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Saving up or settling down: Home ownership over the life cycle

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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 affect propensities to save and move, such as risky house values and transactions costs, are equally important determinants of the ownership rate.

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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.

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.

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 (Fig. 5), to move to a new U.S. state and to move for self-reported "job reasons" (Fig. 7). Similarly, young renters are more mobile than young owners (Fig. 6). Young households are also poorer, with lower wealth and income, on average, than middle-aged households (Fig. 9).

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We find that removing the down payment requirement for buying a house does not make home ownership that much more attractive. In fact, removing the transactions costs of home ownership has a larger affect on home ownership rates, particularly in general equilibrium. We find little evidence that home ownership is a special source of insurance for households.

Our contribution is on two fronts. Models of home ownership choices over the life cycle in general equilibrium (e.g. Gervais, 2002; Chambers et al., 2009a) study incomplete markets settings in the tradition of Aiyagari (1994) and Bewley (1984). We extend the literature by endogenously incorporating location choice, ownership and house price risk into a GE model of housing. 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.

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, 1998). Our economy, which follows from a simpler setting in Halket (2012), 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 at every location.

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,[2] there is little consensus on which determinants of the relative value of owning versus renting offered are quantitatively meaningful. 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, parametrized to match U.S. data from before the recent housing boom and bust, which can measure the relative importance of several prominent theories.

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 more likely to adjust along the intensive margin than the extensive margin, as in Ortalo-Magne and Rady (2006); about twice as many first-time home buyers in the model would buy larger houses rather than buy earlier in their life cycle if down payment requirements were relaxed. Therefore, lower down payment requirements lead to only small changes in the home ownership rate; consistent with the findings in Chambers et al. (2009b).

Moreover households in the model 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[3] positive 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 larger effects on home ownership patterns. 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. When the relative transaction costs of moving into rental and owner-occupied housing are equalized (in the base economy, owner-occupied housing is much more costly), housing consumption and prices go up. Home ownership also increases by 25 percent more than the increase that occurs with no down payment. 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 primarily 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. 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, similar to the findings for income-linked assets in Fuster and Willen (2011).

[2] 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).

[3] "Limited" in part due to the transaction costs of moving and in part due to wealth effects.

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 (2012) that cities with lower price and rent volatilities have higher home ownership rates and higher loan-to-value ratios at origination. Housing risk, which affects precautionary savings and mobility propensities, primarily changes younger households' behaviors. So higher risk in the model economy steepens its home ownership profile while lowering the overall home ownership rate. Reduced-form tests, such as the one in Sinai and Souleles (2005), that implicitly rely on the interaction between risk and the gradient of the home ownership profile could thus misleadingly find evidence in favor of home ownership as insurance against rent volatility.

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. We quote Linneman et al. (1997), Haurin et al. (1996) and Zorn (1989) as representative of the large literature on credit constraints and its impact on ownership choice. Clark and Onaka (1993) and Quigley and Weinberg (1977) find that changes in family size significantly affect housing consumption and the ownership choice of households. Cameron and Tracy (1997) emphasize 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 partially 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. Nordvik (2001) and Sinai and Souleles (2005) explore how changes in a household's expected duration may affect its willingness to hedge against changes in rental prices by owning. Ortalo-Magne and Rady (2006) and Banks et al. (2010) 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).

With recent advances in computing, many dynamic OLG models incorporate housing. The issues addressed range from the ownership choice decision (Chambers et al., 2009a and Diaz and Luengo-Prado, 2008), the evolution of consumer debt, 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. (2009a), 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 the formal definition of the competitive equilibrium. 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 down payment constraints, transactions costs and risk in determining the ownership rate. Section 6 concludes. An online appendix containing further details on calibration and computation is available 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 in the economy.

Time is discrete and each period 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, $\lambda(a)$, which is a function of the age of the head, a. 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, which will be the numeraire, and a durable housing good. The housing good is island specific and in fixed and equal supply on each island, $\bar{H}$. Housing is "putty" within an island though so that households are free to choose housing from a convex subset of $\mathbb{R}_+$.

The consumption good is produced by risk neutral, perfectly competitive firms with access to an island-specific Cobb–Douglas production function so that a firm using labor $\tilde{l}$ and capital $\tilde{k}$ produces $(j\tilde{l})^{1-\alpha}\tilde{k}^{\alpha}$. Each island has a productivity, j, which follows a finite state Markov chain with state space $j \in \{1, \dots, J\}$ and transition probabilities given by the matrix $\pi_J(j'|j)$ and unique invariant measure Π_J. Capital depreciates at rate δ. Consumption goods and capital may be traded across islands frictionlessly so that the rental rate of capital is independent of location while households will receive an island productivity-dependent wage rate $w(j)$ per unit of labor supplied. 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.

2.2. Preferences

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[4]

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

The path for the family size adjustment factor,[5] $S : \mathrm{F} \to \mathbb{R}_{++}$, is a function of the household's family size in that period, $f \in \mathrm{F}$. A household's family size follows a 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.[6]

2.3. Labor productivity

Each household has an ability, indexed by i, which follows a Markov chain with state space $i \subset [-I, I]$ 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 earnings in any period depends on: its effective labor supply, $l(a, f, i)$, which is a function of its household's age, family size, and ability; the productivity of the island on which it chooses to work and whether it chooses to move:

$$l(a, f, i)w(j)(1 - \theta_m 1_m)$$

where 1_m is a dummy variable for whether it chooses to move.

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 subject to a collateral constraint. There is a proportional income tax rate t_y levied on a household's total net labor and interest earnings.

2.5. Housing

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 when buying (selling) a house is a proportion θ_b (θ_s) of the purchased (sold) house value.

[4] Piazzesi et al. (2007) find 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) find that the expenditure share on housing is constant across time and U.S. Metropolitan Statistical Areas, consistent with the Cobb–Douglas specification.

[5] 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).

[6] We could also allow for some loss of wealth in the case of divorce. This would not change the results materially. We abstract from other potential features of divorce like splitting a household into two.

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. If rented, a household pays $q(j)$ per unit of housing h and can buy and sell housing from a real estate agency at unit price $p(j)$ on an island of productivity j. We discuss below why there exists an equilibrium where prices only depend on island productivity.

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 $\tilde{t}_p$ on the value of the house. However they may deduct payments from their income taxes, so that the net effective rate is $t_p = \tilde{t}_p(1 - t_y)$.

A household cannot rent housing that it owns but does not use[7] 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.[8] 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.[9] Thereafter, as long as they continue to be home owners, households may borrow up to $(1 - d(a))$ 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:

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

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 ($b' \geqslant -(1 - d)\tau' p(j)h'$). 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) in such a setting 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 et al., 2011 and others cited below for models with mortgage default), but households can default implicitly by dying or becoming divorced with negative net worth.[10]

Without some wedge between the user cost (the after-tax costs maintenance, property tax and opportunity cost of funds plus any expected capital gains) of owner-occupation and renting, households in the model will not own. We assume that differences in the tax treatment of owner-occupied versus rental housing create such a wedge. Formally, households can deduct their mortgage interest payments while real estate firms pay income tax on any rental earnings (as in Gervais, 2002), maintenance, interest and property taxes, and potentially earn capital gains/losses from housing.[11] The zero-profit condition for the real estate industry is:

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

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

2.6. Birth and death and the government's budget constraint

Households are born with no housing and therefore their initial location is unimportant (since they will pay the moving costs regardless). They draw their initial family size and wealth from densities Π_F and Π_b, respectively. The government collects taxes and any accidental bequests by dead households, after making whole the financial sector on any outstanding

[7] See Chambers et al. (2008) for a model with household landlords.

[8] We also call this a mortgage throughout.

[9] Age dependency will only serve to prevent older households from taking out new loans, thereby ruling out any outlandish borrowing behavior right before death.

[10] The household has negative net worth if $b \leqslant -\tau p(j)h(1 - \theta_s)$. 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.

[11] We assume that landlords can deduct (or carry forward) capital losses. The tax treatment here is a crude approximation of the relevant part of the U.S. tax code. In reality, various wedges could come from a variety of sources depending on whether the landlord/real estate firm was taxed at personal or corporate rates, the extent to which he/she/it could borrow against the rental property, the eccentricities of depreciation allowances, and whether the owner carried out the repairs herself. An alternative is to assume no tax wedge but rather that rentals have a higher maintenance. Given our calibration below, we could obtain exactly the same rental prices if we assumed rentals had about double the maintenance costs, well within the simulated method of moments estimates of Chambers et al. (2008, 2009a, 2009b).

loans to dead households. Newborn households receive their initial wealth from the government.[12] The remainder 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 down payment 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.

2.7. Household's problem

Each period, households choose which island to live on, ε', among other choices. In order to make such a choice, they must know the mapping of islands to their productivities, which is stochastic. Formally, let $\mathrm{J} = \{1, \ldots, J\}$, $\mathscr{E} = [0, 1]$ be the sets of island productivities and island names, respectively. Let Ψ_J be the set of functions $\mu_J : \mathrm{J} \times \mathscr{E} \to \{0, 1\}$ such that (i) $\mu_J(j, \varepsilon) = 1$ if and only if $\mu_J(\tilde{j}, \varepsilon) = 0$ for $j \neq \tilde{j}$ and (ii) $\int \mu_J(j, \varepsilon)\, d\varepsilon = \Pi_J(j)$. In state μ_J, island ε has productivity j if $\mu_J(j, \varepsilon) = 1$.

The household's problem can be split up into three parts: a mover's problem, a stayer's problem and the household's problem where it chooses whether to stay or move to a different location.

2.7.1. 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, location and distribution of location productivities, subject to budget and borrowing:

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

s.t.

$$c + b' + h'\big((1-\tau')q(\tilde{j}) + \tau' p(\tilde{j})(\delta_h + t_p + 1 + \theta_b)\big) \leqslant b^m + w(\tilde{j})(1-\theta_m)l(a, f, i)(1-t_y)$$

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

2.7.2. 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, location and location productivities, subject to budget and borrowing constraints:

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

s.t.

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

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

2.7.3. The household's problem

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: I_d, an indicator for a divorce shock):

$$\begin{aligned} V(a, f, i, j, \tau, h, b, \varepsilon, \mu_J) = {} & (1-I_d)\max\Big\{V^s(a, f, i, j, \tau, h, b, \varepsilon, \mu_J), \max_{\tilde{j}, \varepsilon'} V^m\big(a, f, i, \tilde{j}, b^m, \varepsilon', \mu_J\big)\Big\} \\ & + I_d \max_{\tilde{j}, \varepsilon'} V^m\big(1, i, \tilde{j}, b^m, \varepsilon', \mu_J\big) \end{aligned}$$

s.t.

$$b^m = I_d \max\big\{0, (1+\tilde{r})b + p(j)h\tau(1-\theta_s)\big\} + (1-I_d)\big((1+\tilde{r})b + p(j)h\tau(1-\theta_s)\big)$$

$$\mu_J\big(\tilde{j}, \varepsilon'\big) = 1$$

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. The constraint $\mu_J(\tilde{j}, \varepsilon') = 1$ simply ensures that the household's choice over islands, ε', is consistent with its choice of island productivities, $\tilde{j}$; i.e. that island ε' currently has productivity $\tilde{j}$.

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[12] 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.

This is the only part of the household's decision problem where ε and μ_J meaningfully appear. It is easy then to see that moving households will be indifferent over islands conditional on their productivity. The following lemma formalizes this.

Definition. Let $\mathrm{A} = \{A, A+1, \dots, T\}$, $\mathrm{C} \subset \mathbb{R}_+$, $\mathrm{H} \subset \mathbb{R}_+$, $\mathrm{B} \subset \mathbb{R}$, $\mathrm{I} = [-I, I]$ be the sets of consumption, housing, financial assets and abilities, respectively. Let $\mathrm{S} = \mathrm{A} \times \mathrm{F} \times \mathrm{I} \times \mathrm{J} \times \{0,1\} \times \mathrm{H} \times \mathrm{B} \times \{0,1\}$ with elements $s = (a, f, i, j, \tau, h, b, I_d) \in \mathrm{S}$. The state space $\tilde{\mathrm{S}} = \mathrm{S} \times \mathscr{E} \times \Psi_J$. The optimal choice correspondence is $\tilde{\mathrm{Y}} : \tilde{\mathrm{S}} \rightrightarrows \mathrm{C} \times \mathrm{H} \times \mathrm{J} \times \mathrm{B} \times \{0,1\} \times \mathscr{E}$.

Lemma 1. *For $\forall \tilde{s} = (a, f, i, j, \tau, h, b, I_d, \varepsilon, \mu_J) \in \tilde{\mathrm{S}}$, let $\tilde{y}(\tilde{s}) = (\tilde{c}, \tilde{h}, \tilde{j}, \tilde{b}, \tilde{\tau}, \tilde{\varepsilon}) \in \tilde{\mathrm{Y}}(\tilde{s})$, a solution to the household's problem at $\tilde{s}$.*

(i) *If $\tilde{h} \neq h$, $\tilde{\tau} \neq \tau$ or $\tilde{\varepsilon} \neq \varepsilon$ then*

$$\hat{y}(\tilde{s}) = (\tilde{c}, \tilde{h}, \tilde{j}, \tilde{b}, \tilde{\tau}, \hat{\varepsilon}) \in \tilde{\mathrm{Y}}(\tilde{s}) \quad \forall \hat{\varepsilon}\colon\ \mu_J(\tilde{j}, \hat{\varepsilon}) = 1$$

(ii) *If $\tilde{h} = h$, $\tilde{\tau} = \tau$ and $\tilde{j} = j$, then*

$$\hat{y}(\tilde{s}) = (\tilde{c}, \tilde{h}, \tilde{j}, \tilde{b}, \tilde{\tau}, \hat{\varepsilon}) \notin \tilde{\mathrm{Y}}(\tilde{s}) \quad \forall \hat{\varepsilon} \neq \varepsilon$$

Proof. (i) follows from the fact that, conditional on moving, $\tilde{\varepsilon}$ appears only in the $\mu_J(\tilde{j}, \tilde{\varepsilon}) = 1$ constraint. (ii) follows from the fact that the household will not pay the strictly positive moving cost to live in the same size and tenure house, on an island of the same quality as where it already lives. $\square$

2.8. Stationary competitive equilibrium

Our model has two features that necessitate a slightly more complicated equilibrium definition from the one in Aiyagari (1994) in order to guarantee existence. For one, the model has both discrete and continuous choice variables, so aggregates (e.g. the aggregate supply of capital through savings) are potentially multi-valued correspondences and may therefore be discontinuous – a point discussed at length in Chatterjee et al. (2007). Secondly, there are a continuum of housing markets with stochastic prices. Even in steady state then, there are a continuum of market clearing conditions, each with state-dependent island-aggregate demand functions.

The equilibrium definition is an adaption of Halket (2012) and involves a selection of state-contingent choices in areas of indifference using mixed allocations (defined below) which serve as tie-breaking criteria. Since our economy is populated by a continuum of households and islands, there is no aggregate uncertainty using a mixed allocation.

Definition. Let Ψ be the set of probability measures on $\mathrm{C} \times \mathrm{H} \times \mathrm{J} \times \mathrm{B} \times \{0,1\}$, with elements $\psi : \mathscr{B}(\mathrm{C} \times \mathrm{H} \times \mathrm{J} \times \mathrm{B} \times \{0,1\}) \to [0,1]$. Likewise let $\tilde{\Psi}$ be the set of probability measures on $\mathrm{C} \times \mathrm{H} \times \mathrm{J} \times \mathrm{B} \times \{0,1\} \times \mathscr{E}$, with elements $\tilde{\psi} : \mathscr{B}(\mathrm{C} \times \mathrm{H} \times \mathrm{J} \times \mathrm{B} \times \{0,1\} \times \mathscr{E}) \to [0,1]$.

A *mixed allocation*, $\tilde{\alpha} : \tilde{\mathrm{S}} \to \tilde{\Psi}$ is measurable map that specifies the probability distribution over a choice set given by $\tilde{\mathrm{Y}}(\tilde{s})$.

$$\tilde{\alpha}(\tilde{s}) \in \left\{ \tilde{\psi} \in \tilde{\Psi}\colon\ supp(\tilde{\psi}) \subseteq \tilde{\mathrm{Y}}(s) \right\}$$

Let $\tilde{\Lambda}$ be the space of mixed allocations generated by $\tilde{\mathrm{Y}}$. Likewise let Λ be the space of measurable functions $\alpha : \mathrm{S} \to \Psi$ such that $\alpha(s) \in \{\psi \in \Psi\colon\ supp(\psi) \subseteq \mathrm{Y}(s)\}$. Let $\mathscr{M}$ be the space of probability distributions on S. Let $\tilde{\mathscr{M}}$ be the space of probability distributions $\tilde{\mu} : \mathscr{B}(\mathrm{S} \times \mathscr{E}) \to [0,1]$ such that (i) $\tilde{\mu}(a, f, i, j, \tau, h, b, I_d, \varepsilon) > 0$ implies $\tilde{\mu}(\tilde{s}) = 0$ for any $\tilde{s} = (\cdot, \cdot, \cdot, \tilde{j} \neq j, \cdot, \cdot, \cdot, \cdot, \varepsilon)$ and (ii) $\Pi_J(j) = \int_\varepsilon 1\{\varepsilon\colon\ \tilde{\mu}(\cdot, \cdot, \cdot, j, \cdot, \cdot, \cdot, \cdot, \varepsilon) > 0\}\, d\varepsilon$.

For any optimal choice correspondence $\tilde{\mathrm{Y}}$, define $\mathrm{Y} = \{(\tilde{c}, \tilde{h}, \tilde{j}, \tilde{b}, \tilde{\tau})\colon\ \exists \tilde{\varepsilon} \ni (\tilde{c}, \tilde{h}, \tilde{j}, \tilde{b}, \tilde{\tau}, \tilde{\varepsilon}) \in \tilde{\mathrm{Y}}\}$. Every $\tilde{\mathrm{Y}}$ *implies* a unique Y. Note also that any $\tilde{\mu} \in \tilde{\mathscr{M}}$ implies a particular μ_J.

2.8.1. Stationary competitive equilibrium definition

Definition. A *stationary competitive equilibrium* is a vector of prices, $((p^*)_J, (q^*)_J, (w^*)_J, r^*)$, an optimal choice correspondence $\tilde{\mathrm{Y}}^*$ with implied Y^*, an $\alpha^* \in \Lambda$ and a probability measure $\mu^* \in \mathscr{M}$, a set of capital and labor supplies $\{K_j^*\}_{j=1}^J$ and $\{L_j^*\}_{j=1}^J$ and government expenditures G^* such that:

(i) $\tilde{y}^* = (c^*, h^*, j^*, b^*, \tau^*, \varepsilon^*)$ solves the household's problem for each $\tilde{y}^* \in \tilde{\mathrm{Y}}^*$

(ii) K_j^* and L_j^* solve the firm's optimization problem for each j:

$$r^* + \delta = \alpha \left(\frac{jL_j^*}{K_j^*} \right)^{1-\alpha}$$

$$w_j^* = (1-\alpha) j^{1-\alpha} \left(\frac{K^*}{L^*} \right)^{\alpha}$$

(iii) Goods market clears:

$$\sum_{j=1}^{J} K_j^{*\alpha}\big(jL_j^*\big)^{1-\alpha} = \delta\sum_{j=1}^{J} K_j^* + G^* + \int_{\mathrm{S}}\int_{\mathrm{Y}^*(s)} \big(c^*(s) + 1_m^*(s)\big(\tau^*(s)h^*(s)p^*\big(j^*(s)\big)\big)\theta_b + \tau hp^*(j)\theta_s + p^*\big(j^*(s)\big)h^*(s)\delta_h\big)\,d\alpha^*(s)\,d\mu^*$$

(iv) Capital market clears:

$$\sum_{j=1}^{J} K_j^* = \int_{\mathrm{S}}\int_{\mathrm{Y}^*(s)} \big(b^*(s) + \big((1-t_y)q^*\big(j^*(s)\big) - (1+t_p+\delta_h)p^*\big(j^*(s)\big)\big)\big(1-\tau^*(s)\big)h^*(s)\big)\,d\alpha^*(s)\,d\mu^*$$

(v) Labor market clears for each j':

$$L_{j'}^* = \int_{\mathrm{S}}\int_{\mathrm{Y}^*(s)} 1\big\{j^*(s) = j'\big\}\big(1 - 1_m^*(s)\big)l\big(a, f, i, j^*(s)\big)\,d\alpha^*(s)\,d\mu^*$$

(vi) For each j', total housing demand equals total housing supply:

$$\Pi_J\big(j'\big)\overline{H} = \int_{\mathrm{S}}\int_{\mathrm{Y}^*(s)} h^*(s)\cdot 1\big\{j^*(s) = j'\big\}\,d\alpha^*(s)\,d\mu^* \quad \forall j' \in \mathrm{J}$$

(vii) Government budget constraint holds:

$$G^* = t_y\sum_{j=1}^{J} w_j^* L_j^* + \int_{\mathrm{S}}\int_{\mathrm{Y}^*(s)} \Big[h^*(s)p^*\big(j^*(s)\big)t_p - t_y\big(r^*b^*(s) + \tau^*(s)h^*(s)q^*(j)\big) + \frac{1-\lambda(a-1)}{\lambda(a-1)}\big(\big(1+r^*\big)b^*(s) + \tau^*(s)p^*\big(j^*(s)\big)h^*\big)\Big]\,d\alpha^*(s)\,d\mu^* - \mu_1\int_{\mathrm{B}} b\,d\Pi_b$$

(viii) Zero profits in the real estate sector:

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

(ix) Steady-state distribution:

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

where Υ_{α^*} is the transition function generated by Y^*, α^* and the exogenous stochastic processes; 1_m is the moving indicator and $1\{a = b\}$ is an indicator function which equals 1 if $a = b$.

The definition of a stationary competitive equilibrium does not explicitly ensure that all housing markets clear. Instead it only requires that, at equilibrium prices, the total housing demand by households living on islands with productivity j equals the total housing supply on all such islands (Condition (vi)). The following lemma guarantees that, given Conditions (i) through (ix), we can always ensure each island's housing market clears at the same equilibrium prices:

Lemma 2. *Let* $\{((p^*)_J, (q^*)_J, (w^*)_J, r^*), \tilde{\mathrm{Y}}^*, \mathrm{Y}^*, \alpha^*, \mu^*, \{K_j^*\}_{j=1}^J, \{L_j^*\}_{j=1}^J, G^*\}$ *be a stationary competitive equilibrium. Then for any* $\tilde{\mu} \in \tilde{\mathscr{M}}$ *such that*

$$\mu^*(s) = \int_{\varepsilon\in\mathscr{E}} \mu_J(j,\varepsilon)\tilde{\mu}(s,\varepsilon)\,d\varepsilon$$

where μ_J *is implied by* $\tilde{\mu}$, *there exists an* $\tilde{\alpha} \in \tilde{\Lambda}$ *generated by* $\tilde{\mathrm{Y}}^*$ *such that*

(i) $\alpha^*(s) = \int_{\varepsilon\in\mathscr{E}}\int_{\tilde{s}\in\tilde{\mathrm{S}}} 1\{(a, f, i, j, \tau, h, b, I_d) = s\}\,d\tilde{\alpha}(\tilde{s})\,d\varepsilon$
(ii) *All housing markets always clear*:

$$\overline{H} = \int_{\tilde{\mathrm{S}}}\int_{\tilde{\mathrm{Y}}^*(\tilde{s})} h^*(\tilde{s})\cdot 1\big\{\varepsilon^*(\tilde{s}) = \varepsilon'\big\}\,d\tilde{\alpha}(\tilde{s})\,d\tilde{\mu} \quad \forall\varepsilon' \in \mathscr{E}$$

The mixed allocation $\tilde{\alpha}$ needed for equilibrium is history dependent – it depends on $\tilde{\mu}$. In this sense, there is no "steady state." But for all the objects of interest in the model, including the equilibrium prices of housing, we never need to compute the mixed allocations.

If Y is single-valued, then Conditions (i) through (ix) would resemble typical conditions for Bewley-style stationary competitive equilibria. As in other Bewley-style economies, a particular household moves stochastically around the "state space" S, but the measure of households at any point in S is constant. So in a "steady state," statistics such as the total housing demand on islands with productivity j, $H^d(j)$, are constant. Indeed in our computational solution Y is single-valued, so mixed allocations play no role in our numerical results below.

A formal proof for existence of the equilibrium and Lemma 2 follows from Halket (2012) and is omitted here[13] but the intuition is:

- From Lemma 1, households that move are indifferent between islands of the same productivity: prices are the same on these islands and the transactions costs of moving are the same (in particular, they are not lower for households that move to a new house but remain on the same island). This is true even for large moving costs. Only households that do not move care about which island they choose (in a trivial way since they are remaining on their island).
- Condition (vi) means that the total housing demand over all islands of productivity j, $H^d(j)$, is constant.
- Crucially, since households that prefer to stay in their current house are not changing the size of their house, the total demand for housing from the non-movers on any island cannot be larger than the total amount of housing on the island. All that remains then is for the "auctioneer" to use the appropriate mixed allocation to allocate the indifferent movers to ensure that housing markets on individual islands clear. We know there is just enough demand and supply to do this since $H^d(j) = \Pi_j(j)\bar{H}$. So such an allocation always exists.

Further intuition can be gained from discussing a variation of the model where existence is not guaranteed. Suppose that households could frictionlessly move to a new house within their own island and only paid moving and transaction costs if they moved to a new island. In this case, house prices need not be the same on islands with identical productivities. For instance, prices could be higher on islands with wealthy incumbent residents. These households may strictly prefer housing on their own island even though the price is higher because there are no transaction or moving costs. In contrast, in our model incumbent households are indifferent between moving within their current island and moving to a new island of the same productivity if and only if non-incumbent moving households are also indifferent between the two islands.

3. Calibration

The online appendix contains the full details on our calibration. Here we discuss just some of the parametrization.

3.1. Family size

We use the Panel Study for Income Dynamics (PSID) to estimate the transition matrices for family size. Fig. 2 (left panel) shows the profiles of family size from the larger Current Population Survey (CPS) for 1970–1993. In order to adjust the household's housing and consumption stream we use a household equivalence scale $S()$. The objective of an equivalence scale is to measure the change in consumption needed to keep the welfare of the family constant as the family size varies. Using per capita consumption assumes that the family converts consumption expenditure into utility flow following constant returns to scale. Lazear and Michael (1980) point to the existence of family goods, economies of scale and complementarities, which are all factors that they show to be significant. We therefore use a household equivalence scale from Fernandez-Villaverde and Krueger (2007) that is not constant returns to scale. See Fig. 2 for the profile and the online appendix for more details.

3.2. Housing

Some papers stress the importance of moral hazard in renter-occupied housing, e.g. Campbell and Cocco (2007) and Henderson and Ioannides (1983). Chambers et al. (2009a) find 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 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 National Income and Product Accounts (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 do not suggest that our assumption of equal maintenance rates is unrealistic.

[13] Following Halket (2012), existence is easy to show. Within the class of equilibria for which house prices are only functions of their island's productivity, the equilibrium also seems to be "computationally" unique. There may be additional equilibria where house prices depend on more than just their island's productivity.

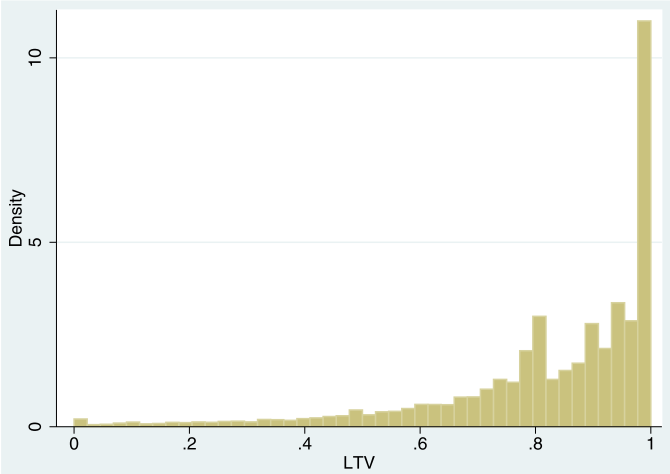

Fig. 1. Household loan-to-value ratios.

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, $\bar{H}$. Martin (2003) finds that the average monetary cost involved in a housing transaction is 7–11 percent, most of which are paid by the seller. We conservatively set $\theta_b = 0.02$ and $\theta_s = 0.06$. 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.

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.[14] Fig. 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. (2009a), Chen (2010), Diaz and Luengo-Prado (2008), Fisher and Gervais (2011) is "reduced-form". We set the down payment constraint to 10 percent, $d(a < 65) = 0.1$. We do not allow retired households to take out new loans: $d(a \geqslant 65) = 1$. In the calibrated equilibrium, this is sufficient to ensure that no one at age T dies in debt.

3.3. The productivity process

We follow the literature on household earnings profiles (e.g. Storesletten et al., 2004) and develop a model of labor ability over the life cycle, $l(a, f, i)$. Fig. 2 (right panel) shows the well known hump-shaped age profile of earnings. The steep rise in expected earnings for young households will be a strong incentive to dis-save.

We estimate the effects of age and family size on household earnings using the CPS.[15] We then take annualized earnings from the PSID and compute the residual of log earnings, w_{ijat}, from the regression of log earnings on age dummies, year dummies and family size.

3.3.1. Parametric model for earnings

For purposes of calibration, we estimate a reduced-form model of household earnings. The reduced-form model assumes that a location's productivity follows an AR(1) process and that the household does not voluntarily move to a new U.S. state in the data. Also, unlike the structural model, it allows for a transitory component to individual earnings.[16] With some abuse of notation, we model residual log earnings as

[14] We follow Amior and Halket (2012) 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.

[15] We assume that single households earn only half of their married counterparts, but that otherwise income does not depend on family size. See the online appendix for complete details.

[16] Though potentially important for the overall savings rate, we choose to not include a transitory component of earnings in the model for computational reasons.

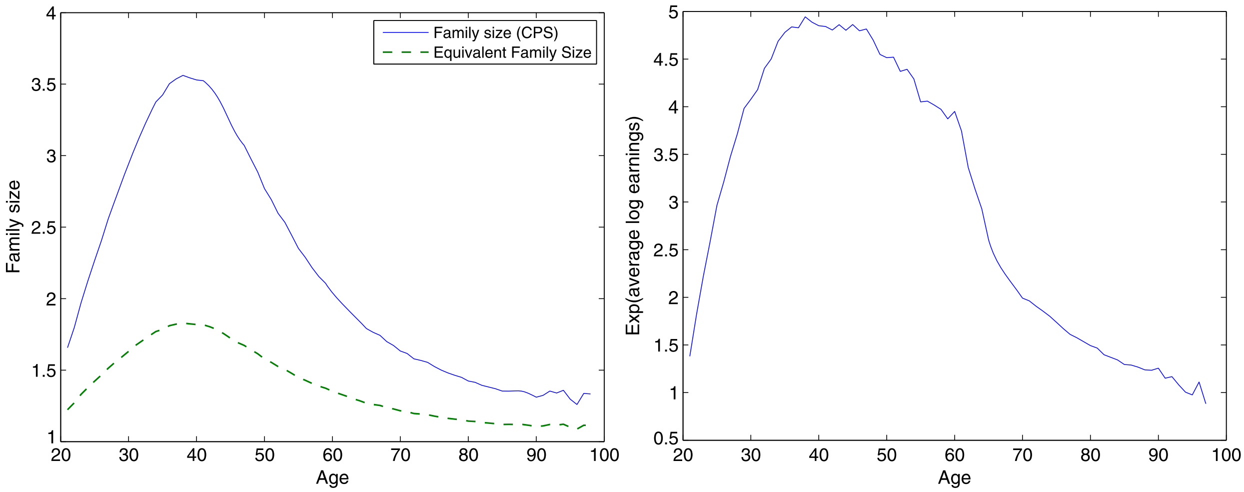

Fig. 2. Adjusted family size and income profiles (yearly bins).

Table 1
Productivity parameters.

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_ε	Std. dev. of the regional productivity shock	0.026
ρ_ι	Persistence of the idiosyncratic shock	1
ρ_ε	Persistence of the regional shock	0.9839

$$w_{ijat} = \sigma_f f_i + \sigma_\nu \nu_{iat} + \iota_{iat} + \varepsilon_{jt}$$
$$\iota_{it} = \rho_\iota \iota_{i,a-1,t-1} + \sigma_\iota e_{it}$$
$$\varepsilon_{jt} = \rho_\varepsilon \varepsilon_{j,t-1} + \sigma_\varepsilon e_{jt}$$

where i indexes the individual household, j indexes the state where the household resides, a indexes the age of the household, and t indexes time. $\sigma_f f_i$ is the fixed effect, $\sigma_\nu \nu_{iat}$ is the temporary shock, ι_{it} is the persistent idiosyncratic shock and ε_{jt} is the persistent regional shock. $f_i, \nu_{iat}, e_{it}, e_{jt} \sim \mathcal{N}(0,1)$.

Storesletten et al. (2004) note that ρ_ι is very close to 1. We set $\rho_\iota = 1$ in our reduced-form model so that the persistent idiosyncratic shock follows a random walk, as in our structural model.

3.3.2. GMM estimation

We estimate the parameters using an overidentified set of moments with the identity matrix as the weighting matrix:

$$m1(k) \equiv E(w_{ijat} w_{i'ja',t-k}) = \rho_\varepsilon^k \sigma_\varepsilon^2 / (1-\rho_\varepsilon^2)$$
$$m2 \equiv E(w_{ijat}^2) = \sigma_f^2 + \sigma_\nu^2 + (a-1)\sigma_\iota^2 + \sigma_\varepsilon^2/(1-\rho_\varepsilon^2)$$
$$m3(n) \equiv E(w_{ijat} w_{ija-n,t-n}) = \sigma_f^2 + (a-1-n)\sigma_\iota^2 + \rho_\varepsilon^n \sigma_\varepsilon^2/(1-\rho_\varepsilon^2)$$

We use $k = \{0, 1, \dots, 15\}$ and $n = \{0, 1, \dots, 9\}$ and restrict our sample to households of ages 26–62, where we have the most data. As in Storesletten et al. (2004), parameters are chosen to match the data's autocorrelogram. Our approach is similar to theirs with the addition that we also attempt to match the autocorrelogram of the component to earnings which is common to households in the same location.

Table 1 shows the estimated parameter values. Regional shocks are highly persistent; in fact the data cannot reject a random walk. We discretize the location productivity AR(1) process following Tauchen (1986). Due to computational constraints we pick a 5-point distribution; we discuss this further in Section 5.2. Homogeneity allows us to normalize the productivity process, j, so that average wages are 1.

3.4. Taxes

There are two 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

Table 2
Parameters calibrated internally.

Parameter	Value	Moment	Data	Model
β	1.01	$\frac{K}{Y}$	2.00	2.08
σ	0.25	Expenditure share	0.24	0.26
θ_m	0.04	Renter moving rate	22.3%	23.0%

household level already. The income tax rate we choose, $t_y = 0.2$, is in the same range that they compute for the U.S. economy.[17]

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.[18] 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 $t_p = 0.01$.

3.5. Setting macroeconomic variables

The remaining variables are r, σ, β, γ, θ_m. We set the inverse of the intertemporal elasticity of substitution, $\gamma = 3$, within the typical range of 2 to 5 (e.g. Piazzesi et al., 2007; Diaz and Luengo-Prado, 2008).

3.5.1. 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.

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 0.24 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. See the online appendix for more details on the simulated methods of moments procedure.

The capital-output ratio also pins down the interest rate: $r = 0.04$. From our equilibrium, we get that $\beta = 1.001$, $\sigma = 0.25$, and $\theta_m = 0.04$ (Table 2). The expenditure share in the model is within the ± 0.02 confidence interval in Davis and Ortalo-Magne (2011).

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.

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 households' 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. Despite these challenges, our model is successful in replicating several key aspects of the home ownership and mobility profiles.

4.1. Ownership over the life cycle

Fig. 3 shows the proportion of home ownership over the life cycle in the model's steady state 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

[17] See Table 1, p. 6 in their paper.
[18] 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.

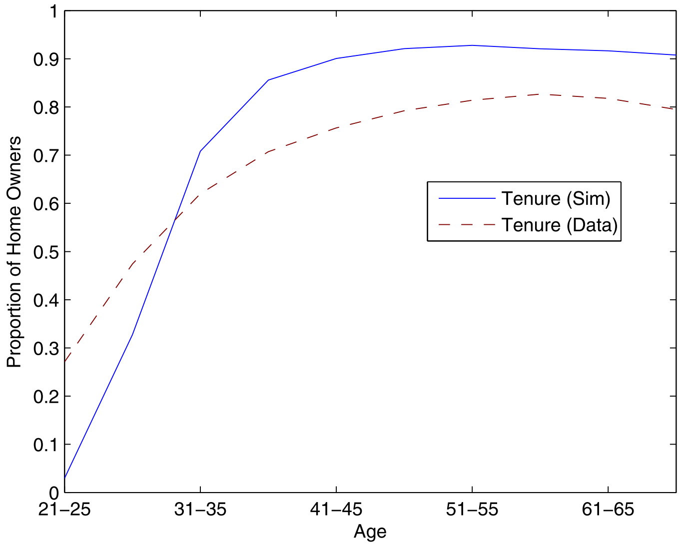

Fig. 3. Home ownership: model and data.

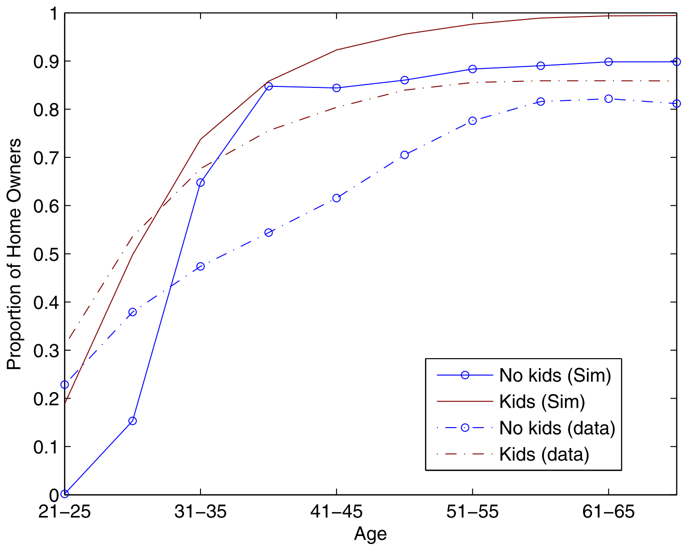

Fig. 4. Home ownership by family size: model and data.

ownership rate for households under 65 in the model is 70.9 percent, close to the data's 72.5 percent.[19] Home ownership in the model starts below the data and peaks above it but well below 100 percent.

Fig. 4 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. 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

In the estimated model's equilibrium, younger households have a lower expected duration in their current home for many 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, due to the steep earnings profile, young households expect their earnings to increase dramatically in the future. However they are unable to borrow against this future income to smooth housing

[19] These figures are from the CPS but use the population weights in the model. See the online appendix for sample selection criteria for all data used.

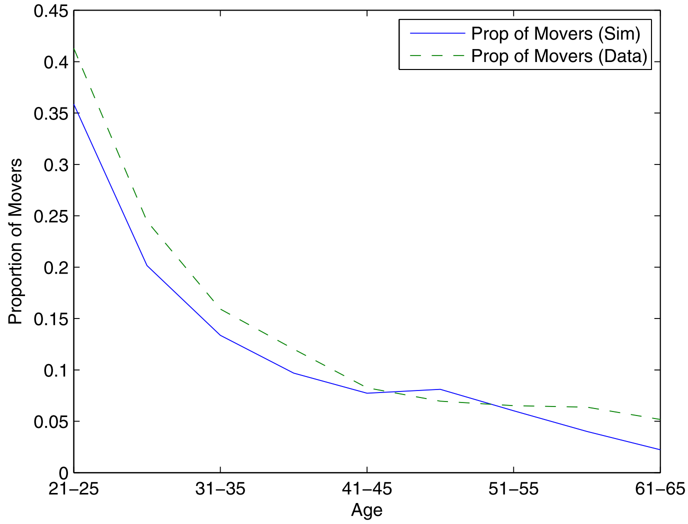

Fig. 5. Household moving over the life cycle: model and data.

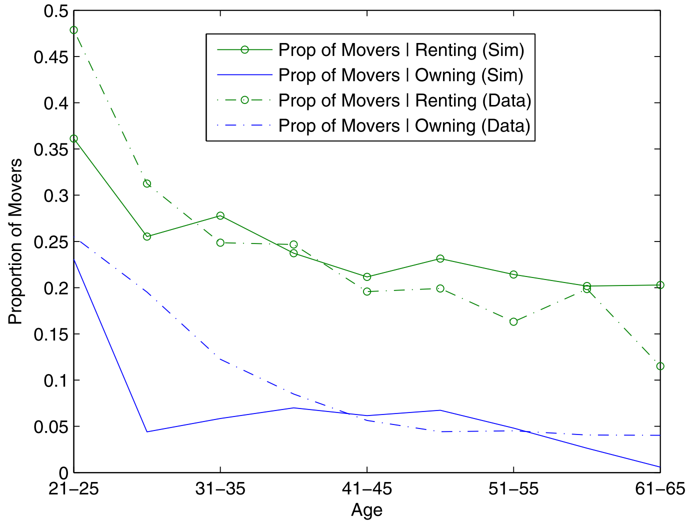

Fig. 6. Household moving conditional on ownership choice: model and data.

consumption over their life cycle. So young households expect to move into larger houses in the future. Third, expected future earnings comprise a large 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.

The model matches the moving rates over of the life cycle very well (Fig. 5). 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, conditional on tenure, mobility falls 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 (Fig. 6), as well as the rates of decline in mobility conditional on ownership.

We use the panel aspect of the PSID to construct measure of regional mobility conditional on previous tenure. Our measure is households that move to a new U.S. state. For comparison, we also show mobility rates for those households

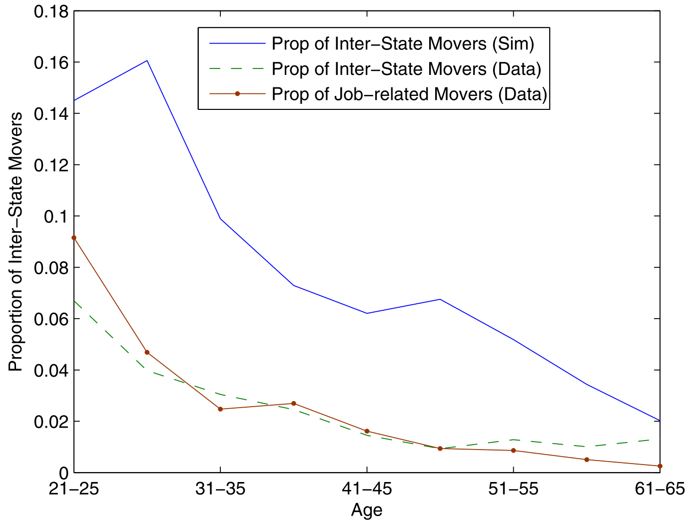

Fig. 7. Inter-state moving over the life cycle: model and data.

that reported moving for "job-related" reasons.[20] 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 Fig. 7, 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.

Many movers in the model move to a new island when they move. The moving costs of moving "next door" (i.e. changing house size or tenure but not island) are the same as moving to a completely new island. If there are enough different islands to choose from, households will often 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 do find a better match on a different island should they choose to move. Including a cost of moving to a new island would clearly lower regional mobility rates in the model to the levels 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 earnings profile in the early part of life (the profile peaks at around age 45) implies that middle aged households' earnings are most sensitive to their location's productivity. 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.

Similar factors explain the heterogeneity in location choices conditional on age (and choosing to move). Everything else equal, households with higher wealth-to-income ratios move to lower productivity, cheaper islands because their present and future earnings are relatively less important than their current wealth for their consumption. Likewise, married families with up to one child tend to prefer high productivity islands whereas very large and small families tend towards lower productivity islands. Large families are relatively size-stable and consume more housing relative to their income, so they prefer to live where housing is cheaper. Due to the economies of scale in family consumption but not in single versus married incomes, single households with average ability also prefer to live where housing is cheaper.

Fig. 8 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.

[20] 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 job-related moving; the correlation between the two is 0.6.

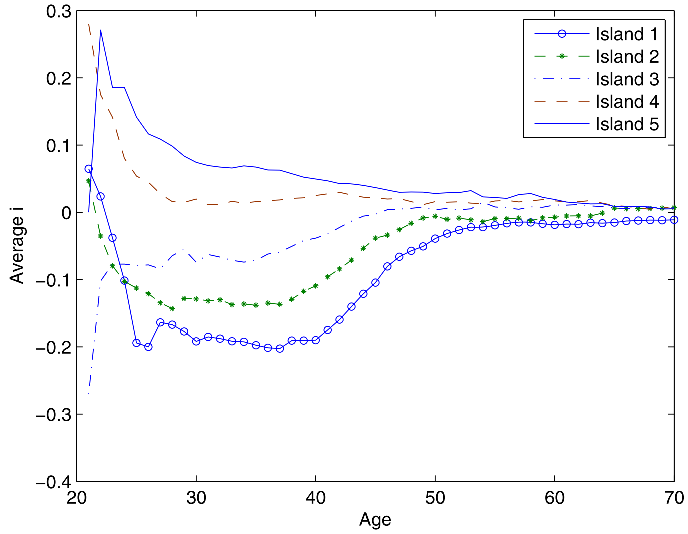

Fig. 8. Sorting across locations. Scaled average idiosyncratic ability over the life cycle by island productivity in the model. Island 1 has the lowest productivity and Island 5 the highest. *Average i* is the average ability of households that choose to live on a given island, conditional on age. The units are in standard deviations of the cross-sectional distribution of ability for each age.

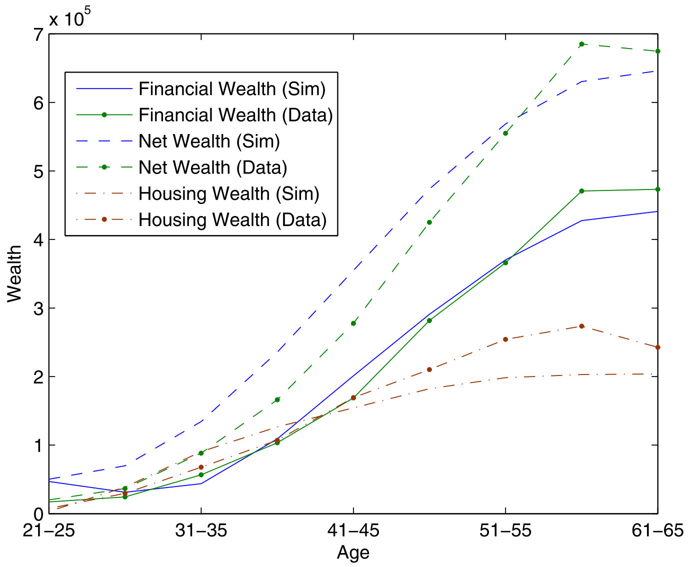

Fig. 9. Wealth over the life cycle: model and data.

4.3. Wealth

Fig. 9 shows the average household financial portfolio over the life cycle. We normalize the simulated financial data so that the average net wealth of the simulated economy is equal to the average net wealth observed in the data.[21] The net wealth and financial wealth of households over the life cycle of the simulated economy closely matches 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.

We compute LTV in the model by taking the ratio of debt to house value for a household at the time of purchase conditional on having any debt. A substantial number of households in the model borrow a lot when buying a house: 38 percent of all home buyers under the age of 30 put down less than 20 percent as a down payment, 63 percent put down less than 40 percent.

[21] Financial wealth is any liquid (non-real-estate) savings or, negatively, debt. Net wealth is financial plus housing wealth. The average net wealth is calculated for the whole economy unconditional on age. The data on wealth are from the Survey of Consumer Finance (SCF) from 1989–2001.

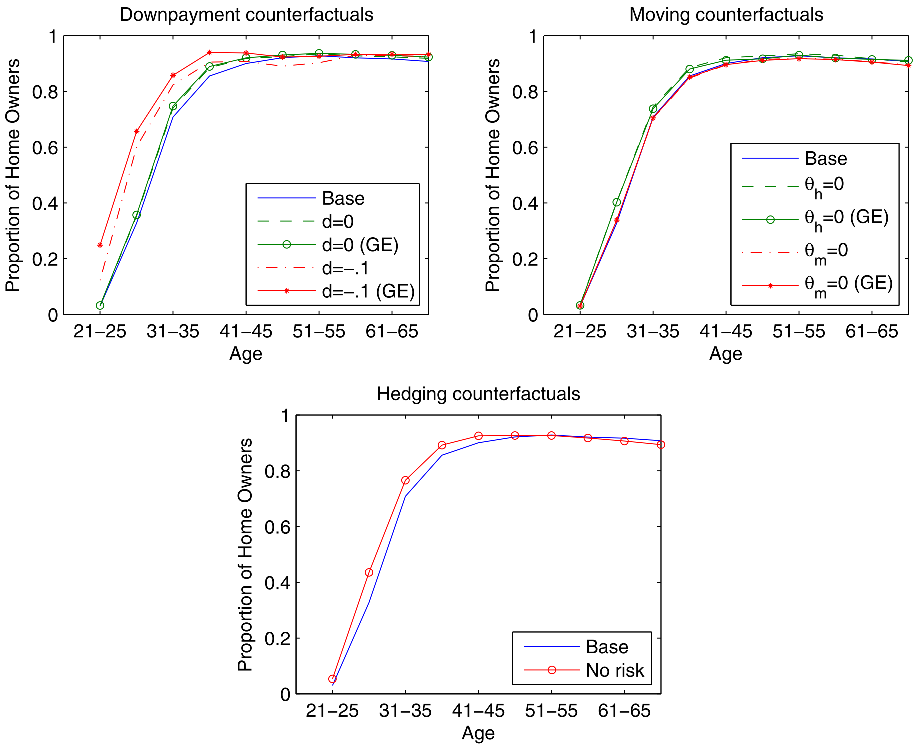

Fig. 10. Home ownership: counterfactuals.

Direct comparisons to the data on LTV are difficult: households in the model cannot hold savings and mortgage debt simultaneously.[22] So there may be many (particularly older) households in the data taking out large LTV loans who are not in fact near their borrowing constraint because they are also simultaneously holding sizable positions in liquid assets like bonds or savings accounts. With that caveat in mind, the LTV figures from the data are higher. For instance, 77 percent of home buyers under 30 have an LTV less than 20 percent.[23]

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 the first two explanations, we conduct several counterfactual experiments: a partial equilibrium version, where all prices are kept constant, and a general equilibrium version where prices adjust.[24] 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: $d(a) = \underline{d} < 0.1$ $\forall a < 65$. We look at two settings: no down payment, $\underline{d} = 0$; and a limited negative equity, $\underline{d} = -0.1$. 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. Fig. 10 (top left) displays the tenure curves for each experiment against the baseline model and Table 3 reports some summary statistics. As can be seen there is little effect on prices when the down payment is lowered to 0.

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

[22] While the AHS has retrospective data on household mortgages and house purchases, it does not have the same for other assets.

[23] This figure comes from the 2001 national sample of the AHS for metro-area housing but otherwise we use the same procedure with the AHS as outlined above.

[24] 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.

Table 3
Selected effects from changes in minimum down payment.

Counterfactual	Ownership	LTV	r	$p(1)$	$p(5)$
Base	73.8%	49.3%	4.0%	1.00	1.30
$\underline{d} = 0$	75.5%	52.5%	4.0%	1.00	1.30
$\underline{d} = 0$ (GE)	75.7%	53.6%	4.0%	1.00	1.33
$\underline{d} = -0.1$	79.1%	66.1%	4.0%	1.00	1.30
$\underline{d} = -0.1$ (GE)	82.2%	71.5%	5.0%	0.90	1.34

$p(1)$ 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.

Table 4
Changes in first owned home.

Counterfactual	Earlier first home	Diff in age	Larger home
$\underline{d} = 0$	16.7%	0.5 years	30.0%
$\underline{d} = 0$ (GE)	18.6%	0.6 years	57.3%
$\underline{d} = -0.1$	41.7%	3.0 years	15.3%
$\underline{d} = -0.1$ (GE)	33.4%	1.6 years	55.6%

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 percent larger home in the counterfactual but do still buy at the same age as they would in the base version.

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.

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 under one year. The difference more than doubles when negative equity is allowed. Though about 20 to 30 percent of households choose to buy a home earlier when the down payment requirements change, a generally larger 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[25] of a house while others choose to buy a smaller home.[26] In other words, households adjust their housing purchases on both the extensive and intensive margins.

5.1.1. General equilibrium effects

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. However the benefits 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 let young households better access these benefits. So more high ability households move to high productivity islands when down payments are lower, increasing the demand for housing on high productivity islands and decreasing it on low productivity islands. 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 equity counterfactual, the fall in savings leads to an increase in interest rates of 100 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. Home ownership rates on the low productivity islands therefore go up while rates on the high islands remain about constant.

Lastly it is worth noting that household behavior and (in general equilibrium) prices change by more when the down payment is lowered from $\underline{d} = 0$ to $\underline{d} = -0.1$ than when it is lowered an equal amount from $\underline{d} = 0.1$ to $\underline{d} = 0$. 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,

[25] 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.

[26] 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 is a convex space and does not depend on whether the household chooses to own or rent. Some models (e.g. Chambers et al., 2009a) have a minimum house size for owner-occupied housing, thus limiting the scope for adjustment along the intensive margin.

Table 5
Selected effects from changes in moving costs.

Counterfactual	Ownership	Size	Own size	Rent size	r	$p(1)$	$p(5)$
Base	73.8%	1.00	1.11	0.70	4.0%	1.00	1.30
$\theta_m = 0$	72.9%	1.02	1.12	0.74	4.0%	1.00	1.30
$\theta_m = 0$ (GE)	72.9%	1.02	1.12	0.95	4.0%	1.00	1.30
$\theta_{b,s} = 0$	75.7%	1.20	1.14	0.70	4.0%	1.00	1.30
$\theta_{b,s} = 0$ (GE)	76.2%	1.00	1.13	0.55	5.25%	1.05	1.33

$p(1)$ 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.

Table 6
Selected effects from changes in risk.

Counterfactual	Ownership	LTV	$p(1)$	$p(5)$	$q(1)$	$q(5)$	Isl Mov Rate
Base	73.8%	49.3%	1.00	1.30	0.075	0.129	7.16%
No island risk	76.4%	51.8%	0.80	1.37	0.068	0.118	4.60%

$p(1)$ 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. Isl Mov Rate is the rate at which households move to a location with a different productivity than the one they entered the period living on.

absent risk, would strongly prefer to borrow in order to smooth their consumption over time. When $\underline{d} = 0$, households do not need to save in order to own but net borrowing is only possible with negative equity, the prospect of which has a great influence on household behavior.

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 costs for buying and selling a home. Table 5 and Fig. 10 (top right) 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 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 costs of owning a home raises the home ownership rate by about 25 percent more than setting $\underline{d} = 0$. It also shifts consumption patterns more and so prices change by more.

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 (2012) 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 without inter-island mobility, Amior and Halket (2012) finds that higher risk leads to more precautionary savings and thus lower LTV ratios at origination and, if anything, lower home ownership rates.

Here we test the hedging hypothesis in a general equilibrium setting. Changes in rental prices in the model are driven by changes in regional productivity. Unlike the down payment constraint or transactions costs, the amount of housing risk in the economy is endogenous. Parameters that affect the amount of housing risk will directly affect other behavior too so the counterfactual will only imperfectly illustrate the effect of housing risk on home ownership. However it will also shed some light on why some reduced-form tests of the hedging hypothesis may also be problematic.

In the counterfactual, we use the baseline economy specification including the relative island productivities. The only thing that will change is the probabilities that islands change productivity, which is set to zero, and prices (Table 6).

Less risk leads to more home ownership and endogenously lower down payments when households do buy, consistent with the findings of Amior and Halket (2012) and counter to the hypothesis that ownership is a significant source of insurance against rental price changes. When housing is risky, as it is in the baseline economy but not in these counterfactuals, many households that purchase a house opt to hold more equity than just the minimally required down payment. 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. This effect is strongest for younger households for whom holding extra precautionary savings is particularly painful. So, when risk goes down, home ownership rates increase most for households in the first half of their life cycle, consistent with the findings for U.S. MSAs in Amior and Halket (2012).

One reduced-form approach used to test for risk's effect on home ownership is to regress home ownership propensities on expected duration interacted with a measure of local rental volatility, as in Sinai and Souleles (2005). Their hypothesis is that increases in rental risk should increase the probability that a household owns if that household expects to stay in a particular location for a relatively long time. In other words, the coefficient on the interaction term of duration and volatility should be positive. Fig. 10 (bottom left) shows that we could generate such a regression result in the model even when risk lowers the home ownership rate since the home ownership profile steepens with more risk and the propensity to move declines with age.

6. Conclusion

The transactions costs of owning a houses and the price risk to owning are as important factors in the decision to own a home as saving for a down payment. The illiquidity and immobility of housing make it expensive for households to move, particularly into and out of owner-occupied housing. So, factors that affect expected mobility and propensities to save all 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 setting where households know the exact law of motion for prices. We find that while only small portions of the population are down payment constrained, more households would choose to own if ownership were a means to borrowing against future income. Households 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 cannot choose to default and the gross interest rate on mortgages is also the risk-free rate that households can save at. LTVs in the base version of the model are below those in the data and they go up in the counterfactuals when the down payment requirements fall. One fear may be that if the model allowed for default, households may be more likely to own and also borrow more. This of course depends on the particulars of the contracting problem between lenders and households.[27] 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. So, our main results perhaps overstate the limited importance of down payment constraints in explaining why many young households rent.

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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Appendix A. Supplementary material

Supplementary material related to this article can be found online at http://dx.doi.org/10.1016/j.red.2013.06.002.

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[27] See Chatterjee and Eyigungor (2011), Corbae and Quintin (2011), Garriga and Schlagenhauf (2009), Guler (2010), Jeske et al. (2011) for various models of default and home ownership.

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