

Housing Over the Life Cycle: A Structural Estimation

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ABSTRACT

This paper estimates a structural model of optimal life-cycle housing consumption and investment in the presence of realistic labor income and house price uncertainty. The model incorporates housing adjustment cost and postulates constant elasticity of substitution between housing service and nondurable consumption. The model fits the cross-sectional and time-series household wealth and housing profiles generated from the Panel Study of Income Dynamics quite well. Our benchmark estimate suggests an intra-temporal elasticity of substitution between housing and nonhousing consumption of 0.76, a parameter key to the understanding of housing market developments on general activities. We use the estimated model to conduct policy experiments and find that consumption responds nonlinearly to changes in housing wealth with an average marginal propensity to consume out of housing wealth of about 5 percent.

KEY WORDS: Life-cycle, Housing, Adjustment Costs, intratemporal substitution, methods of simulated moments

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1. Introduction

This paper extends the seminal work of Gourinchas and Parker (2002) by estimating a standard dynamic stochastic model of life-cycle consumption and saving behavior augmented with housing. We pay special attention to estimation of structural preference parameters and to characterizing optimal behavior pertinent to housing when households face exogenous, stochastic, labor income and house price processes. We are motivated by recent developments in housing markets and housing research.

The U.S. housing market has experienced dramatic price movements in recent years. These movements, coupled with a substantial increase in household indebtedness, have drawn the attention of policy makers and academics to housing market developments and their impact on general activities. Housing models are now increasingly used in policy debate and in many areas of economics to study the implications of housing on nondurable consumption and saving (Campbell and Cocco 2005, Fernandez-Villaverde and Krueger 2005, Li and Yao 2007, and Stokey 2007), on household stock market participation and asset allocation (Cocco 2005, Flavin and Yamashita 2002, and Zhang and Yao 2005), on asset pricing (Fukushima 2005, Davis and Martin 2005, and Piazzesi, Schneider, and Tuzel 2005), and on the effects of monetary policy (Iacoviello 2005).

Two parameters are critical in all of these studies: housing adjustment cost and the complementarity between housing and nondurables. To see this, the key difference between housing services and nondurables is that moving is costly. Thus, even when preferences are homothetic, the consumption mix between housing and nondurables as well as the portfolio, would not only vary with changes in relative prices between housing and nondurables and their relative weights in preference but also with changes in income. And the magnitude of the variation depends crucially on the intra-temporal elasticity of substitution parameter between the two components of consumption.

Despite their importance, there have been limited research directed to econometric estimation of these parameters, especially in a realistic life-cycle setting with housing. Many theoretical studies using numerical calibrations adopt Cobb-Douglas utility function for its simplicity and often ignore housing adjustment cost. Those that estimate the parameters usually are divided as to their exact values, particularly for the intra-temporal elasticity of substitution parameter. Specifically, studies based on macro-level aggregate consumption or

asset price data frequently suggest a value larger than one for the intra-temporal elasticity of substitution between housing and non-housing consumption — implying that economic agents reduce expenditure on housing substantially when house prices move up. These studies have typically ignored housing adjustment cost at the micro-level, and assume the existence of a representative agent (Davis and Martin 2005, and Piazzesi, Schneider, and Tuzel 2007), despite strong evidence of housing adjustment cost and household heterogeneity as documented in the literature (Eberly 1994, Caballero 1993, Carroll and Dunn 1997, and Attanasio 2000).

By contrast, investigations using household-level data recover much lower values for the elasticity parameter, often in the range of 0.15 and 0.50.¹ These studies, however, typically suffer from selection bias in that households make the renting versus owning decision endogenously. Furthermore, regression analysis cannot identify the effects due to elasticity of substitution separately from those due to housing transaction costs. For instance, the lack of adjustment in housing after large house price changes can be caused either by low elasticity in utility preference or by high housing transaction costs.²

In this paper, we jointly estimate housing adjustment cost and the intra-temporal elasticity of substitution between housing services and nondurables, along with other preference parameters, in a structural model using household survey data. We do so by first extending the work of Gourinchas and Parker (2002) by introducing housing and house price uncertainty to an otherwise standard life-cycle model of consumption and saving. The model incorporates housing transaction costs and postulates Constant Elasticity of Substitution (CES) preferences over housing and nondurables. The model, thus, builds on a growing literature examining tenure choice and housing consumption within a life-cycle framework (Ortalo-Magne and Rady (1999), Fernandez-Villaverde and Krueger (2002), Gervais (2002), Campbell and Cocco (2003), Chambers, Garriga, and Schlagenhaut (2005), Yao and Zhang (2005), Li and Yao (2007), and Bajari, Benkard, and Krainer (2005)).

We then estimate the structural parameters of the model using Method of Simulated Moments (MSM). We proceed in two steps. Using the Panel Study of Income Dynamics (PSID), we first construct the average homeownership rate, rents, house value, and wealth profiles

¹See, for example, Flavin and Nakagawa (2008), Hanushek and Quigley (1980), Siegel (2004), and Stokey (2007).

²One exception to this literature is Flavin and Nakagawa (2008), which uses non-movers from the Panel Study of Income Dynamics for their Euler-equation estimation. Their identification, however, requires households having unlimited access to credit at riskfree rate, which contradicts the real practice and, thus, complicates the interpretation of their empirical estimate.

across households of different age groups between 1984 and 2005. For homeownership rate and house values, we further differentiate households depending on their state of residence. Second, using labor income uncertainty measured from the PSID, and house price uncertainty from the Office of Federal Housing Enterprise Oversight (OFHEO), we solve our model numerically for household optimal behavior and aggregate to generate simulated life-cycle housing and wealth profiles. By matching the simulated profiles to their empirical counterparts, we estimate the parameters of our structural model using the Method of Simulated Moments.

To the best of our knowledge, our paper represents the first structural estimation of housing preference parameters that are consistent with both time series and cross-sectional evidence on households' housing consumption and savings decisions.

Our estimation reveals that after explicitly accounting for housing adjustment cost, the intra-temporal elasticity of substitution between housing services and nondurables is around 0.751. This number falls below the value of 1 as used in macro studies but exceeds the small numbers suggested by existing micro studies. Our estimate of the housing transaction costs amounts to 16 percent of house value. Our estimated values of the coefficient of relative risk aversion and the discount factor are also in line with those provided by the previous literature.

The identification of our key preference parameters, housing adjustment cost and the intra-temporal elasticity of substitution between housing and non-housing consumption, comes mainly from two sources: households' mobility profiles and variation of house value and wealth profiles of households residing across different states.

Finally, we use our estimated model to conduct policy experiments. We find that consumption responds nonlinearly to changes in housing wealth. For a 5 to 20 percent change in house value, the marginal propensity to consume out of housing wealth varies between 4 to 6 percent.

The rest of the paper proceeds as follows. In Section 2, we present the model of housing with adjustment cost. In Section 3, we lay out our estimation strategy. Section 4 presents the data. Section 5 discusses our main findings and implications. Finally, we conclude and point to future extensions in Section 6.

2. The Model Economy

Our modelling strategy follows most closely that of Li and Yao (2007). We consider an economy where a household lives for at most T ($T > 0$) periods. The probability that the household lives up to period t is given by the following survival function,

$$F(t) = \prod_{j=0}^t \lambda_j, \quad 0 \leq t \leq T, \quad (1)$$

where λ_j is the probability that the household is alive at time j conditional on being alive at time $j - 1$, $j = 0, \dots, T$. We set $\lambda_0 = 1$, $\lambda_T = 0$, and $0 < \lambda_j < 1$ for all $0 < j < T$.

The household derives utility from consuming a numeraire good C_t and housing services H_t , as well as from bequeathing wealth Q_t . The within-period utility demonstrates a constant elasticity of substitution between the two goods (CES), modified to incorporate a demographic effect:

$$U(C_t, H_t; N_t) = N_t \frac{[(1 - \omega)(\frac{C_t}{N_t})^{1-\frac{1}{\zeta}} + \omega(\frac{H_t}{N_t})^{1-\frac{1}{\zeta}}]^{\frac{1-\gamma}{1-\frac{1}{\zeta}}}}{1 - \gamma}, \quad (2)$$

where N_t denotes the exogenously given effective family size, which captures the economies of scale in household consumption. The parameter ω controls the consumption share of housing services; ζ governs the degree of intra-temporal substitutability between housing and nondurable consumption goods; and γ determines the degree of curvature of the utility function with respect to the composite good. We denote the bequest function as $B(Q_t)$.

In each period, the household receives income Y_t . Prior to the retirement age, which is set exogenously at $t = J$ ($0 < J < T$), Y_t represents labor income and is given by

$$Y_t = P_t^Y \varepsilon_t, \quad (3)$$

where

$$P_t^Y = \exp\{f(t, Z_t)\} P_{t-1}^Y \nu_t \quad (4)$$

is the permanent labor income at time t . P_t^Y has a deterministic component $f(t, Z_t)$, which is a function of age and household characteristics Z_t . ν_t represents the shock to permanent labor income. ε_t is the transitory shock to Y_t . We assume that $\{\ln \varepsilon_t, \ln \nu_t\}$ are independently and identically normally distributed with mean $\{-0.5\sigma_\varepsilon^2, -0.5\sigma_\nu^2\}$, and variance $\{\sigma_\varepsilon^2, \sigma_\nu^2\}$, respectively. Thus, $\ln P_t^Y$ follows a random walk with a deterministic drift $f(t, Z_t)$.

After retirement, the household receives an income which constitutes a constant fraction θ ($0 < \theta < 1$) of its preretirement permanent labor income,

$$Y_t = \theta P_J^Y, \text{ for } t = J, \dots, T. \quad (5)$$

2.1. Housing and Mortgage Contracts

A household can acquire housing services through either renting or owning. A renter has a house tenure $D_t^o = 0$, and a homeowner has a house tenure $D_t^o = 1$. To rent, the household pays a fraction α ($0 < \alpha < 1$) of the market value of the rental house. To become a homeowner, the household pays a portion ρ ($0 < \rho < 1$) of the house value as closing costs to secure the title and mortgage. The house price appreciation rate $\tilde{r}_t^H$ follows an i.i.d. normal process with mean μ_H and variance σ_H^2 . The shock to house prices is thus permanent and exogenous.³

A household can finance home purchases with a mortgage. The mortgage balance denoted by M_t needs to satisfy the following collateral constraint at all time,

$$0 \leq M_t \leq (1 - \delta)P_t^H H_t, \quad (6)$$

where $0 \leq \delta \leq 1$.⁴ The borrowing rate r is time-invariant and the same as lending rate. A homeowner is required to spend a fraction ψ ($0 \leq \psi \leq 1$) of the house value on repair and maintenance in order to keep the house quality constant.

At the beginning of each period, the household receives a moving shock, D_t^m , that takes a value of 1 if the household has to move for reasons that are not modelled here, and 0 otherwise. The moving shock does not affect a renter's housing choice since moving does not incur any cost for him. When a homeowner receives a moving shock ($D_t^m = 1$), he is forced to sell his house.⁵ A homeowner who does not have to move for exogenous reasons can choose to liquidate his house voluntarily. The selling decision, D_t^s , is 1 if the homeowner sells and 0

³Flavin and Yamashita (2002), Campbell and Cocco (2003), and Yao and Zhang (2005) also assume that house price shocks are i.i.d. and permanent. Case, Quigley, and Shiller (2003) explore home price dynamics using data between 1982 and 2003. They find that home buyers' expectations are substantially affected by recent experience. Even after a long boom, home buyers typically have expectations that prices over the next 10 years will show double-digit annual price growth.

⁴By applying collateral constraints to both newly initiated mortgages and ongoing loans, we effectively rule out default. Default on mortgages is relatively rare in reality. According to the Mortgage Bankers Association, the seasonally adjusted three-month default rate for a prime fixed-rate mortgage loans is around 2 percent.

⁵We assume that house prices in the old and new locations are the same. In practice, however, house prices can differ across locations as in Sinai and Souleles (2005).

otherwise. Selling a house incurs a transaction cost that is a fraction ϕ ($0 \leq \phi \leq 1$) of the market value of the existing house. Additionally, the full mortgage balance becomes due upon the sale of the home. Following a home sale, a homeowner faces the same decisions as a renter coming into period t .

2.2. Liquid Assets

In addition to holding home equity, a household can save in liquid assets which earn the same constant riskfree rate r as the borrowing rate.⁶ We denote the liquid savings as S_t and assume that households cannot borrow non-collateralized debt, i.e.,

$$S_t \geq 0, \quad \text{for } t = 0, \dots, T. \quad (7)$$

2.3. Wealth Accumulation and Budget Constraints

We denote the household's spendable resources or "wealth" upon home sale by Q_t .⁷ It follows that

$$Q_t = S_{t-1}(1+r) + P_{t-1}^Y \exp\{f(t, Z_t)\} \nu_t \varepsilon_t + D_{t-1}^o P_{t-1}^H H_{t-1} [(1 + \tilde{r}_t^H)(1 - \phi) - (1 - \delta)(1 + r)]. \quad (8)$$

The intertemporal budget constraint, therefore, can be written as follows:

$$\begin{aligned} Q_t = & C_t + S_t + [(1 - D_{t-1}^o)(1 - D_t^o) + D_{t-1}^o D_t^s] \alpha P_t^H H_t \\ & + [(1 - D_{t-1}^o) D_t^o + D_{t-1}^o D_t^s D_t^o] (\delta + \psi + \rho) P_t^H H_t \\ & + D_{t-1}^o D_t^o (1 - D_t^s) (\delta + \psi - \phi) P_t^H H_{t-1} + tr_t. \end{aligned} \quad (9)$$

The third term represents housing expenditure by those who decide to be renters in the current period; the fourth term represents housing expenditure by households who decide to

⁶Under the assumption of costless refinancing, the household will never simultaneously hold both liquid savings and a mortgage if different lending and borrowing rates are allowed. When the lending and borrowing rates are the same, there is an indeterminacy with respect to liquid saving and mortgage holdings. From the household perspective, paying down the mortgage by \$1 is equivalent to increasing his liquid savings by the same amount as long as the collateral constraint is satisfied (equation (6)). To pin down the investors bond holding, in our subsequent analysis, we assume that the household always carries the maximum mortgage balance allowed, i.e., $M_t = (1 - \delta) P_t^H H_t$.

⁷Under this definition, conditional on selling his house, a homeowner's problem is identical to that of the renter and depends only on his age t , permanent income P_t^Y , house price per unit of housing services P_t^H , and liquidated wealth Q_t .

buy houses; and the fifth term represents housing expenditure of households who reside in their old houses. For the last group of households, we need to subtract from their expenditure housing selling cost that was subtracted from wealth in hand on the left-hand-side. The last term tr_t denotes government transfers. Following Hubbard et. al (1994, 1995) and De Nardi, French, and Jones (2007), we assume that government transfers provide a consumption floor that is proportional to the household's permanent labor income, i.e., ηP_t^Y . In other words, government transfers bridge the gap between the household's total resources and the consumption floor. If the transfers are positive, then the household will consume the consumption floor and the wealth carried to the next period would be necessarily zero.

2.4. The Optimization Problem

We assume that upon death, a household distributes its spendable resources Q_t among "L" beneficiaries to finance their numeraire good consumption and housing services through renting for one period. Parameter "L" thus controls the strength of bequest motives. Under CES utility, this assumption results in the beneficiary's expenditure on numeraire good and housing service consumption at a proportion that is a function of house price:

$$\frac{C_t}{C_t + \alpha P_t^H H_t} = \frac{(1 - \omega)^\zeta}{(1 - \omega)^\zeta + \omega^\zeta (\alpha P_t^H)^{1-\zeta}} \quad (10)$$

Then the bequest function is defined by

$$B(Q_t) = \frac{L^\gamma Q_t^{1-\gamma}}{1 - \gamma} \left[(1 - \omega) \left(\frac{(1 - \omega)^\zeta}{(1 - \omega)^\zeta + \omega^\zeta (\alpha P_t^H)^{1-\zeta}} \right)^{1-\frac{1}{\zeta}} + \omega \left(\frac{\omega^\zeta (\alpha P_t^H)^{-\zeta}}{(1 - \omega)^\zeta + \omega^\zeta (\alpha P_t^H)^{1-\zeta}} \right)^{1-\frac{1}{\zeta}} \right]^{\frac{1-\gamma}{1-\frac{1}{\zeta}}}. \quad (11)$$

The household solves the following optimization problem at time $t = 0$, given its house tenure status (D_{-1}^o), after-labor income wealth (Q_0), permanent labor income (P_0^Y), house price (P_0^H), and housing stock (H_{-1}):

$$\max_{\{C_t, H_t, S_t, D_t^o, D_t^s\}} E \sum_{t=0}^T \beta^t \left\{ F(t) U(C_t, H_t; N_t) + [F(t-1) - F(t)] B(Q_t) \right\}, \quad (12)$$

subject to the mortgage collateral borrowing constraint (equation 6), the borrowing constraint on liquid asset (equation 7), wealth processes (equation 8), and the intertemporal budget constraints (equation 9). The parameter β is the time discount factor.

2.5. Characterization of Individual Housing and Consumption Behavior

An analytical solution for our problem does not exist. We thus derive numerical solutions through value function iterations. Appendix A provides details of our numerical method.

Individual household's optimal decision rules follow closely those of Li and Yao (2007) (Figures 1 - 4). A renter's house tenure decision is largely determined by his wealth-income ratio. The more wealth a renter has relative to his income, the more likely he will buy as more wealth on hand enables the renter to afford the down payment for a house of desired value. The wealth-income ratio that triggers homeownership is U-shaped. This result is driven by the household's life-cycle and mobility profiles as young households face high income growth rates and are more likely to move and old households value bequest motive. A homeowner's continuing house tenure decision is driven by his wealth-income ratio and existing house value-income ratio. The homeowner stays in the house when his house value-income ratio is not too far from the optimal level he would have chosen as a renter given his wealth-income ratio.

A renter's consumption and savings functions are similar to those identified in the precautionary savings literature with liquidity constraints. At low wealth levels, a renter continues to rent and spends all his wealth on numeraire good and rent payment. At relatively higher wealth levels, a renter starts saving for intertemporal consumption smoothing and housing down payment. For a homeowner who stays in his house, the size of his house also affects his non-housing consumption. The magnitude of the effect depends on the complementarity of the two goods.

3. Estimation Procedure

We use a two-stage Method of Simulated Moments (MSM) to estimate the model. This methodology was first introduced by Pakes and Pollard (1989), and Duffie and Singleton (1993) to estimate structural economic models without close-form solutions. Since then, MSM has been successfully applied to estimations of preference parameters estimations in Gourinchas and Parker (2002), Cagetti (2003), and Laibson, Repetto, and Tobacman (2007), labor supply decisions by French (2005), and medical expenses and the savings of elderly singles by De Nardi, French, and Jones (2006), among many others.

In the first stage, we estimate or calibrate those parameters that can be cleanly identified without explicit use of our model. For example, we estimate labor income processes using the raw PSID data. Our house price index by state comes from Office of Federal Housing Enterprise Oversight (OFHEO), the household mortality rate as well as exogenous moving probability for non-housing related reasons are obtained from Current Population Survey (CPS).

In the second stage, we estimate the rest of the model parameters, taking as given those obtained in the first stage. In particular, we find the vector of the second stage parameters that minimize the distance between the simulated moments derived from household decision profiles that best match those observed in the data. Given the interest of the paper, we choose to match the profiles of wealth, home ownership rate, mobility rate, and owners' house value of households of two different age cohorts. For homeowners' house value, we further differentiate households based on their state of residence.⁸ We provide more details on these moments in the estimation results section.

The mechanics of our MSM approach is standard. We first solve the model and obtain household decision rules as described in the previous section. These decision rules together with simulated endowments and shocks allow us to simulate life-cycle histories for a large number of households in our economy. In particular, each of these households is endowed with a value of the state vector $X_t = \{D_{t-1}^o, Q_t, P_t^Y, P_t^H, H_{t-1}\}$ drawn directly from the beginning year of our sample. At every simulation, each household is assigned a series of mortality, moving, income, as well as house price shocks as those observed in the data. We then compute the average profiles for target variables the same way as we compute them in the real data. Finally, we adjust our second stage parameters until the weighted difference between the data and simulated profiles is minimized. The calculation of the standard errors for the second stage parameter estimates takes into account the uncertainty in the first stage parameters.⁹ Appendix B provides more details on our MSM estimation technique.

One major advantage of structural estimation is that it allows us to address potential biases directly, by replicating them in the simulation. For example, our estimation strategy

⁸In principal, we could match renter's profiles as well. Compared to home owners, however, we have relatively smaller number of renters especially for older age cohorts.

⁹We use a diagonal matrix for weighting given our small sample size. According to Altonji and Segal (1996), the optimal weighting matrix, though asymptotically efficient, can be severely biased in small samples. Our weighting matrix takes the diagonal terms of the optimal weighting matrix for scaling, while setting the off-diagonal term to be zero. A similar approach is adopted in De Nardi, French, and Jones (2006).

allows us to take into consideration the endogeneity of households' home ownership status, i.e., households self-select into owning a house versus renting. Furthermore, the explicit modelling of housing adjustment costs and borrowing constraints also insures that our estimates are not contaminated by adjustment costs or credit concerns.

4. Data

4.1. Data Construction

The main data we use in this study are taken from The University of Michigan Panel Study of Income Dynamics (PSID).¹⁰ Wealth variables are only available for years 1984, 1989, 1994, 1999, 2001, 2003, and 2005 while the rent variable is missing for 1989. We therefore only use data from 1984, 1994, 1999, 2001, 2003, and 2005. Our PSID data set is a combined cross-section, time-series sample of PSID households in these years. For households to be included in the sample, they have to be present in the 1984 survey but not in the 1968 sample of low income families. Our raw PSID sample comprises of 22,374 observations with 3729 families. Observations were further deleted for the following reasons:

- The age of the household head is younger than 25 or older than 54 in the 1984 survey.
- The state of residence is missing.
- Households live in public housing project owned by local housing authority or public agency.
- Households neither own nor rent.
- The head of the household is female.
- The head of the household is a farmer or rancher.
- Households obtained housing as a gift, or live in housing paid by someone outside of the family unit, or owned by relatives.
- The head of the household does not have a valid age variable.

¹⁰The PSID is a longitudinal survey that has followed a nationally representative, random sample of families and their extensions since 1968. The survey detailed economic and demographic information for a sample of households annually from 1968 to 1997 and biannually after 1997. At five-year intervals from 1984 through 1999, a wealth supplement to the PSID surveyed the assets and liabilities of each household. The survey becomes biannual after 1999, coinciding with the main survey frequency.

- Information on households' net worth, income, or house value for home owners is missing.

The final sample consists of 5223 observations on 1600 households.

We group households into 3 age cohorts according to their birth year. The first cohort consists of households whose heads were born between 1950 and 1959; the second cohort consists of households whose heads were born between 1940 and 1949; and the third cohort consists of households whose heads were born between 1930 and 1939. At the beginning of our survey, i.e., 1984, the cell sizes are 562, 413, and 190 respectively. These cell sizes declined slightly over time as some households dropped out of the survey. When matching high house price state versus low house price state household economic statistics, we further divide households according to whether they reside in a high house price state or a low house price state and thus obtain 8 age-state cohorts. Between 23 percent and 30 percent of households in each cohort live in a high house price state.

4.2. Life Cycle Income Profiles

We define labor income as total reported wages and salaries, social security income, unemployment compensation, workers compensation, supplemental social security, other welfare, child support, and transfers from relatives. The household labor income is the sum of all of these items from both the head of household and his spouse, if present. The federal and state income tax liabilities are obtained from National Bureau of Economic Research (NBER)'s TAXSIM program (Feenberg and Coutts, 1993), which calculates taxes under the US Federal and State income tax laws from individual data, including marital status, wage and salary of household head and his or her spouse, and number of dependents. We then subtract these estimated tax liabilities from the household labor income defined above to compute the disposable labor income, which is further deflated using the Consumer Price Index with 2005 as the base year. We refer to this deflated disposable labor income as household labor income in the paper. To create a life cycle income process, We use an approach similar to the one used in Cocco, Gomes, and Maenhout (2005) to estimate the exogenous labor income process characterized in Equation (3). The technical details are provided in Appendix C.

4.3. Home Ownership, Mobility, Wealth, and Housing Profiles

The construction of data profiles using PSID are straightforward. Essentially, we follow the cohorts over time and obtain the average of the variables of interest over time for each cohort. Wealth, or net worth, consists of households' liquid savings, financial assets, and home equity. House values are market values reported by home owners. Both wealth and house value are deflated by Consumer Price Index reported by Bureau of labor Statistics with 2004-2005 normalized to 100. A household is considered having moved if his state of residence is different from that reported in the previous year. These data profiles are reported together with model simulations in Figures 2-7.

As can be seen, home ownership rates generally increases with household age within each cohort with the increase more pronounced for young cohorts. Moving rates, by contrast, tend to decrease with household age within each cohort for the two young cohorts, but are stable for the two older cohorts. Wealth and house value both increase with household age for all four age cohorts.

5. Estimation Results

5.1. First-Stage Estimation

The decision frequency is annual. Households enter the economy at age 25 and lives to a maximum age of 80, i.e., $T = 55$. The mandatory retirement age is 65 ($J = 40$).

Using a methodology detailed in Appendix C, we estimate the standard error for the permanent income shock, σ_ε , to be 0.14, and the standard error for the transitory income shock, σ_ν , to be 0.29. The income replacement ratio after retirement θ is estimated to be 0.96. Assuming an average tax rate of 0.30, this amounts to a replacement rate of 0.67, similar to those used in the literature (Storesletten, Telmer, and Yaron (2004)).

We assume that the house price rate of appreciation r_t^H is serially uncorrelated. We set the mean of the rate of return to housing to 0 and the return volatility σ_H to 0.10, similar to estimates in Campbell and Cocco (2003) and Flavin and Yamashita (2002). We further assume that there is no correlation between housing returns and shocks to labor income.

It is important to note that in order to capture household heterogeneity in terms of the realization of house prices, in simulating the model, we feed in the realized real house price rate of return based on households' state of residence. Appendix D provides details on the construction of state level house price index over time.

The conditional survival rates ($\{\lambda_j\}_{j=0}^{j=T}$) are taken from the 1998 life tables of the National Center for Health Statistics (Anderson 2001). Exogenous moving probability are calibrated to the average migration rates for non-housing related reasons between March 2001 and March 2002 in the Current Population Survey as reported by the Census Bureau (2004). We use the same PSID data to calibrate the effective household size at each age (N_t). Specifically, we calculate the average effective household size by the age of household head using the equivalence scale from the U.S. Department of health and Human Services (Federal Register 2001).

Other parameters in the first stage are largely chosen according to the literature. The annual real interest rate is set at 3 percent, approximately the average annualized post-WWII real return available on T-bills. The mortgage collateral constraint is set at 80 percent.¹¹ The consumption floor η is picked at 0.10 of permanent labor income. This number is within the range of those used in the literature (for example, De Nardi, French, and Jones 2006) and rarely binds in our simulation.

Table 2 summarizes some of our first-stage estimation results.

5.2. The Second-stage Estimation

For the baseline specification, we match the following data profiles: the average wealth, mobility rate, homeownership rate, rents for renters, and house value for homeowners for the 3 age-cohorts (25 to 34, 35 to 44, and 45-54 in 1984) in years 1989, 1994, 1999, 2001, 2003, and 2005.¹² In addition, for homeownership rate and house value, we match moments of households residing in the most and least expensive states. We define the most expensive states as the 18 states with the highest house price level in 1995, and least expensive states as the 18 states with the lowest house price level. The choice of 1995 is inconsequential since

¹¹Using the 1995 American Housing Survey, Chambers, Garriga, and Schlagenhauf (2004) calculate that the down payment fraction for first time home purchases is 0.1979 while the fraction for households who previous owned a home is 0.2462.

¹²Wealth information is available only for those years.

the ranking of house prices hardly changed during our sample period. The number of total matched moments amounts to 198.

We present our second stage parameter estimates in Table 3. According to our estimation, the annual discount factor β is 0.93. This is below one over the gross real rate of return, as is in models with uninsurable income risk. The risk aversion parameter is 3.18, well within the range used in both the macro and the finance literature. The bequest strength L is estimated to be 16.8 years.

The parameter ω is estimated to be 0.08. Under this parameter, in our model economy in 2005, the housing expenditure share for renters is between 14 percent to 26 percent of total expenditure, very close to the rental expenditures share to wage and salary income Davis and Ortalo-Magne (2007) calculated for the counties in their sample. The house maintenance cost is estimated to be 4.58 percent of house value. Renting is estimated to incur an extra cost close to 2.26 percent of the property value.¹³ Our estimation of rental premium is within the range albeit at the lower end of the user cost for homeownership as calculated by Himmelberg, Meyer, and Sinai (2005) for 46 metro areas.

The two key parameters, the housing adjustment cost for homeowners and the intra-temporal elasticity of substitution between housing and non-housing consumption are estimated to be 16 percent of the house value and 0.75, respectively. Realtors typically charge a 6 percent commission for selling a house. In addition, closing fees generally include: 1) loan origination fee; 2) loan application fee; 3) title search; 4) title insurance; 5) inspection fee; 6) appraisal fee, 7) credit report fee; 8) attorney / settlement fee; and 9) government recording and transfer charges. Unlike realtors' fees, these fees vary substantially from state to state and often depend on the amount of the loan, the amount of the down payment, and the credit worthiness of the borrower. Furthermore, many mortgage brokers roll some or all of these fees into the mortgage such that the mortgage amount and the rate the borrower pays depend on which fees are included or excluded from the mortgage. Woodward (2003) estimates total closing costs to be \$4,050 on a house with a value of \$162,500, or 2.5 percent of the house value. Regarding the search and psychic cost of moving, using the Housing Allowance Demand Experiment, Bartik, Butler, and Liu (1992) found that the average household was willing to pay 10 to 17 percent of their current income to stay in their current residence rather than

¹³The α parameter, which is the sum of cost of capital, maintenance, depreciation, and rental premium, is therefore, about 9.10 percent.

move. If we use the industry lending standard that house value is about 4 times of annual income, this amounts to 2.5 to 4.3 percent of house value. Adding together the estimated realtors' fee, closing cost, and psychic cost of moving, we obtain number of over 10 percent of house value associated with selling a house.

Our estimation of the intra-temporal elasticity of substitution between housing and non-housing consumption, at 0.761, is smaller than the macro estimates yet larger than most micro estimates. The difference between our estimate and the macro estimates results largely from the fact that the macro literature has examined the aggregate time series consumption data. Indeed, the aggregate housing expenditure share in total consumer expenditures has not fluctuated much since the 1960s. The aggregation, however, masks important heterogeneities among households in terms of their housing expenditure shares. According to the micro consumption data – Consumer Expenditure Survey, from 1980 to 2005, the ratio of rental expenditure to income has trended up from 0.20 to 0.25.

Our estimate is closer to some of the micro estimates. Hanushek and Quigley (1980) look at data from the Housing Allowance Demand Experiment, which involved a sample of low-income renters in Pittsburgh and Phoenix. Households in each city were randomly assigned to treatment groups which received rent subsidies that varied from 20 percent to 60 percent and a control group that received no subsidy. The estimated price elasticities were 0.64 for Pittsburgh and 0.45 for Phoenix. Siegel (2004) estimates the elasticity from the PSID over the period 1978-1997. He limits the sample to home-owners, using total household food expenditure as a proxy for nondurable consumption and the self-reported value of the owner occupied house for housing. Siegel uses a household's first report as the value of a house and assumes durable consumption is constant until the household moves. Aggregating across households and using only the time series information, the estimated elasticity of substitution is about 0.53. Flavin and Nagazawa (2007), by contrast, also use PSID over the period 1975 to 1985 but instead of households' self-reported house value, constructs a housing service measure and their estimate of the elasticity of substitution between housing and nonhousing consumption is a very low 0.13.

Figures 2 to 7 show the fit of our baseline model to the empirical data profiles.

5.3. Identification

Identification of our model parameters depends on the way our simulated moments vary as function the estimated parameters. The risk aversion parameter comes largely from the life-cycle profile of wealth to income ratio as is standard in the buffer stock liquidity constraint consumption literature. Indeed, when we set the life-cycle family size to 1, to capture the hump shape in wealth-income ratio, while the other parameters were hardly changed, the required risk aversion parameter increased to around 5. The discount rate is pinned down by the assumed real interest rate and the risk aversion parameter.

The bequest strength is mostly driven by households' housing and wealth profiles later in life. A rather strong bequest motive is identified in order to match the high homeownership rate and the high house value-income ratio of households approaching terminal age. The house maintenance cost, and, thus, the rental premium helped explain the overall homeownership rate over the life cycle. Housing expenditure share also results from the life-cycle house value-income share and wealth-income share.

The identification of our most important parameters, house selling cost ϕ and the intra-temporal elasticity of substitution ζ comes from the mobility rate over time and the cross section evidence on homeownership rate and house value-income ratio. To see this, suppose we set the house selling cost to 0, homeowners would behave much like renters and will move whether their house value deviates from their optimal level after the realization of their income and house price shocks. In other words, the observed the mobility rate would be much higher. The identification of intra-temporal elasticity of substitution requires heterogeneity in house price growth across households. Indeed, when we treat the whole sample as coming from one house price region, the estimated intra-temporal elasticity of substitution increased substantially to a value close to **0.90**.

The next robustness section also sheds light on our parameter identification.

5.4. Robustness

We conduct the following robustness checks on our benchmark estimation: diagonal weighting matrix, returns to scale in household size, and mobility rate. In particular, instead of using the identity weighting matrix, we use the diagonal weighting matrix with the diagonal values

take on the variance of its corresponding data. In the returns to sale in house size experiment, we set the the life-cycle household size to flat. Finally, we set the house selling cost to 0. Table 4 presents the results.

5.5. Model Validation

6. Policy Experiments

7. Conclusions and Future Extensions

To be written...

Appendix A: Model Simplifications and Numerical Solutions

Given the recursive nature of the problem, we can rewrite the intertemporal consumption and investment problem as follows:

$$V_t(X_t) = \max_{A_t} \{ \lambda_t [U(C_t, H_t; N_t) + \beta E_t[V_{t+1}(X_{t+1})]] + (1 - \lambda_t)B(Q_t) \}, \quad (13)$$

where $X_t = \{D_{t-1}^o, Q_t, P_t^Y, P_t^H, H_{t-1}\}$ is the vector of endogenous state variables, and $A_t = \{C_t, H_t, S_t, D_t^o, D_t^s\}$ is the vector of choice variables.

We simplify the household's optimization problem by exploiting the scale-independence of the problem and normalize the household's continuous state and choice variables by its permanent income P_t^Y . The vector of endogenous state variables is transformed to $x_t = \{D_{t-1}^o, q_t, \bar{h}_t, P_t^H\}$, where $q_t = \frac{Q_t}{P_t^Y}$ is the household's wealth-permanent labor income ratio, and $\bar{h}_t = \frac{P_t^H H_{t-1}}{P_t^Y}$ is the beginning-of-period house value to permanent income ratio. Let $c_t = \frac{C_t}{P_t^Y}$ be the consumption-permanent income ratio, $h_t = \frac{P_t^H H_t}{P_t^Y}$ be the house value-permanent income ratio, and $s_t = \frac{S_t}{P_t^Y}$ be the liquid asset-permanent income ratio. The evolution of normalized endogenous state variables is then governed by:

$$q_{t+1} = \frac{s_t(1+r) + D_t^o h_t [(1 + \tilde{r}_{t+1}^H)(1 - \phi) - (1 - \delta)(1 + r)]}{\exp\{f(t+1, Z_{t+1})\} \nu_{t+1}} + \varepsilon_{t+1}, \quad (14)$$

$$\bar{h}_{t+1} = \left[\frac{1 + \tilde{r}_{t+1}^H}{\exp\{f(t+1, Z_{t+1})\} \nu_{t+1}} \right], \quad (15)$$

$$P_{t+1}^H = P_t^H (1 + \tilde{r}_{t+1}^H). \quad (16)$$

The household's budget constraint can then be written as

$$\begin{aligned} q_t = c_t + s_t + & [(1 - D_{t-1}^o)(1 - D_t^o) + D_{t-1}^o D_t^s] \alpha h_t \\ & + [(1 - D_{t-1}^o) D_t^o + D_{t-1}^o D_t^s D_t^o] (\delta + \psi + \rho) h_t \\ & + D_{t-1}^o D_t^o (1 - D_t^s) (\delta + \psi - \phi) \bar{h}_t + \eta. \end{aligned} \quad (17)$$

Define $v_t(x_t) = \frac{V_t(X_t)}{(P_t^Y)^{1-\gamma}}$ to be the normalized value function, then the recursive optimization problem (13) can be rewritten as:

$$v_t(x_t) = \max_{a_t} \left\{ \lambda_t \left[\frac{N_t^\gamma}{1-\gamma} \left((1-\omega)c_t^{1-\frac{1}{\zeta}} + \omega(h_t/P_t^H)^{1-\frac{1}{\zeta}} \right)^{\frac{1-\gamma}{1-\frac{1}{\zeta}}} \right. \right. \\ \left. \left. + \beta E_t \left(v_{t+1}(x_{t+1}) (\exp\{f(t+1, Z_{t+1})\} \nu_{t+1})^{1-\gamma} \right) \right] \right. \\ \left. + (1-\lambda_t) \frac{L^\gamma q_t^{1-\gamma}}{1-\gamma} \left[(1-\omega) \left(\frac{(1-\omega)^\zeta}{(1-\omega)^\zeta + \omega^\zeta (\alpha P_t^H)^{1-\zeta}} \right)^{1-\frac{1}{\zeta}} \right. \right. \\ \left. \left. + \omega \left(\frac{\omega^\zeta (\alpha P_t^H)^{-\zeta}}{(1-\omega)^\zeta + \omega^\zeta (\alpha P_t^H)^{1-\zeta}} \right)^{1-\frac{1}{\zeta}} \right]^{\frac{1-\gamma}{1-\frac{1}{\zeta}}} \right\},$$

subject to

$$c_t > 0, \quad h_t > 0, \quad s_t \geq 0, \quad l_t \leq 1 - \delta,$$

and equations (15) to (17), where $a_t = \{c_t, h_t, s_t, D_t^o, D_t^s\}$ is the normalized vector of choice variables. Hence the normalization reduces the number of continuous state variables to three with P_t^Y no longer serving as a state variable.

We discretize the wealth-labor-income ratio (q_t) into 320 grids equally-spaced in the logarithm of the ratio, the house value-labor income ratio ($\bar{h}_t$) into equally-spaced grids of 160, and the house price (P_t^H) into 160 grids equally-spaced in the logarithm of the price. The boundaries for the grids are chosen to be wide enough so that our simulated time series path always falls within the defined state space.

Under the assumption that only liquidated wealth will be passed along to beneficiaries, the household's house tenure status and housing positions do not enter the bequest function. At the terminal date T , $\lambda_T = 0$, and the household's value function coincides with the bequest function,

$$v_T(x_T) = \frac{L^\gamma q_t^{1-\gamma}}{1-\gamma} \left[(1-\omega) \left(\frac{(1-\omega)^\zeta}{(1-\omega)^\zeta + \omega^\zeta (\alpha P_t^H)^{1-\zeta}} \right)^{1-\frac{1}{\zeta}} + \omega \left(\frac{\omega^\zeta (\alpha P_t^H)^{-\zeta}}{(1-\omega)^\zeta + \omega^\zeta (\alpha P_t^H)^{1-\zeta}} \right)^{1-\frac{1}{\zeta}} \right]^{\frac{1-\gamma}{1-\frac{1}{\zeta}}}. \quad (18)$$

The value function at date T is then used to solve for the optimal decision rules for all admissible points on the state space at date $T-1$.

For a household coming into period t as a renter ($D_{t-1} = 0$), we perform two separate optimizations conditional on house tenure choices – renting or owning – for the current period. A renter's optimal house tenure choice for the current period is then determined by comparing

the contingent value functions of renting and owning. To calculate the expected next period's value function, we use two discrete states to approximate the realizations of each of the three continuous exogenous state variables ($\ln \varepsilon$, $\ln \nu$, and $\tilde{r}_t^H$) by Gaussian quadrature (Taughen and Hussey 1991). Together with two states for the realizations of moving shocks, the procedure results in sixteen discrete exogenous states for numerical integration. For points that lie between grid points in the state space, depending on the household's current period house tenure choice, we use either a two-dimension or a three-dimension cubic spline interpolation to approximate the value function.

For a household coming into period t as a homeowner, we perform an optimization conditional on staying in the existing house for the current period. In this case, the household cannot adjust its house value-income ratio, i.e. $h_t = \bar{h}_t$, but can adjust its numeraire consumption. The value function contingent on moving – either endogenously or exogenously – is the same as the value function of a renter who is endowed with the same wealth-income ratio (q_t) and house price (P_t^H). We compare the value functions contingent on moving and staying to determine the optimal house liquidation decision. Under our assumption and parameterization, a homeowner always has positive amount of equity in his house after home sales and thus has no incentive to default. A homeowner who cannot satisfy the mortgage collateral constraint or afford the house maintenance cost has to sell his home. This procedure is repeated recursively for each period until the solution for date $t = 0$ is found.

Appendix B: Estimation Mechanics in the MSM Estimator

We assume that the “true” parameter vector

$$\theta^* = \{\beta, \gamma, \xi, L, \bar{w}, \mu_h, \mu_{rent}, \omega, \zeta, \phi, \psi\}$$

lies in the interior of the compact set $\Theta \subset \mathbb{R}^{11}$. Our estimator, $\hat{\theta}$, is the value of θ that minimizes the weighted distance between the estimated life cycle profiles for life cycle profiles for wealth, mobility rate, home ownership rate, house value, and rent observed from the data and the simulated profiles generated by the model. We choose to match these five variables, which are interacted with age cohort ($T = 3$) and calendar year ($C = 3$). Additional interactions are used for last three house related variables, which are further interacted with three house price levels in the state where a household resided. This interaction results in additional six moments. The moment count per year and cohort is therefore equal to $11(5+6)$. The overall count of moments is $11 \times C \times T = 33T$. We combine all these moment conditions by stacking them and solving the optimal problems jointly.

Given a data set of I_c independent individuals within a given age cohort c who are observed repeatedly for T periods, let $\delta(\theta)$ denote a vector of moment conditions with $11T$ elements, with $\hat{\delta}$ representing its sample counterpart. The MSM estimator $\hat{\theta}$ is given by

$$\operatorname{argmin}_{\theta} \sum_{c=1}^C \frac{I_c}{1 + \tau_c} \hat{\delta}_{I_c}(\theta)' \widehat{W}_{I_c} \hat{\delta}_{I_c}(\theta), \quad (19)$$

where $\widehat{\mathbf{W}}$ is a $11T \times 11T$ weighting matrix, and τ_c is the ratio of the number of observations in data for cohort c to the number of simulated observations. If the regularity conditions presented in Pakes and Pollard (1989) are met, our MSM estimator $\hat{\theta}$ is both consistent and asymptotically normally distributed:

$$\sqrt{I}(\hat{\theta} - \theta^*) \rightsquigarrow N(0, V),$$

with the variance-covariance matrix $\mathbf{V}$ given by

$$V = (1 + \tau)(\mathbf{D}'\mathbf{W}\mathbf{D})^{-1}\mathbf{D}'\mathbf{W}\mathbf{S}\mathbf{W}\mathbf{D}(\mathbf{D}'\mathbf{W}\mathbf{D})^{-1},$$

where $\mathbf{S}$ is the variance-covariance matrix of the data, and

$$\mathbf{D} = \frac{\partial \delta(\theta)}{\partial \theta'} \Big|_{\theta=\theta^*}, \quad (20)$$

which is the $33T \times 11$ Jacobian matrix of the population moment vector; and $\mathbf{W} = \text{plim}_{T \rightarrow \infty} \rightsquigarrow \{\widehat{\mathbf{W}}_I\}$. Newey (1985) presents the following χ^2 statistic for specification testing the moment estimator.

$$\frac{I}{1 + \tau} \hat{\delta}_I(\hat{\theta})' \mathbf{Q}^{-1} \hat{\delta}_I(\hat{\theta}) \rightsquigarrow \chi_{33T-11}^2,$$

where $\mathbf{Q}^{-1}$ is the generalized inverse of

$$\begin{aligned} \mathbf{Q} &= \mathbf{PSP} \\ \mathbf{P} &= \mathbf{I} - \mathbf{D}(\mathbf{D}'\mathbf{W}\mathbf{D})^{-1}\mathbf{D}'\mathbf{W}. \end{aligned}$$

Analogous to the optimal weighting matrix in a GMM model, the efficiency of our SMM estimator improves as $\widehat{\mathbf{W}}_I$ converges to $\mathbf{S}^{-1}$, which is the inverse of the sample variance-covariance matrix. If $\mathbf{W} = \mathbf{S}^{-1}$, then $\mathbf{V}$ is reduced to $(1 + \tau)(\mathbf{D}'\mathbf{S}^{-1}\mathbf{D})^{-1}$, and $\mathbf{Q}$ is equivalent to $\mathbf{S}$. According to Altonji and Segal (1996), the optimal weighting matrix, though asymptotically efficient, can be severely biased in small samples. We use a diagonal matrix for weighting given our small sample size. Our weighting matrix takes the diagonal terms of the optimal weighting matrix for scaling, while setting the off-diagonal term to be zero. A similar approach is adopted in De Nardi, French, and Jones (2006).

Appendix C: Constructing Labor Income Process

Using PSID households from 1984 to 2005, we eliminate the Survey of Economic Opportunities subsample and households live in public housing project owned by local housing authority or public agency. We further exclude households that neither own nor rent or whose head is female, a farmer or rancher. We use only households whose heads were between 20 and 65 years of age. We regress the logarithm of household labor income on dummy variables for age, marital status, and household composition, using a household fixed effect model. A fifth-order polynomial is used to fit the age dummies in order to obtain the labor income profile, which is presented in Figure 1. Furthermore, the replacement ratio θ in equation (5), which determines the amount of retirement income, was approximated as the ratio of the average of our labor income variable defined above for retiree-headed households to the average of labor income in the last working year.

Following the variance decomposition procedure described by Carroll and Samwick (1997), we first rewrite equation (3) as follows:

$$\varepsilon_d = [\log(Y_{t+d}) - P_{t+d}^Y] - [\log(Y_t) - \log(P_t^Y)], d \in 1, 2, \dots, 22,$$

therefore

$$Var(\varepsilon_d) = d * \sigma_\varepsilon^2 + 2 * \sigma_\nu^2$$

. We then regress $Var(\varepsilon_d)$'s on d 's to obtain estimates on σ_ε^2 and σ_ν^2 .

Appendix D: Constructing House Price Series at State Level

Our state-level house price index (HPI) comes from the Office of Federal Housing Enterprise Oversight (OFHEO). The HPI is a time series price index that is set to 100 for every state for the base year 1980. This price index is thus not comparable cross-sectionally. To create a series of state-level price index that is also cross-sectionally comparable, we utilize the housing price information from the PSID. In particular, we define house prices as prices per square footage of living space. Unfortunately, PSID does not provide information on living space and we have to impute the square footage of homes for our data. Following Flavin and Nakagawa (2007), we first use data from the American Housing Survey (AHS) (1985-2005) to estimate a model of square footage as a function of the number of rooms and other housing characteristics common to both the AHS and the PSID, such as dummy variables representing whether the household was 1) located in a suburb, 2) located in a non-SMA region, 3) living in a mobile home, and a third order polynomial in the number of rooms. Separate models were estimated for each of the four regions (Northeast, Mideast, South, and West). The regional models estimated from the AHS data, reported in Table 1, were then used to generate estimated square footage data for each PSID household. Using these estimates, we predict house sizes for all homeowners in our PSID sample. The nominal house prices per square foot are then obtained by dividing the house value reported from the PSID by the predicted house size. The nominal house prices for individual households are then collapsed by state and year to obtain average house prices. For each state, we can use the imputed nominal price in any year, along with the HPI from OFHEO to calculate the nominal house price for a benchmark year, 1993, which is the midpoint of the time frame of our data. Given the fact that OFHEO and PSID surveyed different random sample of American households, we anticipate that the nominal prices for 1993 converted from different years might vary. We therefore choose to use the median of these converted values. Once the median nominal price is determined for each state in the benchmark year, we can scale the HPI from OFHEO so that the new HPI for each state i in year t as follows, $HPI_{i,t}^{new} = HPI_{i,t}^{OFHEO} * NominalPrice_{i,1993} / HPI_{i,1993}^{OFHEO}$.

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Table 1
Relationship Between House Size and Housing Characteristics
 (Dependent variable: House size in square feet)

Independent Variables	Northeast	Midwest	South	West
Constant	-69.40 (51.47)	89.45 (45.40)	456.46 (34.71)	221.22 (32.85)
Urban	-75.44 (11.55)	-94.50 (8.05)	-91.32 (5.70)	-113.10 (8.47)
MSA	27.62 (14.07)	67.48 (8.09)	41.41 (5.84)	9.76 (8.88)
Mobile home	-492.63 (25.44)	-467.63 (15.46)	-299.46 (8.87)	-236.33 (12.53)
# rooms	282.68 (21.92)	204.28 (19.98)	-40.10 (15.01)	107.60 (13.86)
(# rooms) ²	20.88 (3.12)	27.39 (2.87)	55.90 (2.12)	34.55 (1.97)
(# rooms) ³	-1.55 (0.14)	-1.71 (0.13)	-2.50 (0.09)	-1.70 (0.86)
Adjusted R ²	0.23	0.25	0.30	0.33
Number of observations	77,126	108,727	159,671	94,800

Notes: Data is from 1987 to 2005 biannual American Housing Survey. Robust standard errors are reported in parentheses. We don't report estimates of survey year dummies.

Table 2
Calibrated Parameters

Parameter	Symbol	Value
<i>Demographics</i>		
Maximum life-cycle period	T	55
Mandatory retirement period	J	40
<i>Labor Income and House Price Processes</i>		
Standard deviation of permanent income shock	σ_v	0.14
Standard deviation of temporary income shock	σ_ε	0.29
Income replacement ratio after retirement	θ	0.96
Standard deviation of housing return	σ_H	0.100
<i>Liquid Savings</i>		
Risk-free interest rate	r	0.030
<i>Housing and Mortgage</i>		
Down payment requirement	δ	0.200

Table 3
Estimated Structural Parameters

Parameter	Symbol	Value	Std Err
Discount rate	β	0.933	0.030
Curvature parameter	γ	3.180	0.061
Bequest strength	L	16.805	0.287
Housing service share	ω	0.080	0.003
Intra-temporal elasticity of substitution	ζ	0.751	0.008
Rental premium		0.023	0.004
Housing selling cost	ϕ	0.157	0.006
Housing maintenance cost	ψ	0.046	0.001

Table 4
Robustness Checks

Parameter	Symbol	Value Benchmark	Weighting Matrix	Value Family Size	Value Selling Cost
Discount rate	β	0.933	0.928	0.850	
Curvature parameter	γ	3.180	3.160	5.131	
Bequest strength	L	16.805	17.754	5.036	
Housing service share	ω	0.080	0.091	0.083	
Intra-temporal elasticity of Substitution	ζ	0.751	0.781	0.793	
Rental premium		0.023	0.021	0.036	
Housing selling cost	ϕ	0.157	0.155	0.130	
Housing maintenance cost	ψ	0.046	0.044	0.036	