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Consumption and Time Use over the Life Cycle*

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Abstract

We incorporate home production in a dynamic general equilibrium model of consumption and saving with illiquid housing and a collateralized borrowing constraint. We show that the model is capable of explaining life-cycle patterns of households' time use and consumption of different categories. Specifically, households' market hours and home hours are fairly stable early in the life cycle. Market hours start to decline sharply at age 50, while home hours begin to increase at age 55. Households' consumption of the market good, home input, and housing services all exhibit hump shapes over the life cycle, with the market good having the most pronounced hump, followed by the home input, and then housing services. A plausibly parameterized version of our model predicts that the interaction of the labor efficiency profile and the availability of home production technology explain households' time use over the life cycle. The resulting income profiles, the endogenous borrowing constraint and the presence of home production account for the initial hump in all three consumption goods. The consumption profiles in the second half of the life cycle are mostly driven by the complementarity of home hours, home input, and housing in home production.

JEL Classification: D13, E21, J22

Key Words: Consumption, Home Production, Life Cycle

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1 Introduction

This paper jointly examines the profile of different types of consumption goods over the life-cycle and the time-use profile of households over the lifecycle. It, thus, represents a departure from the recent life-cycle literature that concentrates primarily on the profile of aggregate consumption. The primary motivation for doing so is generated by the recent empirical work of Aguiar and Hurst (2009). Their work documents a significant amount of heterogeneity in the life-cycle profile of the components of consumption, and that the differential behavior in various components of consumption is systematically linked to whether some portion of the good could be produced at home or whether the good could only be consumed directly from the market. This led the authors to postulate that the differential behavior of consumption across goods over the life cycle was associated with different degrees of nonseparability between consumption and work. Importantly, we find that the profile of hours used in different activities over the life cycle is consistent with the behavior of consumption. That association led us to construct a quantitative life-cycle general equilibrium model with home production, because it provides a natural theoretical setting for exploring the link between time use and consumption over various types of goods. Another motivation for looking at heterogeneity is that its presence implies important distinctions in an individual's response to various economic policies such as changes in taxes and Social Security. These policies will not only have aggregate repercussions, but they could also differentially impact the demand for various goods depending on the degree of substitutability between home production and market work for each particular good. It, therefore, is important to account for both the aggregate and specific-goods behavior of households over their life cycle.

In modeling the process of home production, we include housing as an input into home production. Doing so was desirable for a number of reasons. First, much of time use is spent performing activities associated with owning a home and we are interested in the joint relationship between how time is spent over the life cycle and how time-use decisions are related to consumption decisions. Second, as Fernandez-Villaverde and Krueger (2010) point out, certain financial constraints associated with durable good purchases can help account for life-cycle consumption profiles and housing serves as the durable good in our model. However, housing also possesses some features not usually associated with other durables, namely, the cost of altering the amount of housing as well as its slower depreciation, that turn out to be important in explaining consumption behavior later in life. It is also straightforward to discipline the model with respect to housing services as there exist accurate and detailed data regarding the housing decision. Thus, an accurate depiction of housing decisions is shown to improve the model's ability to fit both hours and consumption choices over the life cycle.

The modeling strategy we use depicts the household as a joint consumption-production unit. Thus, we incorporate home production in a standard life-cycle model that includes precautionary savings motives and endogenous labor supply decisions. Home production uses housing, certain types of market-produced goods that serve as intermediate inputs, and home hours to produce final home goods. The home goods, in turn, are substitutable with market goods that can be directly purchased and consumed. The richness of our framework enables us to broadly match the life-cycle behavior of consumption of both market- and home-produced goods, the time allocation decisions of households, and the amount of housing services consumed at various points in the life cycle.

In particular we are able to match four important aspects of life-cycle behavior. The first, and perhaps least remarkable aspect, is the well-established finding that total household consumption, durable as well as nondurable, exhibits a strong hump shape over the life cycle even after adjusting for economic growth and household size. The second is the substantial heterogeneity across life-cycle profiles of individual consumption expenditures. Using recent releases of the Consumption Expenditure Survey, we confirm the general findings in Aguiar and Hurst (2009). However, instead of analyzing the many different types of consumption goods individually as Aguiar and Hurst (2009) do, we group consumption goods into three broad categories according to their relationship with home production. The first is housing, rented or owned, which is an important component in home production. The second is the home input, consisting of goods purchased from the market but that serve as intermediate inputs for home production, such as food at home, housing appliances, household operations and utilities, etc. The rest of the goods belong to the third category, labeled the market good. We find that the market good exhibits the strongest hump shape over the life cycle, rising sharply early in life and declining substantially late in life. The other two categories, by contrast, do not rise or decline nearly as much. Third, our model produces choices over housing that are consistent with what has been termed the "housing puzzle." Old age homeowners' house values do not decline much, if at all, toward the end of their life cycle, and this puzzle pertains to renters as well.[1] Standard models imply that the housing stock should be consumed aggressively late in life. And fourth, the model matches the observation that households labor supply also exhibits strong life-cycle patterns, with market hours and home hours being fairly stable early in the life cycle. At age 50, market hours start to decline sharply and home hours begin to increase after age 55.

[1] This latter observation poses challenges to the traditional theory of bequests as well adjustment costs of older homeowners' housing consumption behavior. For more discussion on the housing puzzle, see Venti and Wise (2002) and Davidoff (2006).

Our model has three key features that help account for these four observations. First, households are subject to collateralized borrowing constraints; they can borrow only up to a fraction of their house value. This feature, together with the standard assumption regarding the labor efficiency profile and the presence of uninsurable labor income risk, helps to account for the increasing consumption profiles in the early part of a household's life cycle as in Fernandez-Villaverde and Krueger (2010). Second, at each point in time, households divide their time between market hours, hours in home production, and leisure. As households age, their market labor efficiency declines and they devote more and more of their time to home production. As a result, consumption of the market good declines drastically. Consumption of the home input and housing services also declines, but the decline is much more muted due to their complementarity with home hours in home production. Interestingly, home production also has a significant effect on households' consumption early in life. Households find it optimal to produce home consumption and use it to help smooth overall consumption early in life. As a result, households adjust their consumption of the market good relatively earlier in life. In other words, their market consumption rises more steeply early in life and is overall more humped in the presence of home production. Third, we differentiate between owner-occupied housing and rental housing. We assume that housing adjustment is costly for homeowners, but costless for renters. This assumption allows us to directly measure the predictions of our model concerning owners' and renters' consumption and labor supply against those from the data. Housing adjustment costs further contribute to the slow decline in the homeownership rate and the value of the housing stock owned as households age. Moreover, accounting for this aspect of behavior is likely to be crucial for understanding the effects of different collateral requirements on mortgages as well as the effect of Social Security on household behavior.[2]

The rest of the paper is organized as follows. In section 2, we present our empirical analysis in which we construct households' life-cycle profiles of time use and consumption. In section 3, we present the model. We discuss our calibration strategy in section 4 and results in section 5. Further, investigation of the model's different channels in driving households' behavior is presented in Section 6. Section 7 concludes.

2 Related Literature

The paper draws on two strands of the literature: the consumption literature and the home production literature. One of the most prominent observations in the consump-

[2]See Chen (2009) for an exploration of the effects of changes in Social Security when households have a renting-owning choice, but where labor supply is exogenous.

tion literature is that aggregate consumption is hump-shaped over the life cycle. Market incompleteness in the form of a borrowing constraint along with uncertain income leads to precautionary savings, which is the key mechanism of leading theories that account for this observation (Hubbard et al. 1994, Carroll 1997, and Gourinchas and Parker 2002).[3] Fernandez-Villaverde and Krueger (2010) add to this literature by documenting that the hump persists for consumption of both durables and nondurables when considered separately and they propose an incomplete markets model in which durables serve as collateral to explain these stylized facts. Separately, Bullard and Feigenbaum (2007) incorporate leisure into the utility function and show that this additional feature helps explain the hump in the consumption. Huggett and Ventura (1999), Heathcote (2002), and French (2005) combine precautionary saving, leisure and consumption in their model to study retirement issues. Our paper shares many features with these papers, including the precautionary savings motive, liquidity constraint, and endogenous labor leisure decision. The durable good in our model takes the explicit form of owner-occupied residential housing. Our biggest innovation lies in the fact that we examine the heterogeneity of consumption profiles along the lines of Aguiar and Hurst (2009) as discussed in the introduction and that we are jointly interested in the interaction of time use and consumption.

Our paper is also closely related to the recent home production literature. This literature has shown that the introduction of home production in otherwise standard dynamic general equilibrium models is useful in understanding a variety of macroeconomic issues, including domestic and international business cycles, fiscal policies, and asset equilibrium puzzles (Baxter and Jermann 1997, Benhabib, et al. 1991, Bils, et al. 2009, Campbell and Ludvigson 2001, Canova and Ubide 1998, Gomme, et al. 2001, Greenwood and Hercowitz 1991, Greenwood, et al. 1995, and McGratten, et al. 1997). A key way in which models with home production differ from standard dynamic general equilibrium models (that do not include home production) is that home production allows households to substitute along additional margins, both in labor supply and in total consumption. While many recent studies have used time-use data in order to understand household production (Aguiar and Hurst 2007 and Ramey 2008), much less attention has been paid to the other factors involved in the production of home goods (see Rupert, Rogerson, and Wright 2000 and papers cited therein).[4] Our paper fills in

[3] There is also a literature suggesting that time-inconsistent or myopic preferences over consumption can play a role. See Laibson (1997). Several authors including Attanasio et al. (1999) and Browning and Ejrnaes (2002) argue that variation in household size could account for why preferences over consumption by a household might change over the life cycle—that is, consumption is highest when households are largest.

[4] One exception is Heathcote (2002), who studies the effect of home production on retirement.

this gap by tying households' labor supply (including leisure choice) and consumption more closely together and we show that home production affects households' lifecycle consumption of all three goods, both later and early in life.

3 Empirical Observations on Lifecycle Behavior

In this section, we present our empirical findings on time use and consumption over the life cycle. We first study time-use profiles using data from the American Time Use Survey (ATUS), then we study consumption profiles of market goods, home input, and housing services using data from the Consumption Expenditure Survey (CEX). We separate households into owners and renters and deal explicitly with problems of household size, cohort effect, and survey effect using the synthetic cohort strategy widely used in the literature.[5] It is worth noting that some of our empirical results have already been documented in the literature. Our contribution lies in merging and reclassifying the two data sets according to the macro literature on home production. Our differentiation between homeowners and renters is also novel and important in explaining older age households' "housing puzzle."

3.1 Life-Cycle Profiles of Time Use

The ATUS, carried out by the Bureau of Census under contract with the Bureau of Labor Statistics, measures the amount of time people spend performing various activities, such as work, child care, housework, watching television, volunteering, and socializing (see Table 1). The data are strictly cross-sectional as respondents are interviewed only once. Households are top coded at age 80.[6] The survey started in 2003, with the most recent one ending in 2007.

We include in our sample the 2005 to 2007 ATUS, since the ATUS started reporting households' house tenure in 2005. We focus on households whose head is between the ages of 25 and 80 (inclusive) but exclude those whose head is either in school or in the military at the time of the survey. Our final sample consists of 30,720 households, about evenly split across the three survey years. We include both male and female respondents in our sample.

We follow the tradition of Reid (1934) and separate nonmarket time into pure leisure and home hours where home hours comprise time spent on activities performed at home

[5] We follow most closely the linear regression strategy in Gourinchas and Parker (2002) and Aguiar and Hurst (2009).

[6] All households between ages 80 and 84 are assigned age 80 and those that are 85 and above are assigned age 85.

to produce goods and services that can also be purchased in the market and are, for the most part, not enjoyable to produce.[7] According to Robinson and Godbey (1999, Table 0), in a 1985 enjoyment of activities survey, households ranked having sex, playing sports, fishing, enjoying art and music, and going to bars and lounges at the top and doing yardwork, cleaning house/dishes, doing laundry, providing child health care, and going to the car repair shop at the bottom. Indeed, empirical studies of home production or homemaking, as in the earlier literature, typically classify food preparation, cleaning the house, care of family members living in the household, and shopping and managing the household as home production. Some also include gardening, care of others who are not in the household, and entertaining children.[8] We thus define home hours as time spent doing house work, house work service, shopping, pet care, car care, child care, adult care, shop search, car service, child care service and professional service. We define market hours as the time the head of the household spends working, job searching and commuting. We treat the remaining time as leisure. That is, as discussed in Baxter and Rotz (2009), home production activities are associated with disutility, whereas leisure activities provide utility. This decomposition strategy allows us to highlight the substitution of home-produced goods and market goods.

For those households that were interviewed on Saturday or Sunday (holidays are viewed the same as Sunday in the ATUS), we approximate their weekday hours by the average hours of those interviewed on weekdays, in the same year, of the same education, and gender. Similarly, we approximate the weekend and holiday hours for households interviewed during weekdays. We adjust all hours by family size and survey year effects. We also control for families that have young children (under the age of 6). Following Aguiar and Hurst (2009), we identify life cycle from cohort effects by using the multiple cross-sections in our model and use cross-sectional differences in family size and interview year, respectively, to identify family size and interview year effects. Specifically, we estimate the following equations,

$$H_{it}^k = \beta_0^k + \beta_{age}^k AGE_{it} + \beta_y^k Y_{it} + \beta_f^k F_{it} + \beta_{yc}^k YC_{it} + \beta_m^k M_{it} + \varepsilon_{it}^k,$$

where H_{it}^k represents time use in category k (market work or home work), AGE_{it} is a vector of 55 one-year age dummies , Y_{it} is a vector of three one-year interview dummies (2006 is the omitted year), and F_{it} is a vector of family structure dummies that include

[7] In particular, she defines home production as “those unpaid activities which are carried on, by and for the members, which activities might be replaced by market goods, or paid services, if circumstances such as income, market conditions, and personal inclinations permit the service being delegated to someone outside the household group” (Reid 1934, p.11).

[8] See Ramey (2008) for a thorough discussion.

9 family size dummies, 1 to 10, (household of size 2 is the omitted group; 10 includes families with 10 or more family members). YC_{it} is a dummy indicating whether the family has any children under the age of 6. M_{it} is a dummy for marital status. The coefficients on the constant β_0^k together with age dummies, β_{age}^k, capture the impact of the life cycle conditional on family size and interview effects.

Figure 1 charts the share of market hours and home hours by age for the household head. As can be seen, market hours by homeowners and renters track each other pretty closely, with homeowners supplying slightly more market hours earlier in the life cycle and slightly more home hours later in the life cycle than renters. In particular, both homeowners and renters spend roughly 22 percent of their time working until age 50, then they start reducing their market work sharply. By age 70, households spend less than 5 percent of their time working. Home hours hold steady until age 55 for homeowners and renters. Then, they begin to increase and noticeably more so for homeowners.

3.2 Life-Cycle Profiles of Consumption Expenditure

The CEX, also carried out by the Bureau of Census under contract with the Bureau of Labor Statistics, collects household demographic characteristics and consumption information. The data are a rotating panel with each household being interviewed from 2 to 5 quarters, and every quarter 25 percent of the sample is replaced by new households. The short-panel dimension of CEX makes the direct use of panel techniques nearly infeasible. We, thus, pool the data and treat it as one cross-section.

We include in our consumption sample the 2003 to 2006 CEX data. We include in our market good food away from home, alcohol, tobacco, apparel, other lodging, fees and admissions for entertainment, and related equipment such as televisions, radios, sound systems, pets, toys, and playground equipment, reading, and personal care. We also include education expenses and out-of-pocket medical expenses in the market good, but our results are robust to the exclusion of these categories. We include in our home input food at home, household operations, household furnishing and equipment, utilities, fuels, and public services. We prorate transportation expenses by travel time for home production or market production and leisure that we obtained from the ATUS discussed in the previous subsection. For housing expenditures, we use rental payments for renters, and we use homeowners reported house value of owned residence because we believe homeowners typically have a better idea of how much their house is worth than how much their house can be rented for. Using reported rental value for homeowners does not change our results qualitatively.

We delete from our sample households that reported zero or negative consumption of the market good plus the home input, renters who reported less than \$300 in annual rent, and homeowners who reported less than \$1000 in house value. All consumption data are adjusted by their respective 2000 chained consumer price Index. Our final sample consists of $48,048$ households of which about 68 percent are homeowners.

We use the same strategy outlined in the previous subsection to identify life-cycle profiles of the three consumption categories with the exception that we take the log of our consumption data. The results are presented in Figure 2 in log deviations from age 25. As one can see, for homeowners, the market good, home input, and housing services all move up substantially from age 25 to age 50. The hump in housing services, however, is the most pronounced. The increase is over 40 percent as opposed to about 30 percent in market and home goods. Starting in a household's mid 50s, both consumption of the market good and the purchases of home inputs begin to decline with market goods experiencing a more significant drop. Housing services, by comparison, decline very slightly starting in age 60. For renters, the market good starts declining from age 25 and expenditures on home inputs is relatively flat till age 40 at which time it starts to decline. Rental housing services is mostly flat, and this is at least in part due to selection effects. Those households who remain renters are generally ones that have poor productivity draws.

4 Model

We consider a model that is a modification of Fernandez-Villaverde and Krueger (2010), Gervais (2002), Heathcote (2002), and Yang (2009), among others. In particular, it is a discrete-time overlapping generations economy with an infinitely lived government. The government taxes labor income and provides pensions to retirees. The model has several key features. First, consumers value leisure and a composite consumption good that consists of a market good and a home-produced good. We model home production technology along the lines of Benhabib, Rogerson, and Wright (1991), Greenwood and Hercowitz (1991), and Rupert, Rogerson, and Wright (2000). Second, households face uninsurable idiosyncratic shocks to their labor efficiency. Finally, we restrict intertemporal trade by borrowing constraints collateralized by housing.

4.1 Technology

There is only one type of market good produced according to the aggregate market production function

$$F^m(K, N^m) = K^{\alpha}(N^m)^{1-\alpha}, \tag{1}$$

where K is the aggregate market capital stock and N^m is the aggregate market labor input. The final good can be directly consumed, invested in physical capital, or used as an intermediate input in home production.[9] Physical capital, housing input, and housing depreciate at rates δ^k, δ^d and δ^h, respectively.

Home production requires an intermediate home input, housing, and labor. In particular, the home technology has the following nested CES functional form,[10]

(2)

$$c_h = f^H(d, h, n_h) = \{\omega_2[\omega_1 d^{1-\frac{1}{\zeta_1}} + (1-\omega_1)(h+(1-\delta)s)^{1-\frac{1}{\zeta_1}}]^{\frac{1-\frac{1}{\zeta_2}}{1-\frac{1}{\zeta_1}}} + (1-\omega_2)(n_h)^{1-\frac{1}{\zeta_2}}\}^{\frac{1}{1-\frac{1}{\zeta_2}}},$$

where d denotes the intermediate home input, h denotes the housing stock owned by homeowners, s denotes the rental stock of renters, and n_h the labor input in home production. The parameter δ captures the discount of rental housing in home production, implying that owner-occupied housing is more productive than rental housing in home production, thus helping to generate a preference for owning relative to renting.[11] The parameters ω_1 and ω_2 control the weights associated with housing, and composite home capital in home production, ζ_1 governs the intra-class substitutability between home input and housing, and ζ_2 governs the inter-class elasticity of substitution between the composite home input and home hours in home production.[12] Note that a household can either be a homeowner or a renter, but not both. Therefore, h and s cannot simultaneously take positive values.

[9] For simplicity, we have combined both nondurable expenditures such as raw food with consumer durables such as appliances into a composite durable good used in home production. We term this composite good home input. An interesting extension would be to treat these separately, especially for modelling the cyclicality of consumption.

[10] Note that we use a lower case letter to respresent the home production technology as home production takes place at the household level.

[11] Models of the type we are using generally need some feature to help generate a relative preference for owning. Other possibilities include using tax benefits of owning as in Gervais (2002) or assuming higher depreciation of rental properties as in Chen (2010).

[12] Following Sato (1967), we justify our aggregation by the fact that intra-class elasticity (between home input and housing) is potentially higher than the inter-class elasticity (between home input and home hours or housing and home hours) since home input and housing are more similar in techno-economic characteristics.

4.2 Financial Institutions

Following Gervais (2002), we assume there exists a two-period-lived financial institution that pools households capital to supply mortgages and purchase rental housing. It purchases final goods and uses them as housing services, which it then rents out to renters for use in home production. Specifically, at the end of the first period, the intermediary 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 η per unit. At the end of the second period, the financial institution sells the undepreciated residential stock to a new agency. The no-arbitrage condition implies that the rental rate on housing is given by

$$\eta = r + \delta^h. \tag{3}$$

4.3 Demographics

During each model period, a continuum of consumers is born. They immediately begin working and consuming. Each consumer retires at $t = T_r$ and dies by the end of age T. Each consumer faces a positive probability of survival, given by λ_t, where $0 \leq \lambda_t \leq 1$. The probability of survival is exogenous and independent of other household characteristics. Since the demographic patterns are stable, agents at age t make up a constant fraction of the population at any point in time. Annuity markets are assumed to be absent and accidental bequests are distributed to all households in the economy.

4.4 Consumer's Maximization Problem

4.4.1 Preferences

Individuals derive utility from consumption of a composite good c that consists of a market-produced nondurable good, c_m, and a home-produced good, c_h, and leisure, l. 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

$$U(c,l) = \frac{[\omega_4 c^{1-\frac{1}{\zeta_4}} + (1-\omega_4) l^{1-\frac{1}{\zeta_4}})]^{\frac{1-\gamma}{1-\frac{1}{\zeta_4}}} - 1}{1-\gamma}, \tag{4}$$

where

$$c = [\omega_3 c_m^{1-\frac{1}{\zeta_3}} + (1-\omega_3) c_h^{1-\frac{1}{\zeta_3}}]^{\frac{1}{1-\frac{1}{\zeta_3}}}. \tag{5}$$

ω_4 represents the relative weight of the composite consumption good in utility, ζ_4 represents the degree of substitution between the composite consumption good and leisure, γ denotes the relative risk aversion parameter, ω_3 denotes the relative weight of the market good in the composite consumption good, and ζ_3 measures the degree of substitution between the market good and the home-produced good.

4.4.2 Labor Productivity

Labor productivity consists of two components. The first is deterministic and age dependent with all consumers of the same birth cohort facing the same exogenous profile, e_t. The second is stochastic with each worker, i, receiving a stochastic productivity shock ε_t^i, which follows a Markov process

$$\ln \varepsilon_t^i = \rho_\varepsilon \ln \varepsilon_{t-1}^i + \upsilon_t^i, \;\; \upsilon_t^i \sim N(0, \sigma_\varepsilon^2). \tag{6}$$

The Markov process is the same for all households and there is no uncertainty over the aggregate labor endowment. The total productivity of a worker at age t is then given by the product of the worker's age-t productivity shock and age-t deterministic efficiency index: $e_t \varepsilon_t^i$. After age T_r, households begin to receive Social Security income. We assume that the Social Security benefits are functions only of households' age.

4.4.3 Transactions Costs and Housing

Housing markets are characterized by large transactions costs that involve both a considerable amount of time and resources. Some of these costs include the opportunity costs of time associated with 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).

We, therefore specify these costs as

$$\varphi(h, h') = \begin{cases} 0, & \text{if } h' \in [(1-\mu_1)h, \; (1+\mu_2)h]; \\ \rho_1 h + \rho_2 h', & \text{otherwise,} \end{cases} \tag{7}$$

where h' denotes the next period's housing stock. This formulation of costs allows households to change their level of housing consumption without moving by undertaking housing renovation up to a fraction μ_2 of the value of the house or by allowing depreciation up to a fraction 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, we assume that the house has been sold. In that case, the household must pay costs that are a fraction ρ_1 of its selling value. Buying a property incurs a fraction ρ_2 of its purchase price. Finally, there is a minimum house size $\underline{h}$ ($\underline{h} > 0$) that can be purchased, i.e.,

$$h' \geq \underline{h}. \tag{8}$$

4.4.4 Borrowing Constraints

Collateralized credit is the only form of credit in the economy. Further, the borrowing rate, mortgage rate, and deposit interest rate are all assumed to be equal. This implies that mortgages and deposits are perfect substitutes. To buy a house, a household must satisfy a minimum down payment requirement equal to a fraction θ of the value of the house. We use a' to denote the net asset position. Therefore, at any given period the household's financial assets must satisfy[13]

$$a' \geq -(1-\theta)h'. \tag{9}$$

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

$$(1+r)a' + (1-\delta^h)h' + (1-\delta^d)d' \geq 0. \tag{10}$$

4.4.5 Renting Shock

In a model where households differ only by age, income, and wealth, rich households tend to be homeowners and poor ones tend to be renters. In the US, a fraction of rich households are renters.[14] The existence of high-income renters may be due to heterogeneity in house prices, job mobility, preferences, or family composition. To capture factors other than age, income, and wealth that affect households' renting/owning decision, we assume households face renting shocks. A household that 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.

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

[14] As reported by the Bureau of Labor Statistics in 2000, 12 percent of households whose income is in the top quintile are renters, and 25 percent of those whose income is in the fourth quintile are renters.

4.4.6 Timeline

Before we describe the households' optimization problem, we present the timeline for their decisions (Figure 3). At the beginning of each period, after they observe their current idiosyncratic labor shocks, the next period's rental shock, and receive a bequest households make their labor supply decisions and rent capital to firms, and they also purchase home input and rental housing for the current period. At this point, market production takes place. Home production also takes place using labor, the home input, and housing. After production, households receive factor payments and make their consumption and asset allocation decisions. At the end of the period, market capital, housing and home input depreciate and uncertainty about early death is revealed. Accidental bequests from those who die early are distributed to new agents next period to first satisfy an exogenous beginning of period asset position, and if funds are leftover, they are distributed to the other agents in the economy. Households also make rental versus owning decisions if they did not receive a rental shock, and in the event of owning, they choose their house size at the end of the period.

4.4.7 The Household's Recursive Problem

In a stationary equilibrium, the interest rate is constant at r as is the wage rate w per efficiency unit of labor. The household's state variables are given by $(m, t, a, h, d, \varepsilon)$, which denote the agent's rental shock for the next period (m), current age (t), financial assets (a), undepreciated housing stock (h), home input from the previous period (d), and labor productivity of the current period (ε). If $m = 1$, then this household is not allowed to own a house in the next period. If $h = 0$, then the household is a renter for this period. We have

$$V(m,t,a,h,d,\varepsilon) = \max_{\{c_m,d',s,a',n_m,n_h,h'\}} \Big\{ U(c, 1-n_m-n_h) + \beta\lambda_t EV(m', t+1, a', h', d', \varepsilon') \Big\}$$

subject to (8), (9), (10), and

$$\begin{aligned} (11) \quad & c_m + a' + d' + \varphi(h,h') + \eta s 1(h=0) + h' 1(m=0) \leq b + (1+r)a + (1-\delta^h)h + \\ & \qquad (1-\delta^d)d + (1-\tau)[e_t \varepsilon w n_m] + pen(t), \\ (12) \quad & c_m \geq 0, \;\; s \geq 0, \;\; a' \geq 0, d' \geq 0, 0 \leq n_m, n_h \leq 1, \end{aligned}$$

where $1(.)$ is an index function that takes a value of 1 if the statement inside the parenthesis is true and 0 otherwise, τ denotes the Social Security income tax before retirement,

w denotes the wage, and $pen(t)$ is the pension after retirement for $t \geq T^r$. In any sub-period, an agent's resources depend on asset holdings, a, labor endowment, $e_t\varepsilon$, or pension, $pen(t)$, housing stock, h, home input, d, and received bequests, b. Note that agents receive a pension only after retirement. The composite consumption good c is defined as in equation (5), the home-produced good is defined as in equation (2) using current period housing h or s, home input d', and home hours n_h as inputs.

A formal definition of a stationary equilibrium that includes market clearing conditions is provided in Appendix A. The model is solved numerically. Appendix B describes the computation algorithm in greater detail.

5 Calibration and Estimation

5.1 Parameter Calibration

We choose the parameters of our model in two steps. The first step is a standard calibration exercise where we pick parameters individually that are based on economic statistics from the data as well as choosing parameters, such as relative risk aversion, that are consistent with the literature. The second step is more of an estimation in which we jointly choose a set of 12 parameters that minimize a loss function based on the difference between certain model and data moments calculated off households' time use and consumption. The calibrated parameters and the statistics that generate them are given in Table 3 and the estimated parameters are given in Table 4. Table 5 indicates how close the model moments match the data moments. We show that the model does a good job of matching our target moments.

The model period is two years.[15] At age 25, each person enters into the model. The retirement age T_r is 61, and the maximum life length T is 100. Figure 4, panel b, shows the λ_ts, the vector of 2-year conditional survival probabilities. We use the mortality probabilities for people born in 1960, weighted by gender from the Social Security Administration life tables.

The parameter α is the share of income that goes to the nonresidential stock of capital and is set at 0.240. This capital share is lower than in many real business cycle calibrations because housing is not part of our model's capital stock. We set δ^k to 0.10 and δ^h to 0.02. The rate, r, is the interest rate on capital net of depreciation and is set to 0.04. Appendix C explains the rationale behind these choices in greater detail. We assume that the intermediate home input depreciates completely in two years given that

[15] Given the model period, we adjust parameters in the model accordingly. We report parameters at annual frequency, unless stated otherwise.

household appliance and equipment accounts for less than 0.10 of total home input.

The deterministic age profile of the unconditional mean of labor productivity, e_t, taken from French (2005), is shown in the top panel of Figure 4. The labor-efficiency profile is hump-shaped, with a peak at age 50. The persistence ρ_y and variance σ_y^2 of the stochastic productivity process are 0.977 and 0.014, respectively (French 2005). The variance of the initial distribution of productivity is 0.38 (Huggett 1996). For simplicity, we assume the labor efficiency profile for home production to be constant.

We calibrate the Social Security tax τ to 0.096 to match the average payroll tax.[16] We let pension $pen(t)$ depend on the age of the household. In particular, a household after age 65 receives the full pension payment. If he is at age 63-64, he receives 80 percent of the full pension, and if he is at age 61-62, he receives 40 percent of the full pension.

The down payment rate θ is set to be 0.20, which is commonly used in the housing literature. The probability of receiving a renting shock is from Li and Yao (2007), who calibrated to average households migration rates for nonhousing-related reasons; these are shown in the bottom panel of Figure 4. Gruber and Martin (2003) estimate the reallocation cost from the CEX and find that the median household spends 7 percent of a house's value to sell it and 2.5 percent to purchase it. In our simulation, we therefore choose transactions costs from sales to be $\rho_1 = 0.07$ and from purchases to be $\rho_2 = 0.025$. 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. We choose a big range and set $\mu_1 = \delta_h$, $\mu_2 = 4\delta_h$. That is to say, households can change their level of housing consumption by allowing depreciation or renovation as alternatives to moving.

We take the risk aversion parameter, γ, to be 1.5, from Attanasio et al. (1999), and Gourinchas and Parker (2002), who estimate it from consumption data. The initial distribution over state variables (wealth, house size and house tenure) for households of age 25 is calculated using data from the Survey of Consumer Finances (2001, 2004, and 2007) for households whose heads are between ages 23 and 26. Accidental bequests are first distributed to new agents to reproduce the distribution of capital endowments.[17] The rest, if there are any, is distributed evenly to all agents alive, which endogenously determines b.

[16] The Social Security payroll tax rate in the US is about 10 percent after we take out the part of the benefits due to Medicare and disability insurance.

[17] Since 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.

5.2 Estimation

Regarding the estimated moments, we choose the parameters, β, pen, δ, $\underline{h}$, ζ_i, ω_i, ($i = 1, 2, 3, 4$) based on the following moments: K/Y, payroll taxes, the homeownership rate, the average financial wealth of homeowners relative to renters, the average home input of both renters and homeowners (d), the average house size of renters and homeowners (s, h), and the average market hours and home hours of both renters and homeowners. We also normalize the average expenditure by economy-wide income. Thus, we simultaneously choose these 12 parameters to match the 12 selected moments as summarized in Table 4. The moments basically involve various expenditure and asset to income ratios as well as moments pertaining to the use of time. It is important to note that although our procedure jointly uses 12 moments to identify 12 parameters, certain moments are relatively more responsible for pinning down the shares and elasticities in the CES aggregates.

For example, the pension is picked so that the government remits all of the Social Security tax revenue it collects, and β is largely determined by K/Y. Also, δ and $\underline{h}$ are determined by homeownership rates and the relative financial wealth of homeowners and renters. Regarding the eight parameters in our CES aggregates, it is the relative differences between homeowners and renters that allow us to identify these parameters.

As mentioned earlier, the four elasticity parameters (ζ_i, $i = 1, 2, 3, 4$) play crucial roles in determining households' supply of labor to different activities and consumption of different goods. These parameters, along with the share parameters (ω_i, $i = 1, 2, 3, 4$) are largely identified from the shares of house size (rental size) relative to income, the expenditure on home input relative to income, the relative amount of time worked at home and the relative amount of time worked in the marketplace. Because homeownership is more expensive than renting, homeowners tend to have a higher ratio of d/h, and the difference in this moment for the two types of agents allows us to pin down ζ_1 and ω_1. Using the relative amount of time spent in home production across these two types of agents helps to pin down ζ_2 and ω_2. Similarly, the difference across renters and homeowners regarding the relative time worked in the marketplace, because it influences how much of the market good is purchased, helps to pin down ζ_3 and ω_3. Finally, the difference in d/y and h/y as well as the differential use of time, because they help determine the differences in C/y and l, is useful for identifying ζ_4 and ω_4. However, the estimation is a bit more complicated than that and is not totally driven by one set of moment differentials driving one pair of elasticity and share parameters. Substitutability between various components in the CES aggregators affects how productive a home is relative to renting, which in turn affects choices of homeownership and, therefore via a selection effect, all the relative moments of homeowners and renters.

5.2.1 Implications

According to our calibration, the home input and housing are Hicksian substitutes in the production of the composite home good. The composite home good and home hours exhibit strong complementarity in home production.[18] The market good and home good, on the other hand, are substitutes. Finally, the final composite consumption good made up of the market good and home good is substitutable with leisure in households' utility. The existing literature on home production has largely lumped home hours and leisure together into nonmarket hours, making the comparison with our estimates difficult. Nevertheless there is some supporting evidence from the literature. For example, Abbott and Ashenfelter (1976) find that housing, transportation, and other services tend to be complementary with nonmarket time. Barnett (1979) estimates a model of joint goods and leisure consumption and finds non-weakly-separable substitution between consumption and leisure. Greenwood and Hercowitz (1991) argue that to generate comovement in investments in durable goods in the market and at home one needs to have complementarity between durable goods and time in home production.[19] The finding that the home input and housing are complements with home hours in home production explains why after a household moves from being a two-earner family to a one-earner family, home capital typically increases, as documented in Baxter and Rotz (2009). The strong substitutability between market goods and home goods is consistent with the findings in the literature, notably Rupert, Rogerson and Wright (1995). After we present household optimal decision rules and life-cycle profiles, we will conduct additional analysis to further understand the identification of these parameters.

6 Numerical Results

This section compares the model-implied life-cycle patterns with those constructed in the data as discussed in section 2. The profiles are calculated by integrating each variable (consumption or hours used) over the invariant distribution at each age. We show that the model does a good job of matching life-cycle profiles.

[18] The direct partial elasticities of substitution between home input and home hours and housing and home hours can be derived using formulas provided in Sato (1976). Using the economy-wide average consumption, we calculate that the elasticity of substitution between home input and home hours is 0.817 and the elasticity of substitution between housing and home hours is 0.869.

[19] Chang (2002) argues that adjustment costs in capital accumulation can account for the comovement in investments.

6.1 Homeownership

Figure 5 compares the model's prediction of the fraction of homeowners at each age with the data. Our model prediction tracks the data profile with reasonable accuracy–only the very oldest (ages 79 and 80) fall outside of the two-standard-deviations error band.[20] In the model, most young agents rent while accumulating financial assets. As time goes by, more households have accumulated sufficient funds for down payments to become homeowners. Homeownership rates continue to be very high late in life.

In our 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 without paying transaction costs. On the other hand, owning might dominate renting, because owners can borrow against a portion of house value when purchasing a house. This feature distinguishes owner-occupied housing from other expenditures in the model. Also, owner-occupied housing is more productive than rental properties in home production with an efficiency gap of 15 percent. 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. The gradual process of acquiring enough wealth to purchase a home also has implications regarding the distribution of agents who continue to rent over their life cycle. Apart from those that draw a rent shock, they tend to be households that have drawn a low labor productivity profile. Thus, over time there is a selection effect regarding the productivity of agents who rent. Also, the desire to own a house has implications for the life-cycle profile of asset accumulation. As in Fernandez-Villaverde and Krueger (2010) most young households' initial wealth accumulation is in the form of houses.

6.2 Life-Cycle Profiles of Hours

Figure 6 shows the life-cycle profiles of the average fraction of time spent in working and home production in the model. Notice that our model does a good job of capturing the life-cycle profiles of hours spent in market work, home production, and leisure for both homeowners and renters. Young agents, all starting with little wealth, work relatively intensively to buy goods, to accumulate precautionary assets, and to save for future house purchases. As agents age, they spend more time at home and decrease market hours. This is largely driven by the labor efficiency profile, which peaks at around age 50. The distribution of Social Security benefits starting at age 61 provides additional

[20] The error bands of our empirical data profiles are obtained using bootstrap.

incentive for households to reduce their labor supply after age 61. Note that the increase of resources after age 61 from Social Security benefits induces more reduction in market hours for renters in the model. This occurs because in our model pension distribution is a function only of age. Therefore, for old age renters whose labor productivity tends to be low, pension payment may exceed their labor income substantially.

Homeowners spend more time in home production than renters in the same age group. This stems from the fact that under our parameterization, time and houses are complements. Homeowners on average have more housing capital than renters and thus spend more time at home.

6.3 Life-Cycle Profiles of Consumption

The left panel of Figure 7 shows, in percentage deviation from the corresponding value at age 25, the life-cycle profiles of average demand for market consumption, housing and market inputs for homeowners. Again our model prediction falls within the two-standard-deviations error band of the data estimation. Over the life cycle, average consumption of market goods for homeowners is hump-shaped and peaks at age 55. Market goods consumption at age 55 is about 30 percent more than that at age 25. After the peak, market goods consumption decreases dramatically with age. Market goods consumption at age 80 is about 50 percent less than that at age 25. 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 the profile of their overall consumption due to the fact that they are discounting future consumption by more as they age and face a lower survival rate. Their market consumption decreases by more as older households substitute home consumption for market consumption.

The demand for housing in the model reproduces the empirically observed profiles, increasing early in life and downsizing slowly later in life. Households begin their economic lives with little housing stock. During the early part of their lives, because of the existence of borrowing constraints and the role of housing as collateral, they forgo nonhousing consumption and build housing stock quickly. Agents build up their highest housing stock at age 60. The elderly decrease their housing stock quite slowly, due to transactions costs and the increasing home hours, which are complements to home input and housing in home production. Old households are less likely than young households to move and incur the accompanying transactions costs, because they can only live in the new house for a relatively short period of time.

Home input and housing generally track each other over the life cycle as both are complements with home hours in home production. However, the transactions costs in housing adjustment for homeowners make the track less than perfect, which explains why home input declines faster than housing. Using detailed ATUS, Baxter and Rotz (2009) find that when a wife leaves the labor force, home hours rise as expected, but durables also rise, which is unexpected, according to standard home production models. This pattern, however, is entirely consistent with our model as home input is a complement with home hours with the direct partial elasticity of substitution at 0.817 (see our discussion in footnote 17 in the calibration section).

The right panel of Figure 7 shows the life-cycle profiles of average market consumption and demand for housing and home input for renters. For renters, the expenditures on all three goods starts declining from age 30, and the expenditure on market goods has the biggest decline. Note that the life-cycle profiles of renters are strongly affected by selection effects. As renters age, more and more of them become homeowners. Those who remain renters tend to be relatively poor with fewer resources and thus consume less. Since rental housing is costless to adjust, utility optimization implies that the ratio of housing to home input is constant for renters; thus, the profile for home input coincides with the one for housing. Average consumption of market goods for renters does not vary much before age 65, but decreases very dramatically after retirement. Home input and housing decline less dramatically since both are complements with home hours in home production.

6.4 Life-Cycle Profiles of Wealth Composition

Figure 8 displays the evolution of the wealth portfolio over the life cycle for homeowners and renters calculated from the Survey of Consumer Finances (SCF) using the same synthetic cohort method. Figure 9 displays the same profiles generated by our model simulation. Our model matches the qualitative features of the wealth profiles of both owners and renters, although the hump in owners' financial wealth is more pronounced in the data than in the model.

Young households, which 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 progresses, agents have accumulated stocks of houses and start to increase their holding of financial assets. The profiles of financial assets and housing assets intersect in the early 40s. Financial wealth holding peaks at age 55. Afterwards, households start to use their assets to finance consumption. At very old ages, homeowners borrow against their homes and take on debt.

Renters hold fewer financial assets than homeowners. Compared with the data, the financial assets profiles for both owners and renters have humps that are more pronounced. Since we abstract from bequest motives, health expenditure uncertainty, or other shocks, old agents in our model do not have bequest or precautionary saving motives and run down their assets much more quickly than in the data.[21]

7 Inspecting the Model's Mechanisms

In this section, we turn off various parts of the model to help understand the important interrelationships that home production and housing decisions play in matching the profiles of consumption and hours over the life cycle. First, we take away the homeownership decision by making everyone a renter. Then we take away housing by setting $\omega_1 = 1$, and then shut down home production by setting $\omega_1 = 1, \omega_2 = 1$, and $\omega_3 = 1$. Finally, we make labor effort exogenous by setting $\omega_3 = 1$ and $\omega_4 = 1$, leaving us with an exogenous income process and the determination of aggregate consumption as in the initial literature on life-cycle consumption. With each restriction on parameters we do not reestimate the model, creating a presumption that the life-cycle profiles of the model will deteriorate relative to the benchmark. What the experiment is intended to do is to analyze exactly how the fit deteriorates, thus providing intuition regarding the linkage between the various features of the benchmark model. The results of this exercise are displayed in Tables 6 and 7 and Figure 10. The tables, which normalize the life-cycle consumption profiles to the average income in the benchmark, show that the scaling of the model economy is substantially altered by the various changes in parameter settings while the figures, which normalize the life-cycle consumption profiles to age 25 values, indicate how the profiles change.

First, examine the effect of removing owner-occupied housing. There is a significant effect in the life-cycle profile of housing size. Without the need to put down a down payment to buy a house, young households rent larger housing units, maintaining the effective productivity of housing across the two scenarios. However, house size peaks much earlier in the rental economy and peaks at a lower level. House size also declines much more sharply later in life when all households rent, because there are no transactions costs in downsizing houses.[22] As a result, home production is somewhat less

[21] The 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 (2010)). The effect of medical costs on the life-cycle consumption and saving in an environment with housing is left for future research.

[22] Note that in the all-renters economy, housing profiles track exactly that of home input. We,

productive in the renters-only economy and market consumption is somewhat higher as are market hours (see Tables 6 and 7). Regarding the life-cycle profile of home input, it is less steep, peaks earlier, and declines faster. This behavior is a consequence of the greater flexibility in housing in the all-renter economy, since the profile for home input coincides with the one for housing. With respect to market consumption it is slightly flatter early in life, reflecting the removal of the down payment constraint with respect to housing. Overall, however, the effect is not large. In terms of home hours, households work less at home especially later in life when they are downsizing their apartments. They also work a little more intensively in the market early in life, which is in part due to substituting market hours for less productive home hours. All told, while there are meaningful effects from removing owner-occupied housing, the effects are not dramatic.

Removing the need for housing implies that the home input is more productive in home production as it no longer enters through a nested CES aggregator – and, therefore, it is not subject to the same degree of diminishing returns. Households now purchase more home input. However, because renting was cheaper than the home input, the total amount of intermediate inputs in home production declines and households work less intensively in home production. They also work a bit more in the market relative to the benchmark. The change in hours use leads to market consumption replacing some of the loss in home consumption. The profile for the home input peaks much earlier in life than the benchmark and at a lower relative level. Essentially, the profile is the same as in the all-renters economy because the home input and rental housing are purchased in constant proportions. However, the profile for market consumption is only slightly changed from the benchmark and is almost identical to its profile in the all-renters economy.

Without home production ($\omega_3 = 1$), the changes in behavior are now dramatic. Households respond by working a lot harder in the marketplace and the profile for hours declines more slowly later in life. This is driven by the labor efficiency profile and the pension provision and the fact that households don't have the option to spend more time at home later in life, as they do in the benchmark. Because households earn more, the liquidity constraint is not as binding and the profile for market consumption is a good deal flatter. Further, households no longer can smooth total consumption using home production and have a greater desire to smooth market consumption.

Finally, by setting $\omega_4 = 1$, we replicate the Bullard and Feigenbaum (2007) result that when there is no labor-leisure decision the life-cycle profile for market consumption is smoother. The flattening of the profile is due to the lack of substitutability between leisure and consumption. In particular, households work less both early and late in life than they do in middle age. That feature tends to reduce consumption early and late in

therefore, don't chart housing separately.

life relative to middle age consumption when leisure enters utility.

8 Conclusions

We extend a standard life-cycle model of consumption by including housing decisions that involve an important external margin concerning homeownership along with the addition of an explicit home production environment. The model, thus, explicitly distinguishes between market and nonmarket-related labor supply and consumption variables. We show that such a model can account for the observed life-cycle patterns in households' time use as well as consumption of different categories. In particular, the labor efficiency profile together with the availability of households' retirement funds implies that households have incentives to drastically reduce their labor supply at around age 50. As they reduce their market hours, households allocate more of their time to home production and leisure. On the consumption front, households initially increase their consumption of market goods, home goods, and housing as they accumulate more assets to relax their borrowing constraint. Toward retirement age, as households reduce their market hours, the cost of home production is lower. Consequently, the consumption of market goods declines because households substitute home-produced domestic goods for market goods. Home goods and housing also decline slightly as households approach the end of their life cycle, but the decline is partially offset by the requirements of home production. Thus, the additional margins associated with home production help the model not only to match aggregate life-cycle consumption profiles but also to match the profiles of different categories of goods. Importantly, the model can account for how households allocate time to various activities over the life cycle and this time use is empirically consistent with their consumption decisions. Further, the explicit modeling of the housing decision allows us to discriminate between renters and homeowners and to show that our framework is capable of matching both types of household behavior.

Appendix A. Definition of the Stationary Equilibrium

We focus on the stationary equilibrium of the economy where factor prices and agent distribution over state space are constant over time. Each agent's state is denoted by x. Let S denote the aggregate housing stock available for renting, H the aggregate owner-occupied housing stock, D the aggregate stock of home input, C_m the aggregate consumption of the market good, I_h the aggregate investment on housing, I_d the aggregate investment on home input, I_k the aggregate investment on physical capital, T^c the total transactions costs for trading housing, N_m aggregate market hours supplied, and N_h aggregate home hours supplied.

Definition 1. A stationary equilibrium is given by government policies including tax rate τ, and pension $pen(t)$; an interest rate r and a wage rate w; value functions $V(x)$; allocations $c_m(x)$, $a'(x)$, $h'(x)$, $d'(x)$, $s(x)$, $n_m(x)$, $n_h(x)$; bequest b; and a constant distribution of people over the state variables x, $\upsilon(x)$, such that the following conditions hold:

(i) Given the government policies, the interest rate, the wage, and the expected bequest, the value functions and allocations solve the above described maximization problem for a household with state variables x.

(ii) $\upsilon(.)$is the invariant distribution of households over the state variables.

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

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

(iv) The expected bequest is consistent with the actual bequest left

$$\int b\upsilon(dx)+\int_{t=0}(a(1+r)+(1-\delta^h)h+(1-\delta^d)d)\upsilon(dx) = \int(1-\lambda_t)[(1+r)a'+(1-\delta^h)h'+(1-\delta^d)d']\upsilon(dx).$$

(v) Government budget is balanced at each period

$$\tau\int \varepsilon e_t w n_m \upsilon(dx) = \int_{t\geq T^r} pen(t)\upsilon(dx).$$

(vi) All markets clear.

$$\begin{aligned}
H &= \int h' \upsilon(dx), \\
S &= \int_{h'=0} s\upsilon(dx), \\
D &= \int d' \upsilon(dx), \\
K &= \int a' \upsilon(dx) - S, \\
C_m &= \int c_m \upsilon(dx), \\
T^c &= \int \varphi(h, h') \upsilon(dx), \\
N_m &= \int \varepsilon e_t n_m \upsilon(dx), \\
I_h &= \int [h' - (1-\delta^h)h] \upsilon(dx), \\
I_d &= \int [d' - (1-\delta^d)d] \upsilon(dx), \\
I_k &= K' - (1-\delta^k)K, \\
F^m(K, N_m) &= C_m + I_k + I_h + I_d + T^c.
\end{aligned}$$

Appendix B: Computation of the Model

Due to nonconvex transactions costs on housing and the collateralized borrowing constraint, we cannot use either an Euler equation approximation or the policy function iteration. Hence, we solve the model using value function approximation.

To compute the steady state of our model, we first discretize the income process into 5 points. The state space for owner-occupied housing and asset holdings are discretized into unevenly spaced grids. The upper bounds on the grids are chosen to be large enough so that they do not constitute a constraint on the optimization problem. We chose 20 grid points for each of the asset variables. The choice variables are searched over 100 grid points for housing and assets and continuous for other variables. We use linear approximation to approximate valuation functions for the points not on the state grids.

We solve for the steady-state equilibrium as follows:

1. Make an initial guess of interest rate r, the wage rate w and pension.

2. Guess the size of accidental bequests.

3. Set the 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 functions in 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 with the initial guess. If so, continue to step 7. If not, go back to step 2 and update accidental bequests.

7. Check whether market clearing conditions hold, and whether the government budget is balanced. If so, an equilibrium is found. If not, go to step 1 and update the initial guess.

Appendix C: Calibration

We use data from the National Income and Product Accounts and the Fixed Assets Tables for the years 1957-2007. In order to properly calibrate a model with two assets and without government taxes and expenditures, we make some imputations.

In measuring capital income share, we first remove income from the housing sector and the government sector from the national income accounts. Then we 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 nonhousing income Y_p is the sum of Y_{pl}, ACI, UCI, and depreciation. Private capital income Y_{pk} is defined as $UCI + dep_{UCI} + \alpha \cdot (ACI + dep_{ACI}) = \alpha \cdot Y_p$. In other words, we allocate the ambiguous components of capital income and its depreciation according to the share of capital income in measured total output. The share of capital is calibrated as

$$\alpha = (UCI + dep_{UCI})/(Y_p - ACI - dep_{ACI}). \tag{13}$$

We compute an average share of capital $\alpha = 0.240$.

The variable I_k is total private nonresidential investment, K is private fixed nonresidential assets. We calculate the average capital-output ratio $\frac{K}{Y} = 1.61$, and the investment-capital ratio $\frac{I_k}{K} = 0.10$. Given that the paper abstracts from population as well as technology growth, we set the depreciation rate for nonhousing capital δ^k at 0.10. The implied real interest rate is thus $r = \alpha\frac{Y}{K} - \delta^k = 0.05$. Note that this rate is somewhat higher than the 0.027and 0.040 range typically used in the literature. Given that capital stock is measured with considerable error (Gomme and Rupert 2007), we decide to follow the literature and set our equilibrium real rate of interest at 0.04. Holding the nonhousing capital depreciation rate at 0.10, this implies a capital-output ratio of 1.71, slightly higher than the calculated 1.61. We set the depreciation rate on housing capital δ^h to 0.02, well within the range of those used in the literature.

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Table 1. Market Hours versus Home Hours

Category	Definition
Market hour	Working (including work-related as well as income-generating other activities),
	Job search, Job interview
	Commuting
Home hour	Housework (interior cleaning; laundry; sewing; repair and maintenaning textiles; storing interior household items; food and drink preparation, presentation and cleaning; interior arrangement, decoration and repairs; building and repairing furniture; heating and cooling; interior maintenance; exterior cleaning; exterior repair, improvement, and cleaning; lawn, garden, and houseplant care; ponds, pools, and hot tubs; appliance and tool set-up, repair, and maintenance (by self); financial management; household and personal organization and planning; household and personal mail and messages; home security; and related travel)
	Housework service (using interior cleaning services; using meal preparation services, using clothing repair and cleaning services; waiting associated with using household services; using and waiting associated with home maint/repair/décor/ construction services; using and waiting associated with lawn and garden services; telephone calls to/from household service providers; and all related travel)
	Shopping (grocery, gas, food, and others, waiting associated with shopping, security procedures related to consumer purchases; telephone calls to and from salesperson; and all related travel)
	Pet care (care for animals and pets, using and waiting for veterinary services, using and waiting for pet services; and travel related to these services)
	Car care (vehicle repair and maintenance and related services, including travel)
	Child care (physical care for children; reading, playing and talking with children; planning and attending children' activities; doing homework, meeting and school conferences; medical care and associated services to children)
	Adult care (physical care and related services to adult; housework, animal care, vehicle repair and maintenance; financial management; medical care and services; and related travel)
	Shop search (comparison shopping and research purchases)
	Child care service (paid child care services and related travel)
	Professional service (financial; legal; health care; real estate related; related telephone and travel)

Table 2. Market Consumption versus Home Input

Category	Definition
Market good	Food away from home
	Alcoholic beverages
	Tobacco
	Apparel and services
	Other lodging
	Fees and admissions for entertainment
	Televisions, radios, sound and other entertainment-related equipment
	Pets, toys, and playground equipment
	Reading
	Personal care
	Education
	Out-of-pocket medical expenses
	Transportation expenses prorated by travel time for leisure- or market-related activities
Home input	Food at home
	Household operations
	Household furnishing and equipment
	Utilities, fuels, and public services
	Transportation expenses prorated by travel time for home production

Table 3. Calibration According to the Data and the Literature

Parameters		Value	Source
Demographics			
T	maximum life expectancy	100	
T_r	retirement age	61	
λ_t	survival probability	see figure 4	Social Security Administration Life Tables
Technology			
α	capital share in National Income Accts.	0.240	authors' calculation
δ^k	annual depreciation rate of capital	0.100	authors' calculation
δ^h	annual depreciation rate of housing	0.020	authors' calculation
δ^d	biannual depreciation rate of home input	1.00	authors' calculation
Endowment			
e_t	age-efficiency profile	see figure 4	French (2005)
ρ_y	AR(1) coefficient of 2-year income process	0.960	French (2005)
σ_y^2	innovation of 2-year income process	0.045	French (2005)
Government policy			
τ	Social Security tax	0.096	payroll tax minus Medicare and disability insurance
Housing market			
θ	down payment rate	0.200	
ρ_1	transactions costs of selling a house	0.070	Gruber and Martin (2003)
ρ_2	transactions costs of buying a house	0.025	Gruber and Martin (2003)
μ_1	maximum depreciation	0.020	
μ_2	maximum renovation	0.080	
m_t	rental shock	see figure 4	Li and Yao (2007)
Preference			
γ	risk aversion coefficient	1.500	Attanasio, et. al (1999), Gourinchas and Parker (2002)

Table 4. Calibration to Match Data Moments

Parameters (12)		Value
β	discount factor	0.954
pen	Social Security benefit	0.266
δ	renting disutility	0.181
$\underline{h}$	minimum owner-occupied house size	1.072
ζ_1	sub. between d and h	1.369
ω_1	weight on durable	0.703
ζ_2	sub. betw. d and h composite and n_h	0.802
ω_2	weight on d and h composition	0.748
ζ_3	sub. betw. market and home goods	2.063
ω_3	weight on market goods	0.138
ζ_4	sub. betw. consumption and leisure	1.408
ω_4	weight on consumption	0.243

Table 5. Calibration Results

Moments	Model	Data
capital output ratio (K/Y)	1.710	1.700
homeownership	0.680	0.685
Social Security tax rate	0.096	0.096
renter nonhousing wealth/owner nonhousing wealth	0.156	0.156
renters		
average expenditure on home input goods/income	0.370	0.359
average housing value/income	1.872	1.926
average share of home hours	0.138	0.139
average share of market hours	0.151	0.156
owners		
average expenditure on home input goods/income	0.661	0.675
average housing value/income	3.181	3.172
average share of home hours	0.155	0.155
average share of market hours	0.159	0.157

Table 6. Inspecting the Model's Mechanisms – Consumption/Economy-Wide Income

Age	Benchmark	All-renters	No housing	No home prod.	No home prod. or leisure
Housing					
26	2.0255	2.4468	0	0	0
36	2.4467	2.9116	0	0	0
46	2.8458	3.2385	0	0	0
56	3.0938	3.3926	0	0	0
66	3.1273	3.2370	0	0	0
76	2.8266	2.7606	0	0	0
86	2.2497	1.8685	0	0	0
Home input					
26	0.2357	0.2347	0.3711	0	0
36	0.2807	0.2793	0.4414	0	0
46	0.3106	0.3107	0.4901	0	0
56	0.3248	0.3255	0.5151	0	0
66	0.3086	0.3106	0.4916	0	0
76	0.2615	0.2648	0.4181	0	0
86	0.1757	0.1793	0.2830	0	0
Market consumption					
26	0.4975	0.5220	0.5441	2.2434	3.2491
36	0.7110	0.7067	0.7360	2.8522	4.0558
46	0.8327	0.8290	0.8608	3.2863	4.6246
56	0.8653	0.8660	0.9025	3.4481	4.9694
66	0.6911	0.6937	0.7249	3.1079	4.8617
76	0.4783	0.4866	0.5071	2.3360	4.2152
86	0.2237	0.2306	0.2422	1.3550	3.0634

Table 7. Inspecting the Model's Mechanisms – Share of Hours

Age	Benchmark	All-renters	No housing	No home prod.	No home prod. or leisure
Market hours					
26	0.2079	0.2192	0.2218	0.5775	1
36	0.2339	0.2357	0.2388	0.6018	1
46	0.2113	0.2112	0.2153	0.5830	1
56	0.1820	0.1845	0.1870	0.5494	1
66	0.0777	0.0797	0.0813	0.3959	1
76	0.0213	0.0236	0.0245	0.1932	1
86	0.0041	0.0048	0.0051	0.0737	1
Home hours					
26	0.1355	0.1344	0.1255	0	0
36	0.1358	0.1354	0.1264	0	0
46	0.1422	0.1412	0.1317	0	0
56	0.1486	0.1464	0.1369	0	0
66	0.1654	0.1626	0.1521	0	0
76	0.1715	0.1679	0.1571	0	0
86	0.1662	0.1619	0.1514	0	0

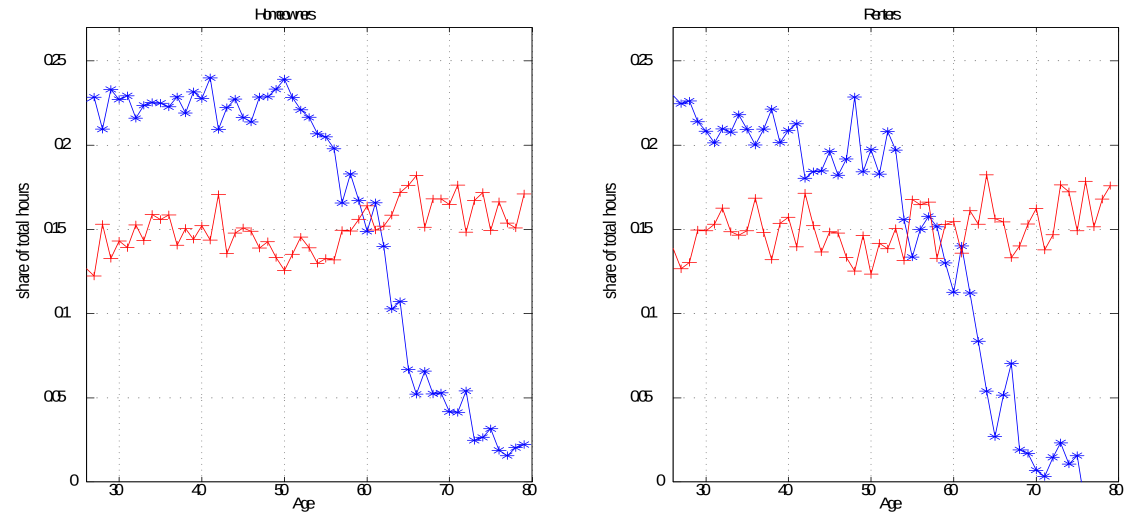

Figure 1. Supply of Hours by Homeowners and Renters (data source: American Time Use Survey 2005-2007. share of market hours: -*; share of home hours: -+)

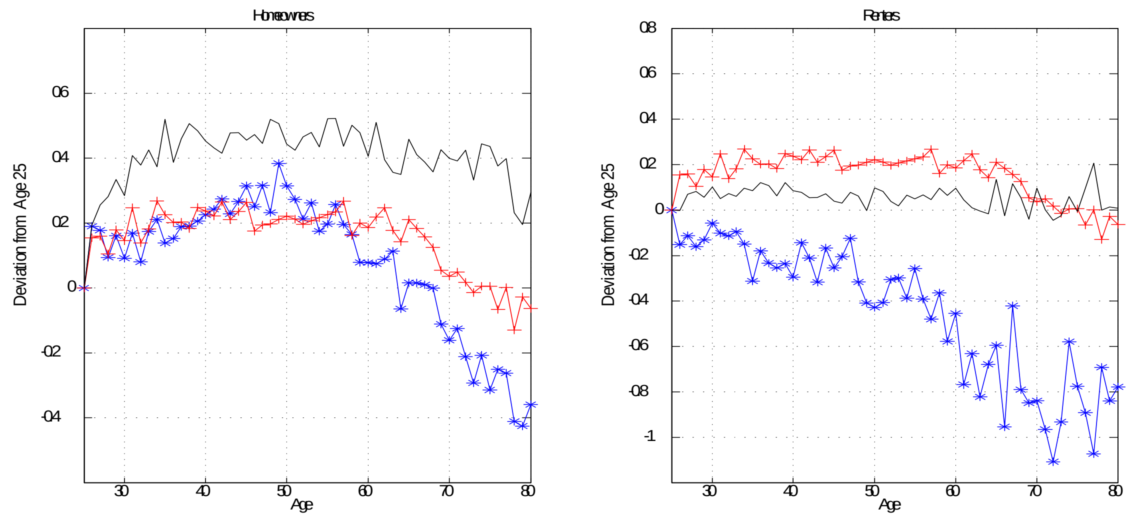

Figure 2. Consumption by Homeowners and Renters (data source: Expenditure Survey 2003-2006; market consumpion: -*; home input: -+; housing: –)

Beginning of period t	$\rightarrow$	labor shock for t, rental shock for t+1, and bequest for t realized, home input from t-1 depreciates	$\rightarrow$	market and home production take place	$\rightarrow$	end of period t whether survive to t+1 revealed
state variable (age, asset, house size if own, home input)				supply labor and capital, purchase home input for t home production, housing depreciates		consume, save, decide tenure and house size for t+1

Figure 3. Households TimeLine of Decisions

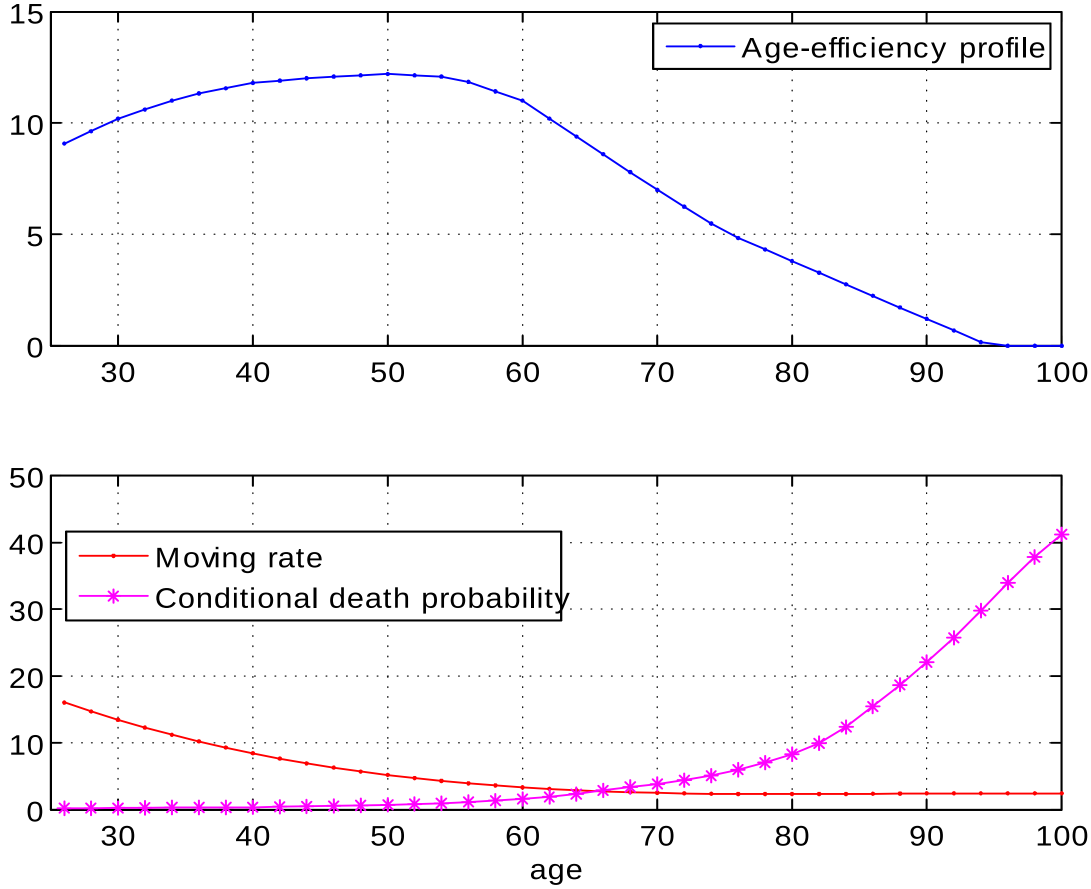

Figure 4. Exogenous profiles

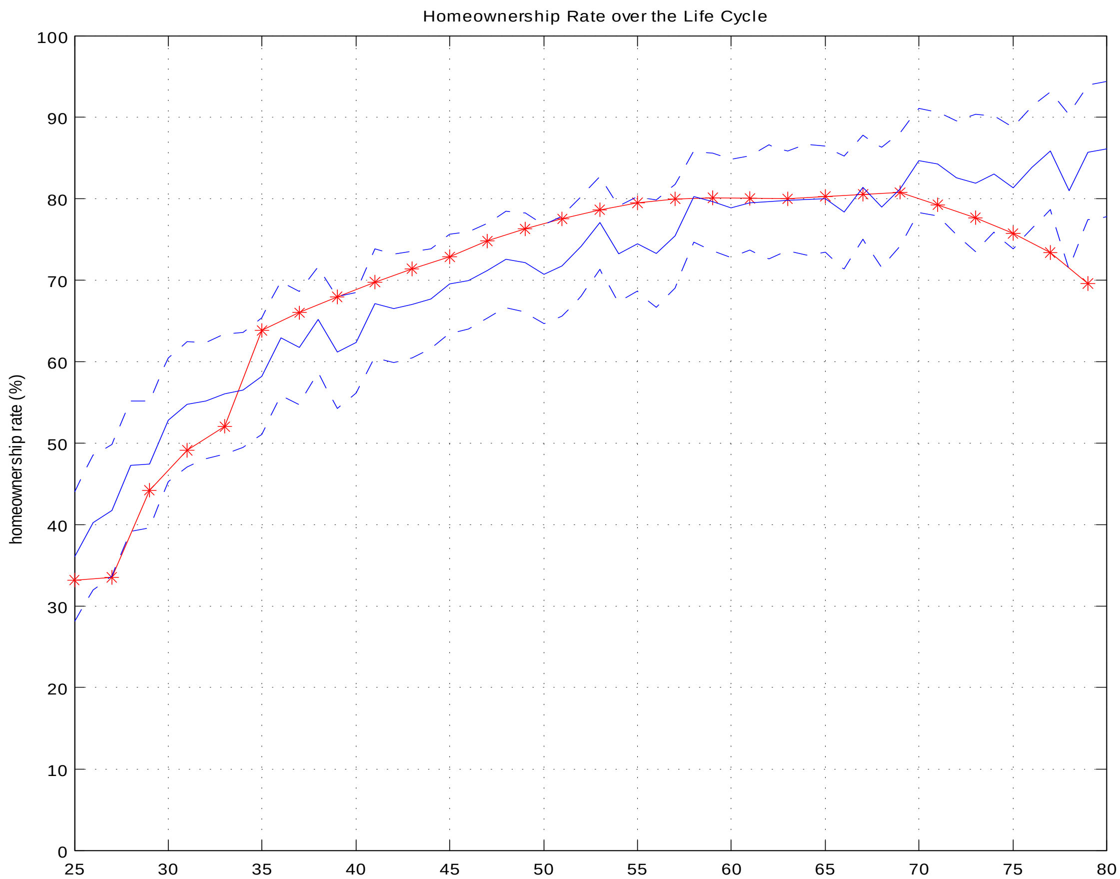

Figure 5. Homeownership Rate over the Life Cycle (data source: CEX) (data –; model: -*. The dotted lines are two standard deviations calculated off the data)

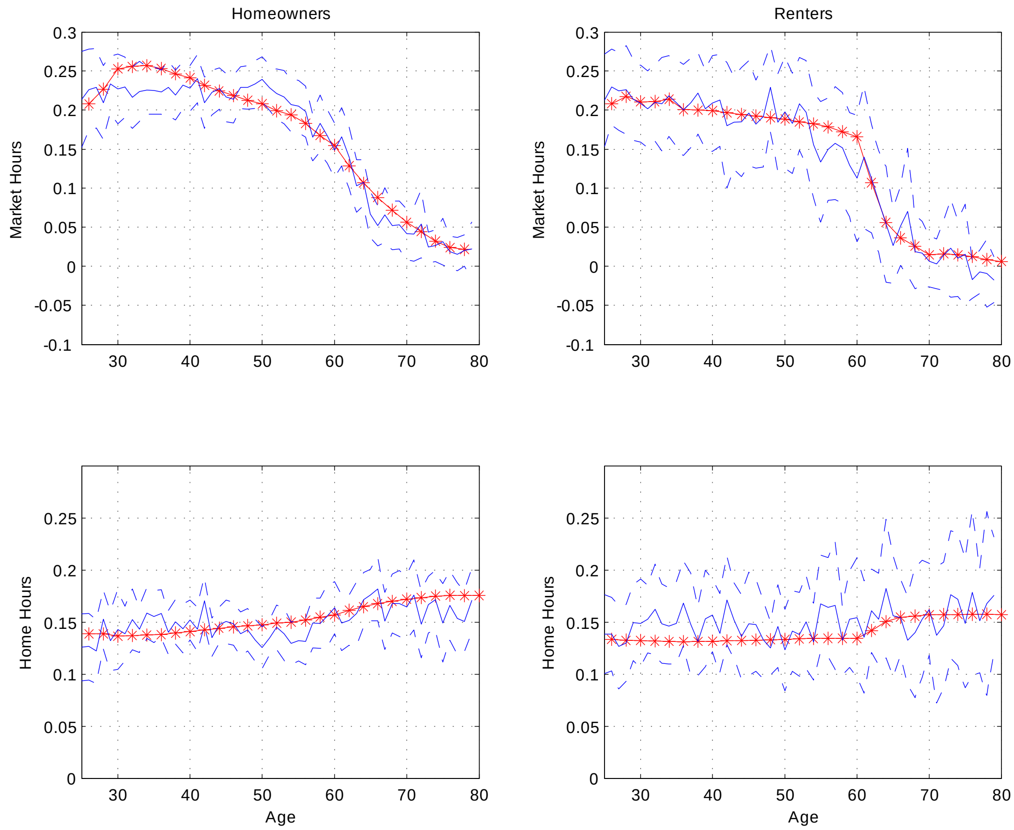

Figure 6. Hours over the Life-cycle (data: –; model: -*; the dotted lines are two standard deviations calculated off the data)

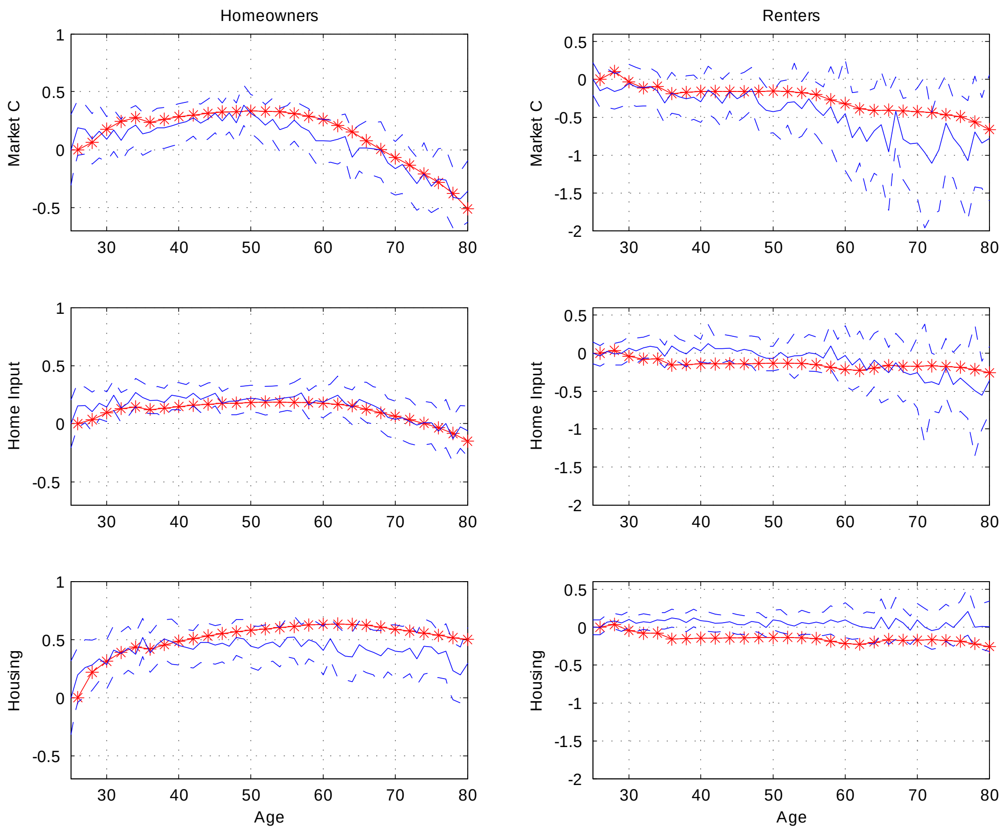

Figure 7. Consumption over the Life-cycle (data: –; model: -*; the dotted lines are two standard deviations calculated off the data)

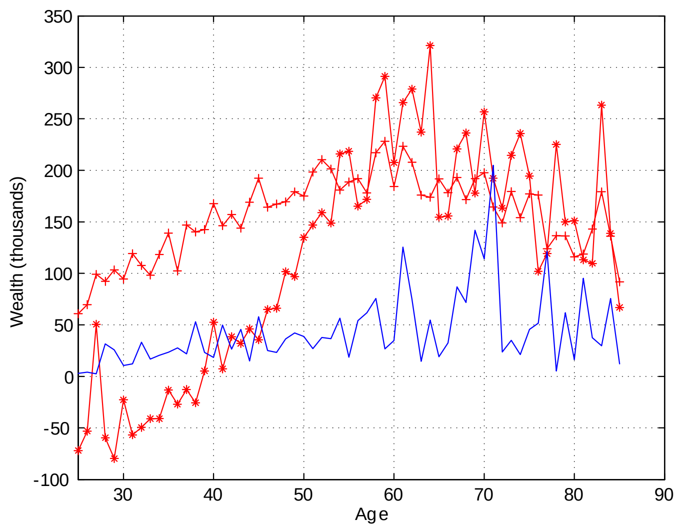

Figure 8. Wealth Profiles over the Life Cycle (SCF 2001, 2004, and 2007; owners' financial wealth: -*; owners' housing asset: -+; renters financial wealth: –)

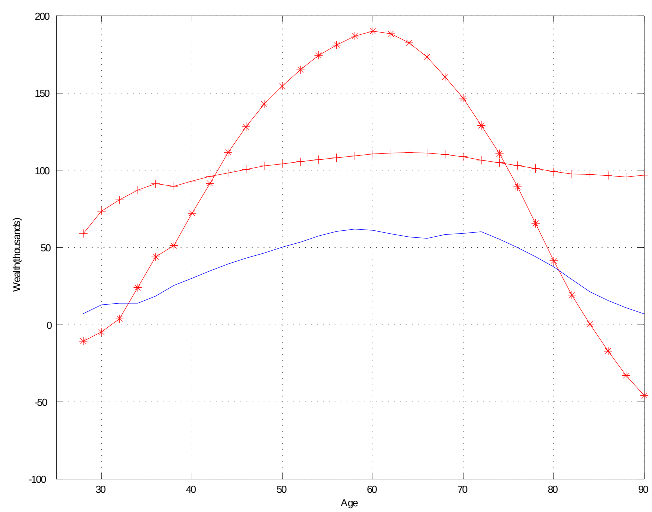

Figure 9. Wealth Profiles over the Life Cycle (model; owners' financial wealth: -*; owners' housing asset: -+; renters financial wealth: –)

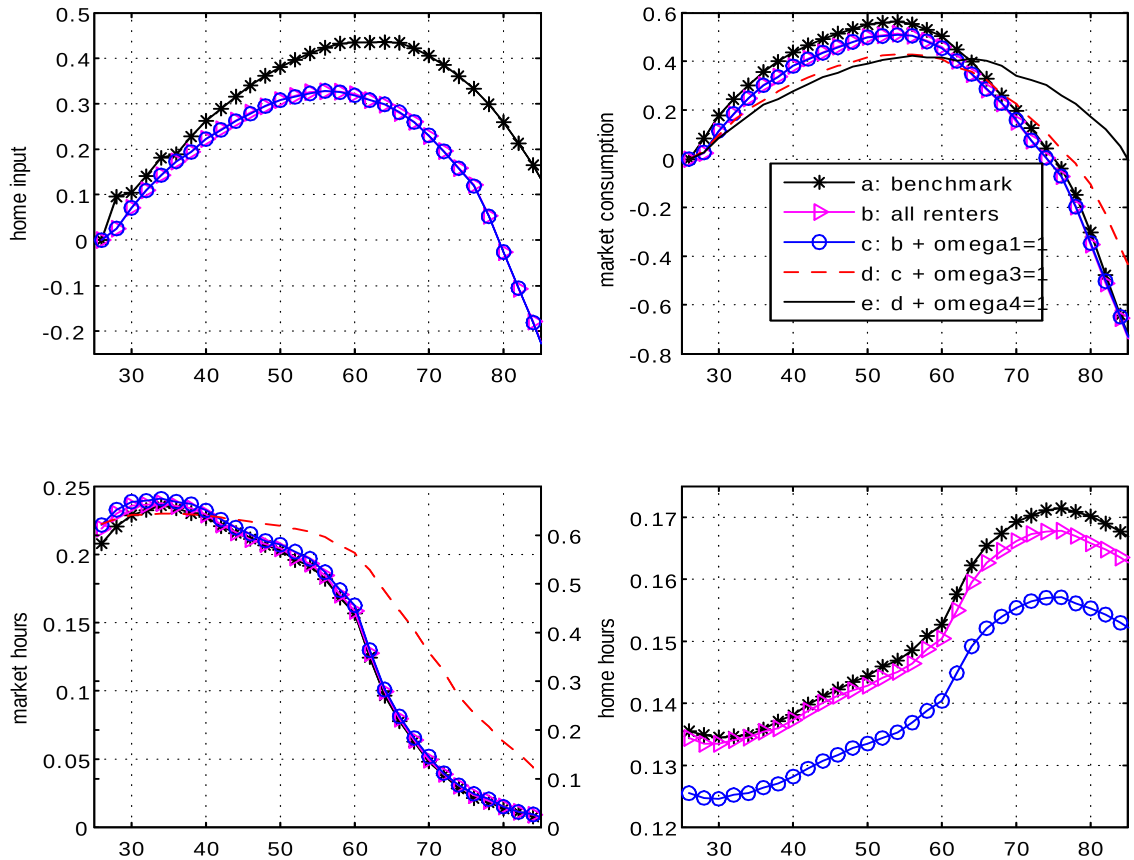

Figure 10. Investigating the Model's Different Mechanisms (benchmark: -*; all-renters: -square; no housing: -circle; no home production: - -; no home production and no leisure: –) (note: in the right bottom panel, market hours of the no home production case uses the right vertical axis)