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Home Equity Withdrawal in Retirement[*]

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Abstract

We study empirically and theoretically the patterns of home equity withdrawal among retirees, using a model in which retirees are able to own or rent a home, save, and borrow against home equity, in the face of idiosyncratic risks concerning mortality, health, medical expenditures, and household size and observed house price changes. The estimated model is found to successfully replicate the patterns of homeownership and the saving/borrowing decisions of retirees. We use the estimated model for several counterfactual experiments. There are three main findings. First, the model predicts that a house price boom suppresses homeownership and increases borrowing, while a decline in house prices has the opposite effect. Second, the costs of home equity borrowing restrict the borrowing of retirees, and thus a reduction of such costs (e.g., lower costs of reverse mortgage loans) might significantly raise home equity borrowing. Third, there are two implications for the retirement saving puzzle. Although the cost of borrowing against equity in the house affects the borrowing of retirees, it does not affect total asset holding, implying that equity borrowing costs do not seem to offer a quantitatively significant contribution to resolving the retirement saving puzzle. On the other hand, the magnitude of the retirement saving puzzle might be exaggerated, because a sizable part of "retirement saving" is due to house price appreciation.

JEL classification: D91, J26, E21, G11
Keywords: Housing, Retirement, Mortgage, Financial development, Health, Life-cycle

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1 Introduction

There is a large literature that studies life-cycle saving, borrowing, and consumption decisions, but in the majority of those models, the life cycle stops at the moment of retirement. Yet retirees are a crucial group in the population, and increasingly becoming more so. As baby boomers age, bringing the average age of the population up, and retire, their aggregate impact is increasing. This in turn has implications for the discussion of Social Security sustainability and reform, health-care reform, and other policy issues.

In this paper, we seek to “complete the life cycle” from theoretical and empirical points of view. We want to better understand the tradeoffs that face households after they have completed their working life. In addition, unlike the few other model-based studies of retirees in the literature, ours is the first to consider homeownership and the management of one’s home equity in retirement explicitly. We are interested in housing in particular because the majority of the working population in the U.S. retires with a house as a major part of their portfolio and they continue well into their old age as homeowners. For many retirees, the house is not only a place to live, but also a source of continued borrowing activity throughout retirement. This has always been the case to some extent, but in recent years, the role of housing as a financial asset has been highlighted as housing values first increased, then dropped dramatically, and at the same time, as it became increasingly easier to borrow against one’s home using home equity lines of credit and reverse mortgage loans. Thus housing has become important both for household portfolios and in the macroeconomy more generally. As the life-cycle literature has not in general considered retirees explicitly, we do not have a good sense yet of how and why retirees decide whether or not to be a homeowner in their old age, and how the home may be used as a source of insurance against uncertainty for retirees. In addition, in light of recent events, we think it is particularly important to understand the effect that booms and busts in the housing market may have on retiree behavior.

We build a model of saving and borrowing in retirement using both financial assets and a house, where households face several types of idiosyncratic uncertainty. With the model, considering housing explicitly, we revisit the so-called retirement saving puzzle. We also examine the impact that the financial market liberalization that we have seen in recent years has had on retirees as well as the impact of a possible continued decline in house prices going forward, from the perspective of homeownership rates and the amount of borrowing in home equity.

The model has the following key components. Retirees can choose whether to own a home or rent, and homeowners have the choice of selling their home and cashing in on the equity. They consume and can save in a financial asset, as well as borrow against their housing asset. They have income from Social Security and face uncertainty in their health status, and accordingly in their medical expenses and their life span (as well as that of their spouse), and finally in the price of their house. We include these shocks to highlight the fact that while retirees no longer face uncertainty in income, they do face significant other uncertainties. We model health status and medical expense uncertainty because health has been shown to be a crucial source of risk to retirees, according to De Nardi et al. (2010). Longevity uncertainty in general is obviously important as households age. We also include a particular shock to the size of the household, where it can transition from being a two-person to a one-person household; this is to reflect the possibility that one's spouse dies. According to empirical studies such as Venti and Wise (2004), the death of a spouse has been shown to be an important precipitating event for certain financial decisions such as selling one's house. Finally, house price dynamics, introduced for now at the aggregate level, are meant to reflect recent changes in the housing market in the U.S.

We use the Health and Retirement Study (HRS) to document in detail various facts about retirees' financial and housing asset holdings, their indebtedness, their income, as well as their health status, survival probabilities, and out-of-pocket medical expenditures. Because HRS is a longitudinal survey, we are able to track households over time, which gives us careful measures of various transition probabilities between states, as well as evolution of asset holdings over time. We track several cohorts over time and construct life-cycle profiles of relevant asset and debt variables, as well as homeownership profiles and household size over time. We use this information to estimate the model's parameters and assess its performance along a set of relevant dimensions. Although we have not completed the second formal stage of estimation, even this relatively simple model is able to replicate fairly well a set of life-cycle facts for retirees, including homeownership rates, financial and housing asset holding, and the proportion of the population in debt. The model comes close in terms of the total amount of debt held by those who choose to borrow, but not for all cohorts.

We then use the estimated model to conduct a series of experiments regarding the effect of house price dynamics on homeownership decisions and borrowing decisions. We perform two experiments: First, we "shut down" the house price boom of the 1996-2006 period; and second, we posit a decline in house prices beyond 2009 until prices reach their 1996 levels. We find that a house price boom of the magnitude seen in the last decade depresses homeownership rates, as rising home values encourage retirees to sell their homes and cash in on the equity. At the same time, holding on to the house allows households to borrow, and we find that rising home prices encourage borrowing, and conditional on borrowing, retirees borrow more. If house prices continue to decline beyond the present day, our model predicts a decline in future equity borrowing, but an increase in homeownership rates – as prices fall, people have less incentive to sell their homes.

The second set of experiments that we conduct concerns developments in housing markets that make it easier to borrow against one's home equity; this is meant to capture the advent of home equity lines of credit and reverse mortgages. These kinds of developments tend to elevate the homeownership rate and encourage borrowing against one's home. We also combine house price dynamics and housing market developments to study the interaction of the two sets of effects. In the data, during the housing boom and bust, we saw homeownership rise; our model predicts that this is the result of the financial market development effect dominating the price increase effect. Using our experiments, we revisit the retirement saving puzzle, which refers to the fact that retirees do not dissave as much as a simple model suggests. Our hypothesis is that retirees want to stay in their house but as they age, borrowing against the value of their house becomes increasingly costly and inflexible, which makes it look as if retirees do not dissave much. Our preliminary finding, however, is that our hypothesis does not seem to explain a sizable part of retirees' savings.

We have three main contributions. First, our careful documentation of the longitudinal data provides a set of facts regarding equity borrowing behavior in more detail than previously described. In addition to the empirical interest of up-to-date life-cycle facts, our data investigation is done with the model in mind and guides the choice of assumptions that we make in the model. We also hope to provide similar guidance for future models of retirement. Second, our model enables us to describe the tradeoff between using housing and nonhousing assets in retirement and conduct experiments pertinent to recent developments in the housing markets. To our knowledge, we are the first to do this in an estimated model of life-cycle behavior in retirement. Third, we contribute to the discussion of the retirement saving puzzle from a new perspective.

The remainder of the paper is organized as follows. Section 2 discusses related literature. Section 3 describes our data and stylized facts. Section 4 develops the model that we use. Section 5 first describes the estimation strategy, and then presents the results of the estimation procedure. Section 6 describes the experiments that we conduct using our estimated model. Section 7 concludes.

2 Related Literature

Our paper is related to a number of papers that study savings decisions and motives in retirement and those that analyze savings decisions with a focus on the role of housing.

An important question in the savings literature is why the elderly do not dissave much in the data, while a simple life-cycle model predicts that the elderly should keep reducing savings so that when death is certain and immediate they leave no savings. Various answers have been proposed to solve the "retirement saving puzzle." Hurd (1989) estimates the life-cycle model with mortality risk and bequest motives, and finds that the intended bequests are small. Love et al. (2009) analyze the retirement saving puzzle using "annualized comprehensive wealth," which is a measure of total wealth, including annuity-like assets as well as financial and nonfinancial assets. Regarding the savings decisions before retirement, Hubbard et al. (1995) argue that means-tested social insurance programs provide a virtual consumption floor and thus strong incentives for low-income individuals not to save; their paper can thus be seen as reinforcing the retirement saving puzzle.

Among the studies of savings of the elderly, the recent paper by De Nardi et al. (2010) is most closely related to ours in terms of approach. They estimate a life-cycle model of retirees using the sub-sample of the HRS, focusing on the oldest old (AHEAD). The model includes mortality risk, bequest motives, and out-of-pocket (OOP) medical expenditure shocks; and they find that large OOP medical expenditure shocks are the main driving force for savings of retirees. Additional papers that study implications of the health and medical expenditure risks on portfolio decision of retirees are Yogo (2009) and Kopecky and Koreshkova (2009), the latter of which focuses on nursing home expenses and studies the implications on aggregate savings and the distribution of wealth as well.

Like De Nardi et al. (2010), we use a life-cycle model of retirees together with the HRS, with health condition and medical expenditures being a major source of uncertainty for retirees. The key difference between our work and theirs is the focus on housing and home equity borrowing; while they aggregate all the assets in the household portfolio, including housing, and study the profile of the consolidated asset position in retirement, we explicitly model housing choice and specifically focus on the decisions of whether to own a home and whether and when to borrow against one's home equity. To the best of our knowledge, since there is no study that uses a structural model with housing to tackle the retirement saving puzzle, our paper contributes to the literature from a new perspective. The empirical part of our paper is related to Venti and Wise (2004), whose main finding, confirmed by our own studies as well, is that retirees rarely downsize their houses even at their older ages, unless a disastrous event such as illness or death of a spouse occurs. They also provide evidence from the HRS that some older households move into larger homes; we will be able to show that this may only appear to be the case based on rising house prices, rather than reflecting purchases of larger homes. Skinner (2004) points out this possibility in his discussion.

An important question regarding the interaction between savings decisions and housing is the wealth effect of house price changes on nonhousing consumption. Papers by Campbell and Cocco (2007) and Li and Yao (2007) investigate the issue. Campbell and Cocco (2007) use UK micro data to quantify the wealth effect and find that the effect is large for older homeowners and insignificant for young renters. Li and Yao (2007) use a calibrated life-cycle model and find that, although the aggregate wealth effect is limited, there is a large degree of heterogeneity: The response of nonhousing consumption is stronger for younger and older homeowners than middle-aged homeowners, and the welfare effect is the strongest for older homeowners who most likely will not buy a new house.

Since the housing market boom and bust are considered to play an important role in shaping the recent business cycles, especially the recent recession, there is an increasing body of work that incorporates housing explicitly into a macroeconomic framework. Fernández-Villaverde and Krueger (forthcoming) and Yang (2009) use a general equilibrium life-cycle model to study the life-cycle profile of housing and nonhousing consumption, with the focus on the difference between the two forms of consumption. Other related studies of housing that use structural models include Davis and Heathcote (2005), who study housing in a business cycle model, and Díaz and Luengo-Prado (2010), who investigate the implications of explicitly considering housing in explaining the observed large wealth inequality in the U.S. Ortalo-Magné and Rady (2006) study the impact of income shocks and credit constraints for business cycle dynamics of the housing market. Our paper complements these studies by focusing on the saving and housing decisions of retirees.

Our paper is also related to the studies of mortgage choices and aggregate implications of mortgage market developments. Chambers et al. (2009a) examine various elements that contribute to the rise in homeownership rates in the U.S. and find that the introduction of new mortgage instruments that allow a lower downpayment at the time of purchase has a sizable effect on the homeownership rate. They use a life-cycle model that captures the rich features of mortgage markets. Chambers et al. (2009b) construct a general equilibrium model with a focus on the optimal choice between conventional fixed-rate mortgages and newer mortgages with alternative repayment schedules, and they study the macroeconomic implications of having different types of mortgages available for households. Campbell and Cocco (2003) investigate the optimal choice for homebuyers between conventional fixed-rate mortgages (FRM) and more recent adjustable-rate mortgages (ARM). Our model is agnostic about specific mortgage options but complements the literature by focusing on home equity borrowing by retirees both empirically and theoretically.

Finally, a natural future direction of our project is to study the implications of retirees' decisions regarding saving and housing on the Social Security program and its reform. The influential work that uses a general equilibrium life-cycle model to analyze Social Security reform is Auerbach and Kotlikoff (1987). Chen (2010) analyzes the effect of Social Security elimination in a life-cycle model with housing.

3 Facts

3.1 Data

The Health and Retirement Survey (HRS) is a biennial longitudinal survey of households of age 50 and above, conducted by the University of Michigan. A total of eight waves are available, from 1992 until 2006. Due to issues with the data on assets (see De Nardi et al. (2010)), we begin our data observation in 1996 and thus use six waves that span 10 years.

We consider everyone present in the sample in 1996 who is of age 63 and above and who reports being retired. We consider both couples and single households. We subdivide the sample into six cohorts, of ages 63-67, 68-72, 73-77, 78-82, 83-87, and 88-97. We follow these cohorts across the waves of the survey and document their life-cycle patterns of asset holding and health, as described below. Because assets are measured in the HRS at household level, while health status and other demographic variables are at the individual level, we adjust the weighting schemes appropriately to construct information for our model households.

The HRS sample is replenished several times over the course of the survey. There are multiple ways to deal with this cohort replenishment: one could only consider those who appear in all six waves of the survey starting in 1996, or include in later waves everyone who belongs to a given cohort by age, even if they appear in the survey after 1996. As a benchmark, we consider only those households that appear in the 1996 wave, without replenishing the cohorts. For robustness analysis, we have considered an alternative analysis in which we allow the cohorts to be replenished after the 1996 wave.

A related issue with the HRS sample is weighting. Since the sample size changes as the sample is replenished, the weight attached to each household changes over the waves. In order to eliminate the artificial composition effects on aggregate statistics due to the changes of weights across households, we apply the weight attached to each household in the initial wave that we use (1996 wave). When we look at the replenished sample for a robustness check, we use the weights specific to each wave, since replenished households do not have a weight in the initial wave by construction. For the purpose of comparing with De Nardi et al. (2010), who do not use sample weights at all, we construct the same statistics without sample weights for another robustness check.

To allow our data measures to map into the model, we measure financial assets as the sum of nonhousing assets (excluding businesses and cars) net of all debt, including home equity debt. We track housing assets separately, including only the primary residence, since other real estate information is not available in all waves of the survey. Finally, we define total assets as the sum

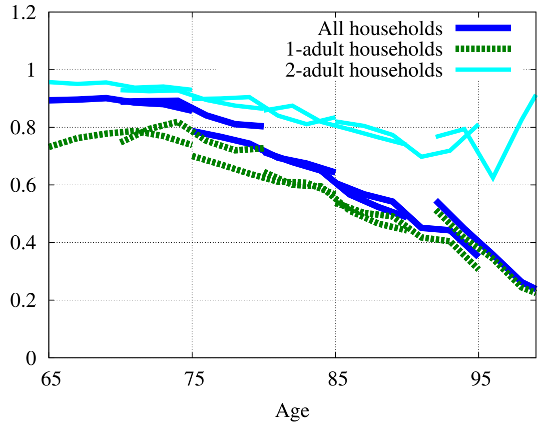

Figure 1: Homeownership Rates. Source: HRS, various waves.

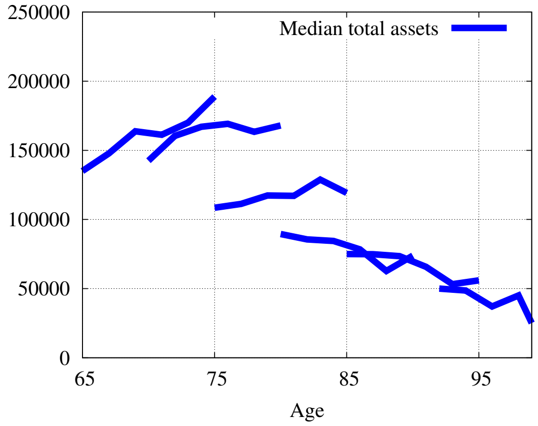

Figure 2: Median Total Assets. Source: HRS, various waves.

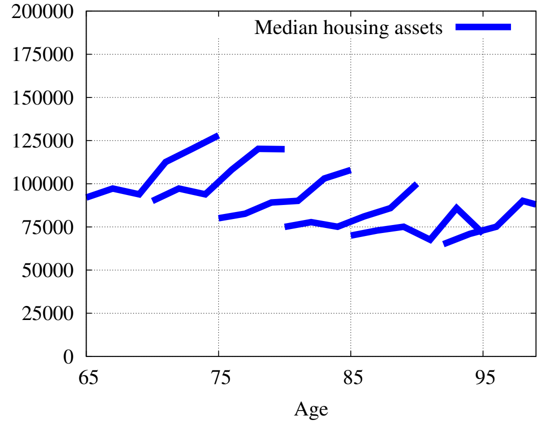

Figure 3: Median Housing Assets, Conditional on Ownership. Source: HRS, various waves.

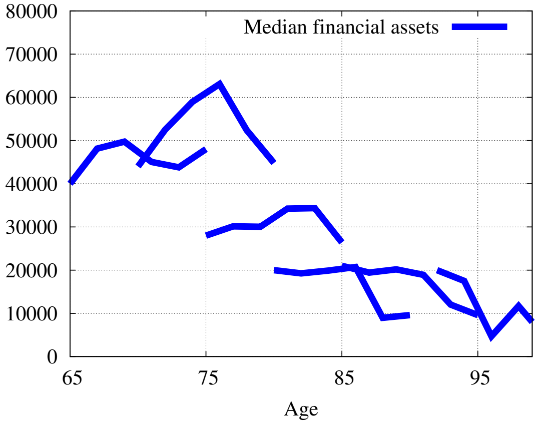

Figure 4: Median Financial Assets. Source: HRS, various waves.

of financial and housing assets, net of all debt.[1]

In the estimation section, we give more details on the use of the data for the purposes of estimation of our model.

3.2 Life-cycle Profiles

Figure 1 shows the life-cycle profile of homeownership rates among retirees. We also break down the rates by the size of the household. In general, homeownership rates are declining with age, from around 90% at age 65 to around 50% by age 95. The breakdown shows that conditional on household size, the decline is milder than the overall average, demonstrating that the overall decline in homeownership is largely driven by the transition from a 2-person to a 1-person household. This agrees with the findings of Venti and Wise (2004) that "precipitating

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[1] We experimented with other definitions of assets and found that the results are not affected.

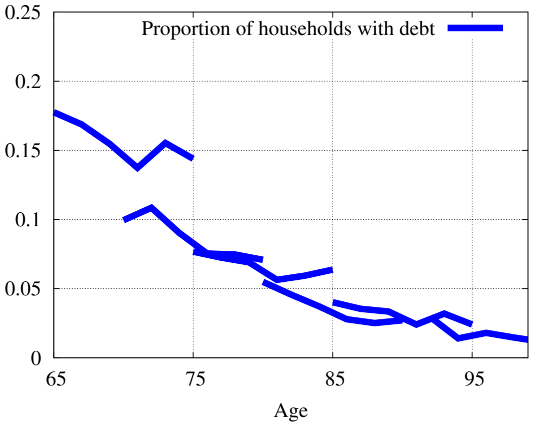

Figure 5: Proportion of Households in Debt. Source: HRS, various waves.

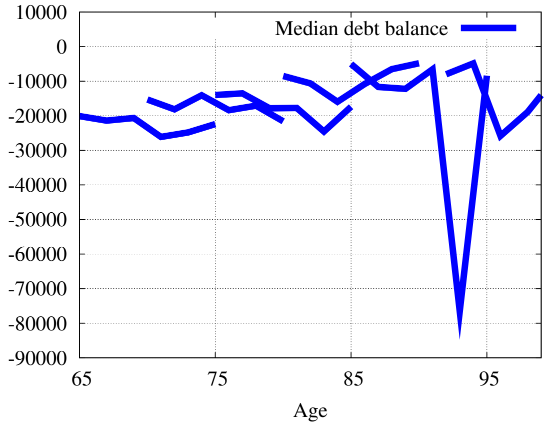

Figure 6: Median Debt Holding Among Debtors. Source: HRS, various waves.

events" such as the death of a spouse are key in determining homeownership.

Figure 2 plots the life-cycle profile of median total asset holding among retirees. Figures 3 and 4 break down these profiles into housing and financial assets. Total asset holding is increasing with age for the youngest three cohorts, while it is flat for the older cohorts. The breakdown into housing and nonhousing assets shows that the increase in total asset value for the younger cohorts is mainly driven by the increasing value of housing that coincides with the house price boom of 1996-2006, while financial assets are relatively flat for each cohort.

Figures 5 and 6 plot the shares of retirees who are in debt by our model definition, that is, those who hold a negative financial asset position, as well as the median amount of debt held, conditional on being a debtor. Overall, the share of debtors is weakly decreasing with age, from around 18% at age 65 for the first cohort, to nearly zero for the oldest cohort. The conditional amount of debt is weakly increasing for the three younger cohorts and is flat or slightly decreasing for the older cohorts.

If we look at profiles of gross secured debt and gross unsecured debt, the proportion of households with both types of debt decreases with age, in a fashion similar to the negative financial asset position. Figure 7 show the profiles. In terms of debt holding conditional on having debt, Figure 8 shows that the profile for secured debt is generally similar to that of negative financial asset position – increasing for the younger cohort and relatively flat for older cohorts, while the amount of unsecured debt holding is relatively small (notice that secured debt profiles use the left scale, while unsecured debt profiles use the right scale), and approximately flat for each cohort.

Finally, for a robustness check, we compute the cohort profiles of median housing and financial assets using alternative weighting schemes. Figure 9 and Figure 10 compare profiles of median housing and financial assets, under (i) the baseline assumptions (no replenishment of cohorts and with sample weighting), (ii) no replenishment and no sample weighting, and (iii) with cohort replenishment. We check the case without sample weight (case (ii)) to make our results align with De Nardi et al. (2010), who do not use sample weighting in their data analysis. The pictures

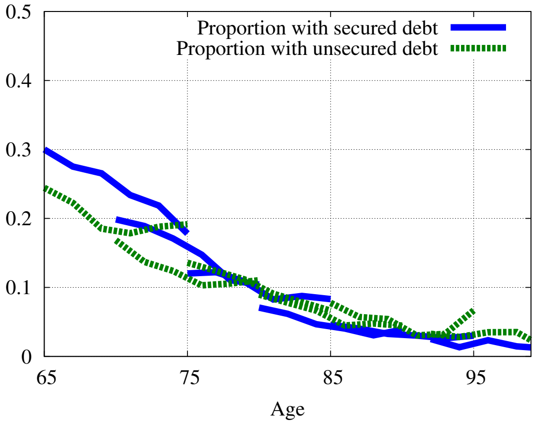

Figure 7: Proportion of Households with Secured and Unsecured Debt. Source: HRS, various waves.

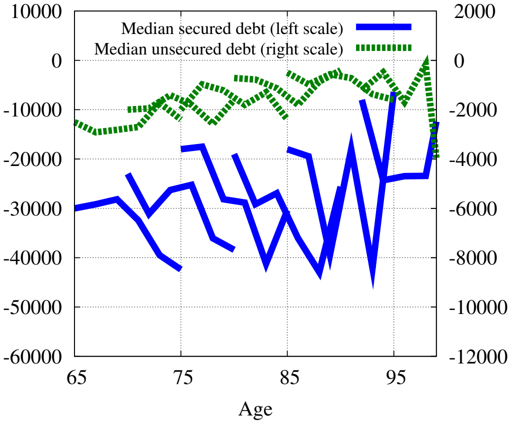

Figure 8: Median Secured and Unsecured Debt among Debt Holders. Source: HRS, various waves.

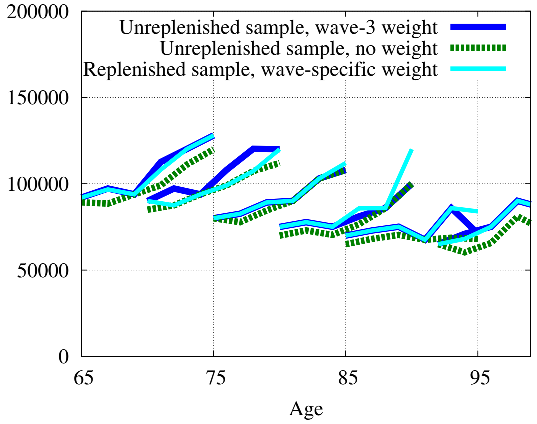

Figure 9: Comparison of Median Housing Asset Profiles. Source: HRS, various waves.

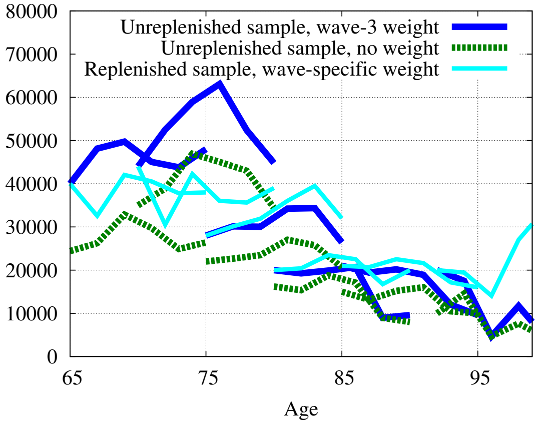

Figure 10: Comparison of Median Financial Asset Profiles. Source: HRS, various waves.

that we found under the baseline assumptions, that is, upward-sloping housing asset profiles for all cohorts, which reflect the house price boom during the sample period, and approximately flat financial asset profiles, are roughly maintained under alternative assumptions.

4 Model

We focus on households with retirees, which allows us to abstract from the labor supply decision, and in particular from the retirement decision. Each period, a retired household chooses consumption and saving or borrowing, and makes a decision regarding housing. For a homeowner, the housing decision is whether to move out of the house or to stay in the same house. For a renter, the choice is the size of the rental property in which the household lives in the current period. We abstract from the decision of a homeowner moving to a different, most likely a smaller, house or a renter buying a house. This abstraction is not a serious problem, since in the data, the proportion of households making such moves is small. A household is subject to four types of shocks: (i) health status (including mortality), (ii) out-of-pocket medical expenditures, (iii) household size, and (iv) house prices. For the household size shock, we focus on the transition from a two-adult household to a one-adult household, caused by the death of a spouse. Since in the data income is stable over time conditional on household size, in the model income is assumed constant conditional on household size as well.

4.1 Preferences

A household is born as a retiree in the model age 1. The household potentially lives up to age I, but dies stochastically; this is discussed more below, together with the health status transition process. The household maximizes its life-time utility. The utility function is time-separable with subjective discount factor β. The period utility function has the following form:

$$u(c, h, s, o) = s\frac{\left(\frac{1}{\mu_s}c^{\eta}(\omega_o h)^{1-\eta}\right)^{1-\sigma}}{1-\sigma} \tag{1}$$

where c is nonhousing consumption, h represents consumption of housing services, $s \in \{1, 2\}$ is the number of adults in the household, and $o \in \{0, 1\}$ is the tenure status. We assume a linear technology from the size of the house to the quantity of housing services, which implies that h represents the size of the house that the household lives in as well. $o = 0$ and $o = 1$ means renting and owning, respectively. Housing and nonhousing consumption are aggregated by a Cobb-Douglas aggregator, which is a special case of a more general CES (constant elasticity of substitution) aggregator with the unit elasticity. η determines the relative importance of the consumption of nonhousing goods and housing services. The period utility function applied to the aggregated goods is a standard CRRA (constant relative risk aversion) type with the risk aversion parameter σ. μ_s is the effective household size or the household equivalence scale conditional on household size, which captures the externality within a household.[2] In particular, if $\mu_1 = 1$ and $\mu_2 \in (1, 2)$, the *household-size multiplier* for a one-adult household is $\frac{1}{\mu_1^{1-\sigma}} = 1$, while the multiplier for a two-adult household is $\frac{2}{\mu_2^{1-\sigma}} > 1$ for $\sigma > 0$. In other words, the assumption captures the benefits of having multiple adults instead of one adult in the household. ω_o captures the extra utility from owning a house rather than renting, such as the ability to modify the house to the individual taste, the ability to invest in the neighborhood, etc. Additionally, the extra utility of homeownership captures the financial benefits of ownership, such as tax exemption of imputed rents of owner-occupied properties and mortgage interest payment deduction, implicitly. Naturally, ω_0 (for renters) is normalized to one, and $\omega_1 > 1$.

As in De Nardi et al. (2010), a household gains utility from leaving bequests.[3] When a

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[2] For a more detailed discussion on the household equivalence scale, see Fernández-Villaverde and Krueger (2007). Li and Yao (2007) assume a similar assumption with respect to the effect on the household size on utility.

[3] De Nardi (2004) finds that the bequest motive is important in capturing the observed wealth distribution, especially the wealth concentration, using a general equilibrium overlapping-generations model with accidental and intended bequests.

household dies with the consolidated wealth of c, the household's utility function takes the form:

$$v(c) = \gamma \frac{(c+\zeta)^{1-\sigma}}{1-\sigma}. \tag{2}$$

Here, γ captures the strength of the bequest motive, and ζ affects the marginal utility of bequests.

4.2 Nonfinancial Income

Since the main sources of nonfinancial income for retirees are Social Security benefits and other pension benefits, and they are typically fixed at the time of the retirement and do not change during the retirement period, we assume that nonfinancial income is $\psi_s b$, where $b \in B = \{b_1, b_2, b_3, ..., b_B\}$ and ψ_s adjusts the nonfinancial income according to the number of adults in the household. Naturally, $\psi_1 = 1$. Notice b is different across households, but b for each household does not change over time.

4.3 Health Status and Mortality Shock

$m \in \{0, 1, 2, ..., M\}$ represents the health status of a household. $m = 0$ indicates that the household is dead. A strictly positive m indicates that the agent is alive and in one of several health states that can vary over time. $m = 0$ is an absorbing state, i.e., $m_j = 0$ for $\forall j \geq i$ if $m_i = 0$. We assume that m follows a first order Markov process. $\pi^m_{i,m,m'}$ is the transition probability from a health state m to m', for an agent of age i. Because of the way we include the death state in the health status, the transition probability $\pi^m_{i,m,m'}$ also includes the survival probability of agents. In particular, the survival probability for an agent of age i and current health status m can be represented as $\sum_{m' \neq 0} \pi^m_{i,m,m'}$.

4.4 Medical Expenditures

Health status introduced in the section above affects two things: (i) the survival probability is lower for a household with a worse health status, and (ii) out-of-pocket medical expenses are on average higher for a household with a worse health status. Both are supported by our data (details will be provided in Section 5). A household is hit by out-of-pocket medical expenditure shocks $x \in \{x_0 = 0, x_1, x_2, ..., x_X\}$. The probability that a x is drawn is denoted by $\pi^x_{i,m,x}$, where i is the age of the household and m is the current health status of the household. The specification allows the distribution of the medical expenditures to vary depending on age and health status. We assume that the shock is uninsurable; the medical expenditure shock corresponds to only the out-of-pocket expenses in the data.

4.5 Household Size

We introduce household size transition because, as we have shown in Section 3, a sizable part of the housing tenure transition (to be more precise, transition from a homeowner to a renter) is associated with the transition from two-adult to one-adult households. $s \in \{1, 2\}$ represents the number of adults in a household. One-adult households ($s = 1$) remain the same for the rest of their life. But two-adult households ($s = 2$) stochastically changes to one-adult households. The transition probabilities of the household size are denoted by $\pi^s_{i,s,s'}$, where i is the age of households. By assumption, $\pi^s_{i,1,1} = 1$, $\pi^s_{i,1,2} = 0$ for all i. We assume that the transition from $s = 2$ to $s = 1$ captures the death of a spouse. We do not consider divorces or remarriages, in order to abstract from consolidation or splitting of assets. According to our data, these events are rare. Household size affects the households' decision in the following three ways. First, two-adult households maximize the sum of the utilities of the two. In order to avoid keeping track of types of each individual in two-adult households, we assume that the two adults have the same utility function. In other words, the utility of a two-adult household is basically that of a one-adult household multiplied by two. Second, consumption is split equally in two-adult households. However, each of the household members can enjoy more than half of the consumption because of the positive externality within the household. This is captured by the effective household size μ_s, which was introduced in Section 4.1. Finally, two-adult households face a shock that may turn them into a one-adult household. Another important assumption related to household size is that, when a two-household dies, both members of the household drop out of the model for simplicity.

4.6 Housing

A household is either a renter ($o = 0$) or a homeowner ($o = 1$). A renter chooses the size of the rental property each period. The available size of housing is $h \in \{h_1, h_2, h_3, ..., h_H\}$. The per-period cost of renting h is hpr_h, where p is the current house price and r_h is the rental rate. We will further discuss the house price p in Section 4.8. For a renter, there is no cost of changing the size of the house each period. All rental contracts are for one period. A homeowner with a house h decides whether to move out of the house and become a renter or stay in the same house. In order to simplify the problem, selling a house and buying another is assumed away. This is justified, since we do not observe many such transitions in our data. When the homeowner sells the house, the selling cost is hp. There is a cost of moving out, which is κhp. Besides, the homeowner has to pay for a maintenance cost δhp each period. The rental rate r_h consists of three components as follows:

$$r_h = r + \delta + \iota \tag{3}$$

where r is the interest rate (discussed more in the following section), and ι is an extra cost of renting. Basically, the rental rate is the competitive cost of an intermediating real estate firm to hold housing and rent out to a renter.[4]

4.7 Saving and Home Equity Borrowing

We use a to denote consolidated financial asset balance. In particular, a denotes saving (in case a is positive) or borrowing (in case a is negative). Households can save at the interest rate r. In addition, home equity borrowing is allowed; homeowners can borrow against the value of their housing. In particular, the borrowing limit in period t has the following form:

$$a \geq -(1 - \lambda)hp \tag{4}$$

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[4] See Nakajima (2010) for a more detailed discussion about the determination of the rental rate.

In other words, a homeowner can borrow up to a fraction $1-\lambda$ of the value of the house (hp) in each period. The parameter λ can be interpreted as the downpayment constraint, since a household has to have at least λhp to own a house of size h. The borrowing interest rate is assumed to be $r+\chi$, where χ is an extra cost of home equity borrowing. Moreover, whenever a homeowner increases the amount of home equity borrowing, the homeowner has to pay νhp. Although our general setup of the home equity borrowing leaves us agnostic about the interpretation of the cost, it loosely corresponds to the closing cost of refinancing, the cost of opening a new home equity line of credit (HELOC), or the closing cost of the reverse mortgage loan (RML). We will estimate the parameter value from the data, rather than pinning down using information of a particular cost. This parameter is important because we found that some of the characteristics of the borrowing behavior of the elderly cannot be replicated without some cost of extra borrowing.

4.8 House Price

The house price p is assumed to have only an aggregate time-varying component; we do not consider heterogeneity of house price change for now. As for the expectation, we assume that households expect the house price to stay at its current level each period in the future. In other words, in simulations in which we feed the observed house price trajectories, all the changes in the house price are taken as a surprise by households. Accordingly, expectations of future house prices are set at the house price observed in the last period. One of the main experiments that we implement is to feed different future house price trajectories and investigate the response of households, especially regarding their decision with respect to housing and home equity borrowing.

A natural alternative in terms of the expectation of the future house price growth is perfect foresight. However, we found that perfect foresight assumption generates a highly counterfactual outcome: If households know the future path of house prices and this path replicates what we saw in the data in the last 15 years, a substantial proportion of households would choose to sell their house at the peak of the market, i.e., in 2006. As a result, homeownership rates would drop at the market peak as well, which does not appear consistent with the data. Although our main data set ends in 2006 (see below) and thus is silent as to homeownership rates after that year, we do not observe such a large drop in homeownership in other data sources. Thus, based on this evidence, we do not use perfect foresight as our baseline assumption.

4.9 Government Transfers

Following Hubbard et al. (1995) and De Nardi et al. (2010), we assume that the government uses means-tested social insurance, which provides a consumption floor. The consumption floor is especially important in our model in that a large out-of-pocket medical expenditure shock could force a household to consume a negative amount in the absence of social insurance. The consumption floor supported by the government is denoted by $\underline{c}$ per adult. Following De Nardi et al. (2010), we assume that the government subsidizes each member of a household up to the consumption floor only when the household sells all of its assets and chooses the minimum rental property available (in case of a renter) but still falls short of the consumption floor.

4.10 Household Problem

We will formalize the households' problem recursively, and separately for homeowners and renters. Following the convention, we use a prime to denote a variable in the next period. In order to save some notation, we use $h = 0$ to represent a renter. $h > 0$ means that a household is a homeowner with a house size of h. Let us start from the problem of a renter. The Bellman equation that characterizes the problem of a renter is as follows:

$$\begin{aligned} V(i, s, b, m, x, p, 0, a) = \max_{\tilde{h}, a' \geq 0} \Big\{ & u(c, \tilde{h}, s, 0) \\ & + \beta \sum_{s'} \pi^{s}_{s,s'} \sum_{m'>0} \pi^{m}_{m,m'} \sum_{x'} \pi^{x}_{i+1,m',x'} V(i+1, s', b, m', x', p, 0, a') + \beta \pi^{m}_{m,0} v(a') \Big\} \end{aligned} \tag{5}$$

subject to:

$$\tilde{c} + a' + r_h \tilde{h} p + x = (1 + r)a + \psi_s b \tag{6}$$

$$c = \begin{cases} \max\{s\underline{c}, \tilde{c}\} & \text{if } a' = 0 \text{ and } \tilde{h} = h_1 \\ \tilde{c} & \text{otherwise} \end{cases} \tag{7}$$

The type of a renter is represented by $(i, s, b, m, x, p, h = 0, a)$. The renter chooses the assets carried over to the next period (a') and the property that he rents in the current period ($\tilde{h}$) to maximize the sum of three components. The first component is the period utility. The second component is the discounted expected future value conditional on surviving in the next period ($m' > 0$). Notice that b does not change; the renter expects the house price p to remain the same as the current level p in the next period, and the renter remains a renter ($h' = h = 0$). The third component of the maximand in the Bellman equation (5) is the utility from bequests. Notice that, for a renter, the only assets left as estate are the financial assets (a'). Equation (6) is the budget constraint of the renter. Equation (7) represents the lower bound of consumption per adult guaranteed through the social insurance program. Notice that the consumption floor is available only when the renter chooses not to save anything ($a' = 0$) and chooses the smallest rental property available ($\tilde{h} = h_1$).

The recursive problem of a homeowner can be characterized by the following Bellman equation:

$$V(i, s, b, m, x, p, h, a) = \max\{V_0(i, s, b, m, x, p, h, a), V_1(i, s, b, m, x, p, h, a)\} \tag{8}$$

$$\begin{aligned} V_0(i, s, b, m, x, p, h, a) = \max_{a' \geq 0} \{ & u(c, h, s, 1) \\ & + \beta \sum_{s'} \pi^{s}_{s,s'} \sum_{m'>0} \pi^{m}_{m,m'} \sum_{x'} \pi^{x}_{i+1,m',x'} V(i+1, s', b, m', x', p, 0, a') + \beta \pi^{m}_{m,0} v(a') \Big\} \end{aligned} \tag{9}$$

subject to:

$$\tilde{c} + a' + x = hp(1 - \delta - \kappa) + (1 + \tilde{r})a + \psi_s b \tag{10}$$

$$c = \begin{cases} \max\{s\underline{c}, \tilde{c}\} & \text{if } a' = 0 \\ \tilde{c} & \text{otherwise} \end{cases} \tag{11}$$

$$\tilde{r} = \begin{cases} r & \text{if } a' \geq 0 \\ r + \chi & \text{if } a' < 0 \end{cases} \tag{12}$$

$$\begin{aligned} V_1(i, s, b, m, x, p, h, a) = \max_{a' \geq -hp(1-\lambda)} & \{u(c, h, s, 1) \\ & + \beta \sum_{s'} \pi^s_{s,s'} \sum_{m'>0} \pi^m_{m,m'} \sum_{x'} \pi^x_{i+1,m',x'} V(i+1, s', b, m', x', p, 1, a') + \beta \pi^m_{m,0} v(hp + a') \Big\} \end{aligned} \tag{13}$$

subject to equation (12) and:

$$\tilde{c} + a' + x + hp\delta + z = (1 + \tilde{r})a + \psi_s b \tag{14}$$

$$z = \begin{cases} hp\nu & \text{if } a' < 0 \text{ and } a' < a \\ 0 & \text{otherwise} \end{cases} \tag{15}$$

First, equation (8) represents the tenure decision: $V_0(.)$ is the value conditional on moving out and becoming a renter in the next period, and $V_1(.)$ is the value conditional on remaining in the same house and thus a homeowner in the next period. Equation (9) is the Bellman equation conditional on a homeowner becoming a renter. There are four differences from the renter's problem shown above. First, the current tenure status is a homeowner ($o = 1$) with the house size of h, as can be seen in the period utility function. Second, the budget constraint (10) does not include the rental cost (since the household owns in the current period) but includes income from selling the house, net of the current maintenance cost (δ) and the selling cost (κ). Third, the interest rate is different depending on whether the homeowner is a net saver (in this case the interest rate is r), or a net borrower (the interest rate is $r + \chi$). Fourth, the household is eligible for the consumption floor if $a' = 0$ because there is no decision of choosing rental property for the current period. In other words, the homeowner has to sell the house and exhaust all the savings in order to be eligible for the social insurance. Also notice that the household begins the next period as a renter (o=0).

Equation (13) is the Bellman equation for a homeowner conditional on remaining a homeowner. Five remarks are worth making. First, since a homeowner can borrow against the house, a' is not constrained from below by zero, but by $-hp(1 - \lambda)$. Second, in case the household does not survive to the next period, the estate is the consolidated asset position, which consists of the value of housing (hp) and the financial asset position (a'). Third, the budget constraint (14) includes the maintenance cost ($hp\delta$). Fourth, the budget constraint also includes z, which is the cost of refinancing. z is zero if the homeowner chooses not to borrow ($a' \geq 0$), or to reduce his debt ($a' \geq a$). Otherwise, the homeowner has to pay the cost of borrowing more, and the cost is the fraction ν of the house value hp. Finally, since the homeowner chooses to keep the house, the homeowner does not have access to the consumption floor.

Table 1: Calibrated Parameters in the First Step

Parameter	Description	Value[1]
μ_2	Household equivalence scale for 2-adult households	1.320
ψ_2	Income multiplier for 2-adult households	1.400
δ	Maintenance cost of housing	0.017
ι	Rent premium	0.000
κ	House selling cost	0.066
r	Saving interest rate	0.040
λ	Downpayment ratio	0.200
ξ	Mortgage interest premium	0.016

[1] Annualized value.

5 Estimation

5.1 Estimation Strategy

Following Gourinchas and Parker (2002) and De Nardi et al. (2010), we use a two-step estimation strategy. In the first step, we estimate the parameters that are taken as exogenous to the model. Parameters associated with all the shocks and prices, as well as the initial conditions, are in this category. In the second step, we estimate the remaining parameters using the simulated method of moments (SMM), taking the estimated parameters in the first step as given. That is, in the second step we pin down parameters so that a set of moments generated from the simulation of the model, given these parameters, is close to the same moments computed from the data, using some criteria of closeness.

5.2 First Step Estimation

Since HRS is biennial, we set one period in the model to two years. Each household can live up to 99 years of age, but there is a probability of an earlier death. We look at three cohorts corresponding to ages 65, 75, and 85 in 1996 – the first wave of the survey that we use. We call them cohorts 1, 2, and 3, respectively. In order to increase the number of data observations that we use, we enclose age groups in five-year bins: For example, we define age 65 as capturing the five-year interval of the actual age between 63 and 67. For each cohort, we have six observations that correspond to years 1996, 1998, 2000, 2002, 2004, and 2006. In simulating and estimating the model, we use the initial type distribution of the three cohorts of households in 1996 as the input. We also feed in the real national house price indices between 1996 and 2006 for simulation. All the values that follow in this section are represented in 1996 dollars.

The subsequent sections provide details about how the first step of the estimation procedure is implemented. Table 1 summarizes the parameters calibrated in the first step.

Table 2: Income Levels[1]

	Cohort 1 (age 65)	Cohort 2 (age 75)	Cohort 3 (age 85)
Group 1	5831	6199	5520
Group 2	12049	9977	8055
Group 3	17844	13593	10481
Group 4	25868	18173	13743
Group 5	50227	37869	26090

[1] Annualized income in 1996 dollars.

5.2.1 Preferences

There are a variety of estimates for the household equivalence scale. We use the value of $\mu_2 = 1.34$ for a two-adult household. It is the estimate of Fernández-Villaverde and Krueger (2007), which is the mean of existing estimates, ranging between 1.06 and 1.7.

5.2.2 Nonfinancial Income

Our definition of nonfinancial income includes Social Security, pension, disability, annuity, and government transfer income. In each cohort, we sort the households according to their nonfinancial income in 1996 (year of the initial wave used) and classify them into five bins so that each bin carries approximately one-fifth of the total sample weight in 1996. For two-adult households, we make an adjustment so that the income of two-adult households is comparable to that of one-adult households. In particular, we look at households whose number of adults changed from two to one. For each of them, we compute the ratio of income when the household was a two-adult household over the income after the same household became a one-adult household. Finally, we compute the median of such ratio. The number obtained as such is our estimate for ψ_2, which is the factor of nonfinancial income for two-adult households. We found that $\psi_2 = 1.4$. This means that a household whose number of adult members changes from two to one report 29% $(= 1 - \frac{1}{1.4})$ lower nonfinancial income on average. In terms of adjustment of income, we divide nonfinancial income of two-adult households by $\psi_2 = 1.4$ when we classify them into income bins. The income representing each of the five income groups is computed by taking the average income of the households in each bin. Table 2 summarizes the resulting income bins by cohort.

5.2.3 Health Status and Mortality Shock

We group the five self-reported health status categories in the HRS (excellent, very good, good, fair, poor) into three categories, combining the top two and the bottom two groups, and leaving the middle group as is. We label the three groups as excellent, good, and poor. Since the age-specific transition rates between different health groups appear stable over the waves of the HRS, we pool all household-age observations across waves for estimation purposes. In other words, we impose stationarity across time of the health status transitions, although we continue to distinguish transitions by age. We compute the probability that a respondent of health status

Table 3: Health Status Transition

Health status transition (age 65)	Dead	Excellent	Good	Poor
Excellent	1.3	72.7	21.5	4.4
Good	1.9	25.9	53.9	18.3
Poor	2.9	6.6	22.5	68.0

Health status transition (age 75)	Dead	Excellent	Good	Poor
Excellent	3.5	61.2	26.5	8.9
Good	3.9	21.9	48.5	25.8
Poor	4.6	5.4	20.8	69.2

Health status transition (age 85)	Dead	Excellent	Good	Poor
Excellent	9.9	47.5	28.0	14.6
Good	9.6	18.0	41.2	31.2
Poor	8.8	7.0	17.5	66.7

Health status transition (age 95)	Dead	Excellent	Good	Poor
Excellent	22.5	32.8	20.9	23.8
Good	23.2	17.5	28.8	30.5
Poor	26.9	5.9	23.1	44.2

m (m is 1 (excellent), 2 (good), or 3 (poor)) is of health status m' in the next wave (two years later), conditional on the age of the respondent. Notice that this procedure includes computing a probability of death ($m' = 0$). Table 3 summarizes health transition probabilities for ages 65, 75, 85, and 95. Several points are worth noting. First, as expected, the probability of dying is generally higher for respondents with a lower health status. Second, probability of death increases with age. Third, health status exhibits persistence. However, fourth, this persistence becomes weaker with age, which corresponds to an increasing probability of death.

5.2.4 Medical Expenditures

We estimate the out-of-pocket medical expenditure shocks from the HRS data conditional on age and current health status, using pooled data of different waves. First, we compute the probability that out-of-pocket medical expenditures are zero, conditional on age and current health status. After taking out the observations with zero medical expenditures, we fit the distribution of medical expenditures using log-normal distribution. Table 4 and Figure 11 exhibit the estimation results for selected age groups. Figure 11 shows that, except for the ages over 95, expected medical expenditures increase with age. The increase is due mainly to the increasing variability of out-of-pocket medical expenditures. Surprisingly, the probability of zero out-of-pocket medical expenses is slightly increasing with age and with deteriorating health.[5]

In constructing the medical expenditure shock, we discretize the log-normal distribution using four grid points: the mean, mean plus-minus one log standard deviation, and mean plus three times the log standard deviation. The last grid is chosen to capture the right tail of the distribution, which is emphasized by French and Jones (2004).

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[5] An individual in the HRS who dies drops out of the sample. However, information on these individuals is then collected in the so-called “exit waves” of the HRS, a separate data set. These exit waves include information on medical expenses, which presumably cover end-of-life care. At present, we are not incorporating exit waves into our sample and thus may not be including significant medical expenses at the end of life. As such, we may be biasing our estimates of medical expense shocks downward, thus understating the degree of uncertainty that retirees face.

Table 4: Medical Expenditure Distribution[1]

Age	Statistics	Excellent	Good	Poor
65	$\mathbb{P}(x=0)$	0.08	0.09	0.12
	Log-mean	6.75	7.08	7.48
	Log-Stdv	1.39	1.37	1.46
	Exp mean[2]	2249	3051	5115
75	$\mathbb{P}(x=0)$	0.10	0.09	0.12
	Log-mean	6.81	7.13	7.42
	Log-Stdv	1.37	1.31	1.41
	Exp mean[2]	2318	2934	4522
85	$\mathbb{P}(x=0)$	0.11	0.10	0.12
	Log-mean	6.92	7.23	7.46
	Log-Stdv	1.42	1.36	1.38
	Exp mean[2]	2764	3504	4530
95	$\mathbb{P}(x=0)$	0.15	0.12	0.18
	Log-mean	6.88	7.52	7.46
	Log-Stdv	1.53	1.62	1.51
	Exp mean[2]	3106	6827	5463

[1] Out-of-pocket medical expenditures for two-year periods in 1996 dollars.

[2] Assuming log-normal distribution, and conditional on nonzero medical expenditures.

5.2.5 Household Size

Figure 12 exhibits the proportion of two-adult households conditional on age. Each line corresponds to each of the three cohorts that we use for the estimation and three additional cohorts (cohorts of age 70, age 80, and age 90 in 1996). The proportion is approximately linearly decreasing with age. Therefore, as with other shocks estimated above, we assume that the household size transition probabilities are time-invariant and estimate the transition probabilities by a pooled sample of all six waves of the HRS. Moreover, we make two assumptions, for tractability. First, in order to abstract from the division or aggregation of assets associated with separations and marriages, we only consider transitions from two-adult households to one-adult households. Second, we assume that all the transitions from two- to one-adult households are caused by death of the spouse. The first assumption is supported by the fact that the transitions from one- to two-adult households are rare among the HRS sample; the probability is around 3% for households in their 60s and 70s, and it is less than 1% for older households. The second assumption is consistent with a very low probability of divorce in the sample, which appears to be true in our data although we cannot identify the transitions caused by divorces and those caused by death of spouses.

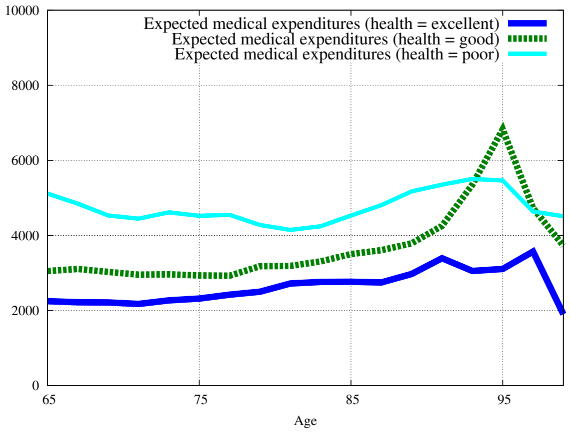


Figure 11: Mean Medical Expenses by Health Status. Source: HRS, various waves.

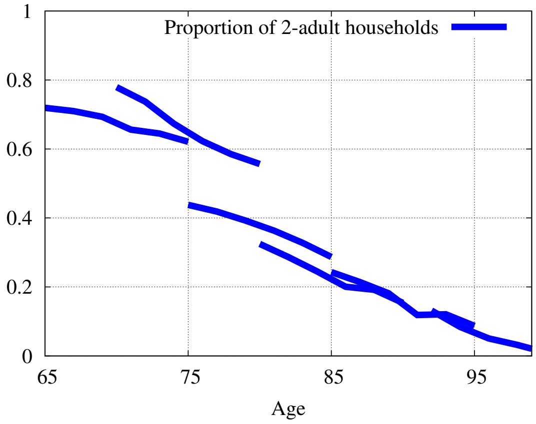


Figure 12: Proportion of Two-Adult Households. Source: HRS, various waves.

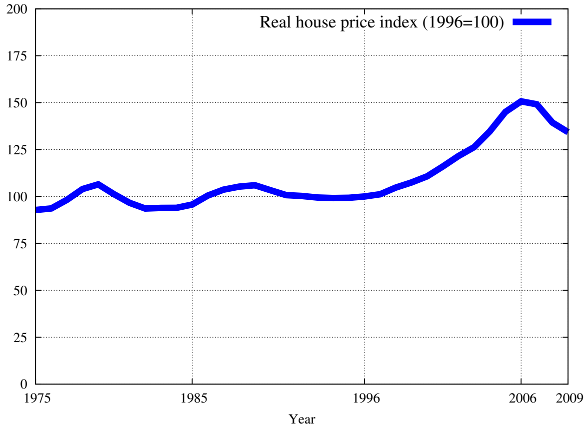


Figure 13: Real House Price Index. Source: FHFA (HPI), BLS (CPI).

5.2.6 Housing

Regarding the house size, for the sake of tractability, we approximate the distribution of house sizes using ten grid points. More specifically, we sort the households in the initial sample year (1996) by cohort and by the value of housing, and classify the households in each cohort into ten bins so that each bin captures approximately 10% of the sample. The house value representing each bin is computed by taking the average house value within the bin. Table 5 summarizes the house value bins constructed by this procedure. In addition, we restrict the choice of property values for renters to the same set of house bins for each cohort.

Maintenance cost δ is set at 3.4% per two-year (annually 1.7%). This is the calibrated value by Nakajima (2010) using data on depreciation of residential capital in National Income and Product Account (NIPA). Rental premium ι is set at zero. The selling cost of a house (κ) is set at 6.6% of the value of the house. This is the estimate obtained by Greenspan and Kennedy

Table 5: House Size Distribution[1]

	Cohort 1 (age 65)	Cohort 2 (age 75)	Cohort 3 (age 85)
Bin 1	21792	18291	16781
Bin 2	44977	37924	35743
Bin 3	63613	50801	47699
Bin 4	77839	64390	55112
Bin 5	88087	77613	64175
Bin 6	101358	93641	77510
Bin 7	125114	110422	88651
Bin 8	152107	137455	108380
Bin 9	195244	183215	148655
Bin 10	360683	345206	265221

[1] Value in 1996 dollars.

(2007). Grueber and Martin (2003) report the median selling cost of 7.0% of the value of the house.

5.2.7 Saving and Home Equity Borrowing

The saving interest rate is set at 8% (annually 4%). The downpayment ratio is set at 20%, which implies that a homeowner can borrow up to 80% of the value of his house. Note that during the recent house price boom, a lower downpayment was more common than before. However, our results are insensitive to the choice of the downpayment ratio because most retirees in the model keep repaying their mortgage debt, and thus the collateral constraint rarely binds. Mortgage debt premium ξ is set at 3.2% (annually 1.6%), which is the average spread between 30-year conventional mortgage loans and Treasury of the same maturity between 1977 and 2009.

5.2.8 House Price

For house price movements in the model, we use data on the real national house price. The real house price is constructed by dividing the house price index (HPI) compiled by the Federal Housing Finance Agency (FHFA) by the consumer price index. We use the real house price index for the period 1996-2006 for estimation. While we are able to observe heterogeneity regarding the house price growth across households, we do not introduce this heterogeneity into the model, to contain the computational burden. As we show below, using the national house price index is largely sufficient to capture the behavior of the median households.

5.2.9 Initial Distribution

We use the initial distribution constructed from the actual distribution in the 1996 wave of the HRS, simulate the model starting from the initial distribution, and use the outcome of the simulation to estimate structural parameters. Table 6 shows the initial distribution sliced

Table 6: Selected Characteristics of the Initial Distribution (in 1996)

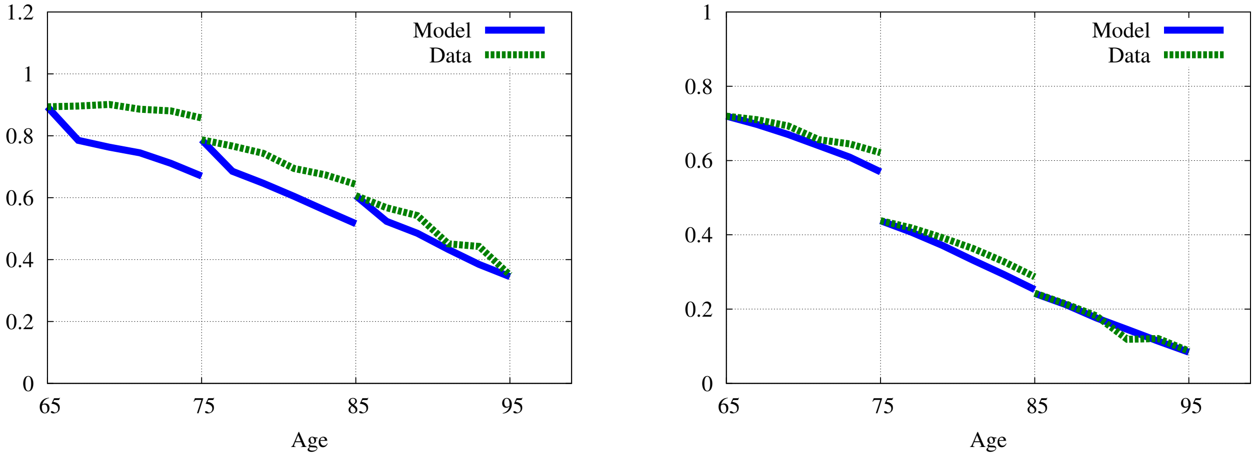
	Cohort 1 (age 65)	Cohort 2 (age 75)	Cohort 3 (age 85)
Household size			
one-adult	0.28	0.56	0.76
two-adult	0.72	0.44	0.24
Health status			
1 (excellent)	0.48	0.39	0.34
2 (good)	0.29	0.32	0.28
3 (poor)	0.23	0.29	0.38
Tenure			
Homeowner	0.89	0.79	0.61
Renter	0.11	0.21	0.39
Net financial asset position			
Saver	0.82	0.93	0.97
Borrower	0.18	0.07	0.03

Table 7: Parameter Estimates

Parameter	Description	Value
β	Discount factor[1]	0.90
η	Consumption aggregator	0.85
σ	Coefficient of RRA	2.00
ω_1	Extra-utility from ownership	2.00
γ	Strength of bequest motive	2.00
ζ	Curvature of utility from bequests	1000
$\underline{c}$	Consumption floor per adult[1]	5000
ν	Cost of increasing debt	0.03

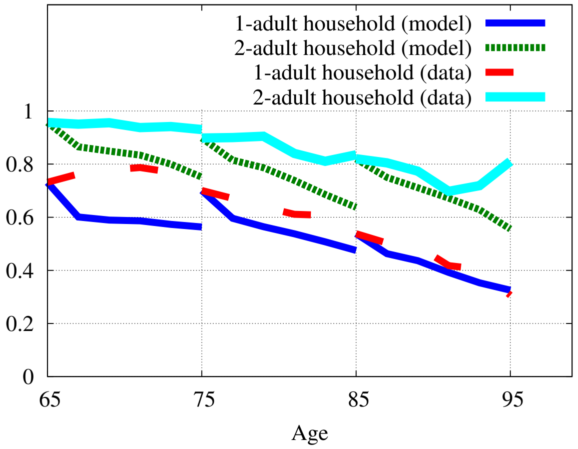
[1] Biennial value.

from various dimensions. We do not show the characteristics of the initial distribution with respect to income and housing assets, since we simply construct equal-sized bins for each of these dimensions. The properties of the initial distribution are intuitive. First, the proportion of two-adult households is lower for older cohorts. Second, health status is on average worse for older cohorts. Third, the homeownership rate is mildly decreasing with age. Finally, the proportion of households with net negative financial assets is lower for older cohorts.



(a) Homeownership Rate, All Households

(b) Proportion of Two-Adult households



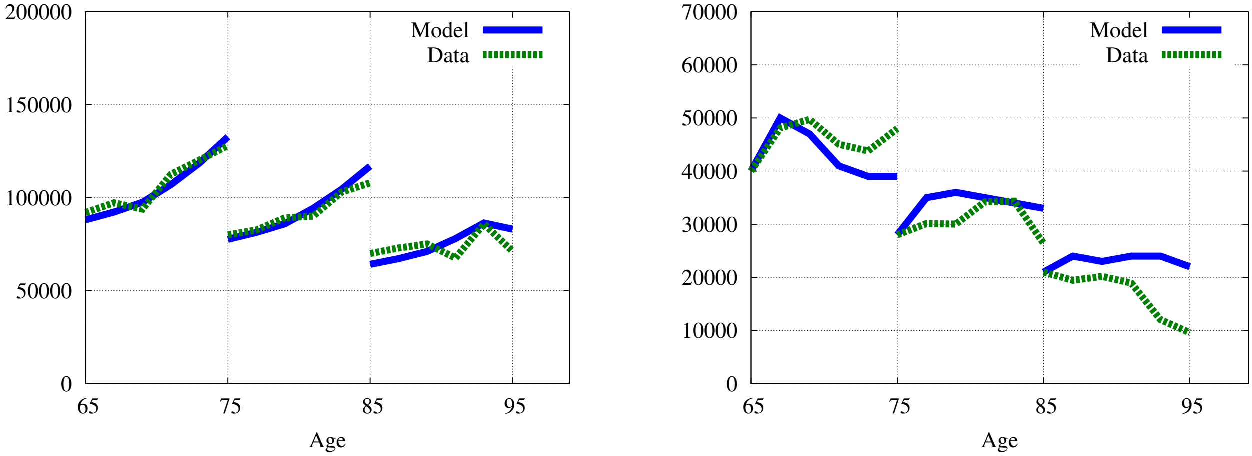
(c) Homeownership Rate, One- and Two-Adult Households

Figure 14: Estimation Results - Homeownership Rate

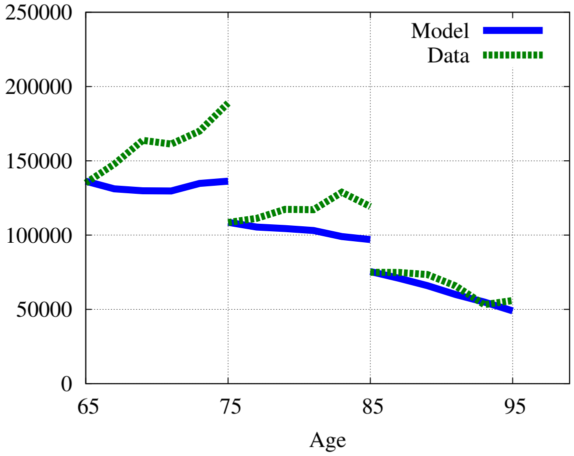
5.3 Second Step Estimation

At this stage, we have not yet implemented the second-step estimation with formal distance criteria. As a preliminary step, we have been searching for a combination of parameter values to give us a reasonable starting point for the estimation procedure, based on the targets of choice, described below. Table 7 summarizes the parameters obtained in the second-step estimation to date.

Figure 14 compares the homeownership rate of three cohorts in the data and the corresponding outputs of the model. Panel (a) compares the overall homeownership rate for each cohort. Panel (b) compares the proportion of two-adult households. This is generated by the shock to household structure calibrated in the first step. Panel (c) offers the decomposition of the homeownership rate, conditional on the number of adults in a household. Since the homeownership rate is lower



(a) Median Housing Assets (b) Median Financial Assets

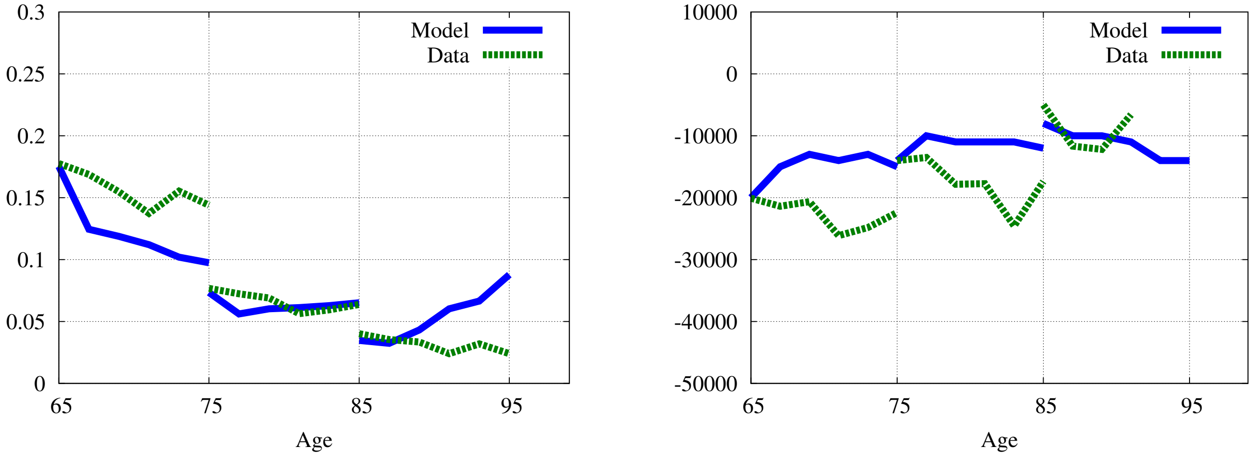


(c) Median Total Assets

Figure 15: Estimation Results - Asset Holding Profiles

for one-adult households (panel (c)), and the proportion of one-adult households increases with age (panel (b)), the observed decline of the homeownership rate with age can be attributed to (i) an increase in the share of one-adult households (death of spouses), and (ii) a decline in homeownership rates conditional on household size. As Figure 14 makes clear, the model slightly over-predicts the decline in the homeownership rate. This is due to element (ii); the model captures the decline of the two-adult households with age in the data but over-predicts the decline in homeownership conditional on the type of household.

Figure 15 compares the median profiles of housing, financial, and total assets of three cohorts in the data and the corresponding outputs of the model. Median housing assets held (panel (a)) and median financial assets held (panel (b)) in the model replicate the corresponding data quite well. The median total assets held (panel (c)) in the model are slightly under-predicted relative to the data counterpart except for the oldest cohort.



(a) Proportion in Debt

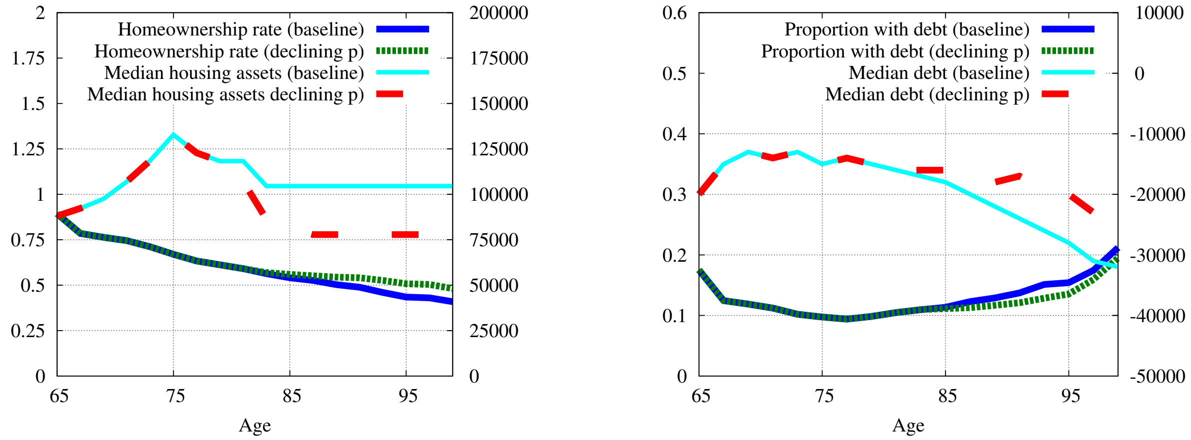
(b) Median Debt among Debtors

Figure 16: Estimation Results - Borrowing Profiles

Figure 16 compares the proportion of households in debt (panel (a)) and median debt among households in debt (panel (b)) between the model and the data. The model is slightly less successful in capturing the proportion of debtors and the amount of debt held by the debtors. Notice that since we define financial assets in the model as the consolidated balance of all the nonhousing assets net of debt, the proportion of debtors in the current definition is not the same as the proportion of households who own *some* form of debt simultaneously with owning positive assets. Let us start from panel (a), which exhibits the proportion of debtors among each cohort and each age. The model replicates the profile of the second cohort (those 75 years old in 1996) quite well, but the model is less satisfactory for other cohorts. Why? For example, it is possible to slow down the decline in the proportion of debtors among the first cohort (those 65 years old in 1996), by slowing down the decline in the homeownership rate or by weakening the saving motive, but that would further increase the borrowing by the oldest cohort, unless there is a substantial cost of borrowing for these older cohorts. This trade-off suggests that there may be a strong restriction against borrowing by older cohorts. Alternatively, this problem might be related to the assumption that all households experience the same house price dynamics; there is no household that experiences house price growth substantially higher than the national average by assumption. We will investigate this channel later on. The same problem is manifested for the profile of median debt among debtors. The youngest cohorts do not increase their borrowing as much as in the data.

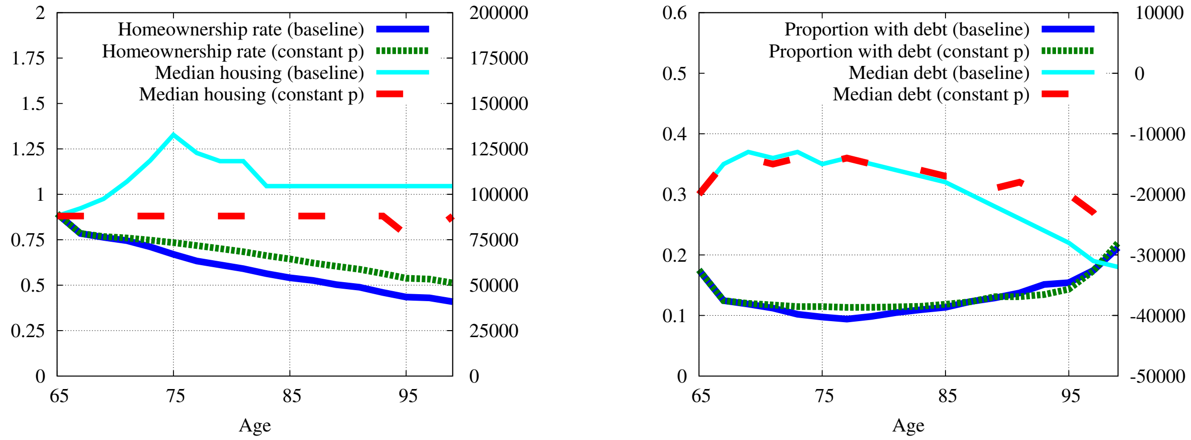
6 Experiments

In this section, we use the model estimated above to implement a variety of counterfactual exercises. We focus on cohort 1 (65 years old in 1996) to clearly show the changes over the lifecycle.



(a) Homeownership Rate (Left Scale) and Median Housing (Right Scale): House Prices Decline Post-2010

(b) Proportion in Debt (Left Scale) and Median Debt (Right Scale): House Prices Decline Post-2010



(c) Homeownership Rate (Left Scale) and Median Housing (Right Scale): House Prices Constant Since 1996

(d) Proportion in Debt (Left Scale) and Median Debt (Right Scale): House Prices Constant Since 1996

Figure 17: Experiments – House Prices

6.1 House Price Dynamics, Home Equity Borrowing, and Homeownership

How do house price dynamics affect households' behavior with respect to homeownership and home equity borrowing? This question is important not only from a theoretical point of view, but from a policy perspective as well: We want to understand the effects of a housing market crisis just seen in the last few years, especially as it impacts retirees, as well as to predict what would happen if house prices continue to stagnate going forward.

In the benchmark model described above, we assumed that house prices after 2009 remain at the 2009 level. In the data, national average real house price increased by about 50% between 1996 and the peak of 2006, and dropped since then, but remains about 35% higher than the level of 1996. We now implement two alternative scenarios. First, instead of assuming that future house price levels remain at the level of 2009, we now assume that the house price gradually drops back to the 1996 level, and we investigate how retirees' homeownership rates and borrowing are affected. Panels (a) and (b) of Figure 17 show the results. Notice that, since we look at cohort 1, which is of age 65 in 1996, they see the same price profile as our benchmark model until they are age 79 (year 2010), after which the two price profiles diverge. The graphs reflect this. Panel (a) shows that the median housing asset holding declines substantially, for example, by about 22% for those who are age 85, due to the decline in the future house prices. More interestingly, the simulation predicts that the homeownership rate would increase if the average house price were to drop further than the 2009 level going forward. The difference in homeownership rates would be as large as 5 percentage points for households in their 80s and 90s. As house prices continue to decline, retirees would find the benefits of selling their house increasingly less attractive and thus would hold on to their houses instead.

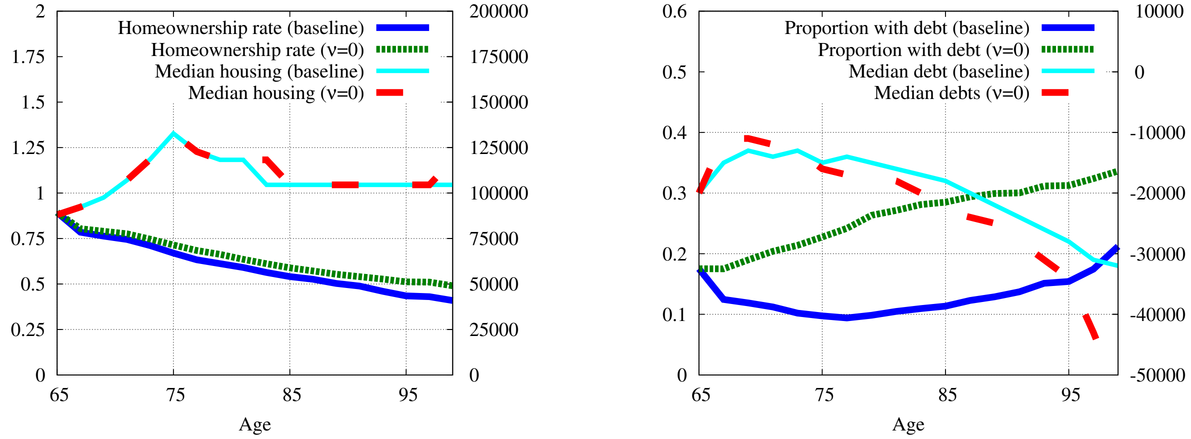
In addition, panel (b) shows how the decision regarding borrowing is affected by the difference in the house price dynamics relative to the benchmark case. If future house prices decline further, the model predicts that fewer households would take out home equity later in their life, and the median debt would also decline. The amount of debt taken out by retirees would decline mainly because the value of housing assets declines, which tightens the borrowing constraint against the house. An additional reason is the negative income effect. Although many of the retirees do not sell their house during their lifetime, a lower expected estate (bequest) has a negative income effect on the retirees, reducing consumption and borrowing. The decline in the proportion of debtors among 80- and 90-year-olds is mainly the result of the income effect.

In the second experiment, we make a counterfactual assumption of not having the house price boom and bust between 1996 and 2009 and keeping the house price constant at the 1996 level. Once again, we investigate the effect of the house price boom and bust on the rate of homeownership and the debt of retirees. Panels (c) and (d) of Figure 17 show the results. Panel (c) clearly shows, based on housing assets, that the house price boom and bust has been eliminated from the model. The effect of these house price dynamics on homeownership is again that the absence of a house price boom induces retirees to stay with their house instead of cashing out and becoming a renter. The effect on borrowing behavior is also similar to the above experiment. The lack of a house price boom induces retirees to avoid borrowing, and those who do borrow, borrow less - once again, a manifestation of a combination of borrowing constraints that are tighter than in the benchmark, together with an income effect.

If a lower house price weakens demand for home equity borrowing, the demand for the reverse mortgage loans would be negatively affected, other things equal. We discuss this issue in more detail in the next section.

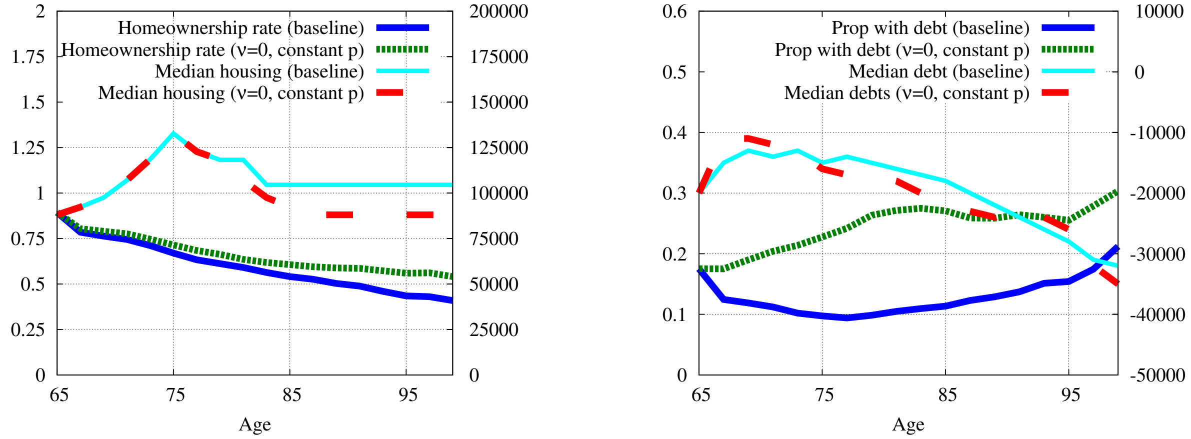
6.2 Mortgage Market Innovation, Home Equity Borrowing, and Welfare

The last decade saw significant innovations in the mortgage markets: Many new instruments that enabled homeowners to extract home equity more flexibly appeared. Furthermore, reverse mortgage loans (RMLs) rapidly increased in popularity, although the number of RML borrowers is still small. How did this kind of innovation in the mortgage markets affect homeownership patterns and the home equity borrowing of retirees? Recall that in the benchmark model, the parameter that controls the cost of increasing the debt balance, ν, is estimated to be fairly large



(a) Homeownership Rate (Left Scale) and Median Housing (Right Scale): $\nu = 0$, Baseline House Price

(b) Proportion in Debt (Left Scale) and Median Debt (Right Scale): $\nu = 0$, Baseline House Price



(c) Homeownership Rate (Left Scale) and Median Housing (Right Scale): $\nu = 0$, Lower House Price

(d) Proportion in Debt (Left Scale) and Median Debt (Right Scale): $\nu = 0$, Lower House Price

Figure 18: Experiments – Lower Cost of Home Equity Borrowing

at 3% of the house value each time a retiree wants to extract home equity. This parameter value is larger than, for example, the average closing cost of refinancing and a home equity line of credit (HELOC). Greenspan and Kennedy (2007) estimate that the typical closing cost of refinancing and of the HELOC is 1.25% of the house value. On the other hand, the estimated value of ν is broadly consistent with the typical closing cost of RML. Since our modeling approach makes us agnostic about the interpretation of the parameter ν, it is difficult to think of a "reasonable" counterfactual value for ν. Therefore, we choose an extreme and run a counterfactual experiment with $\nu = 0$; that is, we set the cost of equity extraction to zero as an approximation of what would happen in a hypothetical world with extremely flexible mortgage markets. The top two panels of Figure 18 show the homeownership pattern (panel (a)) and borrowing behavior (panel (b)) under the counterfactual assumption of $\nu = 0$, compared with the results under the baseline assumptions and estimated parameters. It is apparent that more retirees remain homeowners because the value of owning a home increases as it becomes a cheaper means of borrowing. The homeownership rate for those in their 80s and 90s increases more than 5 percentage points. The median housing asset holding increases under the hypothetical assumption, for the same reason as the rising homeownership rate. Home equity borrowing would increase dramatically, in both the extensive margin (proportion of households in debt) and the intensive margin (median debt of debtors). For example, proportion in debt among 75 year-olds would increase from 10% in the baseline to 23% under the hypothetical. For those of age 85, the proportion would increase from 11% to 29%. Especially because the effect is larger for older households, a further decline in the costs of RMLs, which we consider to be captured by this counterfactual experiment, could significantly affect the homeownership pattern and home equity borrowing of the elderly.

Notice that our experiments imply that absent of a financial market innovation, homeownership would be depressed by rising house prices. This is offset by the type of mortgage market innovation that we have seen in the data in recent years. Also in the data, we have seen an increase in homeownership rates between the late 1990s and the early 2000s; this increase could be attributed then primarily to the innovation in the mortgage market, which offsets to some extent the dampening effect of the house price increase. Another way of looking at this is that if mortgage market innovation occurred without the house price boom, the resulting increase in homeownership would have been even larger than what we saw in the data. Of course, the results shown here are subject to caveats. Most important, it is partial equilibrium analysis, and we do not model the life cycle before retirement, and we take savings at the time of retirement as given.

Similarly, absent financial innovation, a house price increase would loosen borrowing constraints against housing, while a decline in prices would tighten them. Financial innovation makes it easier to borrow against the home, thereby increasing retiree borrowing significantly.

We investigate these points further by studying the interaction of the price dynamics and market innovation: How would the rate of homeownership and the level of indebtedness be affected if mortgage market innovation were dampened by dropping house prices going forward from 2009? To answer the question, we combine the two counterfactual experiments: (i) $\nu = 0$, which we investigate in this section, and (ii) that the house price gradually decreases to the level in 1996, instead of remaining at the 2009 level. The bottom two panels of Figure 18 show the implications of the counterfactual. As can be seen in panel (c), median housing asset holding declines, reflecting the declining trend of the house price. The homeownership rate would be even higher in this case relative to the case with constant prices and financial market innovation; low house price discourages some homeowners from selling their house and cashing out. If the two counterfactual events studied here would happen, homeownership rate of retirees would be lifted. Panel (d) shows that the effect of the reduced costs of increasing home equity borrowing on debt would be mitigated if house prices would have a declining trend.

What are the welfare implications of the lower cost of home equity withdrawal? Table 8 summarizes the welfare effect of reducing ν from the baseline value of 0.03 to zero for retirees in cohort 1 (those of age 65 in 1996). The first column shows the average welfare gain measured by the percentage increase in per-period consumption by moving from $\nu = 0.03$ to $\nu = 0$. We

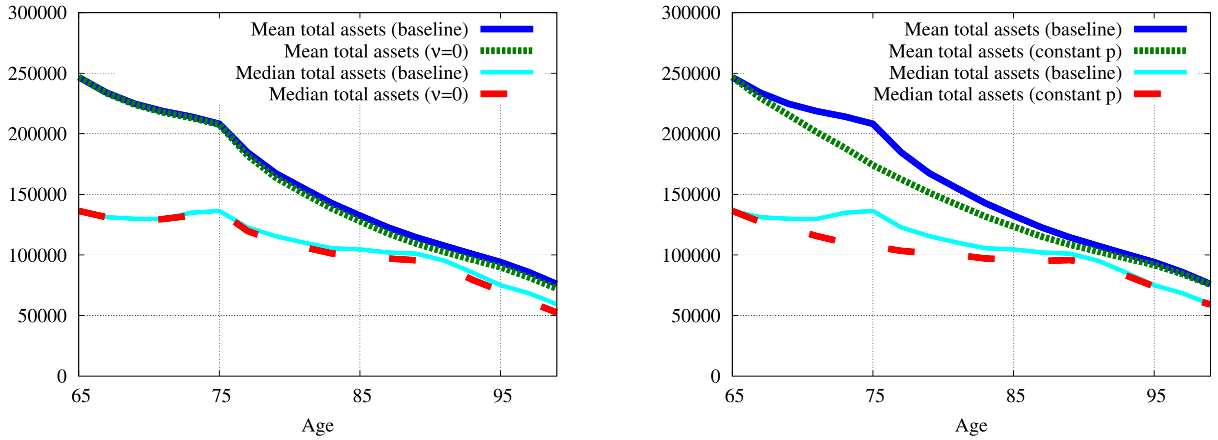
Table 8: Welfare Effect of a Lower Cost of Home Equity Withdrawal (Cohort 1)

	Welfare gain[1] (%)	Proportion with positive gain	Proportion with zero gain
All retirees	0.30	0.796	0.206
Savers	0.28	0.806	0.194
Borrowers	0.41	0.751	0.249
Homeowners	0.34	0.891	0.109
Renters	0.00	0.000	1.000
Excellent health	0.28	0.849	0.151
Good health	0.29	0.793	0.207
Poor health	0.35	0.689	0.311

[1] Measured by per-period consumption growth.

compare the expected lifetime utility of retirees in cohort 1 in age 65. Notice that, because of the particular functional form of the utility from bequests, it is difficult to convert the difference in welfare into per-period consumption. Therefore, we fix the expected utility from bequests; only the difference in utility before death is converted into per-period consumption growth. The second and third columns of Table 8 show the proportion of retirees with strictly positive and zero welfare gain, respectively. Notice that, since the only change considered here is a lower cost of increasing home equity borrowing, there are no retirees who are worse-off by the change.

The first row exhibits the overall welfare effect. The welfare gain of eliminating costs of extra home equity borrowing, measured by per-period consumption growth, is 0.3%. Among all the retirees in cohort 1, about 80% of retirees gain from the cost reduction ex-ante. If we compare the welfare effect on savers and borrowers (second and third rows), borrowers in the initial period gain more (0.41% average welfare gain). This is natural since those in debt in the initial period are more likely to increase their debt in the future periods. If we compare welfare gain for homeowners and renters (fourth and fifth rows), renters do not gain at all because they cannot borrow anyway and they will not be a homeowner. If we disaggregate the population into three groups with different initial health status (sixth to eighth rows), the average welfare gain is higher for poorer health retirees, but more retirees gain among healthier groups. The former is due to the higher probability of increasing debt among less healthy retirees, possibly as a result of higher average medical costs. The latter is due to the fact that the homeownership rate is higher among healthier retirees.



(a) Mean and Median Total Assets: $\nu = 0$

(b) Mean and Median Total Assets: House Prices Constant Since 1996

Figure 19: Experiments – Total Assets

6.3 Retirement Saving Puzzle Revisited

With our preliminary estimates for the model parameters, we can also begin to revisit the retirement saving puzzle. The previous section showed that the costs of borrowing represented by ν, as well as house price dynamics, have a strong effect on retirees' housing and saving/borrowing decisions. Then, what are the implications of these channels for the retirement saving puzzle? The puzzle states that retirees do not dissave as much as a simple life-cycle model suggests. Could it be due to the fact that retirees want to stay in their home but cannot borrow against it, which means that they are *forced* not to dissave? Or might it be that it appears that they do not dissave because the value of their assets has been increased through the house price boom, rather than by active choice?

First, in order to measure the contribution of the implied costs of home equity withdrawal on the retirement savings, we compare in panel (a) of Figure 19 mean and median total asset holding of households in cohort 1 (65 years old in 1996) in the baseline case and in the case with $\nu = 0$. The comparison exhibits the importance of the costs of borrowing against home equity on aggregate savings in retirement. As can be easily seen, the difference under the two scenarios is very small, implying that the cost of borrowing against the value of housing does not affect the aggregate savings in retirement substantially. Why? The lack of sizable change in total assets, combined with the results obtained in the previous section, suggest that although housing asset holding and borrowing against housing are substantially affected by a change in ν, the effect is in shifting the household portfolio from financial assets to housing assets, while total assets remain almost unchanged. In other words, retirees just change their homeownership status without changing their aggregate saving level, in response to a lower cost of home equity withdrawal.

Second, panel (b) of Figure 19 shows how much the total asset holding is affected by the house price boom of 1996-2006 by comparing the total asset holdings under the baseline scenario and the counterfactual scenario in which house prices are fixed at their 1996 level. It is easy to see that the total asset profile is noticeably elevated by the house price boom during the sample period of the HRS. This suggests a note of caution in interpreting the data. In computing the total asset profile from the HRS in the period of HRS existence (1996-2006 for the most accurate data), the retirement saving puzzle might be exaggerated because of the house price boom, while similar longitudinal data for retirees do not exist prior to the recent housing boom.

7 Conclusion

In this paper, we estimate the consumption-saving model of retirees, with the focus on homeownership and home equity withdrawal. Homeowners can cash out of housing to finance life in retirement by taking home equity debt or by selling their house. We use the estimated model to answer three questions. First, we ask how a declining trend of house prices affect future housing and borrowing decisions of retirees. The model predicts that home equity borrowing would decline, in terms of both intensive (median amount of debt) and extensive (proportion in debt) margins. This is a direct consequence of the lower value of housing and a negative wealth effect. More interestingly, the model implies that the homeownership rate would be higher because cashing out by selling the house becomes a less attractive option. Second, we ask how a decline in the costs of home equity borrowing would affect homeownership and borrowing behavior of retirees. Since the model implies that the costs of increasing home equity debt constrain borrowing by retirees, a reduction of the cost increases both indebtedness and homeownership rate of retirees. The intuition is simple. A lower cost of increasing home equity borrowing allows retirees to take home equity borrowing more flexibly. The homeownership rate increases as it becomes cheaper to keep a house and borrow against home equity. Finally, we ask whether we can shed light on the retirement saving puzzle by explicitly considering housing. We find on the one hand that, although the costs of home equity withdrawal have a substantial effect on retirees' decision of housing and home equity borrowing, total asset holding is not sizably affected. The model predicts that retirees change housing tenure, without substantially changing the total asset holding, in response to changes in the cost of home equity withdrawal. On the other hand, we also find that the recent house price boom "exaggerates" the retirement saving puzzle in the data in that the total value of assets of retirees was elevated by the house price boom.

A natural future extension is to use the model for policy analysis. In particular, the model can be used for positive and welfare analysis of the effect of Social Security reform. We are also interested in using our framework, where health and medical expenditure risks play an important role, to analyze the effects of health-care reform on retirees' housing and saving decisions and welfare.

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