# Home Equity in Retirement*

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**Abstract**

Retired homeowners dissave more slowly than renters, which suggests that homeownership affects retirees' saving decisions. We investigate empirically and theoretically the life-cycle patterns of homeownership, housing and nonhousing assets in retirement. Using an estimated structural model of saving and housing decisions, we find, first, that homeowners dissave slowly because they prefer to stay in their house as long as possible, but cannot easily borrow against it. Second, the 1996-2006 housing boom significantly increased homeowners' assets. These channels are quantitatively significant; without considering homeownership, retirees' savings are 24-43% lower.

**JEL classification:** D91, J26, E21, G11
**Keywords:** Housing, Retirement Saving Puzzle, Mortgage, Health, Life-cycle

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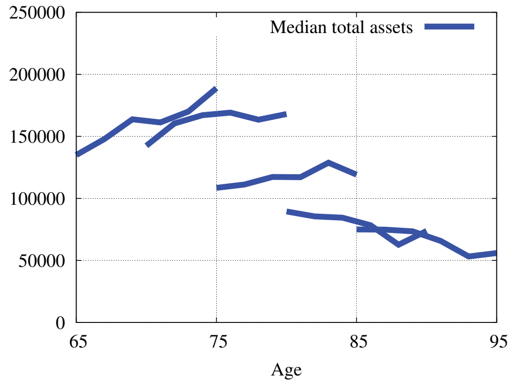



**Figure 1: Median Life-Cycle Wealth Profiles. Source: HRS.**

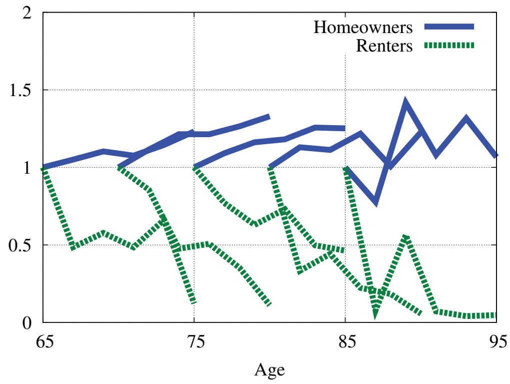



**Figure 2: Normalized Median Life-Cycle Wealth Profiles. Source: HRS**

# 1 Introduction

An important question in the life-cycle savings literature is why the elderly dissave slowly in the data. As figure 1 shows over the period 1996-2006, median net wealth remains high very late into the life cycle. The observation that many people die with significant savings, which is puzzling in the context of a simple life-cycle model, has been termed the "retirement saving puzzle".

However, the picture changes dramatically if we consider the saving behavior of retirees who own homes, compared to those who do not. Consider figure 2, which documents the cohort profiles of median net worth over the same period, normalized by the first observation, for homeowners versus renters.[1] The difference is stark. Homeowners have flat or increasing profiles of net wealth over this period, while renters display a far faster rate of asset decumulation. This suggests that housing may play a major role in determining how retirees save or dissave.

Motivated by this observation, in this paper we examine the role of housing in retirees' saving behavior. Rather than explaining only the life-cycle profile of household net worth, as the literature has done, we seek to understand several facts about saving in retirement concurrently: we consider both housing and nonhousing assets, as well as homeownership rates and collateralized debt. The broad question we are after is what accounts for the retirement saving puzzle. More specifically, we ask (a) what role housing plays in accounting for the puzzle, and (b) what motivates homeownership late in life. We find that considering explicitly the nature of housing as a complex asset with properties different from other assets makes an important difference in understanding retiree saving behavior, and changes our conclusions regarding the retirement saving puzzle, relative to previous literature. In particular, by understanding the motivation for homeownership late in the life cycle, we shed new light on the nature and role of bequest motives, uncertainty and precautionary motives in retirement.

We begin by documenting in detail, using the Health and Retirement Study (HRS) over the period 1996-2006, various facts about retirees' financial and housing asset holdings, and about

[1] In this figure, homeowners are the households that start in our 1996-2006 HRS sample as owners, and remain so throughout the sample; renters are similarly "perpetual" renters.

their use of home equity. Because the HRS is a longitudinal survey, it allows us to study life-cycle asset and debt profiles over time. We also document other relevant changes in retirees' lives pertaining to their income, health, medical expenses, marital status and the like, which are all potential drivers of saving decisions late in life.

We then build a model of household saving decisions in retirement, in which we include both financial assets and a house, which serves as an asset but also provides utility, and in which households face several types of idiosyncratic uncertainty, with the aim of matching the life-cycle facts of interest. In the model, retirees can choose whether to own a home or rent, and homeowners can access their home equity by selling the house or by secured borrowing, with an age-varying borrowing constraint. Retirees have a warm-glow bequest motive, and face uncertainty in their health status, medical expenses, and longevity, as well as that of their spouse. They have Social Security and pension income, and access to a government-provided social insurance program which provides a consumption floor for households who suffer particularly major shocks. House price dynamics, introduced at the aggregate level, reflect recent changes in the housing market in the U.S.

The key potential driving forces of retiree saving behavior in the model are nonfinancial and financial benefits of homeownership, including the housing price boom of 1996-2006, differential liquidity properties of housing and financial assets, as well as bequest motives, longevity risk and medical expense risk. While bequest motives, longevity and medical expense risk have been studied in previous literature, and their importance for the retirement saving puzzle has been debated, the housing-related forces have not been considered previously in the context of a structural model; yet, they may matter on their own, and may interact in important ways with bequest motives and health risk. For example, homeownership in retirement may be motivated by financial considerations and attachment to homeownership, by bequest motives, or by precautionary motives in response to longevity or medical risk. We estimate our model, and use it to quantify the role of each of these forces, as well as to understand their interactions.

To estimate the model, we use the HRS in a two-step estimation procedure. We measure exogenous parameters, such as the shock processes, outside the model, but use the model to estimate other parameters by a minimum-distance estimator, targeting jointly the relevant life-cycle facts mentioned before. Our model successfully replicates these facts, with reasonable resulting parameter values.

To understand the quantitative contribution of the salient model features, we conduct a series of experiments using the benchmark model. First, we shut down these mechanisms one at a time, keeping the rest of the model unchanged. Then, we strip the model down to the basic life-cycle framework, and introduce the main features in sequence in different orders, to understand and quantify the interactions between them.

We find that the high homeownership rate late into the life-cycle that we observe in the data is crucial to consider for understanding retiree saving behavior. Housing-related channels are significant contributors to the retirement saving puzzle. Retirees stay homeowners late in life, but become increasingly locked into their home equity as they age; we find that borrowing constraints on retirees tighten considerably. This means, on the one hand, that those who remain homeowners do not decumulate their home equity, thus creating the kind of flat housing profile that we see in the data, while those who face a large expense may come up against their borrowing constraint and be forced to sell the house. In addition, those who owned a house in the period 1996-2006 became beneficiaries of the housing boom, which further contributes to the flat or increasing net worth profiles of elderly homeowners. These effects together are a big part of what creates the stark difference that we observe between homeowners and renters in the data.

We also use the model to understand why people retirees choose to remain homeowners late in life. We find that the leading motivators are utility benefits of owning a house (which capture also financial benefits, such as tax advantages) and bequest motives. In contrast, precautionary motives in the face of medical expense risk do not affect homeownership significantly, but play a role in the puzzle through financial asset accumulation, although overall this role is quantitatively modest and affects younger retirees more than older ones. Quantitatively, we find that the housing channels – utililty benefits of ownership, collateral constraints, and the housing boom – jointly account for between 24 and 43% of the median net worth profile, depending on age. The bequest motive accounts for up to 31% of the median net worth profile, and its importance increases with age. Medical expense risk accounts for maximum 8% of median net worth, and its importance generally falls with age, due to interaction with Medicaid.

In addition to the quantitative decompositions, we conduct an experiment where we allow households to make a decision on whether or not to maintain their home. We want to evaluate this as an additional, possibly hidden, channel of asset decumulation, consistent with data evidence that homes of elderly owners depreciate more quickly than those of younger owners (Davidoff (2006)). We treat this as a hidden channel because we assume that self-reported housing values of owners who remain in their houses do not take into account the depreciation rate unless they have the house appraised for sale, for example. We find this to be a significant channel of asset decumulation. 30% of our model homeowners choose not to maintain their homes in the 75-85 year old cohort; for the younger cohort, that proportion is over 50%, while it is lower for the oldest cohort. We show that this channel affects median housing asset profiles as well.

We thus have three main contributions. First, our careful documentation of the longitudinal data provides a set of facts regarding retirees' saving behavior in more detail than previously studied. In addition to being of empirical interest, we think it is important that these facts should be considered explicitly by a theory that seeks to explain saving behavior in retirement. Second, our model enables us to describe the tradeoff between housing and nonhousing assets in retirement, and to characterize the reasons for homeownership in retirement. To our knowledge, we are the first to do this in the context of a rich structural model. Third, we address the retirement saving puzzle from a new perspective, and find that modeling housing explicitly makes a crucial difference for the conclusions regarding the puzzle.

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. Section 5 first describes the estimation strategy, and then presents the resulting parameters and assesses the fit of the model. Section 6 describes the quantitative decompositions that we perform in our model, and discusses identification of key parameters based on sensitivity analysis. Section 7 describes the experiment of endogenizing the home maintenance decision. Section 8 concludes. Some details of data analysis are in the appendix.

## 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. On the retirement saving puzzle itself, several answers have been proposed. Hurd (1989) estimates the life-cycle model with mortality risk and bequest motives, and finds that 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. Ameriks et al. (2011) study the relative importance of bequest motives and public care aversion in explaining the related annuity puzzle using a model of retirement and survey data, and find both motives significant in the data.

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 AHEAD sub-sample of the HRS, focusing on singles among the oldest old. Like them, 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 our focus on housing and home equity borrowing; while they aggregate all the assets in the household portfolio, 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, there is no study that uses a structural model with housing to tackle the retirement saving puzzle. We find that the conclusions regarding the retirement saving puzzle are crucially affected by the explicit modeling of housing. In addition, we consider in our sample both single and couple households, while De Nardi et al. (2010) include only singles.

The empirical part of our paper is related to Venti and Wise (2004), one of whose main findings, confirmed by our own data analysis as well, is that retirees rarely downsize their houses even in older age, unless a drastic 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, a possibility pointed out by Skinner (2004).

Other studies of implications of health and medical expenditure risks on portfolio decisions of retirees is Yogo (2009), which treats health expenses as endogenous investment in health, and Kopecky and Koreshkova (2009), who focus on nursing home expenses and study the implications on aggregate savings and the distribution of wealth. Marshall et al. (2010) revisit the measurement of end-of-life medical expenses in an empirical exercise involving HRS data, and find these expenses to be significant.

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), Li and Yao (2007) and Attanasio et al. (2010) 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. Attanasio et al. (2010) also use UK micro data and a structural life-cycle model with housing to disentagle the influence of housing wealth effects on consumption from influence of earnings shocks as a common driving factor of both consumption and house price movements.

More generally, our paper fits with the recently growing 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 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. Chambers et al. (2009b) construct a general equilibrium model with a focus on the optimal choice between different types of mortgages, and study macroeconomic implications of having different such contracts available to households. Ortalo-Magné and Rady (2006) study the impact of income shocks and credit constraints for business cycle dynamics of the housing market.

## 3 Facts

We begin by describing the data facts that we consider the most relevant when thinking about homeownership and saving in retirement. In addition to the facts already presented, these are retirees' life-cycle profiles of homeownership rates, housing and nonhousing assets, the rate of collateralized debt and the amount of debt held. These are the facts that we want to account for using our theory. Thus, we will use these as targets in our estimation. We also present some facts that inform our modeling choices , as we describe below. We then give much more detail on the mapping between the data and the model in the Estimation section.

### 3.1 Data

The Health and Retirement Study (HRS) is a biennial longitudinal survey of households of age 50 and above, conducted by the University of Michigan. The survey began in 1992. Due to issues with the early data on assets (see De Nardi et al. (2010)), we begin our data observation in 1996 and use six waves that span 10 years, through 2006. We use the RAND version of the HRS data set, constructing a full merged set from the flat files provided by RAND; in addition, we merge in information from the exit waves of the survey (concerning members of the sample who die between two waves), in order to accurately measure medical expenses until the end of life.

We consider everyone present in the sample in 1996 who is of age 63 and above and who reports being retired, either fully or partially. 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 in 1996. 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 the survey starting in 1996, or include in later waves everyone who belongs to a given cohort by age, even if they enter 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 in which we allow the cohorts to be replenished after the 1996 wave; see appendix A for details.

A related issue with the HRS sample is weighting. Each individual in the HRS is assigned a wave-specific weight each year he appears in the sample; however, an individual who lives in a nursing home is assigned a weight of zero. We do not want to lose such individuals from the sample. In order to compute weighted statistics, but not lose nursing home residents, we apply the weight attached to each individual in the initial (1996) wave of our sample. This is consistent with our choice of unreplenished cohorts. For robustness, we reconstructed all of our analysis with the replenished sample, where we use the weights specific to each wave; we also constructed unweighted measures, for the purpose of comparing with De Nardi et al. (2010). We discuss these measures in appendix A. Notice that our choices imply that we consider an unbalanced panel in our analysis, since households will drop from the sample due to mortality; however, this choice is the most consistent with our model, where we will construct an equivalent unbalanced panel, with households dying according to the same probability as in the data. We will discuss this more in the Estimation section.

To allow our data measures to map into the model, we measure financial assets as the sum of non-housing 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 of financial and housing assets, net of all debt.[2] Our definition of nonfinancial income includes Social Security, pension, disability, annuity, and government transfer income. Because some of our retirees are only partly retired, we also include labor income in this measure; overall, however, labor income plays a small role in our sample, constituting on average only about 6% of total income.

As homeowners in our data, we take everyone who reports owning their residence. In the other category, labeled “renters”, we include not only actual renters, but also individuals living in nursing homes, with their children, and in other arrangements not involving homeownership. The results presented here are robust to this aggregation of non-owners. A few of the nursing home residents report owning a home. For such individuals in our data we set the value of their home to zero, and fold their house value into their financial assets.

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

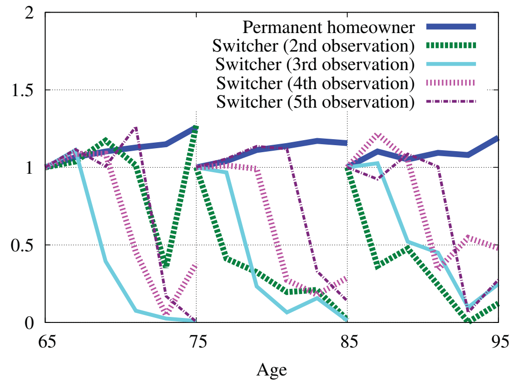



**Figure 3: Normalized Median Net Worth, Perpetual Homeowners versus Switchers**

### 3.2 Life-cycle Profiles

First, to accompany our motivating figure 2, we want to confirm that staying a perpetual homeowner throughout the sample implies different saving behavior than that of anyone who becomes a renter any time in the sample, and in particular, that the difference that we observe is not simply a function of being in different wealth quintiles. To do this, in figure 3, we plot the normalized median asset accumulation profiles of those who are homeowners perpetually in the sample versus those who switch into renting at some point in the sample. We designate them by the wave in which they switch, and present only three cohorts to make the figure legible. This figure confirms the intuition we observe by comparing perpetual owners against perpetual renters, namely that when one sells the house, one decumulates assets more quickly than if one stays in the house, and that this behavior is not simply a function of overall wealth; thus, we need to consider housing separately from other assets.

Figure 4 shows the life-cycle profile of homeownership rates among retirees (dark blue solid line). In general, homeownership rates are declining with age, from around 90% at age 65 to just below 40% by age 95. We also break down the rates by the size of the household. The breakdown shows that conditional on household size, the decline is milder than the overall average for 2-adult households, demonstrating that the overall decline in homeownership may be driven in part by a transition from a 2-person to a 1-person household. This agrees with the findings of Venti and Wise (2004) that "precipitating events" such as death of a spouse are important for determining homeownership. Motivated by this finding, we will allow our model households to change size over time, according to probabilities consistent with the data.

Figure 5 plots the life-cycle profiles of median total asset holding among retirees; we already presented this fact in the introduction. Figures 6 and 7 break down these profiles into housing and financial assets, as defined above. Total asset holdings are increasing with age for the youngest three cohorts, while they are 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 increasing housing assets, while financial assets are relatively flat for each cohort; this further reinforces our motivation to consider housing and nonhousing assets separately in the

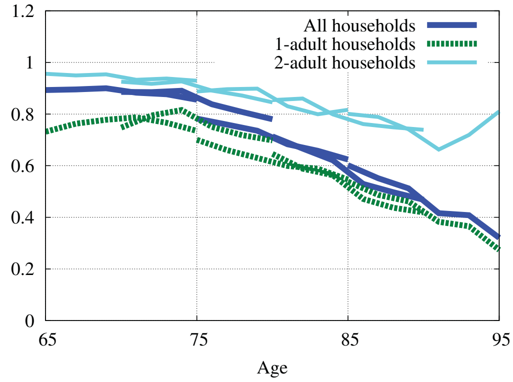



**Figure 4: Homeownership Rates.**

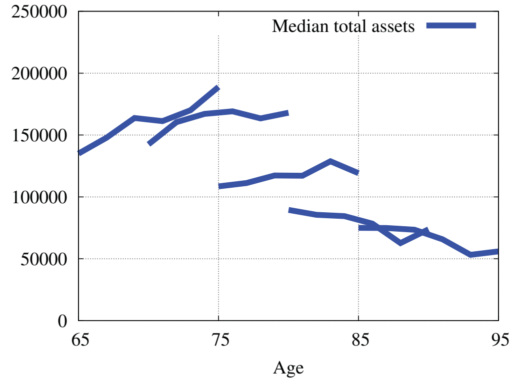



**Figure 5: Median Total Assets.**

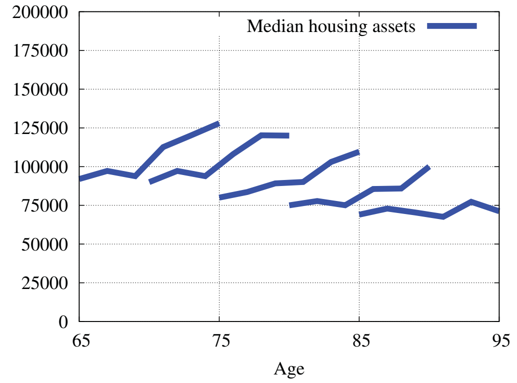



**Figure 6: Median Housing Assets, Conditional on Ownership.**


**Figure 7: Median Financial Assets.**

model. Notice that when we look at median nonhousing assets over time, we include in that profile households who sell their house and convert it into financial assets; this composition effect is likely important in keeping financial asset profiles flat rather than decreasing more quickly.

While the majority of our focus will be on the median asset profiles, it is instructive – and will be useful for estimation – to consider the distribution of assets as well. In figures 8 - 10 we plot total, housing and financial assets by income quintile, where we classify each cohort separately by their nonfinancial income at the start of the sample, as defined above.

Looking at the debt side of the household portfolios, figures 11 and 12 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 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, and is decreasing over the life cycle.

To understand how debt should be modeled, we also consider the profiles of *gross* secured and unsecured debt. The proportion of households with each types of debt in figure 13 decreases with

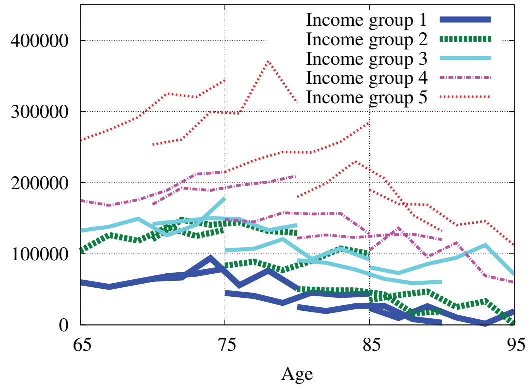



Figure 8: Total Assets by income Quintile

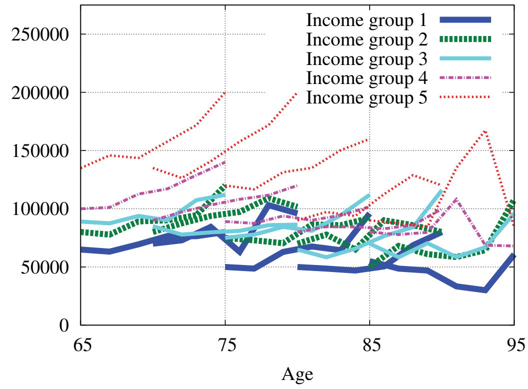



Figure 9: Housing Assets by Income Quintile

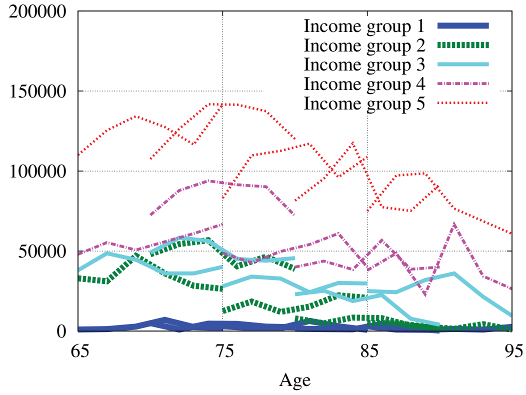



Figure 10: Financial Assets by Income Quintile

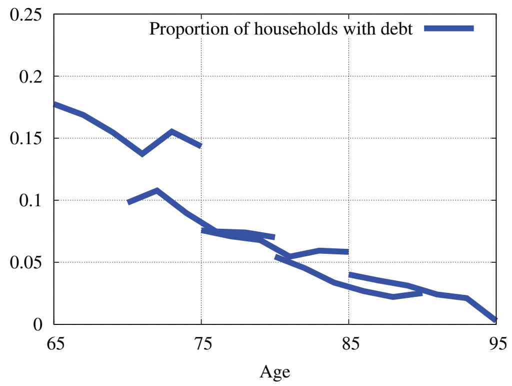



Figure 11: Proportion of Households in Net Debt.

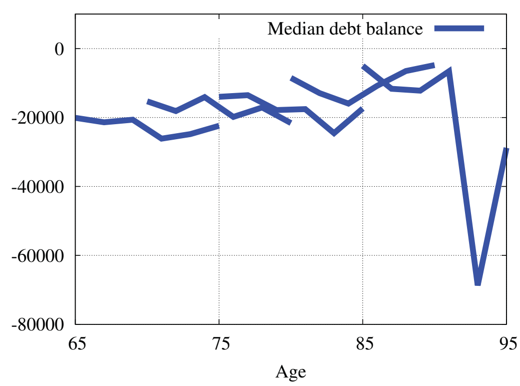



Figure 12: Median Net Debt Holding Among Net Debtors.

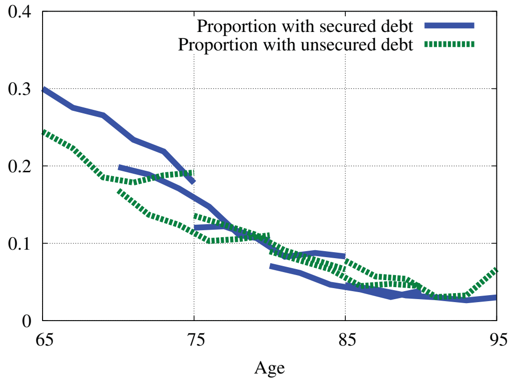



**Figure 13: Proportion of Households with Gross Secured and Unsecured Debt.**

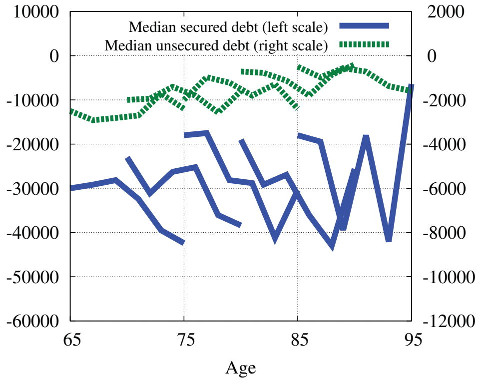



**Figure 14: Median Gross Secured and Unsecured Debt among Debt Holders.**

age, in a fashion similar to the negative financial asset position; slightly fewer retired households have gross unsecured debt than secured debt. In terms of debt holding conditional on having debt, figure 14 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. Instead, the amount of unsecured debt (right scale) is relatively small, at maximum $2,000 for the youngest cohort, compared to $30,000-40,000 in secured debt, decreasing over the lifecycle, and approximately flat for each cohort. Due to the small size of unsecured debt held, and to reduce the computational burden, we will assume unsecured debt away in the model; thus, anyone in the model without a house will not be able to borrow.

# 4 Model

We focus on retiree households, which allows us to abstract from the labor supply and retirement decisions. A household in the model starts out either single or as a couple; couple households can become single if one spouse dies, but single households do not re-marry. This assumption is motivated by the data, where the number of remarriages in retirement is small.

A retiree household starts out as a homeowner or a renter. In each period, the household chooses consumption and financial saving, and makes a decision regarding housing. For a homeowner, the housing decision is whether to move out of the house or to stay in it. Homeownership provides utility benefits, in addition to consumption services from the house; these capture factors such as attachment to one's house and neighborhood, the ability to modify one's house to individual taste, but also some financial benefits of ownership that are not explicitly in the model, such as tax exemption of imputed rents of owner-occupied housing, mortgage interest payment deduction, or insurance against rental rate fluctuation. In addition, homeowners are able to borrow against their home equity; the collateral constraint can change with age, as discussed below. For a renter, the housing choice is only the size of the rental property. We abstract from the decision of a homeowner to move to a different, most likely smaller, house, or the decision of a renter to buy a house. These abstractions are made to simplify the problem, but are motivated by the observation in the data that the proportion of homeowners making downsizing moves is small, as is the proportion of renters who purchase a home late in life. Finally, renters are not able to borrow; as we mentioned in the Data section, the amount of unsecured debt in the data is small and thus supports this restriction.

The aggregate price of housing in the model is increasing to capture the housing boom of 1996-2006. We assume that households anticipate the increase in a deterministic fashion, and do not face idiosyncratic house price shocks. This last assumption is necessary, given the complexity of the problem.

In addition to the household size shock, households are subject to two other types of idiosyncratic shocks: health status, which includes the probability of death and is conditioned on age, and out-of-pocket medical expenditures, conditioned on age, household size, income and health status. Health status is persistent, and thus so are medical expenditures, though they are modeled as i.i.d. conditional on the states.

In addition to income from their financial assets, households have access to pension income. Since in the data nonfinancial income is stable over time conditional on household size, in the model we assume income constant over time as well, as long as household size does not change. In addition, households have access to a government-provided consumption floor, which captures insurance programs for the elderly such as Medicaid. Finally, households have a warm-glow bequest motive. We now turn to the formal description of the model.

### 4.1 Preferences

A household is born as a retiree at model age $i = 1$. 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 $\beta$. 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, $h$ is 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, with $o = 0$ representing renting, and $o = 1$ representing owning . We assume a linear technology from the size of the house to the quantity of housing services, which implies that $h$ is the size of the house that the household lives in as well. Consumption is aggregated by a Cobb-Douglas function, with $\eta$ determining the relative importance of consumption of nonhousing goods and housing services. The period utility function applied to the aggregated goods is a standard CRRA function with risk aversion parameter $\sigma$. $\mu_s$ is the effective household size or the household equivalence scale conditional on household size, which captures the externality within a household.[3] 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

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

assumption captures the benefits of having multiple adults instead of one adult in the household. $\omega_o$ captures the extra utility from owning a house rather than renting. We normalize the renters' $\omega_0 = 1$.

As in De Nardi et al. (2010), a household gains utility from leaving bequests.[4] When a household dies with consolidated wealth of $a$, the household's utility function takes the form:

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

Here, $\gamma$ captures the strength of the bequest motive, and $\zeta$ affects marginal utility of bequests.

### 4.2 Household Structure, Health and Mortality

Households in the model are distinguished demographically in terms of their size and health. The health status of a household is represented by $m \in \{0, 1, 2, ..., M\}$, where $m = 0$ represents death, which is an absorbing state so that $m_j = 0$ for $\forall j \geq i$ if $m_i = 0$. A strictly positive $m$ indicates that the household is alive and in one of several health states that can vary over time. 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 survival probability of agents. In particular, survival probability for an agent of age $i$ and current health status $m$ can be represented as $\sum_{m'>0} \pi^m_{i,m,m'}$.

$s \in \{1, 2\}$ represents the number of adults in a household. We treat household size explicitly because, as we have shown in section 3, data are consistent with it mattering for the decision to sell one's house; in addition, we want to map data and model households as accurately as possible. The transition from $s = 2$ to $s = 1$ can capture the death of a spouse or a divorce; in our estimation, we will abstract from divorces and remarriages, as we find these to be rare in the data. Thus, one-adult households ($s = 1$) remain single for the rest of their life. In contrast, two-adult households ($s = 2$) stochastically change to one-adult households. Household size transition probabilities are denoted by $\pi^s_{i,s,s'}$, where $i$ is the age of the household. By assumption, $\pi^s_{i,1,1} = 1$, $\pi^s_{i,1,2} = 0$ for all $i$.

Household size thus affects household decisions in the following four 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, so the utility of a two-adult household is that of a one-adult household multiplied by two, as captured by $s$ in the utility function above. 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 $\mu_s$ in the utility function. Third, pension income depends on household size. Finally, two-adult households face a shock that may turn them into a one-adult household. This shock, together with the mortality shock embedded in $\pi^m_{i,m,0}$, means that in a two-person

[4]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, one spouse can die first via the stochastic shock to $s$, or both spouses can die at the same time via the household-wide mortality shock.

### 4.3 Medical Expenditures

Household health status introduced above has two effects. First, survival probability is lower for a household in worse health; second, out-of-pocket medical expenses are on average higher for a household in worse health. Both are facts from our data (details will be provided in section 5). A household is hit by out-of-pocket medical expenditure shocks $x \in \{x_0 = 0, x_1, x_2, ..., x_X\}$, which are a function of its age, size, income and health. The probability that a given $x$ is drawn is denoted by $\pi^x_{i,m,b,s}$, where $i$ is the age of the household, $m$ is the current health status of the household, $b$ is its nonfinancial income, and $s$ is its size. Notice that conditional on age, size, income and health, medical expense shocks are i.i.d.; however, because household characteristics, e.g. health status, are persistent, medical expenses are persistent as well. We assume that the shock is uninsurable. We will accordingly estimate this shock using only out-of-pocket medical expenses in the data, abstracting from all expenses covered by Medicare, Medicaid or private health insurance.

### 4.4 Nonfinancial Income

We assume that the household's nonfinancial income is $\psi_s b$, where $b \in \{b_1, b_2, b_3, ..., b_B\}$ and $\psi_s$ adjusts the nonfinancial income according to the number of adults in the household. Naturally, $\psi_1 = 1$. Notice that $b$ is different across households, but is time-invariant for each household. This assumption captures the fact that 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 retirement and do not change during the retirement period, which we confirm in our data.

### 4.5 Housing

A household is either a renter ($o = 0$) or a homeowner ($o = 1$). A homeowner with a house $h \in \{h_1, h_2, h_3, ..., h_H\}$ decides whether to move out of the house and become a renter, or to stay in the same house. In order to simplify the problem, selling a house and buying another is assumed away. As we mentioned above, this is justified by our data, where we do not observe many such transitions. The total value of the house is $p_1 h$, where $p_1$ is the current house price for owners. If a homeowner sells her house, she receives its value net of any debt, from which she pays a proportional cost of moving out, which is $\kappa$, and a capital gains tax, which we specify below. In addition, the homeowner has to pay a proportional maintenance cost $\delta$ each period that she lives in the house. In the benchmark version of the model, we assume that everyone pays this cost. In an experiment later on, we will endogenize the maintenance decision.

The house price $p_1$ is assumed to have only an aggregate time-varying component; we do not consider any heterogeneity of housing prices, in order to keep the problem manageable. We further assume that households expect house prices to grow at a constant rate $g_1$, consistent with the upward price trend in the data during the period that we consider, 1996-2006. As an alternative, we have tried the assumption that households expect house prices to stay constant, treating all growth in house prices from the exogenous price trend as a surprise. These two alternatives yield nearly identical results in terms of household behavior; we choose the former specification as it is consistent with rational expectations.

A renter chooses the size of the rental property $h$ each period. Unlike owners, renters can move between properties of different sizes at no moving cost. All rental contracts are for one period. The per-period rental rate is $r_h$, which consists of two components:

$$r_h = r + \delta \quad (3)$$

where $r$ is the riskless interest rate, discussed more below. The rental rate captures the competitive cost to an intermediating real estate firm of holding housing and renting it out.[5]

Rental properties are evaluated at price $p_0$, which grows deterministically at a constant rate $g_0$, which allows us to capture the effect of the 1996-2006 housing boom on the rental market. As dictated by the data, $g_0 < g_1$.

### 4.6 Saving and Home Equity Borrowing

We use $a$ to denote the household's consolidated financial asset balance. Households can save ($a > 0$) at interest rate $r$. In addition, home equity borrowing is allowed; homeowners can borrow against the value of their house at the rate of $r + \xi$, where $\xi$ is the mortgage premium. The borrowing limit in period $t$ has the following form:

$$a \geq -(1 - \lambda_i)hp_1 \quad (4)$$

In other words, a homeowner can borrow up to a fraction $1 - \lambda_i$ of the value of the house ($hp$) in each period. While the parameter $\lambda_i$ can most directly be interpreted as a downpayment constraint, in this setup we are agnostic about the exact type of equity loan contracts available and the associated cost types. Therefore, we intend for it to capture in a parsimonious way all direct costs of borrowing against home equity, e.g. the costs of refinancing, the costs of opening a new home equity line of credit (HELOC), or the upfront costs of a reverse mortgage. We allow this parameter to be age-specific, to capture possible variation in such costs. While there are no overt age requirements for traditional mortgage loans that we are aware of, Caplin (2002) points out that many older homeowners cannot qualify for conventional mortgages because they fail income requirements of such loans. Our specification can capture such age variation in borrowing constraints. We will estimate the parameters $\lambda_i$ from the model, rather than pinning them down using exogenous information on costs of particular mortgage contracts.

As we previously mentioned, we assume that renters in the model cannot borrow. This assumption is motivated by the observation in the data that the median amount of unsecured debt among retirees is very small.

### 4.7 Government Transfers

Following Hubbard et al. (1995) and De Nardi et al. (2010), we assume that the government uses means-tested social insurance, which effectively provides a consumption floor. The consumption floor is especially important in our model because a large out-of-pocket medical expenditure

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

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 after the household runs down its financial assets. We assume that homeowners are eligible for the consumption floor so long as the value of their house is below some threshold $p_1\overline{h}$, which captures the Medicaid homestead exemption (De Nardi et al. (2012)).

### 4.8 Household Problem

We will formalize the household problem recursively, and separately for homeowners and renters. Following convention, we use a prime to denote a variable in the next period. The state variables of a household are $(i, s, b, m, x, p, h, a)$: its age, size, income, health status, medical expenses, house price, amount of housing, and its financial assets. 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 $h$. Finally, we define $p$ to be the vector of house prices $(p_0, p_1)$, which grow at their respective constant rates $g_0$ and $g_1$.

Beginning with the problem of the renter, the Bellman equation is:

$$V(i,s,b,m,x,p,0,a) = \max_{\tilde{h},a'\geq 0} \Big\{ u(c,\tilde{h},s,0) + \beta \sum_{s'} \pi^s_{s,s'} \sum_{m'>0} \pi^m_{i,m,m'} \sum_{x'} \pi^x_{i+1,m',b,s',x'} V(i+1,s',b,m',x',p',0,a') + \beta\pi^m_{m,0} v(a') \Big\} \quad (5)$$

subject to:

$$\tilde{c} + a' + r_h\tilde{h}p_0 + x = (1+r)a + \psi_s b \quad (6)$$

$$c = \begin{cases} \max\{s\underline{c} - r_h\tilde{h}p_0, \tilde{c}\} & \text{if } a' = 0 \\ \tilde{c} & \text{otherwise} \end{cases} \quad (7)$$

$$p'_i = (1+g_i)p_i \text{ for } i = \{0,1\} \quad (8)$$

The renter chooses the level of assets to carry 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 $(m' > 0)$, with the expectation formed based on the transition probabilities for the household size, health and medical expense shocks. Notice that $b$ does not change, 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, in case of death. 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 guaranteed to the household through the social insurance program, net of rental expenses. As we discussed above, the consumption floor is available only when the renter chooses not to save anything $(a' = 0)$.

The recursive problem of a homeowner is a choice between staying in his current house $(V_1)$, or selling the house and becoming a renter ($V_0$). Formally:

$$V(i,s,b,m,x,p,h,a) = \max\{V_0(i,s,b,m,x,p,h,a), V_1(i,s,b,m,x,p,h,a)\} \tag{9}$$

A homeowner who decides to sell the house and become a renter solves:

$$\begin{aligned} V_0(i,s,b,m,x,p,h,a) = \max_{a'\geq 0} \{& u(c,h,s,1) \\ &+\beta \sum_{s'} \pi^s_{s,s'} \sum_{m'>0} \pi^m_{i,m,m'} \sum_{x'} \pi^x_{i+1,m',b,s',x'} V(i+1,s',b,m',x',p',0,a') + \beta \pi^m_{m,0} v(a') \Big\} \end{aligned} \tag{10}$$

subject to equation (8) and:

$$\tilde{c} + a' + x + (\kappa+\delta)hp_1 + q(s,h,p_1) = hp_1 + (1+\tilde{r})a + \psi_s b \tag{11}$$

$$q(s,h,p_1) = \tau_q(hp_1(1-\kappa) - h\overline{p}_1 - \overline{q}s) \tag{12}$$

$$c = \begin{cases} \max\{s\underline{c}, \tilde{c}\} & \text{if } a' = 0 \\ \tilde{c} & \text{otherwise} \end{cases} \tag{13}$$

$$\tilde{r} = \begin{cases} r & \text{if } a' \geq 0 \\ r+\xi & \text{if } a' < 0 \end{cases} \tag{14}$$

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 (11) does not include the rental cost (since the household owns in the current period), but includes net income from selling the house. The costs of selling are the current maintenance cost ($\delta$), the selling cost ($\kappa$), and capital gains taxes ($q(s,h,p_1)$), which a homeowner has to pay above exemption level $\overline{q}$, on capital gains relative to the initial house purchase price $\overline{p}_1$. 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 $r+\xi$). 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. Also notice that the household begins the next period as a renter ($h' = 0$).

The problem of the homeowner who decides to stay in his house is characterized by:

$$\begin{aligned} V_1(i,s,b,m,x,p,h,a) = \max_{a'\geq -hp_1(1-\lambda_i)} \{& u(c,h,s,1) \\ &+\beta \sum_{s'} \pi^s_{s,s'} \sum_{m'>0} \pi^m_{i,m,m'} \sum_{x'} \pi^x_{i+1,m',b,s',x'} V(i+1,s',b,m',x',p',h,a') + \beta \pi^m_{m,0} v(hp'_1 + a') \Big\} \end{aligned} \tag{15}$$

subject to equations (8), (14) and:

$$c + a' + x + \delta hp_1 = (1+\tilde{r})a + \psi_s b \tag{16}$$

$$c = \begin{cases} \max\{s\underline{c}, \tilde{c}\} & \text{if } h \leq \overline{h}p_1 \text{ and } a' \leq \min(a,0) \\ \tilde{c} & \text{otherwise} \end{cases} \tag{17}$$

**Table 1: First-Step Estimated Parameters**

| Parameter | Description | Value[1] |
|---|---|---|
| $\mu_2$ | Household equivalence scale for 2-adult households | 1.340 |
| $\psi_2$ | Income multiplier for 2-adult households | 1.500 |
| $\delta$ | Maintenance cost of housing | 0.017 |
| $\kappa$ | House selling cost | 0.066 |
| $r$ | Saving interest rate | 0.040 |
| $\xi$ | Mortgage interest premium | 0.016 |
| $g_0$ | Rental rate growth rate | 0.011 |
| $g_1$ | House price growth rate | 0.048 |

[1] Annualized value.

Four features are unique about the owner who chooses to stay in his house. First, since a homeowner can borrow against the house, $a'$ is not constrained from below by zero, but by $-hp_1(1-\lambda_i)$. 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 ($hp_1'$) and the financial asset position ($a'$). Notice that there is no capital gains taxation on the bequest of a house; this assumption is motivated by estate taxation laws in the U.S. that put the exemption level for estate taxes at $600,000 in 1996, and $2,000,000 in 2006, thus making it irrelevant for the asset bins in our model. For the same reason, we do not model estate taxes of financial asset bequests. Third, the budget constraint (16) includes the maintenance cost ($\delta hp_1$). Finally, the homeowner can access the social insurance program only if the value of her house is below the threshold value $\overline{h}p_1$, mirroring homestead exemptions of Medicaid. The condition on financial assets in (17) states that if the homeowner is in debt, the debt is not written off when the Medicaid benefit is received.

# 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 we take 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, given these exogenous parameters, we estimate the remaining parameters using a minimum-distance estimator, taking as targets the set of life-cycle profiles that we presented above.

## 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

**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.

we use, we enclose age groups in five-year bins: For example, we define age 65 as capturing the five-year interval of ages 63-67. For each cohort, we have six data 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 growth rate of rents and house prices between 1996 and 2006 for simulation. All the values that follow in this section are in 1996 dollars. Individual parameters from the first-step estimation are summarized in table 1.

### Preferences

There is a variety of estimates for the household equivalence scale. We use the value of $\mu_2 = 1.34$ for a two-adult household, following Fernández-Villaverde and Krueger (2007). This value is the mean of the existing estimates in the literature, ranging from 1.06 to 1.7.

### Nonfinancial 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. To do this, we look at households whose number of adults changed from two to one while in the sample. For each such household, 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. The median of this ratio is 1.5, so we set our parameter $\psi_2 = 1.5$. That is, in the median, a two-person household that loses a spouse also loses about one-third of its income. To make income comparable across households, we divide nonfinancial income of two-adult households by $\psi_2$ before 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 bins by cohort.

### Household Size

Figure 15 presents the proportion of two-adult households conditional on age. Each line corresponds to one of the three cohorts that we use for the estimation and three additional cohorts

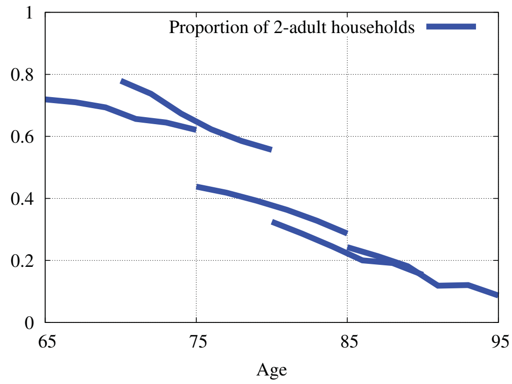



**Figure 15: Proportion of Two-Adult Households.**

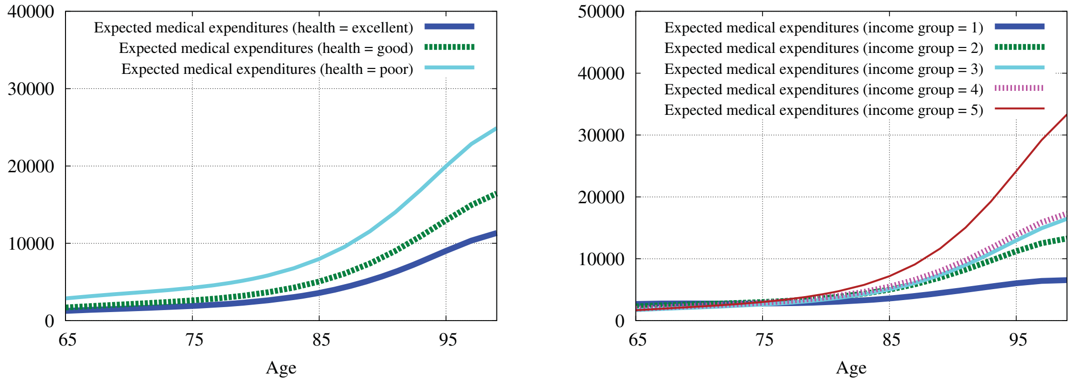
**Table 3: Health Status Transition**

| **Health status transition (age 65)** | | | | | **Health status transition (age 75)** | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Dead | Excellent | Good | Poor | | Dead | Excellent | Good | Poor |
| Excellent | 1.3 | 72.8 | 21.5 | 4.4 | Excellent | 3.9 | 60.1 | 26.9 | 9.2 |
| Good | 2.2 | 25.8 | 53.3 | 18.7 | Good | 6.6 | 21.1 | 46.9 | 25.4 |
| Poor | 9.6 | 6.1 | 20.7 | 63.7 | Poor | 16.3 | 3.8 | 17.6 | 62.3 |
| **Health status transition (age 85)** | | | | | **Health status transition (age 95)** | | | | |
| | Dead | Excellent | Good | Poor | | Dead | Excellent | Good | Poor |
| Excellent | 10.5 | 46.8 | 27.1 | 15.6 | Excellent | 28.5 | 29.5 | 19.8 | 22.3 |
| Good | 14.7 | 17.0 | 37.8 | 30.5 | Good | 32.9 | 12.9 | 26.8 | 27.5 |
| Poor | 28.8 | 5.1 | 13.2 | 52.9 | Poor | 56.9 | 4.2 | 13.6 | 25.3 |

(cohorts of age 70, age 80, and age 90 in 1996). The proportion is approximately linearly decreasing with age. 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 to one-adult households. The HRS data support this assumption: the probability of single-to-couple transitions is only around 3% for households in their 60s and 70s, and it is less than 1% for older households. Second, we assume that all the transitions from two- to one-adult households are caused by death of the spouse, i.e. are involuntary. That is, we assume away divorce, which appears to be rare in our data, though it is somewhat difficult to identify directly.

### Health Status and Mortality Shock Process

We group the five self-reported health status categories in the HRS (excellent, very good, good, fair, poor) into three groups, combining the top two and the bottom two. Since age-specific transition rates between different health groups appear stable over the waves of the HRS, we




(a) Middle Income, by Health

(b) Good Health, by Income

**Figure 16: Expected Medical Expenses of Singles**

pool all household-age observations across waves for estimation purposes. We compute the probability that a respondent of health status $m \in \{1, 2, 3\}$ is of health status $m'$ two years later, conditional on the age of the respondent. In this procedure, we also compute the probability of death ($m' = 0$). Table 3 presents health transition probabilities for ages 65, 75, 85, and 95. First, as expected, the probability of dying is generally higher for older respondents, and those in worse health. Second, health status is persistent. Third, however, this persistence becomes weaker with age, reflecting an increasing probability of death.

### Medical Expenditures

In order to measure medical expenses as accurately as possible, and following De Nardi et al. (2010), we incorporate into our data set the HRS exit waves, which collect medical expenditure information up to the end of life on respondents who die between two waves of the survey. We estimate out-of-pocket (OOP) medical expenditure shocks by regressing the probability of zero out-of-pocket medical expenses, the mean and the standard deviation of log-medical expenses on household size, income, health status, a quartic in age, as well as interaction terms of age and the other variables. Under the assumption of log-normality, we construct expected OOP medical expenses from this estimation. In figure 16, we plot expected medical expenses for single households, by health status and by income. Medical expenditures increase with age, driven both by a rising mean and rising variability over time; the rise is particularly dramatic for those in poor health.

In constructing the medical expenditure shock for the model, 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 point is chosen to capture the right tail of the distribution, which is emphasized by French and Jones (2004).

**Table 4: House Size Distribution**[1]

| | Cohort 1 (age 65) | Cohort 2 (age 75) | Cohort 3 (age 85) |
|---|---|---|---|
| Bin 1 | 21792 | 18267 | 16955 |
| Bin 2 | 44935 | 37938 | 35743 |
| Bin 3 | 63613 | 50803 | 47027 |
| Bin 4 | 77839 | 64390 | 51910 |
| Bin 5 | 88087 | 77583 | 62395 |
| Bin 6 | 101358 | 88868 | 75851 |
| Bin 7 | 125114 | 103150 | 88729 |
| Bin 8 | 152107 | 137364 | 108380 |
| Bin 9 | 195244 | 183191 | 148655 |
| Bin 10 | 360683 | 345206 | 266577 |

[1] Value in 1996 dollars.

### Housing

We approximate the distribution of house sizes in each cohort using ten grid points. We create this grid by classifying the households in each cohort into bins, each with about 10% of the sample, and using the mean house value within each bin as the grid points. Table 4 summarizes the house value bins constructed by this procedure. In the model, we also restrict the choice of property values for renters to the same set of house bins for each cohort.

We set maintenance cost $\delta$ at 3.4% per two years (annually 1.7%). This is the value calibrated by Nakajima (2010) using data on depreciation of residential capital in National Income and Product Accounts. The selling cost of a house ($\kappa$) is set at 6.6% of the value of the house. This is the estimate obtained by Greenspan and Kennedy (2007). Grueber and Martin (2003) report the median selling cost of 7.0% of the value of the house.

### Saving and Home Equity Borrowing

The saving interest rate is set at 8% (annually 4%). The mortgage debt premium $\xi$ is set at 3.2% (annually 1.6%), which is the average interest spread between 30-year conventional mortgage loans and Treasury bonds of the same maturity between 1977 and 2009.

### Housing Prices

For house price movements in the model, we use the data from the CPI and the HRS. For the rate of growth of rents, $g_0$, we use CPI, rent of primary residences component. The rate of growth for 1996-2006 averages at 2.1% per two years. We measure the rate of growth of house prices, $g_1$, from the HRS, by looking at the average rate of growth of house values for the period in question for homeowners who did not report moving between two consecutive waves of the survey. This average rate turns out to be 9.6% per two years, which is slightly above the average price trend in the house price index (HPI) compiled by the Federal Housing Finance Agency, but below the average price trend that results from the Case-Shiller index, which includes jumbo loans and

**Table 5: Initial Distribution – Selected Characteristics**

| | 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) | 0.50 | 0.39 | 0.33 |
| 2 (good) | 0.27 | 0.32 | 0.28 |
| 3 (poor) | 0.23 | 0.29 | 0.39 |
| **Tenure** | | | |
| Homeowner | 0.89 | 0.78 | 0.60 |
| Renter | 0.11 | 0.22 | 0.40 |
| **Net financial asset position** | | | |
| Saver | 0.82 | 0.92 | 0.96 |
| Borrower | 0.18 | 0.08 | 0.04 |

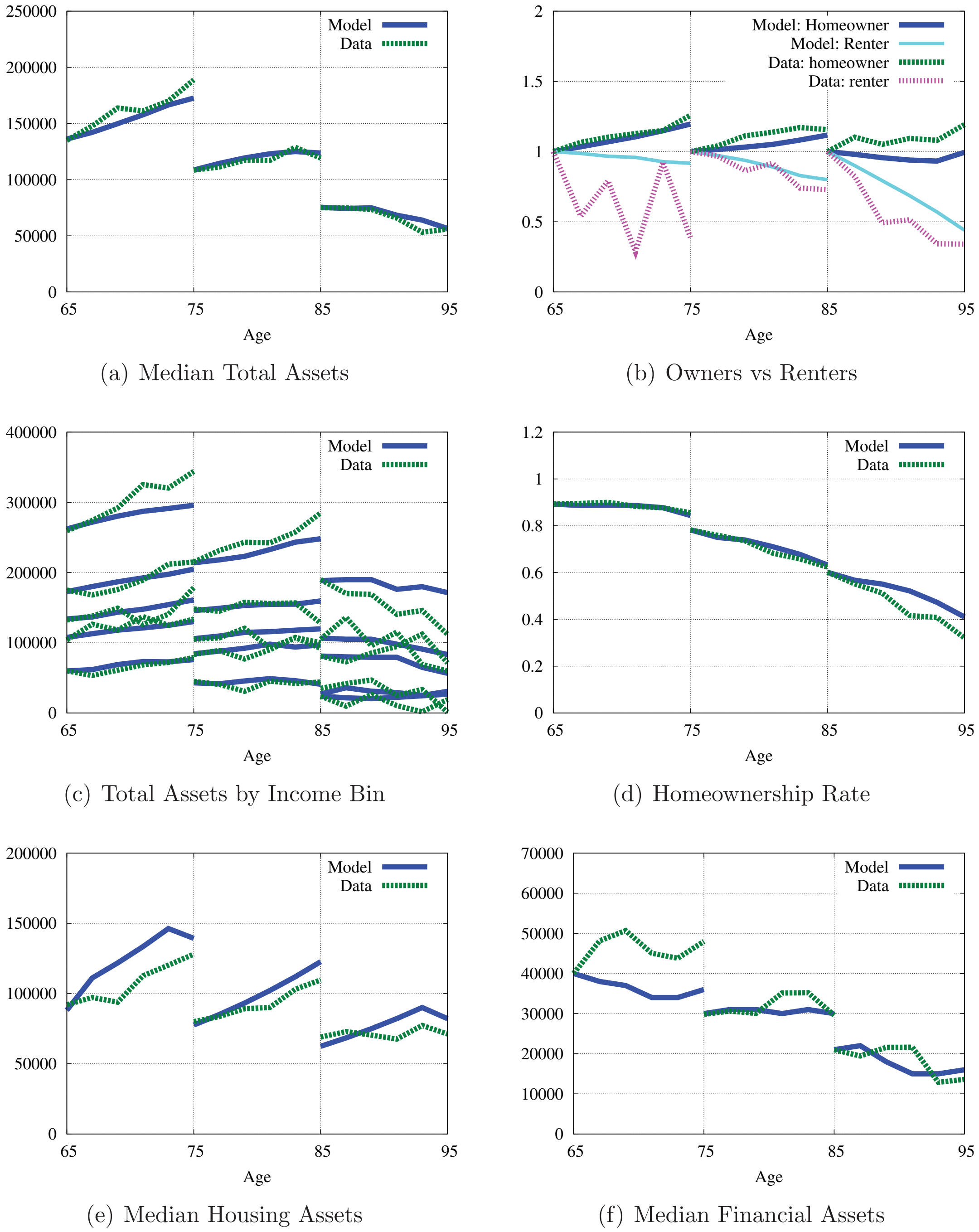
yields the average rate of 13% per two years. As we mentioned above, while we are able to observe house price growth heterogeneity across households in our data, we do not introduce this heterogeneity into the model, to contain the computational burden. As we show below, using the average price trend is largely sufficient to capture the behavior of the median household in each cohort.

**Initial Distribution**

We construct the model's initial distribution along the eight-variable state space from the 1996 HRS sample, simulate the model starting from this distribution, and use the outcome of the simulation to estimate the structural parameters in the second estimation step below. Table 5 shows the aspects of the initial distribution that we did not already describe. The properties of the 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, homeownership rate is decreasing with age. Finally, the proportion of households with net negative financial assets is lower for older cohorts.

### 5.3 Second Step Estimation

In the second-step estimation, we choose parameters to fit the life-cycle profiles discussed in section 3, using a minimum-distance estimator. The targets are cohort profiles of the homeownership rate, lifecycle profiles of median total, financial and housing assets, proportion of households in debt, and median debt of debtors. We also target the separate median net worth profiles for homeowners and renters, as shown in figure 2, as well as total assets by income bin. Finally, for the purpose of pinning down $\underline{c}$, we also target the rate of Medicaid participation by age, and by tenure.




(a) Median Total Assets

(b) Owners vs Renters

(c) Total Assets by Income Bin

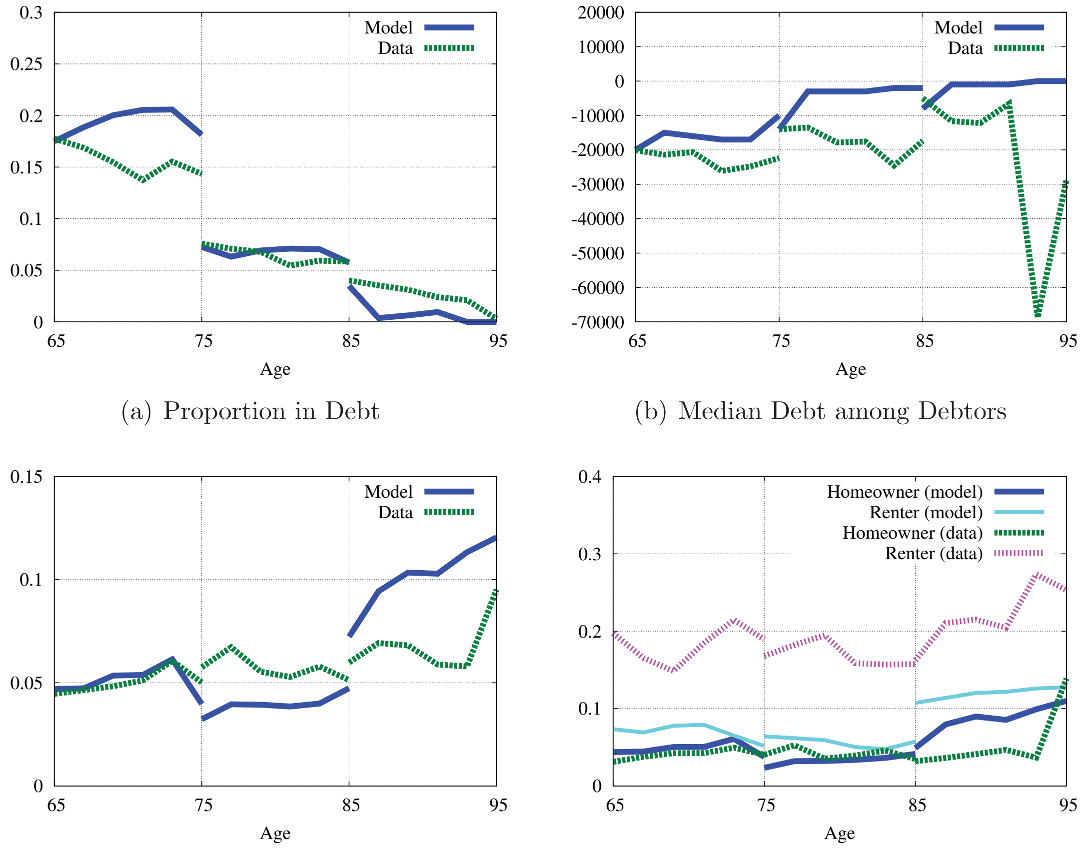
(d) Homeownership Rate

(e) Median Housing Assets

(f) Median Financial Assets

**Figure 17: Benchmark Model Fit - Asset Holding Profiles**

Figure 17 gives the asset profiles of the three cohorts, comparing the model and data. The first panel compares the median total asset profiles of each cohort in the model and data, which is the classic statement of the retirement saving puzzle; the model matches these profiles perfectly.




(a) Proportion in Debt

(b) Median Debt among Debtors

(c) Medicaid Rate

(d) Medicaid Rate by Tenure

**Figure 18: Benchmark Model Fit - Debt and Medicaid Profiles**

The second panel compares owners and renters in the model to those groups in the data, in terms of normalized median total asset profiles. For the first two cohorts, the model matches the normalized net worth profiles of owners and renters fairly well, with the exception of the youngest cohort's renters – but this group is small in the data and the data profile is noisy. For the oldest cohort, the model underpredicts somewhat the extent of asset accumulation of owners, and of decumulation of renters, but generates close to the full empirical difference in the behavior of the two groups, so that the renters decumulate their assets much faster than homeowners. The third panel shows total assets by income group. The model generally does very well on these. The model slightly underpredicts net worth accumulation of the highest quintile in the youngest cohort, and overpredicts the wealth of the oldest wealthiest households. The remaining panels of the figure show homeownership rates, median housing assets of homeowners and median financial assets in the model relative to data. The model nearly perfectly replicates homeownership rates, slightly overpredicting them for the oldest cohort, and comes very close on the asset profiles, with an underprediction on the financial assets of the youngest cohort.

Figure 18 presents debt and Medicaid profiles. The top two panels compare the proportion of

**Table 6: Second-Step Parameter Estimates**

| Parameter | Description | Value |
|---|---|---|
| $\beta$ | Discount factor[1] | 0.96 |
| $\eta$ | Consumption aggregator | 0.81 |
| $\sigma$ | Coefficient of RRA | 2.93 |
| $\omega_1$ | Extra-utility from ownership | 1.42 |
| $\gamma$ | Strength of bequest motive | 4.19 |
| $\zeta$ | Curvature of utility from bequests | 17714 |
| $\underline{c}$ | Consumption floor per adult[1] | 8981 |
| $\lambda_{65}$ | Collateral constraint for age-65 | 0.16 |
| $\lambda_{75}$ | Collateral constraint for age-75 | 0.95 |
| $\lambda_{85}$ | Collateral constraint for age-85 | 0.99 |
| $\lambda_{99}$ | Collateral constraint for age-99 | 1.00 |

[1] Biennial value.

households in debt (panel (a)) and median debt among indebted households (panel (b)) between the model and the data. In general, it is difficult to match both the extensive and intensive margins of debt, given our parsimonious way of capturing the costs of borrowing. Our benchmark model matches the rate of indebtedness quite well, except for the youngest cohort, where it overpredicts the debt rate. On the extensive margin, we capture decently well the amount of debt for the youngest and oldest cohort, but underpredict the amount of debt in the middle. Given that we match the debt profiles by estimating age-specific collateral constraints, which result in very tight borrowing constraints for the oldest households, it is difficult to also match the fact that in the data, the few households that do continue to borrow late in life appear to borrow quite a bit. With more flexible specification of debt costs, we would be able to capture this intensive margin better, but at the cost of additional computational burden. In any event, the extensive-margin discrepancy concerns a small subset of the data's (and model's) population.

The bottom two panels show the rate of Medicaid recipiency for the sample as a whole, and by homeownership status. For the sample as a whole, the model does quite well, particularly considering that Medicaid status is not a variable we build into our initial distribution. We match the youngest cohort very well. For the second cohort, the model underpredicts the Medicaid recipiency rate for the younger retirees by 2-3 percentage points; for the oldest cohort, the model overpredicts recipiency slightly, doing worse for the middle of the cohort. From the second panel, it is clear that the model matches very well the rate of Medicaid recipiency by homeowners – this is an important result, because we do not want to overstate the role of Medicaid in the retirees' decisions to keep or sell their home relative to the data. It is on the renter dimension that the model does less well.

The resulting parameters from the second-step estimation are in table 6. Several are worth pointing out. First, based on the Medicaid recipiency rates, we estimate the consumption floor to be about \$4,490 per person per year in 1996 dollars. Our estimate lines up well with Hubbard et al. (1994), who measure the non-Social-Security consumption floor for the elderly to be \$6,893 per *household* per year in 1984 dollars.

The collateral constraints that we estimate imply that while homeowners of age 65 can still borrow up to 84% of their home equity, that constraint tightens considerably by the time they are 75, to just 5% of home equity, and to just 1% for homeowners who are 85 years old. These numbers should not be interpreted literally as downpayment constraints; rather, these constraints capture the overall cost of equity borrowing, which reflect, for example, the fact we mentioned before that many retirees fail the income requirement for equity loans (Caplin (2002)), so that above age 65, equity borrowing quickly becomes much costlier if not prohibitive. These parameters are based primarily for on the debt profiles, both the extensive and intensive margin, that we observe in the data: as fewer and fewer households borrow as they age, it stands to reason that the model implies a quickly tightening borrowing constraint.[6]

Our estimated parameter of extra utility from homeownership is 1.42, which means that it is 2.42 times more appealing to own a home than it is to rent. To understand this value, we once again remind the reader that this parameter captures all possible nonfinancial benefits of homeownership, as well as those financial benefits that are not explicitly in the model. That is, here we capture not only the attachment to the house, one's neighborhood, the ability to modify the house, but also tax benefits of homeownership, the insurance that ownership provides against rental rate risk, and other such benefits. The estimate that we have is consistent also with the findings in Venti and Wise (2004), who find strong support in the data for an AARP survey statement that retirees like to stay in their current residence as long as possible.

The relative risk aversion parameter that we estimate is $\sigma = 2.93$, in the lower part of the range used in the macro literature. That is, we do not require a high degree of risk aversion to match the slow rate of asset decumulation that we observe in the data. The estimated strength of the bequest motive is 4.19. The interpretation of this number will be clear in the next section in the context of our experiments; at the end of the section, we will also discuss how we identify the parameters based on the experiments and additional sensitivity analysis.

# 6 Experiments: Decomposing the Retirement Saving Puzzle

In this section, we use the estimated model to evaluate the quantitative contribution of key model features to retiree saving behavior, by shutting down these mechanisms one at a time, keeping all other model features constant, and comparing the results to the benchmark model outcome. At the end of this section we measure the relative quantitative importance of all the model features, by stripping the model down to the basic life-cycle case with only longevity risk, then re-introducing the features back in different orders. The mechanisms that we focus on to evaluate how housing affects the retirement saving puzzle are extra utility of homeownership, collateral constraints, and the housing boom of 1996-2006. Then, we also evaluate the impact of medical expenses and bequest motives, to understand *why* retirees choose to hold on to their homes late in life. To save space, we focus on the most salient result graphs for each experiment;

[6]A related matter is that reverse mortgages are instruments available specifically to the elderly, but in separate work, we find these to be very costly, due to insurance costs, which is consistent with our interpretation of $\lambda_i$ as capturing high costs of borrowing in retirement. See Nakajima and Telyukova (2011) for details.


(a) Median Total Assets

(b) Owners v. Renters

(c) Ownership Rate

(d) Debt Rate

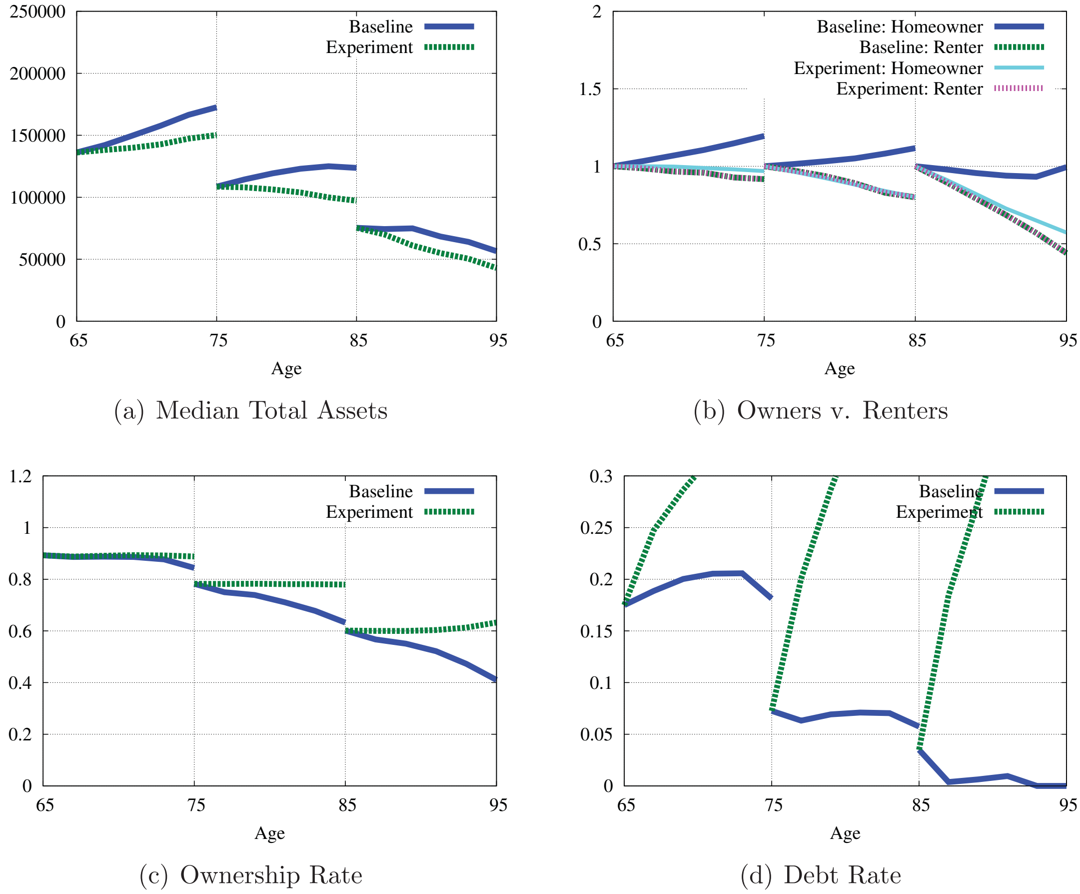
**Figure 19: Decomposition Experiment – No Extra Ownership Utility**

the full set of life-cycle results for each experiment is available in the online appendix.[7]

### 6.1 Role of Extra Utility of Homeownership

In the first experiment, we evaluate the role that financial and nonfinancial benefits of homeownership, independently of precautionary or bequest motives, play in retiree saving decisions. To do this, we set $\omega_1 = \omega_0 = 1$, so that owned and rented homes are the same in terms of utility. The results of this experiment are in figure 19.

Panel (c) shows that, not surprisingly, the utility benefit of homeownership encourages retirees to own homes, in a similar magnitude across cohorts, and from panel (d) it is also clear that it suppresses home equity borrowing, particularly for the youngest cohort. Through extra homeownership, the utility benefit impacts net worth somewhat, as panel (a) demonstrates; overall, however, the contribution of this channel to the retirement saving puzzle for the median household is mild. Not surprisingly, the extra utility of ownership affects only homeowners, as panel (b) shows; however, net worth of homeowners is affected mildly, and the difference in the rate of dissaving between owners and renters remains large.




(a) Median Total Assets

(b) Owners v. Renters

(c) Ownership Rate

(d) Debt Rate

**Figure 20: Decomposition Experiment – Uniform Collateral Constraints**

## 6.2 Role of Collateral Constraints

For this experiment, we make every homeowner's collateral constraint uniform, rather than allowing the constraint to differ by age. Here we want to evaluate how much the stringency of the collateral constraint affects each cohort. We also want to compare these constrained homeowners to renters, to see how much of the difference in asset decumulation between owners and renters is due to the fact that owners are locked into a more illiquid asset. For this purpose, we set everyone's collateral constraint to zero, allowing all homeowners to borrow up to 100% of their equity.[8]

The results of this experiment are in figure 20. First of all, the illiquidity of housing is sufficient to create most of the decline in the homeownership rate, all else equal (panel (c)). This suggests that homeowners in our model sell their homes largely when they are forced against their borrowing constraint. Not surprisingly, the borrowing constraints depress borrowing in panel

[7]The online appendix can be found at http://dss.ucsd.edu/ itelyuko/research.html.

[8]In a second experiment, we made everyone's collateral constraint uniform at 16%, to match the most unconstrained age in the benchmark model; the results are very similar in that case, see online appendix.

(d);[9] if homeowners were able to access their equity freely, they would hold on to their house, motivated by the utility benefit, and borrow against their equity instead, thus decumulating their housing asset more quickly, in the median. This in turn is reflected in the median net worth: part of the reason the net worth profiles stay as flat (or increase) as they do in the benchmark is because homeowners are unable to borrow (panel (a)). Thus, collateral constraints do contribute to the retirement saving puzzle in a significant way, especially for younger cohorts, and the impact is more dramatic than from the utility benefit of homeownership.

Finally, the difference between homeowners and renters is created, it appears, in large part by the collateral constraint, as panel (b) demonstrates. That is, illiquidity of housing plays an important role in accounting for why homeowners do not decumulate their assets more quickly, and more in line with renters. The oldest cohort is the only one where not all of the difference is accounted for by the liquidity constraints.

### 6.3 Role of the Housing Boom

In this experiment, we evaluate how much the housing price boom of 1996-2006 contributed to the median net worth profiles in the data. To do this, we shut down the exogenous increasing trend to the aggregate housing price, assuming instead constant prices.

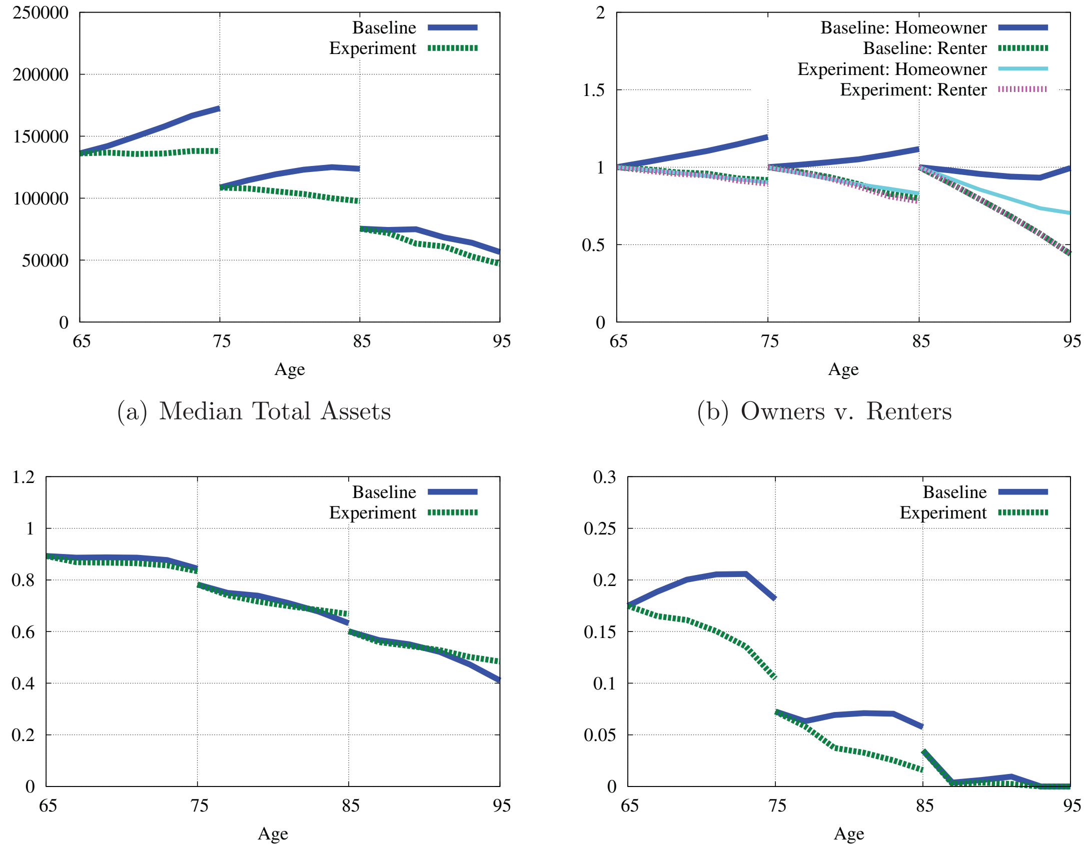
The obvious impact of this experiment, shown in figure 21 , is the flattening of median net worth profiles in panel (a), which happens through two channels. First, obviously there is a significant flattening of median housing asset profiles (see online appendix). In addition, panel (d) shows a significant decline in the debt rate when there is no housing boom; it is also true that the median amount of debt, especially in the younger cohort, declines somewhat. (Not shown). This is intuititive: a housing boom increases the amount of home equity against which households can borrow, and some households take advantage of that; however, many households simply enjoy the capital gain without tapping into equity. The overall impact of the housing boom is an increase in the median net worth for all cohorts; this impact is the most dramatic of the three housing-related channels, although not for the oldest cohort. Note also that the housing boom, like collateral constraints, plays an important role in creating the differences in the dissaving behavior of homeowners versus renters (panel (b)), with the oldest cohort being the biggest exception. In sum, homeowners in the model become beneficiaries of the housing boom, and it obviously contributes to the retirement saving puzzle.

### 6.4 Role of Medical Expenses

Following De Nardi et al. (2010), in this section we perform two experiments. First, we shut down medical expense risk, setting everyone's expenses to the mean for the appropriate age and health status group, as in figure 16. Then, we set everyone's medical expenses to $x = 0$.

The two experiments have similar effects. First, we see that homeownership is not driven primarily by precautionary motive in the face of medical expense risk (panels (c), figures 22 and 23). Except for the oldest cohort, homeownership rates are not affected by medical expenses at all; a small fraction of the oldest old choose to sell their homes relative to the benchmark if we

[9] For ease of comparison, we keep the scale of the graphs constant, at the cost of having this graph partially off the scale.




(a) Median Total Assets

(b) Owners v. Renters

(c) Ownership Rate

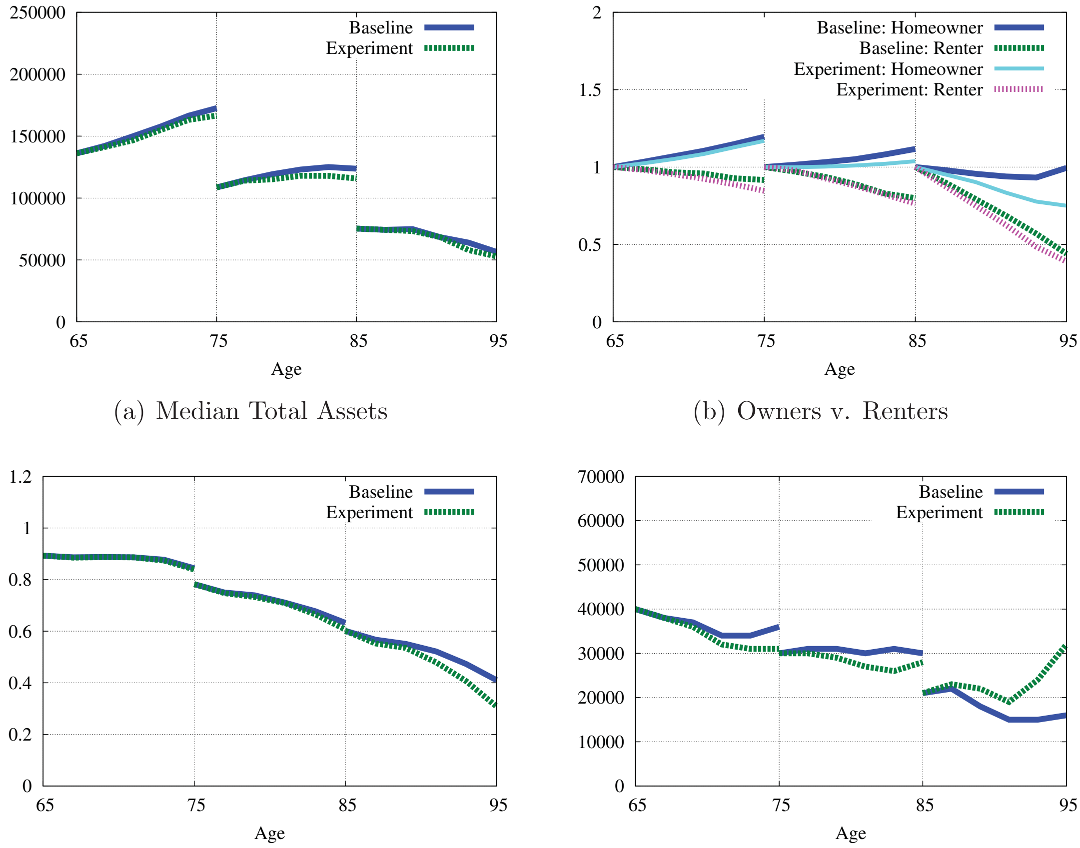
(d) Debt Rate

**Figure 21: Decomposition Experiment – No Housing Boom**

shut down medical expense risk. This effect in oldest age comes from the homestead exemption of Medicaid: in the presence of medical expense risk, a small portion of oldest homeowners have an incentive to hold on to their home and use Medicaid if a big medical expense shock realizes, rather than to sell the home and use the home equity to pay for the expense. This is confirmed if we look at housing assets by income bin (not shown here, see online appendix): the housing assets of the oldest and poorest retirees is most affected.

The overall effect on net worth is moderate (panels (a)), and is driven by a more rapid decumulation of financial assets (panels (d)) for the two younger cohorts, while median housing assets are not affected (not shown). That is, overall, the precautionary motive in the face of medical expense risk affects not housing but the liquid financial assets.

For the oldest cohort, while a few choose to sell their homes, in the median, they have more financial assets if medical expenses are shut down - part of this must come from translating home equity into financial wealth. Thus medical expenses play a dual role: they create a moderate precautionary motive earlier in retirement, but for the oldest old, they are primarily a source of spending. Finally, note that medical expenses contribute slightly to the difference between




(a) Median Total Assets

(b) Owners v. Renters

(c) Ownership Rate

(d) Median Financial Assets

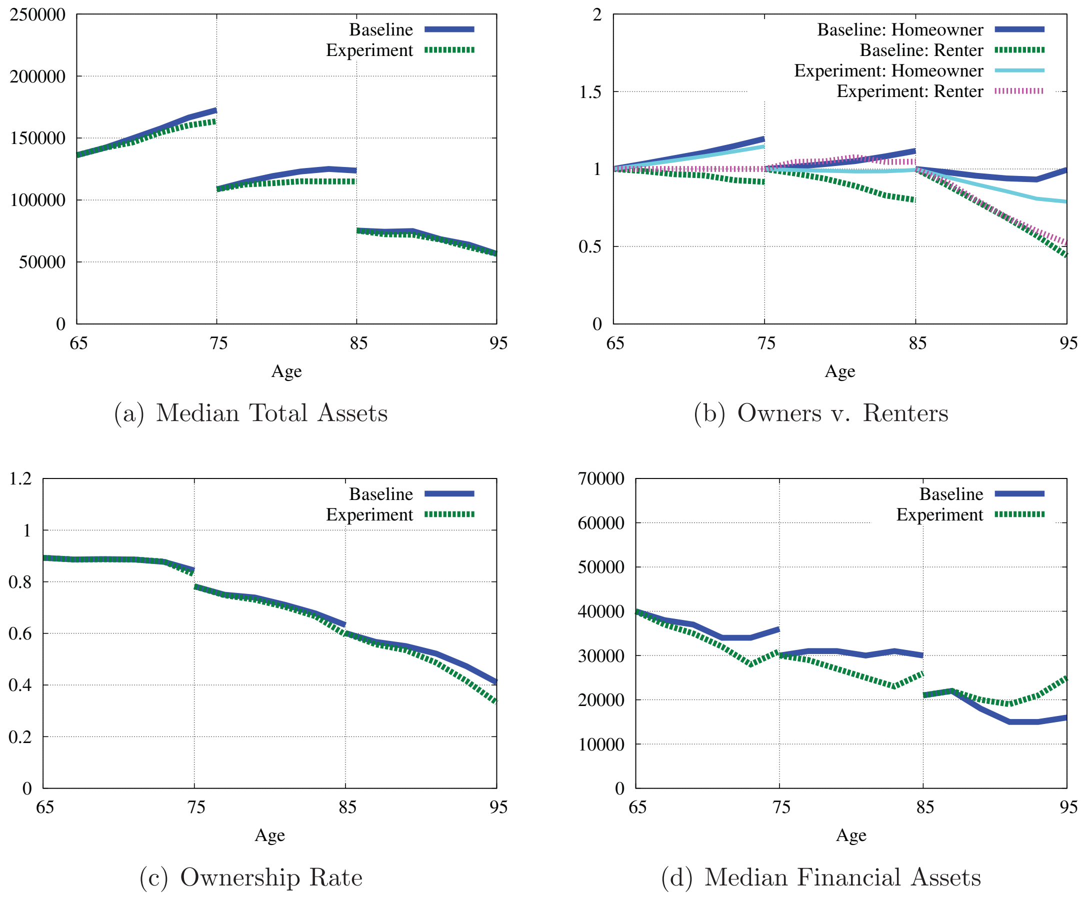
**Figure 22: Decomposition Experiment – No Medical Expense Risk**

homeowners and renters (panels (b)), primarily for the oldest cohort.

### 6.5 Role of Bequest Motive

In order to evaluate the role of the bequest motive in the benchmark, in this experiment we shut it down by setting $\gamma = 0$. As we show in figure 24 panel (c), the bequest motive increases the homeownership rate for the middle and especially the last cohort. The bequest motive also discourages equity borrowing, as panel (d) shows, and is an important contributor to overall median net worth in panel (a). Thus, the bequest motive prevents people from decumulating their equity, either by borrowing or by selling homes and then decumulating their financial assets. In aggregate, the bequest motive is a significant contributor to the retirement saving puzzle. Notice that the the impact of the bequest motive becomes stronger with age.

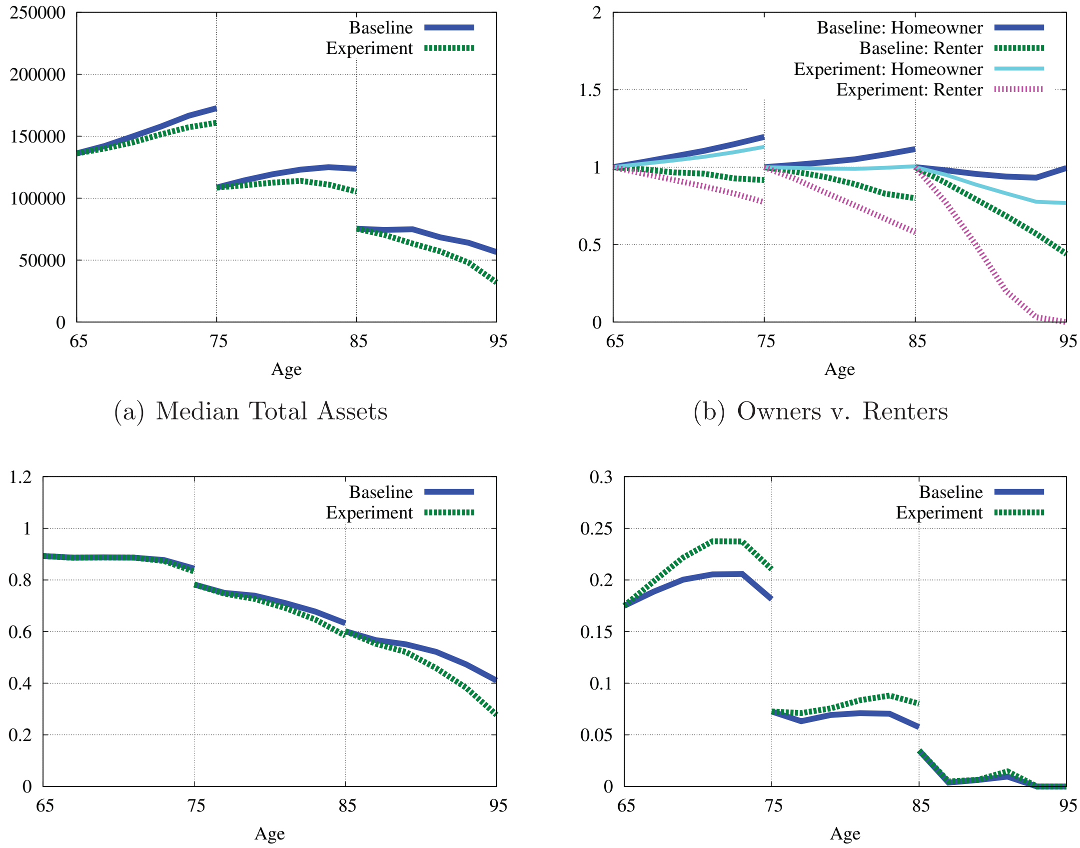
Panel (b) demonstrates additional salient features of the bequest motive. First, it impacts not only homeowners but also renters; without the bequest motive, both groups decumulate assets much more quickly than in the benchmark case, and renters in particular decumulate their financial wealth to zero rapidly, thereafter relying on the consumption floor in case of




(a) Median Total Assets (b) Owners v. Renters

(c) Ownership Rate (d) Median Financial Assets

**Figure 23: Decomposition Experiment – No Medical Expenses**




(a) Median Total Assets

(b) Owners v. Renters

(c) Ownership Rate

(d) Debt Rate

**Figure 24: Decomposition Experiment – No Bequest Motive**

large expense shocks. Second, even without the bequest motive, homeowners retain significant positive wealth late into the lifecycle, so that the difference between homeowners and renters remains significant even without the bequest motive in the model.

### 6.6 Summary: Individual Decomposition Results

Before proceeding, we summarize the key conclusions regarding saving behavior in retirement from the experiments above. In the data, many households are homeowners well into their old age, and this fact turns out to be crucial for the retirement saving puzzle. Retired homeowners choose to remain owners late in life due to a combination of financial and nonfinancial benefits of ownership (expressed in our utility parameter $\omega$, the higher returns to housing, capital gains taxes and the like). Homeownership is further encouraged by *bequest* motives: given these, retirees choose to stay in their homes longer on average, and many choose not to borrow against home equity, to whatever extent they can. Instead, *precautionary* motives in the face of medical expenses affect primarily financial wealth in retirement. Once retirees choose to stay in their homes, they become beneficiaries of positive trends in house prices; the housing boom of 1996-

2006 significantly contributed to the retirement saving puzzle. Finally, as homeowners age, they become increasingly locked into their home equity because of tightening borrowing constraints; this also contributes to the flatness of the net worth profiles that we observe. On the flip side, retirees can hit their borrowing constraints – due to medical and other expenses – and can be forced to sell the house as a result, becoming renters instead.

The decompositions above imply that there may be interactions between the model channels that we are concerned with, which may move optimal choices simultaneously. For example, bequest motives and utility benefits of homeownership may interact and reinforce each other in creating motives for homeownership; so may borrowing constraints and medical expense risk, in causing homeowners to sell their homes late in life. In order to tie the experiments together and understand the quantitative contribution of each channel, we next shut down all of the channels in the estimated model that we singled out above, thus stripping the model down to a basic OLG framework with longevity risk, and then re-introduce those channels in succession. We do this in several different orders, to highlight the interaction between the different mechanisms.

### 6.7 Quantitative Assessment of the Retirement Saving Puzzle

For these sequential experiments, we focus on the most standard statement of the retirement saving puzzle – the median net worth of each age group. Taking the median net worth of each age group at the end of the sample period in our benchmark model as 100%, we quantify how much saving relative to the benchmark is generated for each cohort by each model variant. We present results for selected age groups cumulatively in table 7, and incrementally in table 8. Obviously, the number of possible orderings of the mechanisms is very large; below, we present a small subset of the experiments to demonstrate the salient interactions in the model.

When we shut down the bequest motive, utility benefit of homeownership, collateral constraints, housing price boom, and medical expenses, we obtain the basic life-cycle model where the only source of uncertainty is the length of life, and household saving is due to the precautionary motive against this uncertainty. In this basic model, according to table 7, the median age-75 household would save 50% of that age group's empirical amount (i.e. amount in the benchmark); at age 85, the savings would be at 43% of the observed amount; and by age 95, the median net worth is at 28% of the benchmark. Households of age 99 in the model have zero wealth, because they die with certainty after that period.

In tables 7 and 8, each numbered panel presents a different order in which we re-introduce the model features. We vary the order of bequest motives with medical expense risk, and with the three housing-related channels (utility benefits of homeownership, collateral constraints, and the housing boom). In addition, we investigate changes in the ordering of the housing-related channels themselves, first introducing the housing boom before the collateral constraint, and then after.

In the first two experiments, we vary the order of bequest motive and the three housing channels. The first experiment shows that adding the bequest motive to the model with only longevity risk ( table 8, experiment 1, line 1) implies that it accounts for 23% of the median net worth of age-75 households, for 22% of the net worth of age-85 households, and 31% for households of age 95. Notice that if the bequest motive is introduced after the housing channels

**Table 7: Contribution of Each Channel to Median Net Worth – Sequential Decompositions, Cumulative**

| | Model | Age 75 (cohort 1) | Age 85 (cohort 2) | Age 95 (cohort 3) |
|---|---|---|---|---|
| | Simple life-cycle | 50 | 43 | 28 |
| 1 | Simple life-cycle + bequest motive | 72 | 65 | 60 |
| | Add utility benefit of ownership | 75 | 67 | 64 |
| | Add housing boom | 86 | 79 | 77 |
| | Add collateral constraints | 97 | 94 | 94 |
| | Full model (add medical expense risk) | 100 | 100 | 100 |
| 2 | Simple life-cycle + utility benefit of ownership | 54 | 45 | 30 |
| | Add housing boom | 68 | 60 | 53 |
| | Add collateral constraints | 92 | 81 | 60 |
| | Add bequest motive | 97 | 94 | 94 |
| | Full model (add medical expense risk) | 100 | 100 | 100 |
| 3 | Simple life-cycle + medical expenditure risk | 58 | 52 | 28 |
| | Add bequest motive | 72 | 67 | 59 |
| | Add utility benefit of ownership | 76 | 69 | 63 |
| | Add housing boom | 87 | 81 | 78 |
| | Full model (add collateral constraints) | 100 | 100 | 100 |
| 4 | Simple life-cycle + bequest motive | 72 | 65 | 60 |
| | Add medical expenditure risk | 72 | 67 | 59 |
| | Add utility benefit of ownership | 76 | 69 | 63 |
| | Add housing boom | 87 | 81 | 78 |
| | Full model (add collateral constraints) | 100 | 100 | 100 |
| 5 | Simple life-cycle + bequest motive | 72 | 65 | 60 |
| | Add medical expenditure risk | 72 | 67 | 59 |
| | Add utility benefit of ownership | 76 | 69 | 63 |
| | Add collateral constraints | 80 | 79 | 83 |
| | Full model (add housing boom) | 100 | 100 | 100 |

**Table 8: Contribution of Each Channel to Median Net Worth – Sequential Decompositions, Incremental**

| | Model | Age 75 (cohort 1) | Age 85 (cohort 2) | Age 95 (cohort 3) |
|---|---|---|---|---|
| 1 | Bequest motive | 22.5 | 21.8 | 30.8 |
| | Utility benefit of ownership | 2.9 | 2.3 | 4.4 |
| | Housing boom | 10.4 | 12.0 | 13.7 |
| | Collateral constraints | 10.9 | 14.7 | 16.5 |
| | Medical expenditure risk | 3.5 | 6.4 | 6.2 |
| | *Total housing* | *24.1* | *29.0* | *34.7* |
| 2 | Utility benefit of ownership | 3.6 | 2.5 | 1.3 |
| | Housing boom | 14.9 | 14.9 | 22.9 |
| | Collateral constraints | 23.9 | 20.6 | 7.7 |
| | Bequest motive | 4.2 | 12.8 | 33.6 |
| | Medical expenditure risk | 3.5 | 6.4 | 6.2 |
| | *Total housing* | *42.4* | *38.0* | *31.8* |
| 3 | Medical expenditure risk | 7.7 | 8.8 | 0.0 |
| | Bequest motive | 14.9 | 15.5 | 30.8 |
| | Utility benefit of ownership | 3.4 | 2.3 | 4.2 |
| | Housing boom | 11.6 | 11.2 | 14.5 |
| | Collateral constraints | 12.6 | 19.4 | 22.2 |
| | *Total housing* | *27.6* | *32.9* | *40.9* |
| 4 | Bequest motive | 22.5 | 21.8 | 30.8 |
| | Medical expenditure risk | 0.0 | 2.4 | 0.0 |
| | Utility benefit of ownership | 3.4 | 2.3 | 4.2 |
| | Housing boom | 11.6 | 11.2 | 14.5 |
| | Collateral constraints | 12.6 | 19.4 | 22.2 |
| | *Total housing* | *27.6* | *32.9* | *40.9* |
| 5 | Bequest motive | 22.5 | 21.8 | 30.8 |
| | Medical expenditure risk | 0.0 | 2.4 | 0.0 |
| | Utility benefit of ownership | 3.4 | 2.3 | 4.2 |
| | Collateral constraints | 4.2 | 9.5 | 19.9 |
| | Housing boom | 20.0 | 21.1 | 16.9 |
| | *Total housing* | *27.6* | *32.9* | *40.9* |

(experiment 2), its marginal contribution declines somewhat for younger retirees (to, respectively, 4% and 13%), but increases for the oldest households, to 34%. The robust fact is that the role of bequest motives in retiree saving increases dramatically with age, and that its role overall is significant. The change in the numbers indicates that the three channels of homeownership (utility benefit, collateral constraints and the housing price boom) interact with bequest motives, as we would expect given the experiments above; that is, bequest motives contribute to retirees' decision to own a home.

The role of the three housing channels together is significant. The utility benefit of homeownership is the least influential quantitatively. It contributes 3% of the median net worth for 75-year-olds if introduced after the bequest motive, and 4% if introduced beforehand. This is roughly similar, at 2-3%, for 85-year-olds. For the very oldest households, utility benefit is a bit stronger if introduced before the bequest motive, at 4%, whereas the bequest motive reduces the impact almost to zero. Indeed, looking at the other experiments suggests that if any of the other drivers of saving behavior are already present in the model, the impact on the very oldest households of the utility benefit of ownership is reduced nearly to zero.

The role of the collateral constraints is much more significant. Illiquidity of housing contributes 11% to the youngest group's net worth, if introduced after the bequest motive , and 17% to the oldest group's, whereas in the economy without the bequest motive, the impact is larger for younger households, at 24%, but is reduced for older households to 8%, where the bequest motive dominates the saving decisions. Finally, the housing boom contributes between 10 and 15% to the median net worth of 75-year-old households, depending on whether it is introduced before or after the bequest motive, and between 14 and 23% for the oldest households.

Overall, the contribution of the three housing channels ranges between 24% and 42% of the benchmark amount of the youngest group, depending on whether the economy has a bequest motive already, and between 32 and 35% for the oldest households. The interaction of housing with bequest motives is clearly important.

Experiments 3 and 4 test the contribution of medical expense risk, when interacted with bequest motives; in experiment 3, we introduce medical expenses first, and in experiment 4, after the bequest motive. On its own, introduced to the model only with longevity risk, medical expense risk accounts for 8% of savings of 75-year-old households, but for 0% if the households have a bequest motive. For the very oldest households, the impact is zero regardless. Notice also that the role of bequest motives remains significant and robust even when introduced into the economy with medical expense risk, and plays a greater role than medical expense risk. There is clearly some interaction between the two motives, but it is not quantitatively significant. From experiments 1 or 2, we see that when medical expenses are introduced into the model with both housing and bequest motives, their role lies in the middle of this range. Thus medical expense shocks play a moderate role, by creating a precautionary motive early in life, and a spending motive late in life which is offset by Medicaid, as discussed above.

Finally, experiment 5 reverses the order in which the collateral constraints and the housing boom are introduced into the model; in addition, here like in experiments 3 and 4, we introduce housing into the economy that already has bequest motives and medical expense risk. This experiment shows that overall, the role of housing is still important for the retirement saving puzzle, but that the marginal contribution of the collateral constraints falls a bit, to 4-20% of the median net worth depending on age, and instead that the role of the housing boom is increased to 17-20% of the benchmark.

In sum these experiments show that homeownership and housing are a significant channel that induces retirement saving in a variety of ways, and contributes a signficant portion of the retirement saving puzzle, that bequest motives play a significant and robust role in inducing retirees to save, and that medical expenses play a moderate role.

### 6.8 Identification

The experiments above also shed some light on how the key parameters in the second-stage estimation are identified. Here we summarize this information, and bring in a few more results from the experiments to make the distinctions as clear as possible. Due to the complexity of the problem and the size of the state space, we are severely limited in how much sensitivity analysis we can do, and we are unable to do formal standard error computation for the same reason.

First, as we mentioned before, the government-provided consumption floor $\underline{c}$ is identified by matching the Medicaid recipiency rates by age. The borrowing constraints $\lambda_i$ are pinned down primarily by the debt profiles, particularly the extensive margin – i.e. the share of retirees by age who are in debt.

This leaves six key parameters, of which three – $\sigma$, $\gamma$ and $\omega_1$ – deserve particular mention as they likely interact in affecting homeownership decisions, as well as precautionary and bequest motives.

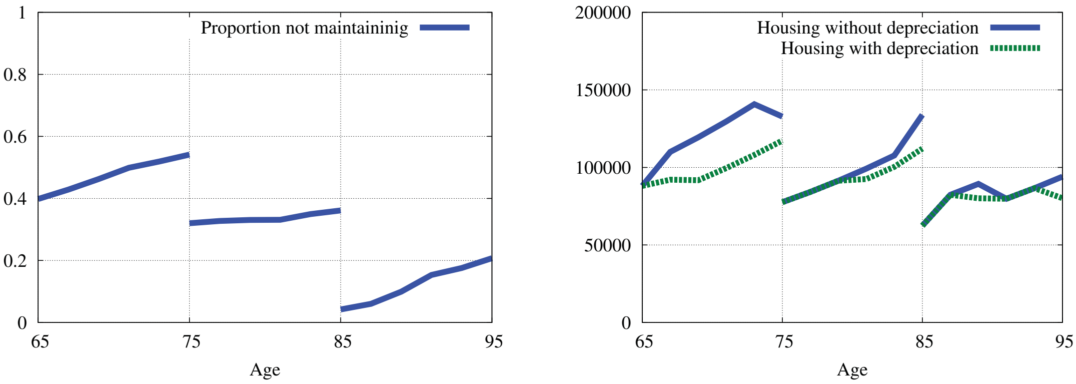
We can identify these parameters by looking at the wealth distribution, and the distinction between homeowners and renters. First, $\omega_1$ affects only homeowners and only housing asset profiles, while $\sigma$, as we showed through the medical expense experiments above, affects primarily financial assets, without affecting the housing side significantly, and more so for the top tail of the distribution. $\gamma$ affects homeownership rates together with $\omega_1$, but affects both homeowners and renters, and the behavior of more of the distribution than $\sigma$ does.

Formal sensitivity analysis is difficult to do, because small changes in parameters do not affect the median profiles, due to the coarseness of the grids on which we are forced to compute the model, given the eight state variables in the recursive problem. Thus we conduct the following experiment: we raise each of the three parameters in question by 50% to show the differing effects on the asset profiles. (To be continued.)

## 7 Experiment: The Role of Home Maintenance

In this section, we conduct one more experiment to evaluate the role of home maintenance as a possible "hidden" channel of asset decumulation. We are motivated by the study of Davidoff (2006), who finds that elderly homeowners spend on average 0.8% less per year on home maintenance than younger owners of a similar house, and that similar houses sell at substantially lower prices if the owner was over 75 years old.

In order to conduct this experiment, we add a choice margin to our model. Whereas in the benchmark, we assume that all households pay the maintenance cost (1.7% of equity per




(a) Proportion Homeowners Not Maintaining

(b) Median Housing Assets

**Figure 25: Experiment: Maintenance Decision**

year) and as a result, the house does not depreciate, now we give the households a choice: they can continue to pay the cost, or they can choose not to pay it, but the house will depreciate as a result at the rate of 4.25% per year. The calibration for this experiment came from the findings in Davidoff (2006), who calculates that the elderly (over age 75) spend about 0.8% per year less on home maintenance than younger homeowners, and that houses of older homeowners appreciate at a rate of 2 percentage points per year lower than houses of younger owners. These two numbers together, in addition to the maintenance cost parameter, give us the parameters specified here.

An additional important point is that in order to conduct this experiment, we make the assumption that self-reported home values that we use in order to estimate our house price process do not take into account depreciation of the house. That is, we assume that homeowners who stay in their homes do not have their house appraised and are not aware of the rate at which their home depreciates. This assumption is supported by Venti and Wise (2004) who find that self-reported home values are exaggerated. Still it may be an extreme assumption, and thus the results of this experiment should be treated with this caveat in mind. On the other hand, the empirical findings of Davidoff (2006) appear to be that the maintenance margin is an important one, and we can use our model to get a sense of how much it might contribute to the retirement saving puzzle in a hidden way.

Figure 25 gives the results of the experiment. First, a large proportion of homeowners in our model choose not to maintain their homes, when given that option. In the youngest cohort, at age 65 40% of homeowners choose not to maintain their home, and this number rises to about 55% by age 75. By age 95 in the oldest cohort, 20% of homeowners choose not to maintain their homes. Given this decision, we compute the median value of housing assets among homeowners. The youngest cohort's median is most affected since the median household in that group chooses not to maintain their house; as a result, the median housing value declines much more rapidly than in the benchmark case. For that cohort, if we take the depreciation of housing into account, the median net worth profile would also decline more rapidly than in the benchmark. In the other two cohorts, the median housing assets move far less dramatically, but still decline for the second half of the middle cohort, and there is a slight decline for the oldest cohort as well. In sum, the choice not to maintain the house may be another contributor to the retirement saving puzzle through the housing channel, and a significant portion of the population exercises this choice in our model, consistent with the data found by Davidoff (2006).

## 8 Conclusion

In this paper, we study homeownership in retirement, to understand what role it plays in accounting for the retirement saving puzzle. We do so by estimating a model of retiree saving that is explicit about differentiating between housing and nonhousing assets, targeting jointly in estimation not only median net worth lifecycle profiles of retirees, but also profiles of homeownership rates, housing and financial assets separately, renters' and homeowners' saving separately, as well as debt rates and amounts. In our estimated model, housing plays a key role in accounting for the retirement saving puzzle, through a combination of utility benefits of homeownership, illiquidity of housing, and the housing boom of 1996-2006. Moreover, bequest motives play an important role by themselves, as well as by affecting homeownership decisions. Finally, medical expense risk plays a moderate role quantitatively. Relative to previous literature, conclusions regarding the retirement saving puzzle change if one considers housing and motives for homeownership late in life explicitly, and separately from overall net worth of retirees.

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APPENDIX

# A Data Analysis Robustness: Weighting and Panel Balancing

In this section, we demonstrate how our choices regarding the weight scheme that we use, as well as the way we treat panel balancing, impact the data facts. To remind the reader, in our data analysis, we chose to use 1996 weights for the households in the sample, which means that the households in our analysis have to be present in the first wave, and that thereafter, we are looking at an unbalanced panel. The choice of first-wave weights was motivated by the fact that we do not want to lose nursing-home residents from our sample, while the unbalanced panel is the most natural mapping of the model to the data, since in the model, we will also generate an unbalanced panel, with realistic mortality rates conditioned on all the state variables of the model.

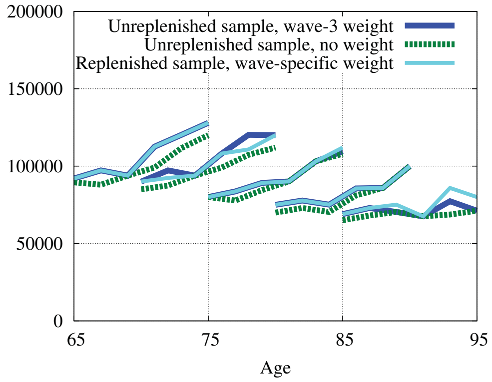


**Figure 26: Median Housing Assets: Weight Comparison.**

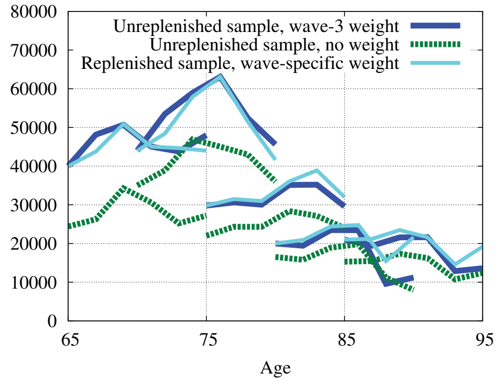


**Figure 27: Median Financial Assets: Weight Comparison.**

First, we compute the cohort profiles of median housing and financial assets using alternative weighting schemes. Figure 26 and figure 27 compare profiles of median housing and financial assets, with (i) the baseline assumptions (using 1996 weights on the sample, with no subsequent cohort replenishment, labeled wave-3 weights in the graphs), (ii) the same sample, with no sample weighting, and (iii) cohort replenishment and using wave-specific weights, which implies losing nursing home residents. We check the case without sample weighting to compare our results with De Nardi et al. (2010), who do not use sample weighting in their data analysis; our results align with theirs well, given that they use only singles in their analysis, while we also use couples. The pictures 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. Using weights – either 1996 or cohort-specific – elevates the levels of assets, especially for younger cohorts. We prefer to use the weighted sample, but in such a way that it still allows us to account for nursing home residents with positive weights.

We also demonstrate the impact of choosing to work with the entire sample (those who were present in 1996), which creates an unbalanced panel, versus working with only those who start

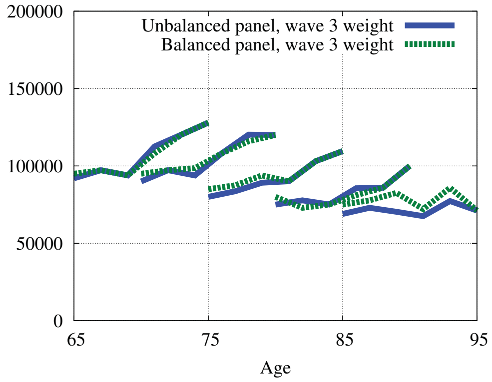


**Figure 28: Median Housing Assets: Balanced vs Unbalanced Panel.**

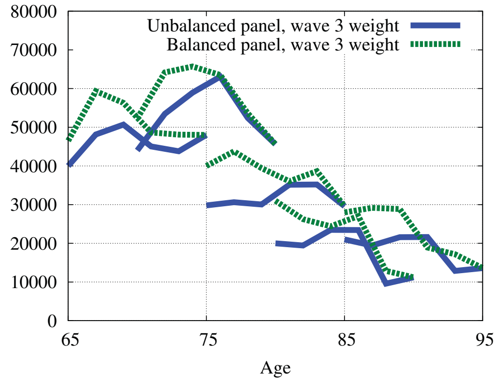


**Figure 29: Median Financial Assets: Balanced vs Unbalanced Panel.**

in 1996 and survive into the eighth wave of the survey (a balanced panel). Figures 28 and 29 plot median housing and financial asset profiles in the balanced and unbalanced panels. We find that especially for financial assets, using the balanced panel makes the asset profiles steeper, so that asset decumulation over the life cycle looks more pronounced. This confirms what De Nardi et al. (2010) called the mortality bias: including non-survivors in the sample alters the sample composition toward those in poorer health, who also tend to have less wealth, so that the median profiles look flatter as a result.