

CONSUMPTION OVER THE LIFE CYCLE: HOW DIFFERENT IS HOUSING?*

FANG YANG[†]

SUNY-Albany

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Abstract

Micro data over the life cycle show different patterns for consumption for housing and non-housing goods: The consumption profile of non-housing goods is hump-shaped, while the consumption profile for housing first increases monotonically and then flattens out. These patterns hold true at each consumption quartile. This paper develops a quantitative, dynamic, general equilibrium model of life-cycle behavior, that generates consumption profiles consistent with the observed data. Borrowing constraints are essential in explaining the accumulation of housing stock early in life, while transaction costs are crucial in generating the slow downsizing of the housing stock later in life.

JEL Classification: E21, J14, R21

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[†]Mailing Address: Department of Economics, BA 123E, University at Albany, State University of New York, Albany, NY 12222. Email: fyang@albany.edu. URL: www.albany.edu/~fy554862.

1 Introduction

Micro data show different patterns for consumption for housing and non-housing goods over the life cycle. Consumption expenditure on non-housing goods is hump-shaped over the life cycle: It starts low early in life, rises considerably around middle age, and then falls at more advanced ages. On the contrary, household holdings of the housing stock are not hump-shaped: The lifetime profile of housing stock is monotonically increasing and rather flat in old age.

Consider a life-cycle model without leisure, borrowing constraints, and transaction costs in trading housing. Suppose further that households have time-separable preferences for consumption with constant relative risk aversion and constant elasticity of substitution between consumption from housing and that from non-housing. Utility maximization then implies that the ratio of housing to non-housing consumption should not be age-dependent. That is to say, housing consumption should follow the same pattern as non-housing consumption.¹

These stylized facts of life-cycle consumption motivate me to ask which modifications of the basic life-cycle framework could produce consumption profiles that more closely resemble the US consumption profiles. To answer this question, I construct a general equilibrium life-cycle model of consumption and saving that explicitly models housing. Owner-occupied housing has a dual role: It directly provides utility, and it can be used as collateral. In my framework, households face several frictions: uninsurable labor-income risk; borrowing constraints; the lack of an annuity market to insure against an uncertain lifetime; and transaction costs for trading houses. Households save in order to self-insure against labor income and life-span risk, for retirement, and to enjoy services from housing.

¹This implication abstracts from leisure. If leisure has different complementarities with housing than with other goods, then the marginal utility from housing consumption could change differently from the marginal utility of non-housing consumption during the life cycle.

I show that a plausibly parameterized version of my model accounts well for the empirical findings. Some parameters, such as the discount factor, are set so that the model-generated data match aggregate targets. Other parameters are based on existing results from the literature. The model is not calibrated to fit these two life-cycle consumption profiles.

The model generates consumption profiles consistent with the observed life-cycle consumption profiles. The interaction between housing (which can be used as collateral) and borrowing constraints leads to the accumulation of housing stock early in life, while transaction costs tend to slow the decline of the housing stock later in life. Households begin their economic lives without any housing stock. During the early part of their lives, because of the existence of borrowing constraints and the role of housing as collateral, they build housing stock quickly, foregoing non-housing consumption. As households age, they begin to decrease their non-housing consumption because the mortality rates are increasing along the life cycle. The high transaction costs associated with trading houses, however, prevent households from decreasing their housing stock quickly later in life.

In addition to explaining life-cycle consumption profiles, the model is able to generate homeownership rates by age. In the model, as in the data, young agents rent while accumulating financial assets. As time progresses, many households accumulate enough wealth to make a down payment and become homeowners. Homeownership rates continue to be high late in life. The benchmark model also matches observed life-cycle wealth portfolio profiles. In the model, as in the data, young households virtually own no liquid financial assets, but hold a major fraction of their wealth as housing. Later in life, households shift their portfolios to financial assets.

Several mechanisms have been offered in the literature to explain the hump-shaped life-cycle consumption profile, without considering the interaction of housing and non-

housing consumption.² I account for most of these mechanisms in my analysis. I incorporate precautionary saving, borrowing constraints, and mortality risk in my model with housing, and see how each feature affects consumption profiles. Instead of modeling the stochastic process for changes in family size, I directly control for the differences in household size when constructing consumption profiles.

There are several papers studying the consumption pattern in models with durable goods. Fernandez-Villaverde and Krueger (2002) build a life-cycle model to explain the expenditure patterns for durable and nondurable goods. However, their model abstracts from housing transaction costs and cannot generate the slow decline of the housing stock. Heathcote (2002) incorporates home production in an otherwise standard model to account for the drop in consumption at retirement. Neither paper incorporates a housing rental market.

This paper builds on the literature that studies various housing-related issues in an environment with borrowing constraints and transaction costs. Examples include Gervais (2002), Gruber and Martin (2003), Yao and Zhang (2005), Cocco (2005), Diaz and Luengo-Prado (2006), Luengo-Prado (2006), Li and Yao (2007), and Chambers, Garriga and Schlagenhaut (2007, forthcoming).

The paper is organized as follows. In Section 2, I present some empirical results from the Consumer Expenditure Survey (CEX) and Survey of Consumer Finances (SCF) documenting households' consumption and asset accumulation over the life cycle. In Section 3, I present my model. The calibration of the model is presented in Section 4. Section 5 presents the quantitative results of the benchmark model. Section 6 investigates the quantitative importance of the transaction costs, renting shock, down payment, and Social Security. Brief concluding remarks are provided in Section 7.

²Examples include, mortality risk (Hansen and Imrohorglu (2005)), precautionary saving (Carroll and Summers (1991), Carroll (1997), and Gourinchas and Parker (2002)), borrowing constraints (Hubbard, Skinner and Zeldes (1994)), variations in household size (Attanasio and Weber (1995), Attanasio, Banks, Meghir and Weber (1999), and Browning and Ejrnaes (2002)), and the substitutability of leisure and consumption (Bullard and Feigenbaum (2007)).

2 Empirical Findings

This section presents empirical evidence on non-housing and housing consumption over the life cycle.³ Consumption data from the CEX and asset data from the SCF is used to construct synthetic cohorts from each data set. I use the age of each household's reference person to define cohorts and follow them through the whole sample, generating a panel. I adjust the data for the change in household size using equivalence scales, which quantify the change in consumption expenditure needed to keep the welfare of families constant regardless of its size (see, for example, Zeldes (1989), and Blundell, Browning and Meghir (1994)).⁴ I then control for cohort, time, and age effects by employing a semi-nonparametric partially linear model following Fernandez-Villaverde and Krueger (2006). All values are denoted in 1983 dollars. Appendix 8.2 describes those two data sets, the equivalence scales used, and the estimation procedure in greater detail.

Consider, first, the life-cycle profile of non-housing consumption per adult-equivalent for renters. Figure 1 plots the household annual non-housing consumption per adult-equivalent against the age of the renting households' heads.^{5, 6} We observe that the average non-housing consumption for renters increases until age 25, flattens out, and then decreases late in life. The ratio of consumption expenditure between the peak and the beginning of the life cycle is around 1.49. Mean consumption is higher than the median and lower than the 3rd quartile at each age, indicating that the distribution of consumption at each age is skewed to the right.

³I differentiate goods and services into housing and non-housing categories. Housing has unique features: It is durable, therefore, household out-of-pocket expenditure on housing is not equal to its service flow; housing can be used as collateral to borrow in financial markets; and it incurs large transaction costs when traded. Other durables are included in the non-housing consumption category. They depreciate much faster than housing and are of less importance as assets in most household portfolios.

⁴The profiles without controlling for household size are similar. The results are available from the author.

⁵The sample is divided into owners and renters before estimation. To be consistent with the endogeneity, the model I propose in Section 3 allows the endogenous choice of renting or owning.

⁶Each graph is scaled so that the curves pass through the average values in the data at age 40.

Now, consider the life-cycle profile of non-housing consumption for homeowners. Figure 2 plots the household annual non-housing consumption per adult-equivalent against the age of the homeowners' heads. The estimated consumption profile is hump-shaped and has a peak at age 51. The ratio of consumption expenditure between the peak and the beginning of the life cycle is around 1.56. The consumption expenditure on non-housing goods declines later in life.

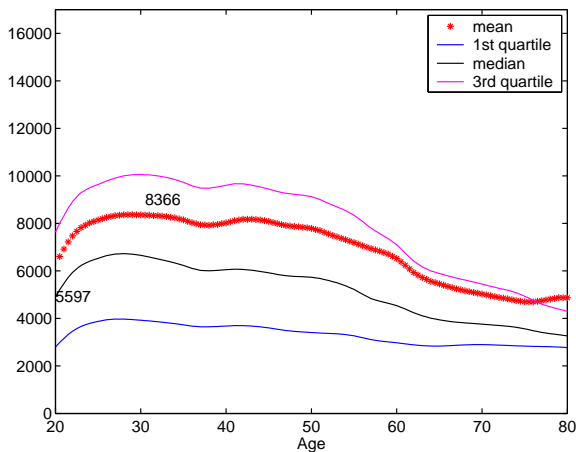


Figure 1: Renter's non-housing consumption (adult equivalent)

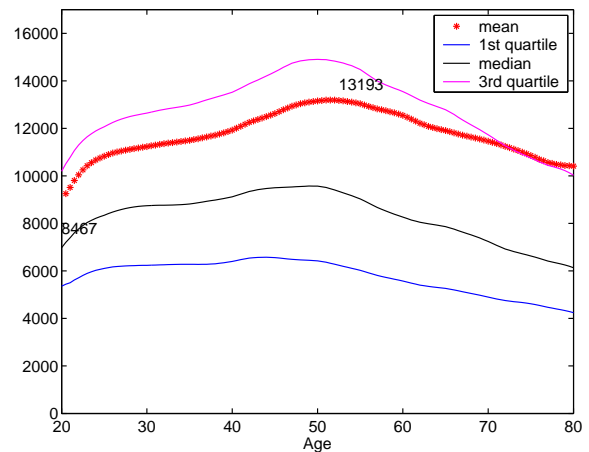


Figure 2: Owner's non-housing consumption (adult equivalent)

Now, consider consumption on housing. Figure 3 plots renters' annual per-adult-equivalent expenditure on housing goods (rent of dwelling and rent as pay) against age.⁷ Estimated housing consumption increases quickly and then flattens out. Also, mean consumption is higher than the median at each age, indicating that the distribution of housing consumption at each age is also skewed to the right.

Figure 4 plots estimated housing stock per adult-equivalent over the life cycle for homeowners from the SCF at the mean, and at each quartile. The estimated housing value increases until age 65, and then flattens out until the end of the life cycle. That is to say, if the service flow from housing is proportional to housing stock, then per-adult-equivalent consumption is proportional to housing stock, and consumption from

⁷This measure of housing consumption may be biased upwards. It may include items, such as utilities, heating, garage or parking facilities, or furnishings in addition to shelter, which can not be separated in CEX.

housing is not hump-shaped.⁸

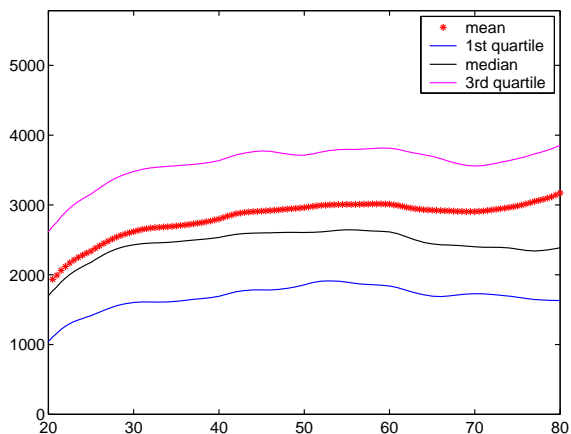


Figure 3: Housing consumption per adult-equivalent (renter)

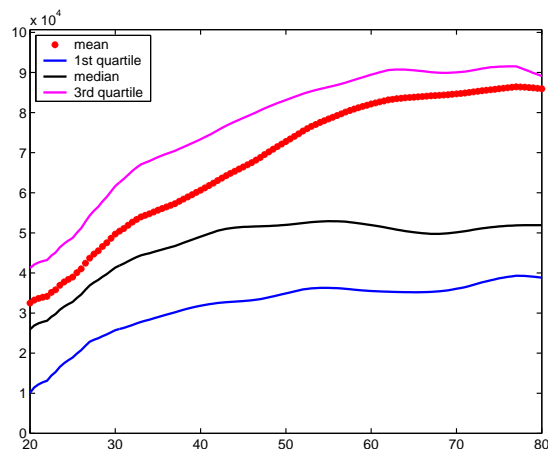


Figure 4: Housing consumption per adult-equivalent (owner)

The finding that elderly households do not decrease their housing consumption is consistent with the empirical findings from other literature. For example, Feinstein and McFadden (1989) suggest that more than one-third of elderly households live in dwellings with at least three more rooms than the number of inhabitants, and are thus consuming a large share of housing services per adult-equivalent. Fernandez-Villaverde and Krueger (2006) show that, when controlling for time and cohort effects, market-valued housing service increases until age 55, decreases slightly, and flattens out until the end of the life cycle.

The different patterns for housing and non-housing consumption over the homeowners' life cycle contradicts a key prediction of the standard life-cycle model which excludes market frictions, age-dependent utility of consumption, or home production. The standard model implies that the ratio of housing to non-housing consumption should not be age-dependent. That is to say, consumption of housing should follow

⁸This measure of housing consumption can include both shelter services and consumption of other goods for which the house provides access. For example, housing values for the elderly can include value from accessing 24/7 health services in the community. I thank a referee for pointing this out. Alternative ways to measure housing consumption include square footage (Chambers, Garriga and Schlagenhaut (forthcoming)).

the same pattern as non-housing consumption.⁹

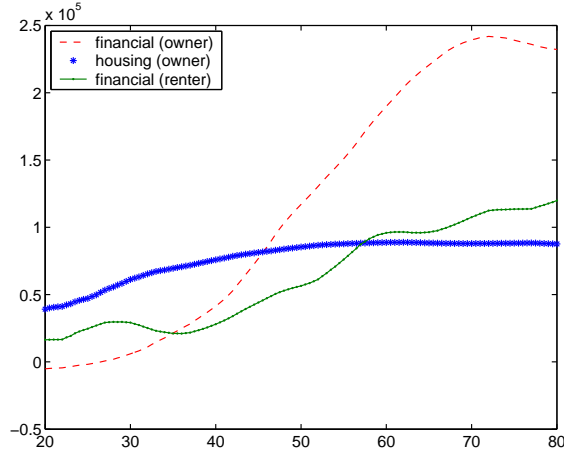


Figure 5: Age profile of wealth composition

Next, I show the patterns for wealth accumulation and portfolio composition over the life cycle. Figure 5 plots mean housing stock and financial assets against age for renters and owners. Renters on average hold much less financial wealth than owners. Figure 5 shows that, early in life, households borrow to buy houses, and thus save in the form of housing. As time goes by, homeowners have accumulated stocks of housing and begin to increase their holding of financial assets. The profiles of financial assets and housing assets for homeowners intersect in their early 40s. However, I do not observe a rapid decline in wealth later in life. Instead, homeowners continue to hold large amounts of wealth into very old age.

3 The Model

The economy is a discrete-time overlapping generations world with an infinitely lived government. The government taxes labor earnings and provides Social Security benefits to retirees. There are uninsurable idiosyncratic income shocks. The only financial instrument is a one-period bond. Owner-occupied housing has a dual role: It provides utility as a consumption good, and it can be used as collateral so that the borrowing

⁹see Appendix 8.1 for more details.

limit of each household depends on the value of the house. The purchase or sale of a house incurs transaction costs. Renters, on the other hand, can change the quantity of their housing services without paying any transaction costs.

3.1 Technology and Timing

There is one type of good produced according to the aggregate production function $F(K; L) = K^\alpha(AL)^{1-\alpha}$, where K is the aggregate capital stock and L is the aggregate labor input. Labor-augmenting technical progress, given by A , grows at a constant rate g . The final good can be consumed, invested in physical capital, or transformed into housing. Physical capital and housing depreciate at rates δ^k and δ^h , respectively.

At the beginning of each period, households observe their idiosyncratic earning shocks and may receive a bequest. Next, labor and capital are supplied to firms and production takes place. After production, households receive factor payments and make their consumption and asset allocation decisions. At the end of the period, housing depreciates, and uncertainty about early death is revealed. Accidental bequests from those early death are distributed to new agents in the next period.

3.2 The Rental Market

Following Gervais (2002), there is a two-period-lived financial institution that supplies rental housing.¹⁰ At the end of first period, it accepts deposits and buys residential capital. In the second period, it repays deposits with interest at rate r . Residential capital is rented to agents at a price p^h per unit. At the end of the second period, the financial institution sells the undepreciated residential stock to a new agency. The

¹⁰Chambers, Garriga and Schlagenauf (2007, forthcoming) propose an alternative model of the rental market, allowing only households to supply rental housing.

no-arbitrage condition implies that the rental rate on housing is given by

$$(1) \quad p^h = r + \delta^h.$$

3.3 Demographics

During each model period, a continuum of people is created. They immediately begin working and consuming. Each agent retires at $t = T_r$ and dies by the end of age T . Each person faces a positive probability of dying, given by $(1 - p_t)$. The probability of dying is exogenous and independent of other household characteristics. The population grows at rate n . Since the demographic patterns are stable, agents at age t make up a constant fraction of the population at any point in time.

3.4 Consumer's Maximization Problem

3.4.1 Preferences

Individuals derive utility from consumption of non-housing goods, c , and from the service flow of the housing, s . Preferences are assumed to be time separable, with a constant discount factor β . The momentary utility function from consumption is of the constant relative-risk aversion class given by

$$(2) \quad U(c, s) = \frac{g(c, s)^{1-\eta} - 1}{1-\eta},$$

with the two kinds of consumption aggregated as

$$(3) \quad g(c, s) = (\omega c^\sigma + (1 - \omega)s^\sigma)^{\frac{1}{\sigma}}.$$

3.4.2 Labor Productivity

In this economy, all agents of the same birth cohort face the same exogenous age-efficiency profile, ϵ_t . Each worker i also faces stochastic productivity shocks y_t^i , which follows a Markov process

$$\ln y_t^i = \rho_y \ln y_{t-1}^i + \varepsilon_t^i, \quad \varepsilon_t^i \sim N(0, \sigma_y^2).$$

This Markov process, Q_y , is the same for all households so that there is no uncertainty over the aggregate labor endowment. The total productivity of a worker at age t is given by the product of the worker's age- t productivity shock and age- t deterministic efficiency index: $y_t^i \epsilon_t$.

After age T_r , households retire and receive Social Security income. I assume the Social Security benefits level is a function of the household's income in the last period before retirement.¹¹

3.4.3 Transaction Costs

Due to the heterogeneity and the spatial fixity of housing, both potential buyers and sellers in the housing market are forced to spend considerable amounts of time and resources to acquire information about the value of a specific housing unit. As a consequence, there are both implicit and explicit search costs associated with moving (Chinloy (1980)). These include the opportunity costs of time associated with market search, brokerage and agent fees, recording fees, legal fees, and origination fees. Moreover, households have to physically move to a new house, which entails moving costs and psychological costs of changing neighborhoods (Smith, Rosen and Fallis (1988)).

I consider non-convex transaction costs in the housing stock, similar to those in

¹¹A more realistic assumption is that the Social Security benefit is a concave function of the accumulated lifetime contributions. Under this assumption, however, the accumulated contribution becomes a state variable, which increases the computation time dramatically.

Grossman and Laroque (1990). The specification of the transaction costs is

$$(4) \quad \tau(h, h') = \begin{cases} 0 & \text{if } h' \in [(1 - \mu_1)h, (1 + \mu_2)h] \\ \rho_1 h + \rho_2 h' & \text{otherwise.} \end{cases}$$

This formulation of transaction costs allow households to change their level of housing consumption without moving by undertaking housing renovation up to a fraction of μ_2 of the value of the house, or by allowing depreciation up to a fraction of μ_1 of the value of the house. If the house depreciates by more than a fraction μ_1 of the value, or appreciates by more than a fraction μ_2 of the value, I assume that the house has been sold. In those cases, the household must pay the transaction costs as a fraction ρ_1 of its selling value and ρ_2 of its buying value.

3.4.4 Borrowing Constraints

I assume that only collateralized credit is available and that the borrowing interest rate, mortgage interest rate, and deposit interest rate are all equal. This implies that mortgages and deposits are perfect substitutes. I use a_t to denote the net asset position. To buy a house, a household must satisfy a minimum down payment requirement equal to a fraction θ of the value of the house. Housing also serves as collateral for loans (through home equity loans or refinancing) up to a fraction $(1 - \theta)$. Therefore, at any given period the household's financial assets must satisfy¹²

$$(5) \quad a' \geq -(1 - \theta)h'.$$

¹²For a household without a house, the borrowing constraint reduces to the standard form $a' \geq 0$.

In addition, to rule out negative bequests, net worth is bounded below by 0 according to

$$(6) \quad (1 + r)a' + (1 - \delta^h)h' \geq 0.$$

3.4.5 Renting Shock

In a model where households differ only by age, income, and wealth, rich households tend to be homeowners and poor tend to be renters. In the US, a fraction of rich households are renters. As reported by the Bureau of Labor Statistics in 2000, 12% of households whose income is in the top quintile are renters, and 25% of those whose income is in the fourth quintile are renters. The existence of high-income renters may be due to heterogeneity in house prices, job mobility, preferences, or family composition. For example, a high-income household that lives in a city, where house prices are much higher than the national average, might not be able to afford to buy a house. Additionally, an individual who dislikes the responsibility of owning a home or is likely to move to another city for work might choose to be a renter.

To capture factors other than age, income, and wealth that affect household's renting/owning decision, I assume households face renting shocks. A household who receives a renting shock is not allowed to own and can only rent. Let q_t denote the probability of receiving a renting shock at age t . The shock is exogenous and independent of other household characteristics.

3.4.6 The Household's Recursive Problem

In a stationary equilibrium, the interest rate is constant at r and the wage rate w is growing at rate g . The household's state variables are given by (m, t, a, h, y) , which denote the agent's renting shock, age, financial assets, housing stock carried from the

previous period, and labor productivity, respectively.¹³ If $h = 0$, then this household was renting in the previous period. If $m = 1$, then this household is not allowed to own a house. Denote $V(0, t, a, h, y)$ as the value function of an agent in state $(0, t, a, h, y)$. If $m = 0$, the consumer chooses whether to rent or to be a homeowner by comparing the value of being a homeowner, $V^o(t, a, h, y)$, against the value of renting a house, $V^r(t, a, h, y)$, so that, $V(0, t, a, h, y) = \max\{V^o, V^r\}$. If $m = 1$, the household can only rent, and thus $V(1, t, a, h, y) = V^r(t, a, h, y)$. If the agent chooses to rent, then

$$(7) \quad V^r(t, a, h, y) = \max_{c, a', s} \left\{ U(c, s) + \beta p_t \left((1 - q_t) E(V(0, t+1, a', 0, y')) + q_t E(V(1, t+1, a', 0, y')) \right) \right\}$$

subject to

$$(8) \quad \begin{aligned} c + a' + p^h s + \tau(h, 0) &= Y(t, y) + (1 + r)a + (1 - \delta^h)h + b_t, \\ c &\geq 0, \quad s \geq 0, \quad a' \geq 0, \end{aligned}$$

where $Y(t, y)$ denotes earnings after taxes. In any subperiod, an agent's resources depend on asset holdings, a , labor endowment, $\epsilon_t y$, housing stock, h , and received bequests, b_t . Government taxes labor income below e_{max} at the rate τ_l , so that $Y(t, y_t) = w(1 + g)^t \epsilon_t y - \tau_l (1 + g)^t \min(w \epsilon_t y, e_{max})$. After retirement agents receive Social Security benefits, which are a function of the income level at $T_r - 1$. The constraints for retired agents are given by (8), and

$$(9) \quad c + a' + p^h s + \tau(h, 0) = P(y_{T_r-1}) + (1 + r)a + (1 - \delta^h)h + b_t.$$

If the agent chooses to own, then

¹³As a result of homotheticity, policy functions and value functions of a household born one period later is scaled up by g .

(10)

$$V^o(t, a, h, y) = \max_{c, a', h'} \left\{ U(c, h') + \beta p_t ((1 - q_t) E(V(0, t+1, a', h', y')) + q_t E(V(1, t+1, a', h', y'))) \right\}$$

subject to (5), (6), and

$$(11) \quad \begin{aligned} c + a' + h' + \tau(h, h') &= Y(t, y) + (1 + r)a + (1 - \delta^h)h + b_t, \\ c &\geq 0, \quad h \geq \underline{h}, \end{aligned}$$

where \underline{h} is the minimum house size available for purchase. After retirement, the constraints are given by (5), (6), (11), and

$$(12) \quad c + a' + h' + \tau(h, h') = P(y_{T_r-1}) + (1 + r)a + (1 - \delta^h)h + b_t.$$

3.4.7 Definition of Stationary Equilibrium

A formal definition of a stationary equilibrium is provided in Appendix 8.3. The model is solved numerically. Appendix 8.4 describes the computation algorithm in greater detail.

4 Calibration

Some parameters used in the benchmark model are based on estimates in other studies. The remaining parameters are chosen so that the data generated by the model's equilibrium match a given set of aggregate targets. None of the parameters are calibrated against the life-cycle consumption profiles.

One period in the model is equal to 5 years. At age 25, each person enters into the model. The retirement age T_r is set to be age 65, and the maximum life expectancy T

is set to be 85. The rate of population growth, n , is set to equal the average population growth from 1950 to 1997 from the Economic Report of the President (1998). The p_t s is the vector of conditional survival probabilities. I use the mortality probabilities for people born in 1960, weighted by gender.¹⁴

| Parameters | Calibrations |
|--|---------------------------------|
| Demographics | |
| T maximum life expectancy | 85 |
| T_r retirement age | 65 |
| n annual population growth | 1.2% |
| p_t survival probability | see text |
| Technology | |
| g annual productivity growth | 1.6% |
| α capital share in National Income | 0.263 |
| δ^k annual depreciation rate of capital | 5.9% |
| δ^h annual depreciation rate of housing | 1.4% |
| Endowment | |
| ϵ_t age-efficiency profile | see text |
| ρ_y AR(1) coefficient of 5-year income process | 0.85 |
| σ_y^2 innovation of 5-year income process | 0.30 |
| Government policy | |
| τ_l Social Security tax | 9.55% |
| e_{max} Social Security tax cap | 1.33 of annual household income |
| P Social Security benefit | see text |
| Housing market | |
| \underline{h} minimum housing price | 1.4 of annual household income |
| θ down payment rate | 0.1 |
| q_t renting shock probability | 10% |
| ρ_1 transaction costs of selling a house | 7% |
| ρ_2 transaction costs of buying a house | 2.5% |
| μ_1 maximum depreciation | 7% |
| μ_2 maximum renovation | 7% |
| Preference | |
| η risk aversion coefficient | 1.5 |
| σ substitutability of housing and non-housing | 0 |
| ω weights of non-housing in utility function | 0.90 |
| β discount factor | 0.93 |

Table 1: Parameters used in the benchmark model

I choose an average productivity growth of 1.6% annually. I construct measures of output Y , capital K , housing H , and their investment counterparts using data from the National Income and Product Accounts (NPIA) and the Fixed Assets Tables (FAT) for

¹⁴The reason that I use birth cohort of 1960 is that the youngest cohort in the SCF was born in 1957-1962. I use weighted mortality probability because the model is a gender neutral model.

the years 1959-2001. Aggregate ratios for the US economy are calibrated to explicitly consider the existence of housing that comprises residential assets. Output is defined as measured gross domestic product (GDP) minus housing services plus government capital income. Capital is defined as the sum of nonresidential private and government fixed assets plus the stock of inventories. The housing stock is defined as the stock of private and government residential assets plus the stock of inventories. Investments in capital and in housing are defined as changes in stocks. The term α is the share of income that goes to the nonresidential stock of capital and is set at 0.263. This capital share is lower than that in other calibrations which abstract from housing. I calibrate δ^k to be 5.9% and δ^h to be 1.4%. The rate r is the interest rate on capital net of depreciation and is 8.2%. Appendix 8.5 explains the rationale behind these choices in greater detail.

The deterministic age-profile of the unconditional mean of labor productivity, ϵ_t , is taken from Emre (2007), who estimates household-level age-efficiency profiles. The persistence ρ_y and variance σ_y^2 of the stochastic productivity process are estimated from Panel Study of Income Dynamics data, aggregated into 5 years in order to be consistent with the model period (Altonji and Villanueva (2002)).¹⁵ The persistence is low and variance is high because this refers to income in a 5-year period. The discretized income process produces a cross-sectional income distribution that is similar to the data reported in De Nardi (2004).

The retirement benefit is calculated to mimic the Old Age and Survivor Insurance component of Social Security system. Let n_t denote earnings at age t , normalized by average household income and capped at the maximum earnings level: $n_t = \min(w\epsilon_t y, e_{max})$. Let n denote the annual average of the highest 7 earnings realizations (35 highest years of earnings) of n_t . The Social Security benefit is equal to

¹⁵De Nardi (2004) provides a detailed discussion of the estimation process.

$$\left\{ \begin{array}{ll} 0.9n & n < 0.112 \\ 0.1008 + 0.32(n - 0.112) & 0.112 < n < 0.673 \\ 0.2803 + 0.15(n - 0.673) & 0.673 < n < e_{max} \end{array} \right\}.$$

The Social Security income cap is $e_{max} = 1.33$. The bending points, marginal rates, and Social Security income cap are calculated from the Social Security Handbook (2003).¹⁶ The variable $P(y_{T_r-1})$ is calculated as the average retirement benefit among all agents with the same income level at $T_r - 1$.¹⁷ The labor income tax for earnings below the Social Security income cap, $\tau_l = 9.55\%$, is chosen to balance the government budget.¹⁸

Accidental bequests are first distributed to new agents at age 25 to reproduce the distribution of capital endowments for households at age 24-25 according to SCF 1998 data.^{19, 20} The remaining bequests are then distributed evenly to new agents at age 25, which endogenously determines b_t .

The down payment rate θ is set to be 0.1, which is commonly used in the housing literature. Recently, some households have been allowed to purchase houses without much initial wealth. However, Caplin, Chan, Freeman and Tracy (1997, p. 31) argue that “it is almost impossible for a household to buy a home without available liquid assets of at least 10% of the home’s value”. I show the effect of the down payment rate in Section 6. The probability of receiving a renting shock is chosen to be 10%, and I

¹⁶According to the 2000 Social Security rules, the Social Security cap is \$76,200. Marginal rates are 0.90, 0.32, 0.15 and bend points of average indexed monthly earnings are \$531 and \$3,202. I multiply these bend points by 12 and normalize them with the mean household income for 2000, \$57,135 (from the Census).

¹⁷I first calculate the joint distribution of earnings along the life cycle from the model. Then I calculate the distribution of n and Social Security benefits at age $T_r - 1$.

¹⁸Since the model focuses on retirement benefits, this rate should be compared with payroll taxes excluding the Medicare and Disability Insurance (10.6%). Under current benefit and tax system, the current Social Security system has surplus, while the model imposes a balanced Social Security budget and thus implies a lower payroll tax rate.

¹⁹The purpose of this procedure is to generate some heterogeneity at the beginning of the life cycle. Otherwise, income will be the only factor to determine the renting/owning decision for agents at age 25. Assuming that all households start with zero capital does not change the results noticeably.

²⁰Since the model does not allow negative wealth, negative wealth holdings in the data are treated as zero. Most households start with wealth endowments close to zero.

show the effect of this parameter in Section 6.

Since one of my main goals is to look at the effect of transaction costs on consumption and saving decisions, one key calibration is the type of transaction costs that I choose. Gruber and Martin (2003) estimate the reallocation cost of tax and agency costs from CEX and find the median household spends 7 percent of a house's value to sell it and 2.5 percent to purchase. In my simulation, I choose transaction costs from sales to be $\rho_1 = 7\%$ and from purchases to be $\rho_2 = 2.5\%$. Davidoff (2006) shows that homeowners over age 75, compared with younger owners of similar homes, spend about 0.8 percent of home value less per year on routine maintenance. I choose a big range and set $\mu_1 = \mu_2 = 5\delta_h$. That is to say, households can change their level of housing consumption by allowing depreciation or renovation up to 7% of the value of the house as an alternative to moving. I show the effects of μ_1 and μ_2 in Section 6.

I take the risk aversion parameter, η , to be 1.5, from Attanasio, Banks, Meghir and Weber (1999), and Gourinchas and Parker (2002), who estimate it from consumption data. This value is in the commonly used range (1-5) in the literature. The parameter σ governs the elasticity of substitution between housing and non-housing. Ogaki and Reinhart (1998) use aggregate data and a similar specification, and obtain an estimated $\sigma = 0.145$, not significantly different from zero. Therefore, I choose σ to be 0 so that the momentary utility function $g(c, h)$ takes the Cobb-Douglas form. I show the effect of the elasticity of substitution between housing and non-housing in Section 6.

The remaining parameters are chosen so that the model-generated data match a given set of aggregate targets. I choose β , ω , and \underline{h} to match the capital-output ratio of 1.86, housing-output ratio of 1.19, and homeownership rate of 67.6%.²¹

²¹The first two are calculated using NIPA and FAT and the last is calculated from CEX 1984-2000 using samples of households whose heads were between age 25-90 in each year.

5 Numerical Results

This section studies the implications of the model economy for homeownership rates by age, and for the life-cycle consumption and wealth profiles for both homeowners and renters. All figures are normalized by average household income.

5.1 Homeownership

Figure 6 compares the fraction of homeowners at each age in the model with that estimated from CEX. In the model, as in the data, young agents rent while accumulating financial assets. As time progresses, more households have accumulated sufficient funds for down payments to become homeowners. Homeownership rates continue to be high late in life. In this model, renting has several advantages over owning. First, since there is no minimum size in rental units, relatively poor households can rent relatively small units rather than buy a large one. Second, renters can adjust housing consumption without paying transaction costs for trading houses. On the other hand, owning might dominate renting. Owned housing can be used as collateral and relaxes borrowing constraints. Also, in the absence of indivisibility and transaction costs of owner-occupied units, the cost of buying is $1 - \frac{1-\delta^h}{1+r} = \frac{r+\delta^h}{1+r}$, which is lower than the cost of renting, $p^h = r + \delta^h$, when the interest rate is positive. For young agents, who face future income shocks and on average receive lower income than middle-aged agents, renting is more attractive than owning. Once agents have accumulated a down payment and most uncertainty in income has been revealed, they choose to own.

5.2 Life-cycle Profiles of Consumption

Figures 7 and 8 compare the life-cycle profiles of average non-housing and housing consumption in the model with those in the data reported in Section 2.²² Housing

²²Discussions of the distributions of consumption by age are provided in Appendix 8.6.

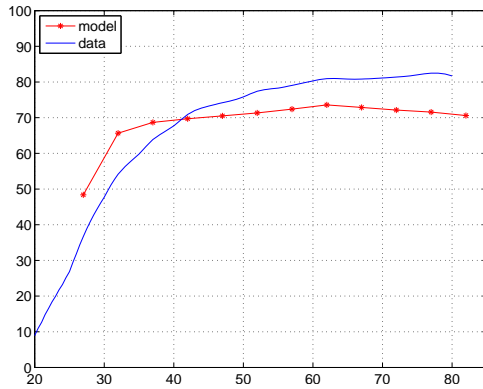


Figure 6: Homeownership rates by age

consumption for renters is transformed into housing value using the same p^h as in the model. In the model, the family size is constant, so I use the per-adult-equivalent non-housing and housing consumption data and multiply them by the average number of equivalent adults.²³ I adjust the results from the model so that aggregate non-housing consumption and the aggregate housing stock are the same in the data as in the model.²⁴ From Figure 7, we see that average non-housing consumption for homeowners is hump-shaped and peaks at age 60. Non-housing consumption at age 60 is 90% more than that at age 25. After the peak, non-housing consumption decreases steadily with age. Non-housing consumption at age 60 is 29% more than that at age 80. Facing an increasing future income profile, young agents would like to borrow to finance their current consumption but they are borrowing-constrained. This explains why early in life consumption increases as income does. As households age, they start to decrease their non-housing consumption due to the fact that the mortality rates are increasing along the life cycle. Since there are no perfect annuity markets to insure against mortality risk, old agents discount their future consumption at a higher rate. This implies that the consumption profile is declining later in life. Compared with the

²³I multiply non-housing consumption for renters and for owners in the data by 1.44 and 1.56, respectively. I multiply housing consumption for renters and for owners in the data by 1.14 and 1.16, respectively.

²⁴In the model, I match aggregate consumption to its value in the NIPA. Compared with NIPA, CEX underreports consumption (Attanasio, Battistin and Ichimura (2004)) and SCF overreports housing value. Thus, I multiply non-housing consumption in the model by 0.68 and housing consumption by 1.8.

data, the model under-predicts non-housing consumption for renters.

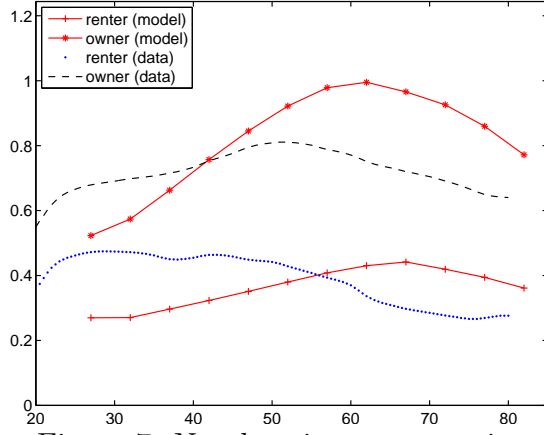


Figure 7: Non-housing consumption

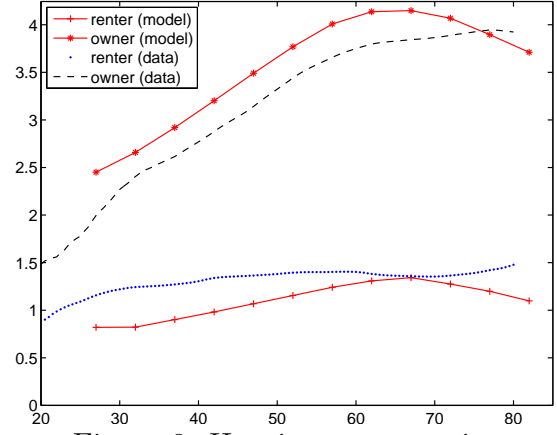


Figure 8: Housing consumption

The housing consumption profile in the model reproduces the empirically observed profiles, increasing early in life and downsizing slowly later in life. Households begin their economic lives without any housing stock. During the early part of their lives, because of the existence of borrowing constraints and the role of housing as collateral, they build housing stock quickly, foregoing non-housing consumption. Agents build up their highest housing stock at age 65. The elderly do not decrease their housing stock until very late in life.

The introduction of transaction costs induces agents to reduce the frequency of transactions in the housing market. Agents do not change their stock of housing by moving unless their non-housing assets and housing stocks are too unbalanced. Given any level of housing stock, there is a wide range of non-housing assets within which households will not move to adjust their housing stock. The inactive region can be defined by two boundaries, $(a_L(h), a_H(h))$. If a household with a housing stock of h holds non-housing assets greater than the upper boundary $a_H(h)$, the household will move to a bigger house in the next period and hold a smaller fraction of non-housing assets in the wealth portfolio. If instead it holds non-housing assets less than the lower boundary $a_L(h)$, the household will move to a smaller house next period and hold a larger fraction of non-housing assets in the wealth portfolio. The size of the

inactive region differs across ages and income and also is affected by parameters such as the size of transaction costs. Figure 9 shows the boundaries of the inactive region for a 70-year-old agent, for a 65-year-old agent, and for a 45-year-old agent each with the median income. Even for relatively small transaction costs, those inactive regions are quite large. One reason that the upper and lower bounds for a 65-year-old agent are higher than a 70-year-old agent is because a 65-year-old agent has a longer life expectancy and needs more financial assets to support non-housing consumption. The same large amount of financial assets could trigger a 70-year-old household to upgrade to a large house, but might not trigger a 65-year-old household to upgrade. Similarly, the upper bound for a 45-year-old agent is higher than a 65-year-old agent. However, the lower bound for a 45-year-old agent is lower than a 65-year-old agent at low level of housing assets. This can be explained by the different levels of income by age. The median income at age 45 is highly than that at age 65. A higher income level may lower the upper and lower boundaries. At lower level of housing assets, the effect of higher income level dominates the effect of life expectancy, thus the lower bound for a 45-year-old agent is lower than a 65-year-old agent. At higher level of housing assets, the effect of higher income level is dominated by the effect of life expectancy, thus the lower bound for a 45-year-old agent is higher than a 65-year-old agent.

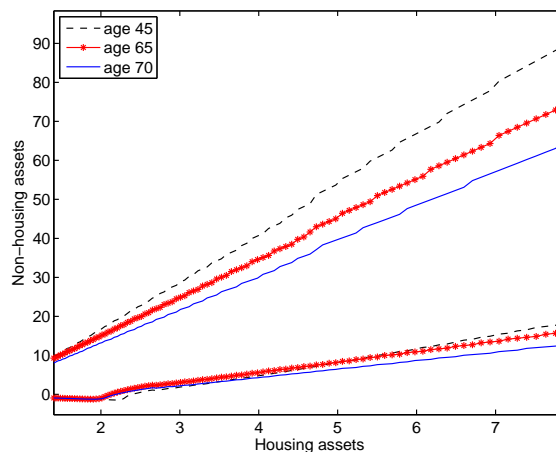


Figure 9: Boundaries of inactive zones

The existence of transaction costs affects young agents and old agents differently. Young households face increasing income profiles and would like to purchase large houses, but they lack the non-housing assets to make the down payment. As a result, they have to increase their housing stock fairly often. As households age and their income profile stabilizes, households prefer a constant level of housing stock, given that trading of housing stock would incur transaction costs. In addition, old households are less likely to move than young households, because they can only live in the new house for a relatively short period of time. Table 2 shows the fraction of households moving at the beginning of each period for each age group. Moving rates by age are calculated from the 2005 Current Population Survey (CPS).²⁵ We see moving rates for all households, and for owners both decline with age in the model, as in the data. Moving rates for all households in the model are slightly higher than in the data. One reason is that in the model renters do not pay costs when moving and thus change their housing consumption very often.

| Age | 25 | 30 | 35 | 40 | 45 | 50 | 55 | 60 | 65 | 70 | 75 | 80 |
|---------------|----|----|----|----|----|----|----|----|----|----|----|----|
| Data (all) | 70 | 61 | 48 | 39 | 31 | 26 | 24 | 22 | 18 | 17 | 15 | 16 |
| Model (all) | - | 62 | 48 | 45 | 44 | 43 | 41 | 39 | 34 | 22 | 19 | 17 |
| Data (Owner) | 58 | 51 | 40 | 30 | 24 | 20 | 19 | 18 | 15 | 13 | 10 | 10 |
| Model (Owner) | - | 43 | 24 | 22 | 20 | 20 | 19 | 17 | 10 | 9 | 9 | 9 |

Table 2: Moving rates by age (in percentage)

5.3 Life-cycle Profiles of Wealth Composition

Figures 10 and 11 display the evolution of the wealth portfolio over the life cycle. Young agents, who start with little wealth and expect to have much higher earnings in the future, do not hold much wealth. Early in life, households borrow as much as possible to buy houses, and thus save in the form of housing. As time goes by,

²⁵CPS records whether the respondent had changed residence in the past five years. Those who reported that they were living in the same house as five years ago were considered non-movers. I thank a referee for the suggestion.

agents accumulate stocks of houses and start to increase their holding of financial assets. The profile of financial assets and housing assets intersect in the early 40s, slightly earlier than what is observed in the data. Wealth holding peaks at age 65, the year at retirement. After retirement, households start to use their assets to finance consumption. Compared with the data, the financial assets profiles for both owners and renters have humps that are more pronounced. In fact, at a very old age, homeowners borrow against their homes and take on debt. Since I abstract from bequest motives, health expenditure uncertainty or other shocks, old agents in my model do not have bequest or precautionary saving motives and run down their assets much more quickly than in the data.²⁶

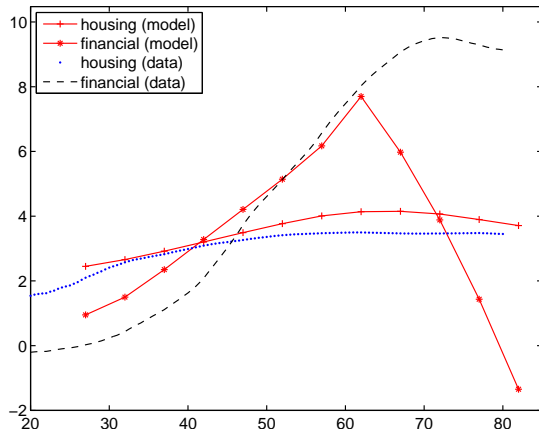


Figure 10: Life-cycle patterns for wealth composition (owner)

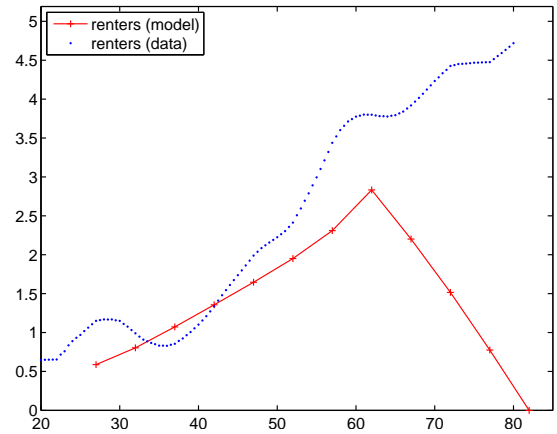


Figure 11: Life-cycle patterns for financial assets (renter)

6 Decomposition

Given that the benchmark model does a good job in generating the different patterns for housing and non-housing consumption and the evolution of asset composition, it is useful to investigate how each ingredient of the model affects the results. I change

²⁶The risk of incurring substantial medical expenses such as out-of-pocket medical expenses and uninsurable nursing home expenses might generate precautionary savings and affect the wealth profile (De Nardi, French and Jones (2005)). The effect of medical costs on the life-cycle consumption and saving in an environment with housing is left for future research.

one parameter at a time, keeping other parameters as in the benchmark economy. To measure the evolution of consumption and assets over the life cycle, I report the average homeownership rate, and non-housing consumption at the peak (age 60) relative to that at age 25 and age 80 ($\frac{c_{60}}{c_{25}}$ and $\frac{c_{60}}{c_{80}}$), and housing consumption at the peak (age 65) relative to that at age 25 and age 80 ($\frac{h_{65}}{h_{25}}$ and $\frac{h_{65}}{h_{80}}$). I also show the ratio of housing to financial assets at age 65 ($\frac{h_{65}}{a_{65}}$), and assets at age 65 relative to that at age 25 and age 80 ($\frac{a_{65}}{a_{25}}$ and $\frac{a_{65}}{a_{80}}$).²⁷

6.1 Transaction Costs

First, I investigate the effects of transaction costs on household consumption and asset holdings by setting the costs to 0. Line 2 in Table 3 shows that in a model without transaction costs, more households, mostly young households, become homeowners since removing transaction costs makes owning more attractive than renting.²⁸ Housing consumption declines more dramatically in old age so that housing consumption at age 65 relative to age 80, $\frac{h_{65}}{h_{80}}$, is higher than the benchmark model. This shows that transaction costs play an important role in explaining the slow decline of housing consumption later in life. We also see that $\frac{h_{65}}{a_{65}}$ is higher, indicating that a household's portfolio shifts from financial assets to housing assets. The reason is that removing transaction costs makes housing assets more attractive. As more relatively poor young households become homeowners, assets at age 25 and consumption at age 25 for homeowners decrease, and $\frac{c_{60}}{c_{25}}$ and $\frac{a_{65}}{a_{25}}$ increase.

To better understand the effects of transaction costs on life-cycle consumption profiles, I compare, in Figure 12, the life-cycle profiles of non-housing and housing consumption for homeowners in the model without transaction costs with those in the benchmark model. We see a hump-shaped non-housing consumption profile, which is

²⁷In all the cases presented in this section, homeowners are borrowing against their houses at age 80-85, so the assets holdings for homeowners at age 80-85 are negative.

²⁸There is still a down payment so homeownership rates at each age are less than $1 - q_t$.

| | | rate | owner | | | | | | renter | | | |
|---|-----------------------|------|-------------------------|-------------------------|-------------------------|-------------------------|-------------------------|-------------------------|-------------------------|-------------------------|-------------------------|-------------------------|
| | | % | $\frac{c_{60}}{c_{25}}$ | $\frac{c_{60}}{c_{80}}$ | $\frac{h_{65}}{h_{25}}$ | $\frac{h_{65}}{h_{80}}$ | $\frac{h_{65}}{a_{65}}$ | $\frac{a_{65}}{a_{25}}$ | $\frac{a_{65}}{a_{80}}$ | $\frac{c_{60}}{c_{25}}$ | $\frac{c_{60}}{c_{80}}$ | $\frac{a_{65}}{a_{25}}$ |
| 1 | Benchmark | 68 | 1.9 | 1.29 | 1.69 | 1.12 | 0.38 | 6.3 | -4.4 | 1.59 | 1.19 | 3.75 |
| 2 | $\rho_1 = \rho_2 = 0$ | 69 | 2.06 | 1.21 | 1.73 | 1.16 | 0.41 | 9.7 | -4.3 | 1.79 | 1.28 | 3.94 |
| 3 | $\mu_1 = \mu_2 = 0$ | 68 | 1.91 | 1.3 | 1.68 | 1.02 | 0.37 | 6.3 | -4.2 | 1.59 | 1.19 | 3.75 |
| 4 | $q_t = 0.0$ | 79 | 2.11 | 1.32 | 1.73 | 1.11 | 0.39 | 8.9 | -4.3 | 0.88 | 0.82 | 0.02 |
| 5 | $\theta = 0.5$ | 66 | 1.91 | 0.99 | 1.67 | 0.97 | 0.37 | 6.4 | -5.2 | 1.59 | 1.06 | 3.72 |
| 6 | $\sigma = 0.2$ | 55 | 1.62 | 1.27 | 1.45 | 1.08 | 0.28 | 4.2 | -5.8 | 1.41 | 1.2 | 2.88 |
| 7 | $\sigma = -0.2$ | 72 | 2.03 | 1.3 | 1.81 | 1.13 | 0.48 | 9 | -3.6 | 1.87 | 1.21 | 4.52 |
| 8 | $P = 0$ | 71 | 1.96 | 1.28 | 1.74 | 1.12 | 0.24 | 9.4 | -7.1 | 1.52 | 1.4 | 5.21 |

Table 3: Decomposition

similar to the one reported in the data and in the benchmark model. Compared with the benchmark case, a model without transaction costs generates a faster decrease of housing stock later in life.

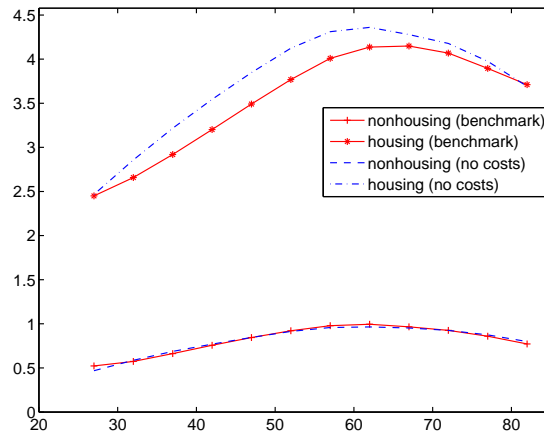


Figure 12: Life-cycle patterns for consumption (owners)

6.2 Remodeling-maintenance Option

Now, I remove the remodeling-maintenance option by setting $\mu_1 = \mu_2 = 0$. That is to say, if the value of the housing stock increases or decreases, I assume that the house has been sold. The results are summarized in line 3 in Table 3. This option does not affect young and middle-aged households much, so that housing consumption at age 65 relative to age 25 ($\frac{h_{65}}{h_{25}}$) is similar to that in the benchmark model. In the last

period, elderly households are not allowed to let the house depreciate, so that housing consumption at age 65 relative to age 80 ($\frac{h_{65}}{h_{80}}$) is almost constant. Facing transaction costs when moving and not being able to let the house depreciate, elderly homeowners barely change housing consumption.

6.3 Renting Shock

Next, I consider the effect of the renting shock in the model by setting $q_t = 0$ so that all agents can freely choose to be homeowners. The results are summarized in line 4 in Table 3. Without a renting shock that may force households to sell their houses and incur transaction costs, housing becomes more attractive and the aggregate homeownership rate increases. When more young households become homeowners, $\frac{c_{60}}{c_{25}}$ and $\frac{c_{60}}{c_{80}}$ for renters are both less than 1, indicating that the life-cycle non-housing profile for renters is actually U-shaped. The reason is that, without renting shocks, wealth is the main factor that affects the renting/owning decision and those who have low wealth tend to become renters. Since homeownership peaks at age 60, renters at age 60 are on average poorer than renters in other age groups and thus consume less. This also explains why $\frac{a_{65}}{a_{25}}$ for renters is much less than 1. The existence of renting shocks might not affect consumption profiles for homeowners much but it affects the ratio of consumption for homeowners to that for renters. Without renting shocks, rich households tend to own and poor households tend to rent. Thus the consumption levels of homeowners are much higher than those of renters. In this case average housing consumption for homeowners is 5.7 times the housing consumption for renters. In contrast, under the benchmark renting shocks, some rich households could become renters and thus average housing consumption for homeowners is 3.2 time the housing consumption for renters, much closer to that of the data.

6.4 Down Payment

Now I check the effect of the down payment rate on consumption paths and wealth composition by increasing the down payment rate to 0.5 (line 5 in Table 3).^{29, 30} When the down payment rate is high, less households can afford a house, and homeownership rate decreases. In a model without bequest motives, homeowners borrow against their houses late in life. A higher down payment rate implies that elderly households cannot borrow as much against their houses, thus housing becomes less attractive. Households shift consumption from housing to non-housing and wealth from housing to financial assets late in life, so that $\frac{h_{65}}{a_{65}}$ and $\frac{h_{65}}{h_{25}}$ are lower than the benchmark case. When the borrowing constraint becomes tighter, relatively poor elderly homeowners choose to be renters and the homeownership rate at age 80 declines. This selection mechanism increases the consumption of both renters and owners at age 80. Therefore, both $\frac{c_{80}}{c_{80}}$ and $\frac{h_{65}}{h_{80}}$ decrease.

6.5 Elasticity of Substitution between Housing and Non-housing Consumption

The elasticity of substitution between housing and non-housing consumption affects the fraction of expenditures on each of the goods as well as the renting/owning decision. For example, for renters, $c = h * (\frac{\omega p^h}{1-\omega})^{\frac{1}{1-\sigma}}$ holds. Thus under parameters in the benchmark model, non-housing consumption relative to housing consumption rises with σ . When housing consumption decreases, minimum housing size is more likely to bind, and homeownership decreases. Line 6 in Table 3 shows the results when the elasticity of substitution is 1.25 ($\sigma = 0.2$). When the elasticity of substitution is high, households

²⁹In the benchmark, inequality (6) is stronger than inequality (5), so the effective down payment rate θ is 0.34.

³⁰A tight borrowing constraint increases accidental bequests, which in turn relaxes the borrowing constraint faced by the young. To isolate this effect, I use the distribution of bequests from the benchmark instead.

shift consumption from housing to non-housing and wealth from housing to financial assets during their middle age years, so that $\frac{h_{65}}{a_{65}}$ and $\frac{h_{65}}{h_{25}}$ are lower than the benchmark case.

Line 7 in Table 3 sets the elasticity of substitution to 0.83 ($\sigma = -0.2$). When the elasticity of substitution between the housing and non-housing consumption is lower, minimum housing size is less likely to bind and homeownership increases. Households shift consumption from non-housing to housing and reallocate their wealth portfolios from financial assets to housing assets during their middle age years. Therefore, $\frac{h_{65}}{a_{65}}$ and $\frac{h_{65}}{h_{25}}$ are higher than the benchmark case.

6.6 Pay-as-you-go Social Security System

Line 8 in Table 3 shows the results for an economy without a Social Security system. Aggregate capital increases by 54%, so that households on average have higher consumption of both housing and non-housing. Without a Social Security system providing an annuity, accidental bequests increase. Therefore, more young agents become homeowners. In addition, more young households are able to buy houses due to the increase in their after-tax income. Thus, homeownership rates increases. As more relatively poor young households become homeowners, consumption at the age 25 for homeowners decreases, and $\frac{c_{60}}{c_{25}}$ and $\frac{h_{65}}{h_{25}}$ increase. Abandoning a Social Security system encourages private saving for retirement, so that financial assets at retirement age are much higher than in the benchmark case. Additionally, households portfolios shift to financial assets at age 65, as evidenced by a higher $\frac{a_{65}}{a_{25}}$ for both renters and homeowners, and a lower $\frac{h_{65}}{a_{65}}$ and a higher $\frac{a_{65}}{a_{80}}$ for homeowners.

7 Conclusions

I develop a quantitative and realistically calibrated dynamic general equilibrium model of optimal housing and non-housing consumption decisions for finitely lived individuals who face several market frictions. The model is able to match two basic patterns observed in the data: the hump-shaped non-housing consumption profile and the non-hump-shaped housing consumption profile. Households begin their economic lives without any housing stock. During the early part of their lives, they choose to accumulate housing, foregoing non-housing consumption. As households age, they decrease their non-housing consumption as the mortality rates are increasing along the life cycle. The high transaction costs for trading houses prevent households from decreasing their housing stock quickly later in life.

In addition to explaining life-cycle consumption profiles, the model is able to generate homeownership rates by age. In the model, as in the data, young agents rent while accumulating financial assets. As time goes by, many households accumulate enough wealth to make a down payment and become homeowners. Homeownership rates continue to be high late in life.

The model is also able to replicate observed life-cycle wealth portfolio profiles. In the model, as in the data, young households virtually own no liquid financial assets, but hold a major fraction of their wealth as housing. Later in life, households shift their portfolios to financial assets.

I have assumed that there is no cost of borrowing using housing as collateral. Hurst and Stafford (2004) explore the use of equity as a mechanism by which households smooth their consumption over time. Their analysis assumes households have fixed housing stocks and focuses on the impact of temporary income shocks on refinancing decisions. It would be interesting to extend my model to look at the effect of income shocks on households' moving decisions and refinancing decisions jointly.

8 Appendix

8.1 Consumption Ratio in a Standard Life-cycle Model

Consider a life cycle model without borrowing constraints and transaction costs in trading housing. Households have time-separable preferences on consumption with constant relative risk aversion and constant elasticity between consumption from housing and non-housing.

$$(13) \quad U(c, h) = \frac{g(c, h)^{1-\eta} - 1}{1-\eta}$$

$$(14) \quad g(c, h) = (\omega(c)^\sigma + (1-\omega)h^\sigma)^{\frac{1}{\sigma}}.$$

Given budget constraints, a household chooses c_t, a_{t+1}, h_{t+1} to maximize its expected lifetime utility,

$$\max_{c_t, a_{t+1}, h_{t+1}} \left\{ \sum_{t=1}^T \beta^t E(s_{t-1} U(c_t, h_{t+1}) + (1-s_t)V((1-\delta_h)h_{t+1} + (1+r)a_{t+1})) \right\}$$

subject to

$$(15) \quad c_t + a_{t+1} + h_{t+1} = y_t + (1+r)a_t + (1-\delta^h)h_t$$

$$(16) \quad c_t \geq 0, h_{t+1} \geq 0,$$

where c_t is consumption of non-housing goods at age t , a_{t+1} is non-housing assets at age $t+1$, h_{t+1} is housing stock at age t , y_t is stochastic labor income at age t , s_t is the probability of surviving up to age t , where s_0 is 1, r is the interest rate, δ^h is the depreciation rate of housing, and V is the utility from leaving bequest to the children, such that $V = 0$ implies no bequest motive.

Theorem 1: The ratio of consumption of housing to non-housing goods should be age-independent.

Proof of Theorem 1: Utility maximization implies that the following first order conditions hold

$$\begin{aligned} [c_t] : & \quad \beta^t s_{t-1} U_1(c_t, h_{t+1}) = \lambda_t \\ [a_{t+1}] : & \quad (1+r)\beta^t(1-s_t)V'_{t+1} + (1+r)E_t\lambda_{t+1} = \lambda_t \\ [h_{t+1}] : & \quad \beta^t s_{t-1} U_2(c_t, h_{t+1}) + (1-\delta_h)\beta^t(1-s_t)V'_{t+1} + (1-\delta^h)E_t\lambda_{t+1} = \lambda_t. \end{aligned}$$

Therefore from the above equations, we get

$$(17) \quad \beta^t s_{t-1} U_2(c_t, h_{t+1}) + \frac{1-\delta_h}{1+r}\lambda_t = \lambda_t,$$

which implies that

$$(18) \quad \frac{U_2(c_t, h_{t+1})}{U_1(c_t, h_{t+1})} = \frac{(r + \delta^h)}{1 + r}.$$

Then the ratio of housing to non-housing consumption is independent of age t given by

$$(19) \quad \frac{h}{c} = \left(\frac{(r + \delta^h)\omega}{(1 + r)(1 - \omega)} \right)^{\frac{1}{\sigma-1}}.$$

The above model implies that the ratio of consumption of housing to non-housing goods should not be age-dependent. The implication of the above model is not consistent with the facts that, later in life, consumption of housing is flat while consumption of non-housing goods is declining.

8.2 Estimation Procedure

This appendix describes data sources and explains the non-parametric regression used to construct life-cycle profiles reported in Section 2.

I first study the life-cycle profile of consumption of non-housing goods, and housing expenditure for renters, using data from the CEX (1984-2000). Non-housing data is deflated to be in 1983 dollars using the CPI for non-housing. Housing expenditure is deflated using the CPI for shelter.

The CEX is the only micro-level data set reporting comprehensive measures of consumption expenditure for a large cross-section of households in the US. I use the age of the reference person to define 11 cohorts with a length of 5 years, and follow them through the whole sample, generating a panel. For example, the households born in 1964-1968 were 18-22 years old in 1986. The pseudo panel approach treats the 19-23 year-old households in the 1987 wave as if they were the same people as the 18-22 year-old in the 1986 data. The data on “expenditure on non-housing consumption” include food, alcoholic beverages, tobacco, personal care, other lodging, utilities, household operations, household furnishings and equipment, transportation, books and electronic equipment, apparel, out-of-pocket health expenditure, life insurance, entertainment, cash contribution, and miscellaneous expenditures. For renters, housing consumption includes rent for dwelling and rent as pay. Only households with positive consumption expenditure and all the necessary demographic information for household size adjustment are selected. Renters with zero housing expenditure are also dropped. I take non-housing consumption expenditure from the CEX and the demographic information of the household, and adjust consumption using the equivalence scales. I use the equivalence scales for non-housing consumption as Fernandez-Villaverde and Krueger (2006), which are close to the equivalence scales used in the literature. Nelson (1988) finds that the economies of scale in shelter is so high that two can live as cheap as one-half. Thus I choose Equivalence scales for shelter that reflect this feature. Table 4 shows the equivalence scales I use.

| Family Size | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|----------------------------------|---|------|------|------|------|------|------|
| Equivalence scales (non-housing) | 1 | 1.34 | 1.65 | 1.97 | 2.27 | 2.57 | 2.87 |
| Equivalence scales (housing) | 1 | 1.1 | 1.2 | 1.3 | 1.4 | 1.5 | 1.6 |

Table 4: Equivalence scales

I then use the six waves of the SCF (1983-1998) to estimate the life-cycle profile of housing stock and non-housing assets controlling for cohort and time effects. The SCF, sponsored by the Federal Reserve Board and conducted by the University of Michigan and the National Opinion Research Center, has become the main source of microeconomic data on wealth for the US. It is conducted triennially and collects detailed information about wealth for a cross-section of households. Standard weights are used. The survey defines wealth as owner-occupied housing, other real estate, cash, financial securities, unincorporated business equity, insurance and pension cash value, miscellaneous assets less mortgages, and other debt. Consumer durables and housing inventories are not measured in the survey data. I define the housing asset to be the value of the primary residential house. Housing value is deflated to be in 1983 dollars using the housing price index. Non-housing assets are deflated to be in 1983 dollars using the CPI. Housing consumption per adult-equivalent for home-owners is calculated using equivalence scales reported in Row 3, Table 4.

As in Fernández-Villaverde and Krueger (2006), I control for cohort, time, and age effects by employing a semi-nonparametric partially linear model. Since there are no obvious patterns for the time and cohort effects, dummy variables seem to be appropriate. On the other hand, consumption and wealth changes along the life cycle are the main focus of my paper; I thus choose to model age effect non-parametrically.

In particular, I specify the following partially linear model to control for age, cohort and time effects,

$$w_{it}^p = \pi_i^p cohort_i + \pi_t^p \gamma_t + m^p(age_{it}) + \varepsilon_{it}^p,$$

where w_{it}^p is the variable at moment p of the distribution of households who are age j at time t , $cohort_i$ is a dummy for each cohort, γ_t is a dummy for each year and age_{it} is the age of cohort i at time t . The term $m^p(age_{it})$ is a smooth function of age_{it} , and I assume that this function represents a smooth unparameterized functional relationship. The error terms ε_{it}^p are assumed to be uncorrelated with zero mean and variance σ^p .

I estimate the partially linear model using the two-step estimator proposed by Speckman (1988). The nonparametric component is estimated using a Nadaraya-Watson estimator. The kernel chosen in Nadaraya-Watson estimator is an Epanechnikov kernel. Details of the estimation are available in Yang (2006).

8.3 Definition of the Stationary Equilibrium

I focus on an equilibrium concept where factor prices and age-wealth distribution are constant over time. Each agent's state is denoted by x . Let H^r denote the aggregate housing stock available for renting, H^o denote the aggregate owner-occupied housing

stock, C the aggregate consumption of non-housing, I^h the aggregate investment on housing, I^k the aggregate investment on physical capital, and Tc the total transaction costs for trading housing, respectively. An equilibrium is described as follows.

Definition 1 *A stationary equilibrium is given by government policies τ_t, P ; an interest rate r and a wage rate w ; value functions $V(x)$, allocations $c(x)$, $a'(x)$, $h(x)$, $s(x)$; bequest $b(t)$ for a person at age t ; and a constant distribution of people over the state variables x : $m^*(x)$, such that the following conditions hold:*

(i) *Given the government policies, the interest rate, the wage, and the expected bequest b_t , the functions $V(x)$, $c(x)$, $a'(x)$, $s(x)$ and $h(x)$ solve the above described maximization problem for a household with state variables x .*

(ii) *m^* is the invariant distribution of households over the state variables for this economy.³¹*

(iii) *All markets clear.*

$$\begin{aligned} H^o &= \int (1+g)^{-t} h m^*(dx), \\ H^r &= \int (1+g)^{-t} s m^*(dx), \\ K &= \int (1+g)^{-t} a m^*(dx) - H^r, \\ C &= \int (1+g)^{-t} c m^*(dx), \\ L &= \int \epsilon y m^*(dx), \\ Tc &= \int \tau(h', h) m^*(dx), \\ F(K, L) &= C + I^k + I^h + Tc. \end{aligned}$$

(iv) *The price of each factor is equal to its marginal product.*

$$r = F_1(K, L) - \delta^k, \quad w = F_2(K, L).$$

(v) *Government budget is balanced at each period.*

(vi) *The expected bequest is consistent with the actual bequest left.*

8.4 Computation of the Model

Since I introduce non-convex transaction costs on housing, I can not use either Euler equation approximation or policy function iteration. Hence I solve the model using approximation of value functions.

³¹I normalize m^* so that $m^*(X) = 1$, which implies that $m^*(\chi)$ is the fraction of people alive that are in a state χ .

To compute the steady state of my model, I first discretize the income process into 7 points following Tauchen and Hussey (1991). The state space for owner-occupied housing and asset holdings are discretized into 150 and 300 unevenly spaced grids, respectively. The upper bounds on the grids are chosen to be large enough so that they do not constitute a constraint on the optimization problem. Using these grids I can store the value functions and the distribution of households as finite-dimensional arrays.

I solve the approximated optimal consumption and saving plans recursively. Households surviving to the last period T have an easy problem to solve. Based on the period T policy functions, I solve the consumption and saving decisions that maximize the period $T - 1$ value function. The same procedure is carried back until decision rules in the first period are computed for a large number of states.

I solve for the steady state equilibrium as follows:

1. Given an initial guess of interest rate r , use the equilibrium conditions in the factor markets to obtain the wage rate w .
2. Guess the size of accidental bequests.
3. Set value function after the last period to be 0 and solve the value function for the last period of life for each of the points of the grid. This yields policy functions and value function at the last period.
4. By backward induction, repeat step 3 until the first period in life.
5. Compute the associated stationary distribution of households by forward induction using the policy functions starting from the known distribution over types of age.
6. Check whether the associated accidental bequests are consistent the initial guess. If so, continue to step 7. If not, go back to step 2 and update accidental bequests.
7. Given the stationary distribution and prices, compute factor input demands and supplies and check whether market clearing conditions hold. If all markets clear, an equilibrium is found. If not, go to step 1 and update interest rate r .

8.5 Calibration

I calibrate my model following Cooley and Prescott (1995) and Diaz and Luengo-Prado (2006). I use data from the National Income and Product Accounts and the Fixed Assets Tables for the years 1957-2001. In order to properly calibrate a model with two assets and without government taxes and expenditures, I make some imputations.

In measuring labor's share, first, I remove income from the housing sector and the government sector from National Income accounts. Then I define private labor income, Y_{pl} , as compensation of employees, unambiguous capital income (UCI) as rental income, corporate profits and net interest, and ambiguous capital income (ACI) as other income excluding employee compensation, UCI , and depreciation. Thus total private non-housing income Y_p is the sum of Y_{pl} , ACI , UCI , and depreciation. Private capital income Y_{pk} is defined as $UCI + dep_{UCI} + \alpha \cdot (ACI + dep_{ACI}) = \alpha \cdot Y_p$. The share

of capital is calibrated as

$$(20) \quad \alpha = (UCI + dep_{UCI}) / (Y_p - ACI - dep_{ACI}).$$

To explicitly consider the existence of residential housing I subtract rental income from residential housing from GDP. I add to GDP the imputed flow to government capital, Y_{gk} . I define measured GDP as the sum of final expenditures

$$(21) \quad Y = GDP - sh + Y_{gk} = C + I_k + I_h,$$

where total non-housing consumption expenditure C is the sum of private expenditures and services excluding housing and government consumption expenditures. The variable I_h includes total private residential investment. The term I_k is the sum of private nonresidential investment, change in private inventories, net exports of goods and services, and government gross investment. The variable K is private fixed non-residential assets, government fixed non-residential assets and inventory. The term H includes private fixed residential assets, government fixed residential assets and inventory.

I compute an average share of capital $\alpha = 0.263$, an average capital-output ratio $\frac{K}{Y} = 1.8624$, an investment-capital ratio $\frac{i_k}{k} = 0.1624$, a housing stock to output ratio $\frac{H}{Y} = 1.1900$, an investment-housing stock ratio $\frac{i_h}{H} = 0.0420$, and a non-housing consumption-output ratio $\frac{C}{Y} = 0.7876$. The implied depreciation rate is $\delta^k = \frac{i_k}{k} - n - g = 0.0592$, $\delta^h = \frac{i_h}{H} - n - g = 0.014$. Interest rate net of depreciation in a steady state is $r = \alpha \frac{Y}{K} - \delta^k = 8.2\%$.

8.6 Distribution of Consumption

Moving beyond mean consumption, Figures 13 and 14 plot non-housing and housing consumption for homeowners at the mean level and at each quartile, respectively. The benchmark economy generates hump-shaped non-housing consumption at each quartile. We also see that mean consumption is higher than the median at each age, indicating that the distribution for each age group is skewed to the right. There is an increase housing stock early in life and a flat portion later in life at each quartile. The distribution of housing consumption in each age group is skewed to the right. All of these features are consistent with the data shown in Figures 2 and 4.

Figure 15 plots non-housing consumption for renters. As in Figure 1, we see that mean consumption is higher than the median at each age, indicating that the distribution for each age group is skewed to the right. In the model, mean non-housing consumption is even higher than the 3rd quartile. This occurs because renting shocks are independent from household characteristics, forcing some rich households to become renters and add their high consumption to the mean.

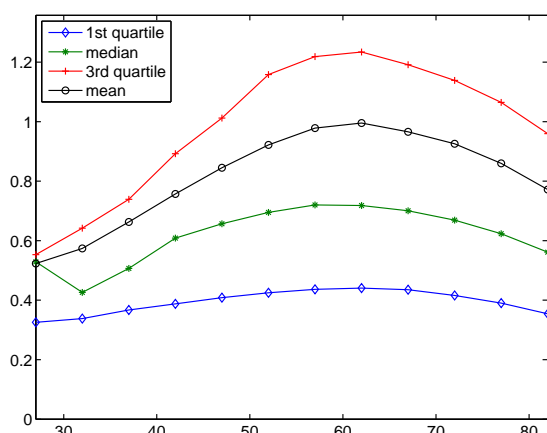


Figure 13: Non-housing consumption for owners (quartiles)

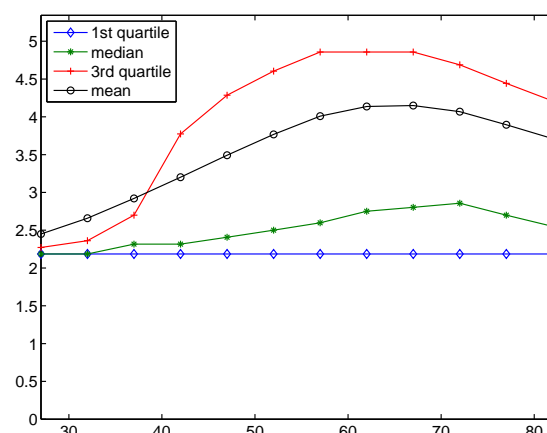


Figure 14: Housing consumption for owners (quartiles)

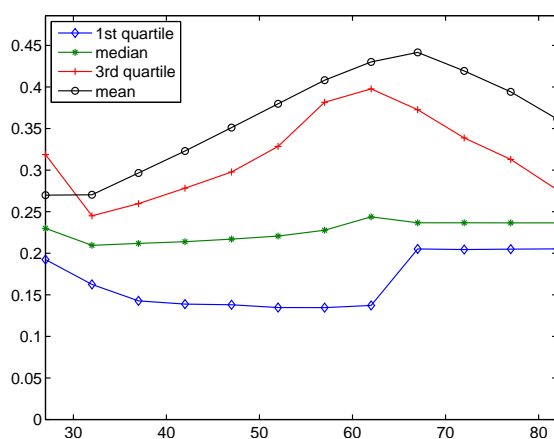


Figure 15: Non-housing consumption for renters (quartiles)

References

- [1] Altonji, Joseph G., and Ernesto Villanueva, "The Effect of Parental Income on Wealth and Bequests," NBER Working Paper No. 9811, 2002.
- [2] Attanasio, Orazio, James Banks, Costas Meghir and Guglielmo Weber, "Humps and Bumps in Lifetime Consumption," *Journal of Business and Economic Statistics*, 17 (1999), 22-35.
- [3] ———, Erich Battistin, and Hidehiko Ichimura, "What Really Happened to Consumption Inequality in the US?" NBER Working Paper No. 10338, 2004.
- [4] ———, and Guglielmo Weber, "Is Consumption Growth Consistent with Intertemporal Optimization? Evidence for the Consumer Expenditure Survey," *Journal of Political Economy*, 103 (1995), 1121-1157.
- [5] Blundell, Richard, Martin Browning, and Costas Meghir, "Consumer Demand and the Life-Cycle Allocation of Household Expenditures," *Review of Economic Studies*, 61 (1994), 57-80.
- [6] Browning, Martin, and Mette Ejrnæs, "Consumption and Children," Centre for Applied Microeconometrics Working Paper, 2002.

- [7] Bullard, James, and James Feigenbaum, "A Leisurely Reading of the Life-cycle Consumption Data," *Journal of Monetary Economics*, 54 (2007), 2305-2320.
- [8] Chambers, Matthew, Carlos Garriga, and Don E. Schlagenhauf, "The Tax Treatment of Homeowners and Landlords," Federal Reserve Bank of St. Louis Working Paper, 2007.
- [9] ———, ———, and ———, "Accounting for Changes in the Homeownership Rate," *International Economic Review*, forthcoming.
- [10] Caplin, Andrew, Sewin Chan, Charles Freeman, and Joseph Tracy, *Housing Partnerships: A New Approach to a Market at a Crossroads*, Cambridge: MIT Press, 1997.
- [11] Carroll, Christopher D., "Buffer-Stock Saving and the Life-Cycle/Permanent Income Hypothesis," *Quarterly Journal of Economics*, 112 (1997), 1-55.
- [12] ———, and Lawrence H. Summers, "Consumption Growth Parallels Income Growth: Some New Evidence," in B. Douglas Bernheim and Jonh Shoven ed., *National Saving and Economic Performance*, Chicago: University of Chicago Press, 1991.
- [13] Chinloy, Peter, "An Empirical Model of the Market for Resale Homes," *Journal of Urban Economics*, 7 (1980), 279-292.
- [14] Cocco, Joao F., "Portfolio Choice in the Presence of Housing," *Review of Financial Studies*, 18 (2005), 535-567.
- [15] Cooley, Thomas F., and Edward Prescott, "Economic Growth and Business Cycles," In Thomas F. Cooley, ed., *Frontiers of Business Cycle Research*, Princeton: Princeton University Press, 1995, 1-38.
- [16] Davidoff, Thomas, "Maintenance and the Home Equity of the Elderly," Working Paper, 2006.
- [17] De Nardi, Mariacristina, "Wealth Inequality and Intergeneration Links," *Review of Economic Studies*, 71 (2004), 743-768.
- [18] ———, Eric French, and John B. Jones, "Differential Mortality, Uncertain Medical Expenses, and the Saving of Elderly Singles," Federal Reserve Bank of Chicago Working Paper No. 2005-13, 2005.
- [19] Diaz, Antonia, and Maria J. Luengo-Prado, "The Wealth Distribution with Housing," Working Paper, 2006.
- [20] Emre, Onsel, "Improving Social Security: Welfare Gains from a Mandatory Savings Plan," Working Paper, 2007.
- [21] Feinstein, Jonathan, and Daniel McFadden, "The Dynamics of Housing Demand by the Elderly: Wealth, Cash Flow, and Demographic Effects," in David Wise, ed., *The Economics of Aging*, Chicago: University of Chicago Press, 1989.
- [22] Fernandez-Villaverde, Jesus, and Dirk Krueger, "Consumption and Saving over the Life Cycle: How Important are Consumer Durables?" *Proceedings of the 2002 North American Summer Meetings of the Econometric Society*, 2002.

- [23] ——— and ———, “Consumption over the Life Cycle: Some Facts from Consumer Expenditure Survey Data,” *Review of Economics and Statistics*, 89 (2006), 552-565.
- [24] Gervais, Martin, “Housing Taxation and Capital Accumulation,” *Journal of Monetary Economics*, 49 (2002), 1461-1489.
- [25] Gourinchas, Pierre-Olivier, and Jonathan A. Parker, “Consumption over the Life Cycle,” *Econometrica*, 70 (2002), 47-89.
- [26] Grossman, Sanford, and Guy Laroque, “Asset Pricing and Optimal Portfolio Choice in the Presence of Illiquid Housing Consumption Goods,” *Econometrica*, 58 (1990), 25-51.
- [27] Gruber, Joseph, and Robert F. Martin, “The Role of Durable Goods in the Distribution of Wealth: Does Housing Make Us Less Equal?” Working Paper, 2003.
- [28] Hansen, Gary D., and Selahattin Imrohorglu, “Consumption over the Life Cycle: The Role of Annuities,” Working Paper, 2005.
- [29] Heathcote, Jonathan, “Home Production and Retirement,” Working Paper, 2002.
- [30] Hubbard, R. Glenn, Jonathan Skinner and Stephen P. Zeldes, “The Importance of Precautionary Motives in Explaining Individual and Aggregate Saving,” *Carnegie-Rochester Conference Series on Public Policy* 40 (1994), 59-125.
- [31] Hurst, Erik, and Frank Stafford, “Home Is Where the Equity Is: Mortgage Refinancing and Household Consumption,” *Journal of Money, Credit, and Banking*, 36, Dec. 2004, 985-1014.
- [32] Li, Wenli, and Rui Yao, “The Life-cycle Effects of House Price Changes,” *Journal of Money, Credit, and Banking*, 39 (2007), 1375-1409.
- [33] Luengo-Prado, Maria J., “Nondurables, Down Payments, and Consumption Excesses,” *Journal of Monetary Economics*, 53 (2006), 1509-1539.
- [34] Nelson, Julie, “Household Economics of Scale in Consumption: Theory and Evidence,” *Econometrica* 56 (1988), 1301-1304.
- [35] Ogaki, Masao, and Carmen M. Reinhart, “Measuring Intertemporal Substitution: The Role of Durable Goods,” *Journal of Political Economy*, 106 (1998), 1078-1098.
- [36] Smith, Lawrence B., Kenneth T. Rosen, and George Fallis, “Recent Developments in Economic Models of Housing Markets,” *Journal of Economic Literature*, 26 (1988), 29-64.
- [37] Speckman, Paul, “Kernel Smoothing in Partial Linear Models,” *Journal of the Royal Statistical Society*, B50 (1988), 413-436.
- [38] Tauchen, George, and Robert Hussey, “Quadrature-Based Methods for Obtaining Approximate Solutions to Nonlinear Asset Pricing Models,” *Econometrica*, 59 (1991), 371-396.
- [39] Yang, Fang, “How Do Households Portfolio Vary with Age?” Working Paper, 2006.

- [40] Yao, Rui, and Harold H. Zhang, “Optimal Consumption and Portfolio Choices with Risky Housing and Borrowing Constraints,” *Review of Financial Studies*, 18 (2005), 197-239.
- [41] Zeldes, Stephen, “Consumption and Liquidity Constraints: An Empirical Investigation,” *Journal of Political Economy*, 97 (1989), 305-346.