at around age 45) implies that middle aged households' earnings change the most by moving to more productive locations. Secondly, since location and idiosyncratic shocks are persistent, younger households have a larger expected future earnings gain from relocating to more productive locations as they have a longer expected life span. Finally, middle-aged households have more wealth and income and larger families and so tend to have larger houses. This increases their housing cost, so that relocation is less desirable (*ceteris paribus*) for middle-aged households.

Figure 7 shows the adjusted average idiosyncratic ability of households conditional on location productivity as a function of age; an indirect measure of the urge to move for purely relocation reasons. We scale each household's ability by the cross-sectional standard deviation of the permanent idiosyncratic component for its age so that any spread in the adjusted average reflects the effect of the complementarity between the idiosyncratic and island components. Evidently this complementarity is stronger earlier in life as the spread in average ability is highest in these years, when the expected life-span is high and the earnings stream is rising.

4.3 Wealth

Figure 8 shows the average household financial portfolio over the life cycle. We normalize the simulated financial data so that the average net wealth[23] of the simulated economy is equal to the average net wealth observed in the data[24]. The net wealth and financial wealth of households over the life cycle of the simulated economy matches closely the patterns in the data. The average house value in the simulated economy rises over the life cycle, but not as far as it does in the data.

The average loan-to-value (LTV)[25] in the model economy is 54%. Amior and Halket [2011] find that the average LTV in the American Housing Survey is 78%. Since households in the model cannot hold savings and mortgage debt simultaneously however, direct comparisons to this data are

[23]Financial wealth is any liquid savings or, negatively, debt. Net wealth is financial plus housing wealth.

[24]The average net wealth is calculated for the whole economy unconditional on age. Data are from the SCF as described above.

[25]We compute the LTV in the model by taking the average ratio of debt to house value for a household at the time of purchase conditional on having any debt.

difficult. Still, 54% is indicative that many, particularly young, households are willing to borrow significantly when they purchase a house.

5 Counterfactual experiments

In this section, we look at several prominent explanations for observed home ownership behavior: that households do not own because they are financial constrained, that households do not own when they expect to be relatively mobile, and finally that households own to hedge their exposure to changes in rental prices. For each, we conduct several counterfactual experiments. Each experiment comes in at least two flavors: a partial equilibrium version, where all prices are kept constant, and a general equilibrium version where prices adjust[26]. The results presented are the steady states for each counterfactual economy and should thus be thought of as the partial and total "derivatives" (for the partial and general equilibrium versions, respectively) of some of the economy's moments with respect to various parameters.

5.1 The down payment constraint

Financial constraints are ameliorated by reducing the down payment required: $d(a) = \underline{d} < .1\ \forall a < 65$. We look at two settings: no down payment, $\underline{d} = 0$; and a limited negative amortization, $\underline{d} = -.1$. Setting the down-payment constraint to zero (or less) does not eliminate financial constraints (households still cannot explicitly borrow against expected future income), but is a way of relaxing the financial constraint related to the housing market. Figure 9 displays the tenure curves for each experiment against the baseline model and table 3 reports some summary statistics. As can be seen there is no noticeable effect on prices (to the second decimal) when the down payment is lowered to 0.

Counterfactual	Ownership	LTV	r	$p(1)$	$p(5)$
Base	63.4%	54.1%	4.0%	1.00	1.27
$\underline{d} = 0$	64.7%	58.6%	4.0%	1.00	1.27
$\underline{d} = 0$ (GE)	64.2%	58.7%	4.0%	1.00	1.29
$\underline{d} = -.1$	67.6%	57.7%	4.0%	1.00	1.27
$\underline{d} = -.1$ (GE)	65.1%	59.6%	4.5%	0.95	1.28

Table 3: Selected effects from changes in minimum down payment

$p(1)$ and $p(5)$ refer to the price of housing on islands 1 (the lowest productivity) and 5 (the highest), respectively. (GE) refers to the general equilibrium version of the counterfactual.

[26] We also adjust tax rates to balance the government budget constraint. We assume that the income tax is the tax that adjusts. In all counterfactuals, the adjustments are slight and inconsequential to the results reported below.

In general, home ownership becomes unequivocally more attractive when a lower down payment is required. Still, households can adjust to changes in the down payment constraint on either the intensive or extensive margin. On the extensive margin, households that chose to rent because they did not wish to save for a down payment can now own. On the intensive margin, relaxing the constraint means that households can own larger houses and/or move to more expensive locations. To observe these separate margins, we simulate a large number of households for their entire life cycle in the baseline economy and in the counterfactuals, giving them the same shock values in each economy. Table 4 reports some statistics from these households.

Counterfactual	Earlier first home	Diff in age	Larger home
$d = 0$	21.1%	1.1 years	17.4%
$d = 0$ (GE)	23.6%	1.2 years	27.8%
$d = -.1$	30%	2.3 years	6.7%
$d = -.1$ (GE)	34.1%	2.4 years	27.6%

Table 4: Changes in first owned home

Earlier first home is the proportion of households that ever own that choose to own their first home earlier in the counterfactual than in the base version of the economy. *Diff in age* is the average difference in the age that households first become home owners. *Larger home* is the proportion of households that ever own that choose to buy an at least 5

The average difference between the age at which households first own in the baseline economy and the age of first ownership in the economy with no down payment is over one year. The difference rises to over two years when negative amortizations are allowed. Though 20 to 30 percent of households choose to buy a home earlier when the down payment requirements change, an equivalent percentage end up buying at the same age but opting for a significantly larger (at least 5 percent larger) house instead. Evidently, some of the households that are down payment constrained choose to delay their purchase[27] of a house while others choose to buy a smaller home.[28] In other words, households adjust their housing purchases on both the extensive and intensive margins.

As down payment requirements fall, young households sort better, increasing demand for housing on high productivity islands. Young households in particular weigh the tradeoff between higher earnings on high productivity islands and cheaper housing on low productivity islands. Due to the transaction costs of moving, the decision of where to live is a durable one. However the benefits

[27]There are, of course, a few households that end up buying later in the counterfactual economies. For example, with no down payment needed to buy a house, younger households that anticipate buying no longer need to save as much prior to the purchase and are thus (optimally) more exposed to shocks that may lead them away from their planned purchase time.

[28]This trade-off is also discussed in the context of a 4-period model by Ortalo-Magne and Rady [2006]. In our model, the housing choice space $\mathscr{H}$ is a continuous space and does not depend on whether the household chooses to own or rent. Some models (e.g. Chambers et al. [2009b]) have a minimum house size for owner-occupied housing, thus limiting the scope for adjustment along the intensive margin.

of higher earnings (now and in the future) are lower when the household cannot borrow against those future earnings to smooth consumption. Lower down payment requirements and especially negative amortization let young households better access these benefits. So more high ability households move to high productivity islands when down payments are lower, increasing demand for housing on high productivity islands and decreasing it on low productivity islands.

5.1.1 General Equilibrium Effects

When the borrowing constraints are relaxed, demand for housing rises and by more on the high productivity islands where more of the younger households live. At the same time, savings falls since households no longer need to save as much in order to buy a house: LTVs rise by as much as 5 percentage points.

In the general equilibrium, negative amortization counterfactual, the fall in savings leads to an increase in interest rates of 50 basis points. Higher interest rates imply higher rent-to-price ratios and increases the tax incentive to own from mortgage deductibility. Better sorting implies that demand goes up by more on high productivity islands. The net effect is that housing gets cheaper to buy but not to rent on the low productivity islands and gets uniformly more expensive on high productivity islands.

Lastly it is worth noting that household behavior and (in general equilibrium) prices change by more when the down payment is lowered from $\underline{\mathrm{d}} = 0$ to $\underline{\mathrm{d}} = -.1$ than when it is lowered an equal amount from $\underline{\mathrm{d}} = .1$ to $\underline{\mathrm{d}} = 0$. The reason is that young households are not keen savers. Their expected earnings profiles are steeply upward sloping: from age 21 to their peak, earnings are expected to about double. Even with a family size that is also expected to grow, young households, absent risk, would strongly prefer to borrow in order to smooth their consumption over time. When $\underline{\mathrm{d}} = 0$, households do not need to save in order to own, but neither are they able to use their home as a "piggy-bank." Net borrowing is only possible with negative amortization.

5.2 Mobility

In this section, we discuss several experiments designed to illustrate the response of home ownership to changes in the costs of moving. In the first set of counterfactuals here, we eliminate the cost of moving, $\theta_m = 0$. In the second set, we eliminate the transaction cost for buying a home, $\theta_h = 0$. Table 5 and figure 10 display the results. These counterfactuals complement some counterfactuals in Li and Yao [2007]. They look at the effect of house price changes on household behavior in a partial equilibrium model with and without transaction costs for housing. In our case, prices themselves will also respond to any change in transaction costs.

The effects from eliminating some mobility costs are straightforward. Eliminating either cost

Counterfactual	Ownership	Size	Own size	Rent size	r	$p(1)$	$p(5)$
Base	63.4%	1.00	1.07	0.90	4.0%	1.00	1.27
$\theta_h = 0$	70.0%	1.12	1.24	0.85	4.0%	1.00	1.27
$\theta_h = 0$ (GE)	70.2%	1.04	1.15	0.78	4.25%	1.05	1.33
$\theta_m = 0$	61.5%	1.02	1.06	0.95	4.0%	1.00	1.27
$\theta_m = 0$ (GE)	61.4%	1.02	1.06	0.95	4.0%	1.00	1.27

Table 5: Selected effects from changes in moving costs

$p(1)$ and $p(5)$ refer to the price of housing on islands 1 (the lowest productivity) and 5 (the highest), respectively. (GE) refers to the general equilibrium version of the counterfactual. *Size*, *Own size*, and *Rent size* are the sizes of the average house, average owner-occupied house and average rental house in the economy relative to the average house size in the base economy.

makes households richer as transaction costs are deadweight losses. Households consume more non-durables and live in bigger houses. Shifting the cost of moving, $\theta_m = 0$, moves the relative costs of moving from rental versus owner-occupied housing in favor of renting (which is now costless to move from), lowering the home ownership rate. Eliminating the transaction cost of buying a home raises the home ownership rate. Changes in θ_h shift consumption patterns more and so prices change by more. Eliminating θ_h has about an order of magnitude larger effect on home ownership rates than eliminating the down payment requirement.

5.3 Owning as a hedge

In this section, we provide an alternative test of the hypothesis in Sinai and Souleles [2005] that some households own (those that expect to stay in a given location for long enough) as a hedge against changes in the rental, spot price of housing. Sinai and Souleles [2005] test the hypothesis by looking at how home ownership profiles across MSAs change as the volatility of their rents change. Amior and Halket [2011] shows that across-city differences in price volatilities are closely correlated to across-city differences in price levels, which can lead to bias in the reduced-from approach in Sinai and Souleles [2005]. Using a partial-equilibrium model, Amior and Halket [2011] finds that higher risk leads to more precautionary savings and thus lower LTV ratios at origination and, if anything, lower home ownership rates.

In this section, we test the hedging hypothesis in a general equilibrium setting. Changes in rental prices in the model are driven by changes in regional productivity. We present three counterfactuals. In all three we use the baseline economy specification, including the relative island productivities. The only thing that will change is the probabilities that islands change productivity and, possibly, prices. In the first - labeled PE in figure 11 and table 6 - we take the baseline economy's prices and rents and change only $\sigma_j = 0$. So islands with the highest productivity in the PE counterfactual have the same rents and prices as in the baseline case.

In the second counterfactual - labeled PRE - we take the same specification but now allow rents to change so that landlords make zero profits given prices and $\sigma_j = 0$. However, the housing markets are still not in equilibrium: demand does not equal supply. In the third counterfactual - labeled GE - all prices can change.

Counterfactual	Ownership	LTV	$p(1)$	$p(5)$	$q(1)$	$q(5)$
Base	63.4%	54.1%	1.00	1.27	0.077	0.127
$\sigma_e = 0$ (PE)	64.8%	54.3%	1.00	1.27	0.077	0.127
$\sigma_e = 0$ (PRE)	60.6%	50.3%	1.00	1.27	0.086	0.109
$\sigma_e = 0$ (GE)	64.5%	57.4%	0.85	1.43	0.073	0.122

Table 6: Selected effects from changes in risk

$p(1)$ and $p(5)$ refer to the price of housing on islands 1 (the lowest productivity) and 5 (the highest), respectively. $q(1)$ and $q(5)$ refer to the rental price of housing on islands 1 (the lowest productivity) and 5 (the highest), respectively.

Reducing risk with no changes in prices or rents leads to higher home ownership and slightly higher LTVs, consistent with the findings of Amior and Halket [2011] and counter to the hypothesis that ownership is a peculiar source of insurance. However, given prices, rents are now misaligned: rent-to-price ratios are now too low on low productivity islands. With $\sigma_j = 0$, there are no capital gains on any island, so price-to-rent ratios should be equal across islands. In PRE, only rents adjust to equalize the price-to-rent ratios. In GE, both rents and prices can adjust.

When housing risk drops, housing demand rises, particularly on the higher productivity islands where the risk is that prices fall when productivity falls. More households live on the high productivity islands when there is less risk and buy bigger houses there as well. When only the rents adjust (in PRE), rents fall on the higher islands and the higher demand for housing on the high islands manifests itself primarily in the rental markets. When all prices are allowed to adjust, however, home ownership rates and LTVs climb above the baseline economy's.

Less risk leads to more home ownership and endogenously lower down payments when households do buy. When housing is risky, as it is in the baseline economy but not in these counterfactuals, many households that purchase a house opt to save more than just the minimally required down payment. The extra wealth held is extra precautionary savings. Households want to hold some precautionary savings against changes in their earnings. If they hold this savings in home equity, their precautionary savings is positively correlated with their earnings and therefore a less effective form of insurance. In other words, households have to hold more wealth to achieve the same amount of insurance when they hold that wealth in home equity. Reducing risk in the housing market thus makes owning more attractive to households and manifests itself in lower down payments (higher LTVs) and high ownership rates.

6 Conclusion

The illiquidity and immobility of housing and the inability to borrow against future income are at least as important as housing affordability in determining the ownership choice of young households. Illiquidity and immobility make it expensive for households to move, particularly into and out of owner-occupied housing. Factors that affect expected mobility and propensities to save play a large role in determining ownership choices. Family size and career concerns, which are important determinants of expected mobility and savings, significantly affect the ownership choice of the household.

We construct a general equilibrium, over-lapping generations, incomplete markets (Bewley) model. Our model incorporates risky assets (housing) in a general equilibrium where the households know the exact law of motion for prices. We use the model to measure the relative importance of career concerns, family size change and down payment constraints in determining the home ownership rate over the life cycle.

We find that small portions of the population are down payment constrained and that more households would like to use their house as a "piggy-bank." Households do not use owning as a hedge but instead frequently wait until uncertainties over family composition and earnings prospects are lower before buying due to high transaction costs.

Our model abstracts from many potentially interesting features in the mortgage market. In particular, households can not choose to default and the gross interest rate on mortgages is also the risk-free rate that households can save at. Our guess is that if everything is publicly observable, allowing for default and pricing that probability into the price of loans would reduce the role the mortgage market plays in explaining the home ownership profile. Instead of having to raise enough wealth to buy a home (as in our model), a household would have a second option: buy a home with little wealth but pay a higher interest rate. Changes in the amount of wealth necessary to obtain a low-priced loan would thus have smaller effects on ownership decisions: the home ownership profile would be flatter, *certeris paribus*. If our guess is correct, our results - which find relatively small effects from changes in down payment constraints - are biased in favor of finding larger effects. We leave it to current and future work to examine whether changes to, for instance, the assumptions concerning information may make the interaction between down payments and default more important to home ownership rates.

Given the importance of expected duration in explaining the life cycle pattern of ownership, interesting further investigations should include endogenous family sizes (along the lines of Fisher and Gervais [2011]), a search model over job markets, and a deeper investigation into the choices of older households and the role of housing in bequests of the elderly and the role of bequests in housing purchases of the young.

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A Definition of Equilibrium

A.1 Mixed allocations and the distribution of households

Definition. The state space $S = \mathscr{A} \times F \times \mathscr{I} \times \mathscr{J} \times \{0,1\} \times \mathscr{H} \times \mathscr{B} \times \{0,1\} \times \mathscr{E}$. A state can be written as $s = (a, f, i, j, \tau, h, b, I_d, \varepsilon) \in \mathscr{S}$. $\bar{j} : \mathscr{E} \to \mathscr{J}$ is the function that maps an island to its productivity. The vector of house prices is $(p)_J = (p_1, ...p_J)$. The vector of rents is $(q)_J =$

$(q_1, ...q_J)$. The price vector, $\overrightarrow{p} = ((p)_J, (q)_J, r, \omega) \in \mathscr{P} \subset \mathbb{R}^{2J+2}$. $\mathscr{Y} = \{0,1\} \times \mathscr{H} \times \mathscr{B} \times \mathscr{J} \times \mathscr{E} \times \mathscr{C}$ is the choice space. $y = (\tau', h', b', \tilde{j}, \varepsilon', c) \in \mathscr{Y}$ is a particular choice vector.

Since $\mathscr{Y} \in \mathbb{R}^n$, $(\mathscr{Y}, \mathrm{B}(\mathscr{Y}))$ is a measure space[29] where $\mathrm{B}(\mathscr{Y})$ is the standard Borel space on $\mathscr{Y}$. We can then define the probability space, and a mixed allocation as an element of the probability space.

Definition. Let $\tilde{\Lambda}$ be the set of probability measures on $\mathscr{Y}$, with elements $\lambda^y : \mathrm{B}(\mathscr{Y}) \to [0,1]$. Let Δ be the space of functions $f : \mathscr{S} \to \tilde{\Lambda}$.

Now we can define a mixed allocation as a state-contingent distribution over optimal choices.

Definition. A *mixed allocation*, $\alpha : \mathscr{S} \times \mathscr{P} \to \tilde{\Lambda}$ is map that specifies the probability distribution over the optimal choice set given by $Y(s, \overrightarrow{p})$.

$$\alpha(s, \overrightarrow{p}) \in \{\tilde{\alpha} \in \tilde{\Lambda} : supp(\tilde{\alpha}) \subseteq Y(s, \overrightarrow{p})\}$$

Let Λ be the space of mixed allocations. We will at times find it convenient to abuse notation by referring to the value of the c.d.f given by $\alpha(s, \overrightarrow{p})$ at a point $\tilde{y}$, $\lambda^y(\tilde{y})$, as $\alpha(s, \overrightarrow{p}, \tilde{y})$.

In this paper we consider only stationary competitive equilibria. Before we define the equilibrium we set out the notion of the distribution of households over the state space. Our stationary equilibrium requires that this distribution does not change over time.

Definition. The *household distribution over states*, $\mu : \mathrm{B}(\mathscr{S}) \to [0,1]$ is a probability measure on $\mathscr{S}$. Let $\mathscr{M}$ be the space of probability distributions on $\mathscr{S}$.

A.2 Stationary competitive equilibrium

Definition. A stationary competitive equilibrium is a vector of strictly positive prices, $\vec{p}^*$, a set of correspondences

$$Y^*(s; \overrightarrow{p}^*) = (H^*(s, \overrightarrow{p}^*), B^*(s, \overrightarrow{p}^*), \tau^*(s, \overrightarrow{p}^*), J^*(s, \overrightarrow{p}^*), \varepsilon^*(s, \overrightarrow{p}^*), C^*(s, \overrightarrow{p})),$$

a mixed allocation $\alpha^* \in \Lambda$, a probability measure μ^*, firm capital and labor holdings K^* and L^*, government expenditures G^*, and a $J^*(s; \overrightarrow{p}^*)$ such that:

(i) y^* solves the household's problem for each $y^* \in Y^*(s, \overrightarrow{p})$

[29] For a set $X \subseteq \mathbb{R}^n$, we assume that the standard Borel space is used in constructing measure and probability measure spaces. That is, the statement "μ is a probability measure on X" implies that $(X, \mathrm{B}(X), \mu)$ is a probability measure space.

(ii) K^* and L^* solve the firm's optimization problem:

$$r^* + \delta = (\frac{L^*}{K^*})^{1-\alpha}$$

$$w^* = (\frac{K^*}{L^*})^{\alpha}$$

(iii) Goods market clears:

$$(K^*)^{\alpha}(L^*)^{1-\alpha} = \delta K^* + G^* + \int_{\mathscr{S}} \int_{Y^*(s,\vec{p}^*)} (c^* + 1^*_m(\tau^* h^* p^*(j^*)\theta_h + p^*(j^*)h^*\delta_h) d\alpha^*(s, \overrightarrow{p}^*, y^*) d\mu^*$$

(iv) Capital market clears:

$$K^* = \int_{\mathscr{S}} \int_{Y^*(s,\overrightarrow{p}^*)} (b^* + ((1-t_y)q^*(j^*) - (1+t_p+\delta_h)p^*(j^*))(1-\tau^*)h^*) d\alpha^*(s, \overrightarrow{p}^*, y^*) d\mu^*$$

(v) Labor market clears:

$$L^* = \int_{\mathscr{S}} \int_{Y^*(s,\vec{p}^*)} l(a, f, i, j^*, 1^*_m) d\alpha^*(s, \overrightarrow{p}^*, y^*) d\mu^*(s)$$

(vi) Housing market clears:

$$\overline{H} = H(\varepsilon) = \int_{\mathscr{S}} \int_{Y^*(s,\vec{p}^*)} h^* \cdot 1\{\varepsilon^* = \varepsilon\} d\alpha^*(s, \overrightarrow{p}^*, y^*) d\mu^*(s) \qquad \forall \varepsilon \in [0,1]$$

(vii) Government budget constraint holds:

$$G^* = t_y w^* L^* + \int_{s\in\mathscr{S}} \int_{y^*\in Y^*(s,\vec{p}^*)} [h^* p^*(j^*) t_p - t_y(r^* b^* 1^*_{b^*<0} + \tau^* h^* q^*(j)) + \frac{1-\lambda(a-1)}{\lambda(a-1)}((1+r^*)b^* + \tau^* p^*(j^*)h^*)] d\alpha^*(s, \overrightarrow{p}^*, y^*) d\mu^*(s) - \mu_1 \int_{\mathscr{B}} b \, d\Pi_b \quad (1)$$

(viii) No arbitrage in the real estate sector:

$$(1-t_y)q^*(j) = (\delta_h + t_p + \frac{r^*}{1+r^*})p^*(j) - \frac{1}{1+r^*}E(p^*(j') - p^*(j)|j), \qquad \forall j \in J$$

(ix) Steady-state distribution:

$$\mu^* = \Upsilon_{p,\alpha}\mu^*$$

where $\Upsilon_{p,\alpha}$ is the transition function generated by the optimal choice correspondence of the household and the mixed allocation, α and $1^*_{b^*<0}$ is an indicator function which equals 1 if $b^*(s,y^*) < 0$.

Figures

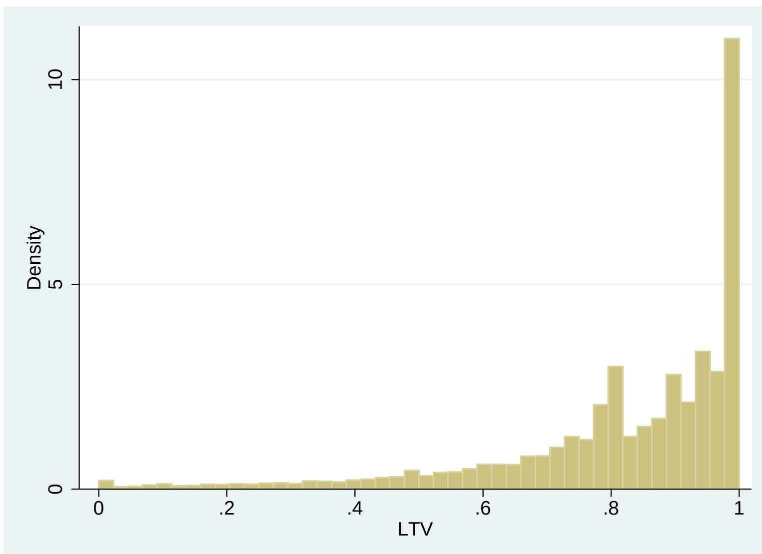

Figure 1: Household Loan-to-Value ratios

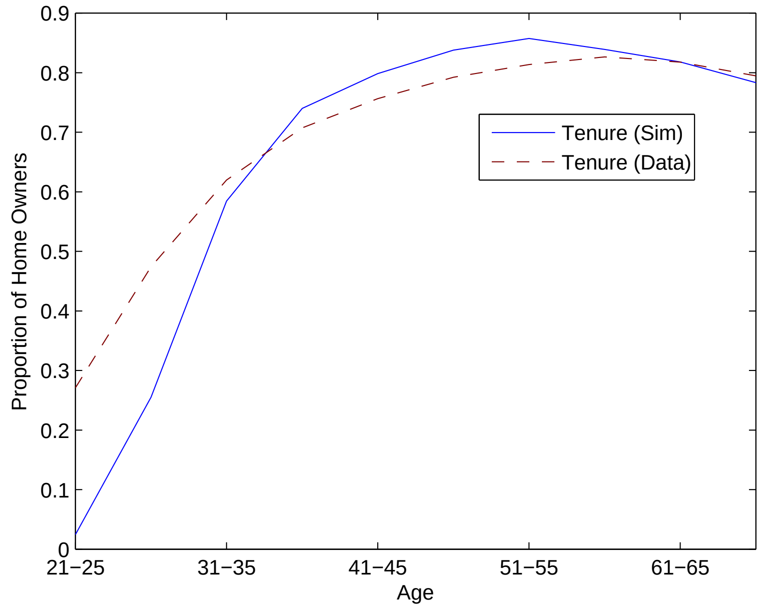

Figure 2: Home ownership: model and data

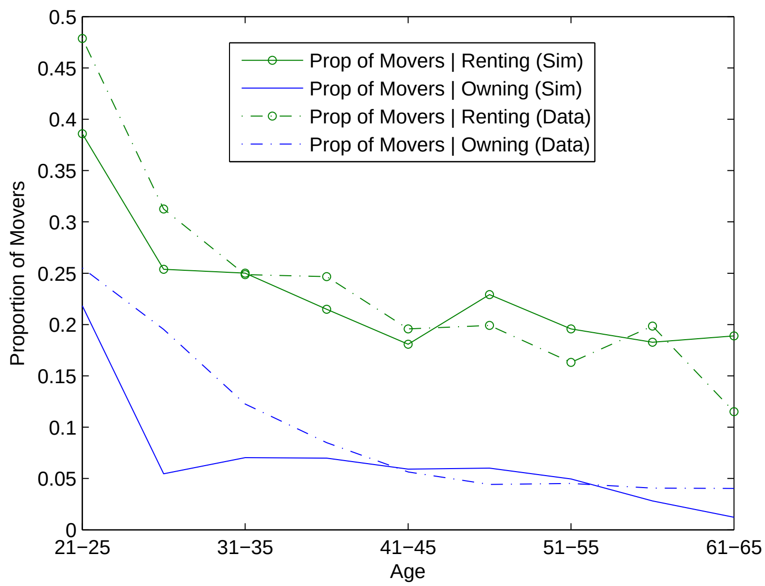

Figure 5: Household moving conditional on ownership choice: model and data

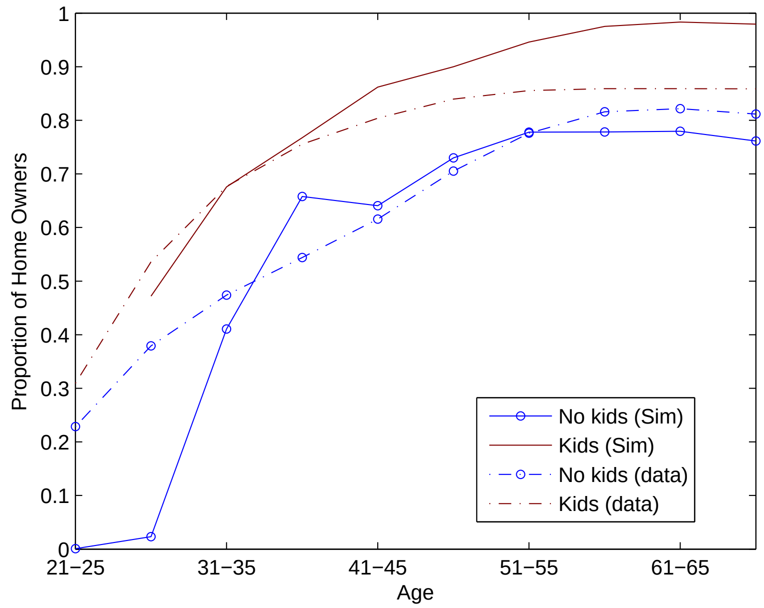

Figure 3: Home ownership by family size: model and data

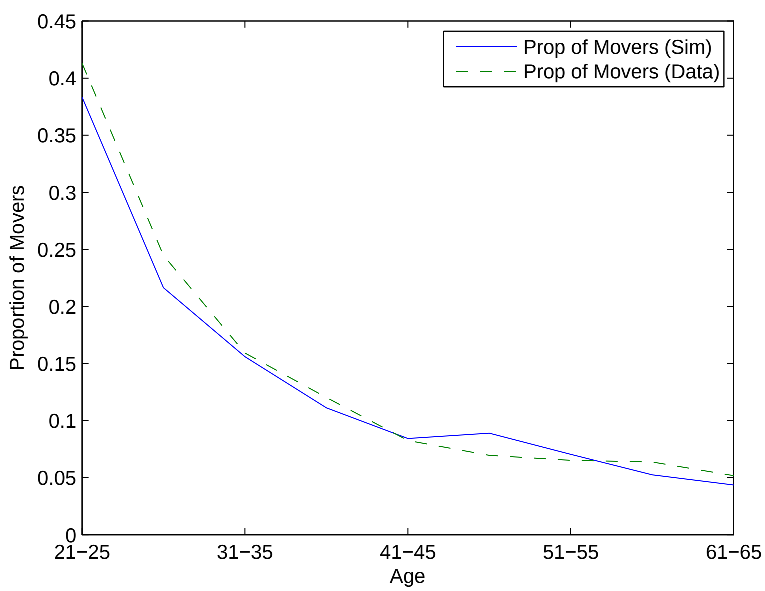

Figure 4: Household moving over the life cycle: model and data

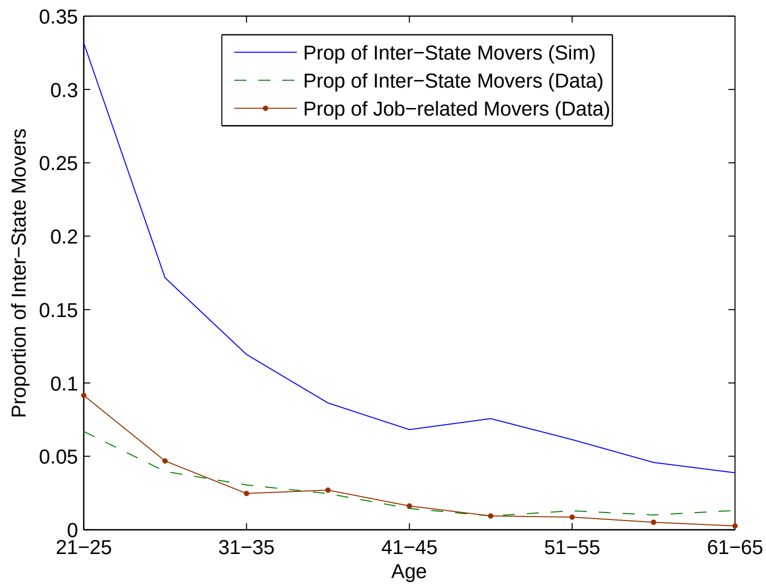

Figure 6: Inter-state moving over the life cycle: model and data

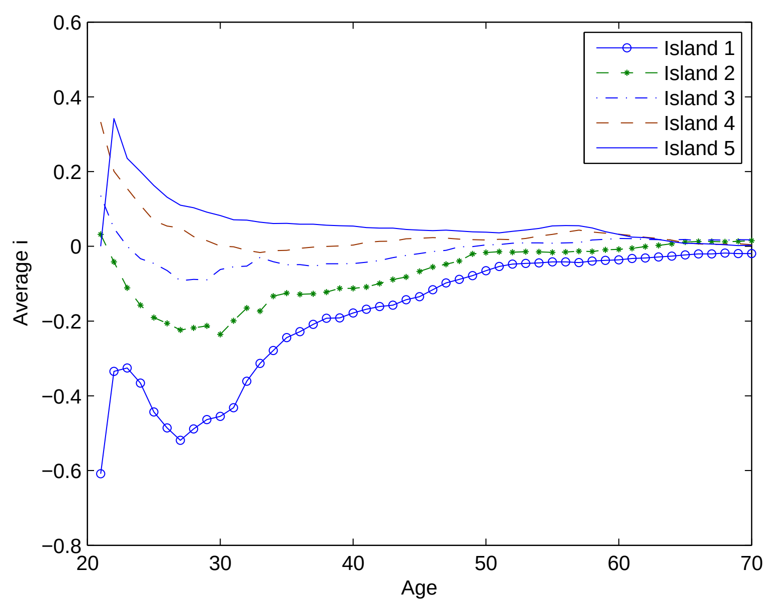

Figure 7: Sorting across locations

Scaled average idiosyncratic ability over the life cycle by island productivity in the model. Island 1 has the lowest productivity and Island 5 the highest. *Average i* is the average ability of households that choose to live on a given island, conditional on age. The units are in standard deviations of the cross-sectional distibution of ability for each age.

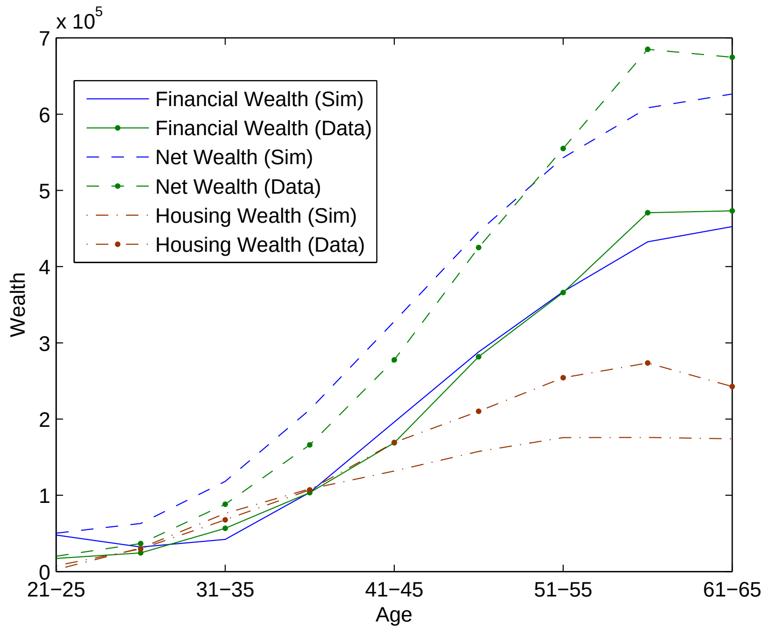

Figure 8: Wealth over the life cycle: model and data

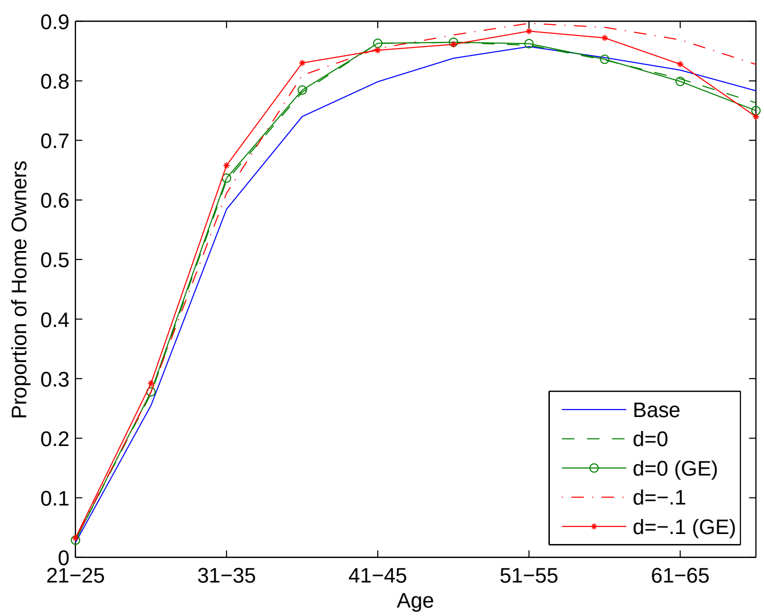

Figure 9: Home ownership: down payment counterfactuals

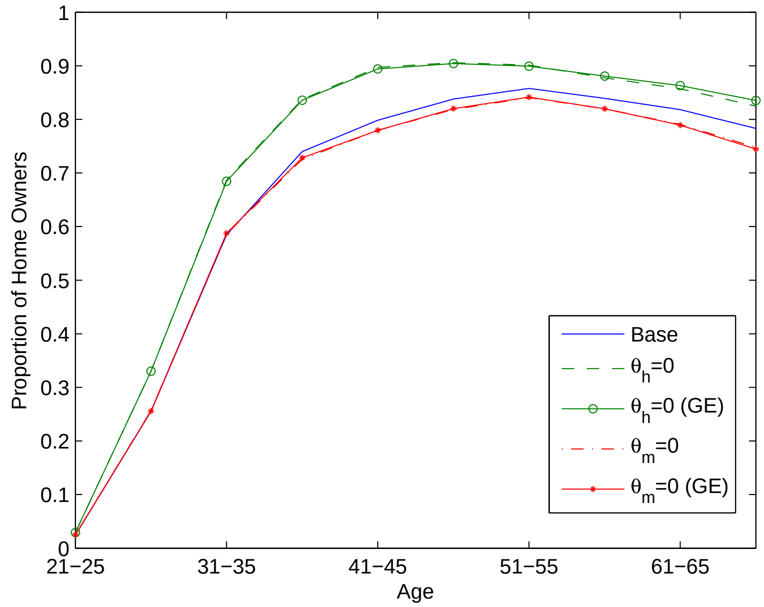

Figure 10: Home ownership: mobility counterfactuals

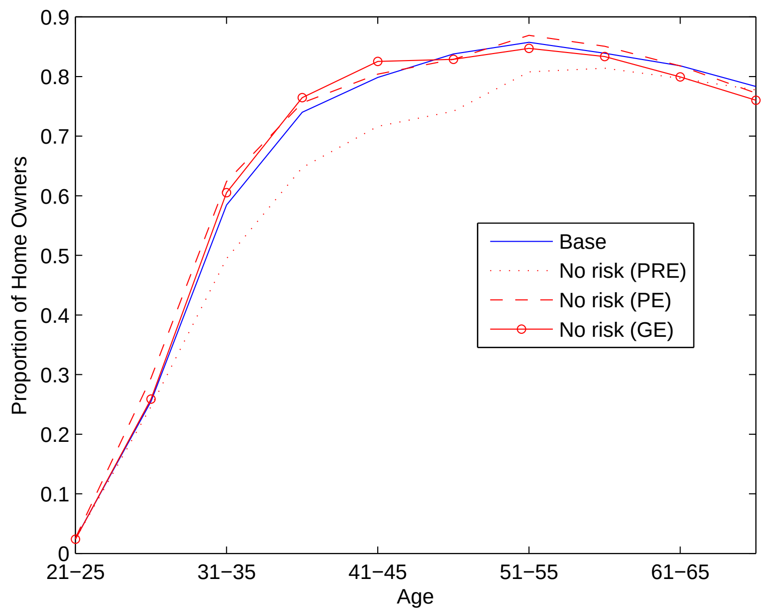

Figure 11: Hedging counterfactuals