Reverse Mortgage Loans: A Quantitative Analysis*

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Abstract

Reverse mortgage loans (RMLs) allow older homeowners to borrow against housing wealth without moving. Despite rapid growth in this market, only 1.9% of eligible homeowners had RMLs in 2013. In this paper, we analyze reverse mortgages in a calibrated life-cycle model of retirement. The average welfare gain from RMLs is $252 per homeowner, and $1,770 per RML borrower. Bequest motives, uncertainty about health and expenses, and loan costs account for low demand. According to the model, the Great Recessions impact differs across age, income and wealth distribution, resulting in a threefold increase in RML demand for lowest-income and oldest households.

JEL classification: D91, E21, G21, J14

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1 Introduction

Reverse mortgage loans (RMLs) allow older homeowners to borrow against their housing wealth without moving out of the house, while insuring them against significant drops in house prices. Despite potentially large benefits to older individuals, many of whom want to stay in their house as long as possible, frequent coverage in the media, and the attempts by the Federal Housing Administration, which administers RMLs, to modify the terms to increase the appeal to borrowers, research on reverse mortgages is not extensive. This paper is intended to fill some of the void.

In previous work, Nakajima and Telyukova (2013) found that older homeowners become borrowing-constrained as they age, as it becomes more costly to access their home equity, and that these constraints force many retirees to sell their homes when faced with large medical expenses. In this environment, it seems that an equity borrowing product targeted toward older homeowners may be able to relax that constraint, and hence potentially benefit many owners later in life. Empirical studies have suggested a similar possibility, though estimates range widely. For example, Merrill et al. (1994) suggest that about 9% of homeowner households over age 69 could benefit from RMLs. Using a less conservative approach, Rasmussen et al. (1995) argue, using 1990 U.S. Census data, that that number is nearly 80%.[1] Despite the apparent benefits, RMLs were held by just 1.9% of older homeowners in 2013, down slightly from its all-time high of 2.1% in 2011.

In this paper, we study determinants of demand for reverse mortgages, and its future post-Great Recession, in the face of complex tradeoffs that retirees face in deciding whether to borrow. Specifically, we answer four questions about RMLs. First, we want to understand who benefits from reverse mortgages and how much, in welfare terms. Second, we ask, given the current available RML contract, what prevents more retirees from taking RMLs. Here we focus on retirees' environment, such as the magnitude of risk that they face, and preferences, such as their bequest motives. Third, we evaluate the impact of the 2013 RML reform, and study more generally whether and how the existing reverse mortgage contract can be modified to make the RML more attractive. Finally, we study how reverse mortgage demand may change as a result of the Great Recession, which may have both short-run and long-run impact on financial security and incomes of future retirees.

To answer these questions, we use a rich structural model of housing and saving/borrowing decisions in retirement based on Nakajima and Telyukova (2013). In the model, households are able to choose between homeownership and renting, and homeowners can choose at any point to sell their house or to borrow against their home equity. Retirees face uninsurable idiosyncratic uncertainty in their life span, health, spouse's mortality, medical expenses, and house prices, and no aggregate uncertainty. Bad health states may force older individuals into nursing homes, which we capture with an idiosyncratic involuntary moving shock. The model is estimated to match life-cycle profiles of net worth, housing and financial assets, homeownership rate, and home equity debt, which we construct from Health and Retirement Study data, controlling for time effects. Into this model, we introduce reverse mortgages, study their use and value to different types of households, and conduct counterfactual experiments to answer the questions posed above. We find that the model reproduces well key characteristics of the data, including many, though not all, characteristics

[1] Rasmussen et al. (1995) assume that elderly households with home equity exceeding $30,000 and without mortgage loans in 1990 benefit from having the option of obtaining reverse mortgages. Merrill et al. (1994) assume that households with housing equity between $100,000 and $200,000, income of less than $30,000 per year and strong commitment to stay in the current house (i.e. those who had not moved for the previous 10 years) and who own their house free and clear benefit from reverse mortgages.

of debt distribution, which are not targeted as part of the estimation process.

The model predicts that the ex-ante welfare benefit of reverse mortgages is equivalent to providing a lump-sum transfer of \$252 per retired homeowner at age 65, which amounts to 0.84% of median annual after-tax income in this group. The welfare gains are of course much larger for eventual borrowers, amounting to \$1,770 per borrower or 5.1% of median annual income. All homeowners value, ex-ante, the option of being able to tap their equity some time during their retirement; however, ex-post, only 0.89% of eligible retirees use RMLs in our model, which is close to the long-term data average of 0.84% for 1997-2013. Reverse mortgage demand is dampened by a combination of substantial risks that households face late in life, such as health, medical expense and long-term care risks and house price uncertainty, as well as bequest motives and significant costs of the contract. We find that the 2013 RML reform is likely to further dampen demand going forward, stemming from its tighter borrowing limit for most retirees, and in spite of lowered costs for some borrowers.

In more detail, we find that retirees who use reverse mortgages tend to have low income, low wealth and poor health, and use them primarily to support consumption expenditure in general, or in some cases large medical expenses. While the aggregate take-up rate is less than 1%, it is 2.2% for the lowest income quintile, and 3.9% for low-income households of age 90 and above. Bequest motives not only dampen RML demand, but also change the way homeowners use RMLs; without a desire to bequeath, retirees are over 17 times more likely to take RMLs, even without being pushed to do so by a medical expense shock, and use them overwhelmingly for non-medical consumption. On the contract side, we find that eliminating upfront costs of the loan more than triples demand for RMLs. In addition, reverse mortgages are non-recourse loans, meaning that if the price of the collateral falls below the loan value during the life of the RML, the lender cannot recover more than the collateral value. Strikingly, we find that retirees do not value this insurance component of RMLs, due to low borrowed amounts and availability of government-provided programs such as Medicaid. Thus, making the reverse mortgage a recourse loan, which removes substantial insurance premia from the cost of the loan, would triple RML demand. In this sense, the oft-heard claim that large contract costs suppress RML demand is supported by our model. The FHA's 2013 RML reform, in contrast, dampens demand, in spite of lower upfront insurance cost for some retirees; this is because it also significantly tightens the borrowing limit for most homeowners, and raises insurance costs for the most heavily indebted.

The Great Recession is likely to affect the RML market in different ways in the short run and the long run. As a result of the recession, current retirees across the board have seen significant declines in housing and financial wealth. Thus in the short run, the aggregate RML take-up rate is likely to decline, from 0.89% to 0.71% in our model. However, the impact of the recession is heterogeneous across the income and wealth distributions: the most vulnerable retired homeowners – those in the lowest income quintile in their 80s and 90s – may have to rely increasingly on RMLs to finance their expenses. In this part of the distribution, demand for RMLs may increase threefold. This raises important policy tradeoffs between the potentially increasing riskiness of the RML portfolio held by the government, and the need to provide access to their home equity to those who most need it. In the long run, one impact of the Great Recession will be lower incomes at retirement, stemming from protracted underemployment spells earlier in the life-cycle. As a result of lower incomes across the board, demand for reverse mortgages is predicted to increase somewhat across the income and age distribution.

This paper makes three key contributions to the literature. We are the first, to our knowledge, to model reverse mortgages in a standard life-cycle environment that incorporates both key sources of risk that retirees face, and aspects of preferences of older households previously deemed important by the literature, such as bequest and precautionary motives. Second, we use our model as a lab to evaluate not only RML demand by current retirees, but also the future of the market, post-recent reform and following the Great Recession. Finally, our model allows rich distributional analysis, so we quantify demand, welfare gains, and effects of the Recession for different types of households, and across the income and age distribution.

Our paper is related to three branches of literature. First, the literature on reverse mortgage loans is developing, reflecting the growth of the take-up rate and the aging population. Shan (2011) empirically investigates the characteristics of reverse mortgage borrowers, and Haurin et al. (2013) study empirically the influence of house price dynamics on RML demand. Redfoot et al. (2007) explore better design of RMLs by interviewing reverse mortgage borrowers and those who considered reverse mortgages but eventually decided not to utilize them. Davidoff (2012) investigates under what conditions reverse mortgages may be beneficial to homeowners, but in an environment where many of the idiosyncratic risks that we model are absent. Michelangeli (2010) is closest to our paper in approach. She uses a structural model with nursing home moving shocks and finds that, in spite of the benefits, many households do not use reverse mortgages because of compulsory moving shocks. Our model confirms this, but also takes into account many other important risks that older households face, such as health status, medical expenditures, and price of their house. Moreover, we incorporate into the model the initial type distribution of older households from the data, which allows us to capture crucial empirical correlations between household characteristics, such as wealth, income, home ownership and health, important to household decisions on whether to borrow. Finally, we model the popular line-of-credit reverse mortgage loan, while Michelangeli (2010) assumes that borrowers have to borrow the maximum amount at the time of loan closing.

The second relevant strand of literature addresses saving motives for the elderly, the so-called "retirement saving puzzle." Hurd (1989) estimates the life-cycle model with mortality risk and bequest motives and finds that the intended bequests are small. Ameriks et al. (2011) estimate the relative strength of the bequest motives and public care aversion, and find that the data imply both are significant. De Nardi et al. (2010) estimate in detail out-of-pocket (OOP) medical expenditure shocks using the Health and Retirement Study (HRS), and find that large OOP medical expenditure shocks are the main driving force for retirement saving, to the effect that bequest motives no longer matter. Venti and Wise (2004) study how elderly households reduce home equity, and Yogo (2016) studies portfolio choice decision in retirement. In our previous work, Nakajima and Telyukova (2013) emphasize the role of housing in shaping retirement saving. We find that housing and homeownership motives are key in accounting for the retirement saving puzzle, in addition to bequest motives and medical expense uncertainty. In this paper, we model mortgages and mortgage choice in a lot more detail, with a very different focus on understanding reverse mortgages as a market and financial choice for current and future retirees. In addition, we have not previously studied the Great Recession in this context.

Related to the retirement saving puzzle is the large literature on retirement saving products, such as life insurance and annuities. Some examples are Yaari (1965), Mitchell et al. (1999), Dushi and Webb (2004), Turra and Mitchell (2004), Inkmann et al. (2011), Pashchenko (2013), Lockwood (2012), Koijen et al. (2014). Our paper is related because reverse mortgages, in their tenure form, can be seen as a way of annuitizing home equity. However, because line-of-credit RMLs are by far the most popular choice, we do not focus on the tenure option in this paper.

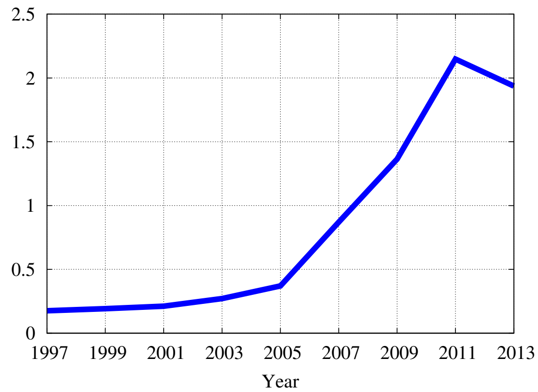


Figure 1: Percentage of Older Homeowners with Reverse Mortgages. Source: AHS.

Third is the literature on mortgage choice using structural models, which is growing in parallel with developments in the mortgage markets. Chambers et al. (2009) construct a general equilibrium model with a focus on the optimal choice between conventional fixed-rate mortgages (FRMs) and newer mortgages with alternative repayment schedules. Campbell and Cocco (2003) and van Hemert et al. (2009) investigate the optimal choice for homebuyers between FRMs and more recent adjustable-rate mortgages (ARMs). We model the choice between conventional mortgages and line-of-credit reverse mortgages, focusing only on retirees.

The remainder of the paper is organized as follows. Section 2 provides an overview of reverse mortgages. Section 3 develops the structural model that we use for experiments. Section 4 discusses calibration of the model and the model fit, including the implications for the distribution of debt. In section 5, we use the model to analyze the demand for reverse mortgages through a number of counterfactual experiments. Section 6 concludes. Many details of the calibration of the model, as well as sensitivity analysis, is relegated to the appendix.

2 Reverse Mortgage Loans: An Overview

The most popular reverse mortgage is currently administered by the Federal Housing Administration, which is part of the U.S. Department of Housing and Urban Development (HUD), while the private market for reverse mortgages has been shrinking.[2] The government-administered reverse mortgage is called a home equity conversion mortgage (HECM). According to Shan (2011), HECM loans represent over 90% of all reverse mortgages originated in the U.S. market.[3]

The number of households with reverse mortgages has been growing. Figure 1 shows the proportion of homeowner households of age 65 and above that had reverse mortgages between 1997 and 2011, constructed from the American Housing Survey (AHS). As the figure shows, the use of reverse mortgages was limited before 2005. In 2001, the share of eligible homeowners with reverse mortgages was about 0.2%. This share increased rapidly since then, reaching 2.1% in 2011. The recent growth motivates our general interest in reverse mortgages, and is all the more impressive

[2]This section is based on, among others, AARP (2010), Shan (2011), Nakajima (2012), and information available on the HUD website.

[3]Many other reverse mortgage products, such as Home Keeper mortgages, which were offered by Fannie Mae, or the Cash Account Plan offered by Financial Freedom, were recently discontinued, in parallel with the expansion of the HECM market. See Foote (2010).

if one considers that the popularity of RMLs continued to rise even as other mortgage markets remained stagnant through the recent housing market downturn. Moreover, while the take-up rate is small, the size of the RML market it implies is nontrivial and can be expected to grow: there were 26.8 million households with heads of age 65 and above in 2012, which with the 2.1% take-up rate implies 563,700 RMLs outstanding among this age group. At the projected population growth, by 2030 there will be 46 million households with heads of age 65 and above. If the RML take-up rate stayed stagnant, this would imply a near-doubling of RMLs originated, to 966,000.

Reverse mortgages differ from conventional mortgages in six major ways. First, as the name suggests, a reverse mortgage works in the *reverse* way from the conventional mortgage loan. Instead of paying interest and principal and accumulating home equity, reverse mortgage loans allow homeowners to cash out the home equity they've accumulated.

Second, government-administered HECM loans have different requirements than conventional mortgage loans. These mortgages are available only to borrowers age 62 or older, who are homeowners and live in their house.[4,5] Moreover, borrowers must have repaid their other mortgages at the time they take out a reverse mortgage. On the other hand, RMLs do not have income or credit history requirements, because repayment is made not based on the borrower's income but solely on the value of the house the borrower already owns. According to Caplin (2002), RMLs may be beneficial to older homeowners since many of them fail to qualify for conventional mortgages because of income requirements.

Third, reverse mortgage borrowers are required to seek counseling from a HUD-approved counselor in order to qualify for a HECM loan. The goal is to ensure that older borrowers understand what kind of loan they are getting and what the potential alternatives are before taking out a RML.

Fourth, there is no pre-fixed due date or a gradual repayment schedule; repayment of the borrowed amount is due only when all the borrowers move out or die. As long as at least one of the borrowers (loan co-signers) continues to live in the house, there is no need to repay any of the loan amount. Repayment is made in a lump sum from the proceeds of the sale of the house.

Fifth, HECM loans are non-recourse. Borrowers (or their heirs) can repay the loan either by letting the RML lender sell the house, or by repaying. Most use the first option. If the sale value of the house turns out to be larger than the sum of the total loan amount and the various costs of the loan, the borrowers receive the remaining value. In the opposite case, if the house value cannot cover the total costs of the loan, the borrowers are not liable for the remaining amount, which insures them against downward house price risk. The mortgage lender does not absorb the loss either, because the loss is covered by government insurance, with the premium included as a part of a HECM loan cost structure.

Finally, there are five ways to receive payments from the RML, which can be changed during the life of the loan at a small cost. The first option is a *tenure* RML, where borrowers receive a fixed monthly amount as long as one of the borrowers lives in the house. The second is a *term* RML, where borrowers receive a fixed amount for a fixed length of time. The third option is a *line of credit*, which allows borrowers to withdraw flexibly, up to a limit, during a pre-determined drawing period. Finally, *modified tenure* and *modified term* options combine the line-of-credit RML with tenure and term features, respectively. Of the payment options listed, the line-of-credit option

[4]For a household with multiple adults who co-borrow, "age of the borrower" refers to the youngest borrower in the household.

[5]Properties eligible for HECM loans are (1) single-family homes, (2) one unit of a one- to four-unit home, and (3) a condominium approved by HUD.

has been by far the most popular. HUD reports that the line-of-credit plan is chosen either alone (68%) or in combination with the tenure or term plan (20%). In other words, it appears that older homeowners have used reverse mortgages mainly to flexibly withdraw funds out of accumulated home equity.

How much can one borrow using a reverse mortgage? The starting point is the appraised value of the house, but there is a federal limit for a HECM loan. Currently, the limit is $625,500 for most states.[6] The lesser of the appraised value and the limit is the Maximum Claim Amount (MCA).[7] Reverse mortgage borrowers cannot receive the full amount of the MCA because there are non-interest and interest loan costs that have to be paid from the house value as well. Moreover, if borrowers have outstanding mortgages, part of the RML will be used to repay any outstanding mortgage balances. Non-interest costs include an origination fee, closing costs, the insurance premium, and a loan servicing fee. The insurance premium depends on the value of the house and how long the borrowers live and stay in the same house. More specifically, the insurance premium is 2% of the appraised value of the house (or the limit, if the value is greater) initially, and 1.25% of the loan balance annually.[8] Interest costs depend on the interest rate, the loan amount, and how long the borrowers live and stay in the house. The interest rate can be either fixed or adjustable. In case of an adjustable interest rate, the borrowing interest rate is the sum of the reference interest rate and a margin charged by the mortgage lender, typically with a ceiling on how much the interest rate can go up per year or during the life of a loan. The Initial Principal Limit (IPL) is calculated by subtracting expected interest costs from the MCA.[9] The Net Principal Limit is calculated by subtracting various upfront costs from the IPL.

The IPL is thus larger the larger the house value, the lower the outstanding mortgage balance, the older the borrower, and the lower the interest rate. Until recently, many homeowners could borrow around 60 to 70% of the appraised house value using reverse mortgages (Shan (2011)). In October of 2013, HUD instituted a HECM reform, that has made the borrowing limits tighter while changing the upfront insurance cost structure to lower it for those with low initial balances, but increase it for others. We will discuss and evaluate this reform in the Experiments section.

3 Model

We set up the decision problem of retirees extending our previous work (Nakajima and Telyukova (2013)). Time is discrete. All households are either single or couples, and face uninsurable idiosyncratic risk in health status, mortality, household size (spouse mortality), and medical expenses, and there is no aggregate uncertainty. Household size in the model affects the income, consumption and medical expenses of the household, and allows us to include both couples and single households in our data sample. Appendix A details how we treat and interpret household size dynamics in the model and the data.

Households can be either homeowners or renters. Renters choose consumption, saving and the

[6] The limit was raised in 2009 from $417,000 as part of the Housing and Economic Recovery Act of 2008.

[7] Private mortgage lenders offer jumbo reverse mortgage loans, which allow borrowers to cash out more than the federal limit. Borrowers have used jumbo reverse mortgages less and less often as the federal limit has been raised.

[8] Annual mortgage insurance premium was raised from 0.5% to 1.25% in October 2010.

[9] The lender computes, based on the current age and life expectancy of the borrower, how much interest and other costs a loan will accumulate through its life, if the household borrows up to the maximum allowed amount right away given an interest rate. The IPL is computed such that together with this expected cost, the loan does not exceed the appraised value of the house.

size of the house to rent each period. We do not allow renters to buy a house. This assumption is based on our HRS sample, in which the proportion of retired households switching from renting to owning is negligible, at 0.2% per year. Homeowners choose how much to consume and save, and whether to stay in their house, or sell and become a renter. Homeowners can borrow against their home equity using conventional mortgages; the collateral constraint that they face depends on their income and other household characteristics, capturing income and credit checks of conventional mortgage lenders. In addition to the demographic shocks mentioned above, homeowners face idiosyncratic house price and moving shocks. The moving shock forces the homeowner out of her house, and is intended to capture the possibility of moving involuntarily, and permanently, into a nursing home as a result of deteriorating health.

Into this benchmark, we introduce reverse mortgage loans for homeowners, which we model as lines of credit, by far the most frequently used option.[10] As we specify later, reverse mortgages offer different, just age-dependent, collateral constraints and cost structure from conventional mortgages. Finally, like in the data, homeowners who use reverse mortgages cannot simultaneously borrow using a traditional mortgage.

We characterize the problem recursively. The set of household state variables consists of its age i, pension income b, household size s, health status m, medical expenditures x, house price p, reverse mortgage indicator k, house size h ($h = 0$ means the household is a renter), and financial asset holdings a. $k = 0$ means a homeowner does not have a RML, while $k = 1$ means that she does.[11] Following convention, we omit time subscripts, and use a prime to denote a variable in the next period $(t + 1)$.

3.1 Renters

Every period, the renter – the simplest household type – solves:

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

subject to:

$$\tilde{c} + a' + x + r_h \tilde{h} = (1 + r)a + b\chi_s \quad (2)$$
$$c = \begin{cases} \max\{\underline{c}\chi_s - r_h \tilde{h}, \tilde{c}\} & \text{if } a' = 0 \\ \tilde{c} & \text{otherwise} \end{cases} \quad (3)$$

[10] It is easy to show that the term option, under which a homeowner receives a fixed amount of money every period for a fixed period of time, can be replicated using the line-of-credit modeling option, by drawing a fixed amount of money every period for a fixed period of time. The tenure option adds insurance against longevity, and thus theoretically cannot be replicated only by the line-of-credit option. However, the amount that a borrower can receive every period under the tenure option is calculated with conservatively estimated life expectancy. This implies that a borrower rarely outlives a reverse mortgage, so the tenure option can be roughly replicated by the line-of-credit option as well.

[11] Although the states (p, k, h) are irrelevant for renters, we keep them as part of the renters' state variable, to keep the set of state variables the same for renters and owners.

Equation (1) is the Bellman equation for a renter. Naturally a renter has no house ($h = 0$), and no reverse mortgage ($k = 0$). A renter, taking the states as given, chooses consumption ($\tilde{c}$, where tilde indicates consumption before consumption floor is applied), savings (a'), and the size of the house to rent ($\tilde{h}$). $\tilde{h}$ is chosen from a discrete set $H = \{h_0 = 0, h_1, h_2, ..., h_{\overline{H}}\}$, where h_1 is the smallest and $h_{\overline{H}}$ is the largest house available. $a' \geq 0$ implies that renters cannot borrow. In other words, only home equity borrowing is available in the model, which is motivated by the data, where holdings of unsecured debt among retirees are small. $\pi^s_{i,s,s'}$, $\pi^m_{i,m,m'}$, $\pi^x_{i,b,s,m,x}$ and $\pi^p_{p,p'}$ denote the transition probabilities of the shocks (s, m, x, p), respectively. $m > 0$ indicates health levels, while $m = 0$ denotes death. Note that household size, health and mortality shocks are age-dependent, and medical expense shocks depend on age, income, household size, and health of the household, as in the data. Finally, pension income b is different across households, but is assumed to be constant throughout the life-cycle. This is also consistent with our sample, where pension income varies little during retirement.

The current utility of the renter depends on household size s, non-housing consumption c, services generated by the rental property (assumed linear in the size of the rental property $\tilde{h}$), and tenure status o. $o = 1$ represents ownership, while $o = 0$ indicates renting. Tenure in the utility function captures different private values of owned versus rented housing, due to financial and nonfinancial benefits of ownership that are not explicit in the model. Household size s differentiates utility of couples and single households. The continuation value is discounted by the subjective discount factor β. Following De Nardi (2004), we assume a warm-glow bequest motive with utility function $v(a)$.

Equation (2) is the budget constraint for a renter. The expenditures on the left-hand side include consumption ($\tilde{c}$), savings (a'), current medical expenditures x, and rent payment with the rental rate r_h. We assume that rents are constant; adding realistically mild rent fluctuations did not affect the results. The right-hand side includes financial assets and interest income $(1 + r)a$ and pension income b, multiplied by a household size factor χ_s to capture the fact that two-adult households have higher pension income on average. For simplicity, we assume that households invest only in risk-free bonds whose return is r.[12] Moreover, since both bonds and mortgage loans are risk-free, and mortgage interest rates are higher than the saving interest rate, households never choose to hold simultaneously risk-free bonds and mortgage loans. Therefore, without loss of generality, we can assume that a household either holds risk-free bonds ($a \geq 0$), or a mortgage ($a < 0$). Following standard practice in the literature, equation (3) represents a consumption floor, which is provided by the government and approximates Medicaid in the data.[13] The household qualifies for this program if it runs down its savings ($a' = 0$), and if net of its rent, the household cannot afford the consumption floor $\underline{c}$ multiplied by the household size factor χ_s.

3.2 Homeowners Without a Reverse Mortgage

The choice of a homeowner with no reverse mortgage ($k = 0$) is characterized by the following:

$$V(i, b, s, m, x, p, k = 0, h, a) = \pi^n_{i,m} V_0(.) + (1 - \pi^n_{i,m}) \max\{V_0(.), V_1(.), V_2(.)\}. \tag{4}$$

With probability $\pi^n_{i,m}$, the homeowner experiences a compulsory moving shock. In this case, she is forced to sell the house and become a renter in model parlance; we denote her value function, at the

[12] In the HRS, 29% of retirees hold stocks or mutual funds, and 49% of retirees hold stocks, mutual funds, or IRAs. However, it is likely that retired holders of mutual funds or IRAs often invest in bonds more than stocks.

[13] Hubbard et al. (1994) and De Nardi et al. (2010).

moment of the shock realization, by $V_0(i,b,s,m,x,p,k=0,h,a)$. This shock represents a compulsory *permanent* move to a nursing home, so the probability depends on age i and health status m. If the owner is not forced into a nursing home, she has three choices: sell the house and rent, stay in the house ($V_1(i,b,s,m,x,p,k=0,h,a)$), or stay and take out a RML ($V_2(i,b,s,m,x,p,k=0,h,a)$).[14]

For a homeowner with no RML, who decides to move out or is forced out by the moving shock,

$$V_0(i,b,s,m,x,p,k=0,h,a) = \max_{\tilde{c},a'\geq 0}\Bigg\{u(s,c,h,1)$$
$$+\beta\sum_{s'}\pi^s_{i,s,s'}\sum_{m'>0}\pi^m_{i,m,m'}\sum_{x'}\pi^x_{i+1,b,s',m',x'}\sum_{p'}\pi^p_{p,p'}V(i+1,b,s',m',x',p',0,0,a')+\beta\pi^m_{i,m,0}v(a')\Bigg\} \quad (5)$$

subject to:

$$\tilde{c}+a'+x+\delta h = (1-\kappa)ph + (1+r+\mathbb{1}_{a<0}\iota^m)a + b\chi_s \quad (6)$$
$$c = \begin{cases} \max\{\underline{c}\chi_s,\tilde{c}\} & \text{if } a'=0 \\ \tilde{c} & \text{otherwise} \end{cases} \quad (7)$$

Compared to the problem of the renter, the new features are that the owner, in the current period, may have a different utility function as represented by $o=1$ in the function $u(i,c,h,1)$, has to pay a maintenance cost δh to keep the house from depreciating, and receives the proceeds from selling her house ph net of the selling cost κph. In addition, if the homeowner is in debt at the time of house sale, the interest rate has a mortgage premium ι^m, and all debt must be repaid ($a'\geq 0$). The mortgage premium is represented by $\mathbb{1}_{a<0}\iota^m$, where $\mathbb{1}$ is the indicator function that takes the value 1 if the attached condition ($a<0$) is true, and 0 otherwise. Finally, the consumption floor does not include a rental payment, because the owner still lives in her house.

The Bellman equation of a homeowner who stays in the house and does not take out a reverse mortgage in the next period is

$$V_1(i,b,s,m,x,p,k=0,h,a) = \max_{c,a'\geq -\lambda^m_{i,b,s,m,p}ph}$$
$$\Bigg\{u(s,c,h,1)+\beta\sum_{s'}\pi^s_{i,s,s'}\sum_{m'>0}\pi^m_{i,m,m'}\sum_{x'}\pi^x_{i+1,b,s',m',x'}\sum_{p'}\pi^p_{p,p'}V(i+1,b,s',m',x',p',0,h,a')$$
$$+\beta\pi^m_{i,m,0}\sum_{p'}\pi^p_{p,p'}v((1-\kappa)p'h+a')\Bigg\} \quad (8)$$

subject to:

$$c+a'+x+\delta h = (1+r+\mathbb{1}_{a<0}\iota^m)a + b\chi_s \quad (9)$$

[14] An additional potential option for older homeowners may be to borrow from their children, instead of taking a reverse mortgage, and then leaving the house to the children upon death. If the child has sufficient liquid assets, the amount of resulting inheritance is below the estate tax exemption, the saving interest rate is equal to the RML interest rate, and/or the capital gains tax paid on the sale of the parental home does not exceed the differential in interest costs, then elderly homeowners may be indifferent between borrowing on a RML and from their children. Exploring the model with intergenerational transfer decisions is out of the scope of this paper.

This homeowner can borrow on a conventional mortgage with a collateral constraint $\lambda^m_{i,b,s,m,p}$. In the event of death, the estate includes the value of the house $(p'h)$, net of the selling cost to liquidate it $(\kappa p'h)$. Again, it is not possible for a household to have, simultaneously, positive mortgage debt and positive financial assets, as both are captured by the variable a; this is without loss of generality. Moreover, as long as the household is a homeowner, she cannot access the consumption floor. That is, we assume that there is no homestead exemption to qualify for the program.[15]

We formulate the collateral constraint for conventional forward mortgage, $\lambda^m_{i,b,s,m,p}$, to capture the idea that, like in reality, the household's ability to borrow against its home equity depends on its ability to service its debt each period, as measured by a debt-to-income (DTI) ratio. Conventional mortgage lenders conduct extensive income and credit checks and impose the debt-to-income ratio explicitly. Caplin (2002) argues that older households, especially lower-income ones, are borrowing-constrained because of this income requirement. Specifically, $\lambda^m_{i,b,s,m,p}$ is characterized recursively as follows:

$$\sum_{s'} \pi^s_{i,s,s'} \sum_{m'>0} \pi^m_{i,m,m'} \alpha b \chi_{s'} = ph\lambda^m_{i,b,s,m,p}(1+r+\iota^m) - \sum_{s'} \pi^s_{i,s,s'} \sum_{m'>0} \pi^m_{i,m,m'} \sum_{p'} \pi^p_{p,p'} \lambda^m_{i+1,b,s',m',p'} p'h \quad (10)$$

The left-hand side represents a fixed fraction α of expected income in the next period, where α represents the DTI ratio. The income is multiplied by the survival probability for a household of type-(i,m) $(\sum_{m'>0} \pi^m_{i,m,m'})$. On the right-hand side is the principal and interest that has to be paid if the borrower borrows up to the maximum amount of debt that is characterized by $\lambda^m_{i,b,s,m,p}$, net of the maximum amount the borrower can borrow in the next period. $\lambda^m_{i,b,s,m,p}$ is solved backwards, starting from the last period of life, when DTI constraint implies $\lambda^m_{i,b,s,m,p} = 0$ since the borrower cannot pay anything in the following period.

Note that we do not explicitly model mortgage default or foreclosure. However, a retiree can find it optimal, or can be forced, to "sell", i.e. walk away from, the house, especially following a large medical expense shock, health deterioration sock, or a household size shock, all of which tighten the collateral constraint, in order to access government insurance inherent in the consumption floor. A forced sale would be equivalent to default and a foreclosure. We find that in our calibrated model, the occurrence of such de-facto mortgage defaults and foreclosures is rare, impacting fewer than 1% of households.

Comparing to other approaches in the literature, Yogo (2016) assumes, following Sinai and Souleles (2008), that homeowners can borrow up to 50% of their house value, regardless of age. Although this implies a looser collateral constraint than ours, especially for older homeowners, his calibrated model replicates the observed life-cycle pattern on home equity borrowing. However, crucial differences are that that paper focuses on single households, who decumulate assets more quickly in the data, and thus fewer households have an incentive to borrow against home equity.[16] Moreover, in that model, housing assets are significantly more liquid than in our model, and there is no renting. Both imply that homeowners reduce housing assets gradually, with less need to borrow against home equity.

[15]Many states allow homeowners to keep their house, below a threshold value, and still qualify for Medicaid. In Nakajima and Telyukova (2013), we model the homestead exemption explicitly, and find that Medicaid is not a quantitatively important reason for homeowners to stay in their homes, unless they are at a very advanced age. In the data, relatively few homeowners receive Medicaid. Finally, in the data it appears difficult to borrow on an RML and claim Medicaid simultaneously, because the RML is likely to violate income requirements for Medicaid.

[16]These empirical facts are documented in Venti and Wise (2004) and Nakajima and Telyukova (2013).

Next is the problem of a homeowner who stays in the house and takes out a reverse mortgage:

$$V_2(i,b,s,m,x,p,k=0,h,a) = \max_{c,a' \geq -\lambda_i^r ph}$$
$$\Bigg\{ u(s,c,h,1) + \beta \sum_{s'} \pi^s_{i,s,s'} \sum_{m'>0} \pi^m_{i,m,m'} \sum_{x'} \pi^x_{i+1,b,s',m',x'} \sum_{p'} \pi^p_{p,p'} V(i+1,b,s',m',x',p',1,h,a')$$
$$+ \beta \pi^m_{i,m,0} \sum_{p'} \pi^p_{p,p'} v(\max\{(1-\kappa)p'h + a', 0\}) \Bigg\} \tag{11}$$

subject to:

$$c + a' + x + \delta h + (\nu^r + \nu^i)ph = (1 + r + \mathbb{1}_{a<0}\iota^m)a + b\chi_s \tag{12}$$

There are three new features. First, the collateral constraint of the reverse mortgage borrower is λ_i^r, which depends only on age.[17] In contrast with conventional mortgages, RMLs are secured purely by the value of housing and thus reverse mortgage lenders do not conduct income and credit checks, so the collateral constraint does not depend on other household characteristics. We explain further the nature of these constraints in the Calibration section. Second, in order to take out a reverse mortgage, the household pays upfront costs and insurance premium proportional to the value of the house, ν^r and ν^i. Finally, there is a max operator in the utility from bequests. This captures the non-recourse nature of the reverse mortgage; if the household dies, and the consolidated balance of housing assets and reverse mortgage ($(1-\kappa)p'h + a'$) turns out to be negative, the heirs of the household are not liable for the loss.

3.3 Homeowners With a Reverse Mortgage

Similar to the household without a RML, a household with a RML ($k = 1$) makes the following tenure decision, subject to not being forced into a nursing home with probability $\pi^n_{i,m}$:

$$V(i,b,m,x,p,k=1,h,a) = \pi^n_{i,m} V_0(.) + (1 - \pi^n_{i,m}) \max\{V_0(.), V_1(.)\} \tag{13}$$

where $V_0(i,b,m,x,p,k=1,h,a)$ and $V_1(i,b,m,x,p,k=1,h,a)$ are values, for a RML holder, of moving out, voluntarily or involuntarily, and becoming a renter, and of staying and keeping the reverse mortgage, respectively.

The homeowner with a reverse mortgage who chooses to sell solves

$$V_0(i,b,s,m,x,p,k=1,h,a) = \max_{\tilde{c},a' \geq 0} \Bigg\{ u(s,c,h,1)$$
$$+ \beta \sum_{s'} \pi^s_{i,s,s'} \sum_{m'>0} \pi^m_{i,m,m'} \sum_{x'} \pi^x_{i+1,b,s',m',x'} \sum_{p'} \pi^p_{p,p'} V(i+1,b,s',m',x',p',0,0,a') + \beta \pi^m_{i,m,0} v(a') \Bigg\} \tag{14}$$

[17]Notice that we model both conventional forward mortgages, including HELOCs, and RMLs as series of rolling one-period adjustable-rate loans. Both types of loans in the model are more flexible than in reality, since borrowers can adjust balances costlessly in any period in the model. Because this added flexibility is the same for both mortgage types, we expect the effect of the one-period assumption on RML demand to be minor.

subject to:

$$\tilde{c} + a' + x + \delta h = (r + \mathbb{1}_{a<0}(\iota^r + \iota^i))a + b\chi_s + \max\{(1-\kappa)ph + a, 0\} \tag{15}$$

$$c = \begin{cases} \max\{\underline{c}\chi_s, \tilde{c}\} & \text{if } a' = 0 \\ \tilde{c} & \text{otherwise} \end{cases} \tag{16}$$

The max operator in the budget constraint (15) captures that moving out entails repayment of the reverse mortgage. Notice that current RML borrowers are likely to have $a < 0$; the max operator captures the non-recourse nature of the loan, where the lender cannot recover more than the value of the house at the time of repayment. Next, the flow payment for the loan includes the reverse mortgage premium (ι^r) and insurance premium (ι^i).

Finally, the homeowner with a RML who chooses to stay in her house solves:

$$V_1(i, b, s, m, x, p, k = 1, h, a) = \max_{c, a' \geq -\lambda_i^r ph}$$
$$\Bigg\{ u(s, c, h, 1) + \beta \sum_{s'} \pi^s_{i,s,s'} \sum_{m'>0} \pi^m_{i,m,m'} \sum_{x'} \pi^x_{i+1,b,s',m',x'} \sum_{p'} \pi^p_{p,p'} V(i+1, b, s', m', x', p', 1, h, a')$$
$$+ \beta \pi^m_{i,m,0} \sum_{p'} \pi^p_{p,p'} v(\max\{(1-\kappa)p'h + a', 0\}) \Bigg\} \tag{17}$$

subject to:

$$c + a' + x + \delta h = (1 + r + \mathbb{1}_{a<0}(\iota^r + \iota^i))a + b\chi_s \tag{18}$$

Notice that in our model, households borrowing on a reverse mortgage can flexibly increase or decrease their loan balance at any time. In reality, reverse mortgage lines of credit are typically restricted from partial repayment until the loan is repaid in full. However, in reality households also can save in financial assets simultaneously with borrowing against a RML, which in our model is ruled out. Thus, we think of the flexible adjustment of RML balance in the model as capturing this missing additional saving channel. However, we are thus possibly understating the cost of RML borrowing, because the interest rates earned on savings are typically lower than interest and insurance costs of reverse mortgages, a spread that our model does not capture for equity borrowers.

4 Calibration

We first calibrate the baseline version of the model without reverse mortgages, and then add RMLs to this calibrated benchmark. For the baseline, we use a two-stage estimation procedure in the style of Gourinchas and Parker (2002). Our data set is the Health and Retirement Study (HRS), which is a biennial panel survey of older households. We focus only on retirees of age 65 and above, so that we do not have to account for labor supply decisions. We use self-reported retirement status, and include both couples and single households. To make data cells sufficient in size, given the richness of our state space, we pool households into 5-year age bins. Thus, age-65 households in our sample are of ages 63-67, and each household appears in up to 5 bins, of its actual age plus/minus 2 years.

To match the HRS, the model period is set to two years. Model households start at age 65, may live up to age 99, and have constant relative risk aversion period utility with discount factor β:

$$u(s, c, h, o) = \frac{\left(\left(\frac{c}{\psi_s}\right)^{\eta} \left(\frac{\omega_o h}{\psi_s}\right)^{1-\eta} \right)^{1-\sigma}}{1-\sigma} \tag{19}$$

Table 1: Calibration Summary: Model Parameters[1]

Parameter	Description	Value
First-Stage Estimation		
ψ_2	Consumption equivalence for two-adult HHs	1.340
χ_2	Income multiplier for two-adult HHs	1.480
r	Saving interest rate	0.026
ι^m	Margin for conventional mortgage	0.017
α	Max. debt-to-income ratio, conventional mortgages	0.350
δ	Maintenance cost	0.017
κ	Selling cost of the house	0.066
ρ_p	Persistence of house price shock	0.859
σ_p	Standard deviation of house price shock	0.125
Second-Stage Estimation		
β	Discount factor	0.906
η	Consumption aggregator	0.762
σ	Coefficient of RRA	2.006
ω_1	Extra utility of homeownership	4.918
γ	Strength of bequest motive	20.534
ζ	Curvature of utility from bequests	7,619
$\underline{c}$	Consumption floor per adult	13,919
Reverse Mortgages		
ν^r	Up-front cost of RML	0.050
ν^i	Up-front cost of RML insurance	0.020
ι^r	Interest margin for RML	0.017
ι^i	RML insurance premium	0.013
λ_i^r	RML collateral constraints	See text

[1] All parameter values are annual, except for ρ_p and σ_p, which are biennial.

η is the Cobb-Douglas aggregation parameter between non-housing consumption goods (c) and housing services (h). σ is the risk aversion parameter. ω_o represents the extra utility of owning a house. For renters ($o = 0$), ω_0 is normalized to unity. For a homeowner ($o = 1$), $\omega_1 > 1$ represents nonfinancial benefits of homeownership, such as attachment to one's house and neighborhood, as well as financial benefits not captured explicitly by the model, such as tax benefits and insurance against rental rate fluctuation. ψ_s is the household consumption equivalence scale.

Households get utility from leaving bequests. When a household dies with wealth a, its utility function takes the following form, with bequest motive strength γ and bequest marginal utility ζ:[18]

$$v(a) = \gamma \frac{(a + \zeta)^{1-\sigma}}{1 - \sigma}. \tag{20}$$

Table 1 summarizes the calibrated parameter values. The three panels of the table correspond to the first and second stages of the estimation, and the calibration of RMLs.

[18] De Nardi et al. (2010) also use the same risk aversion parameter σ for utility from bequests.

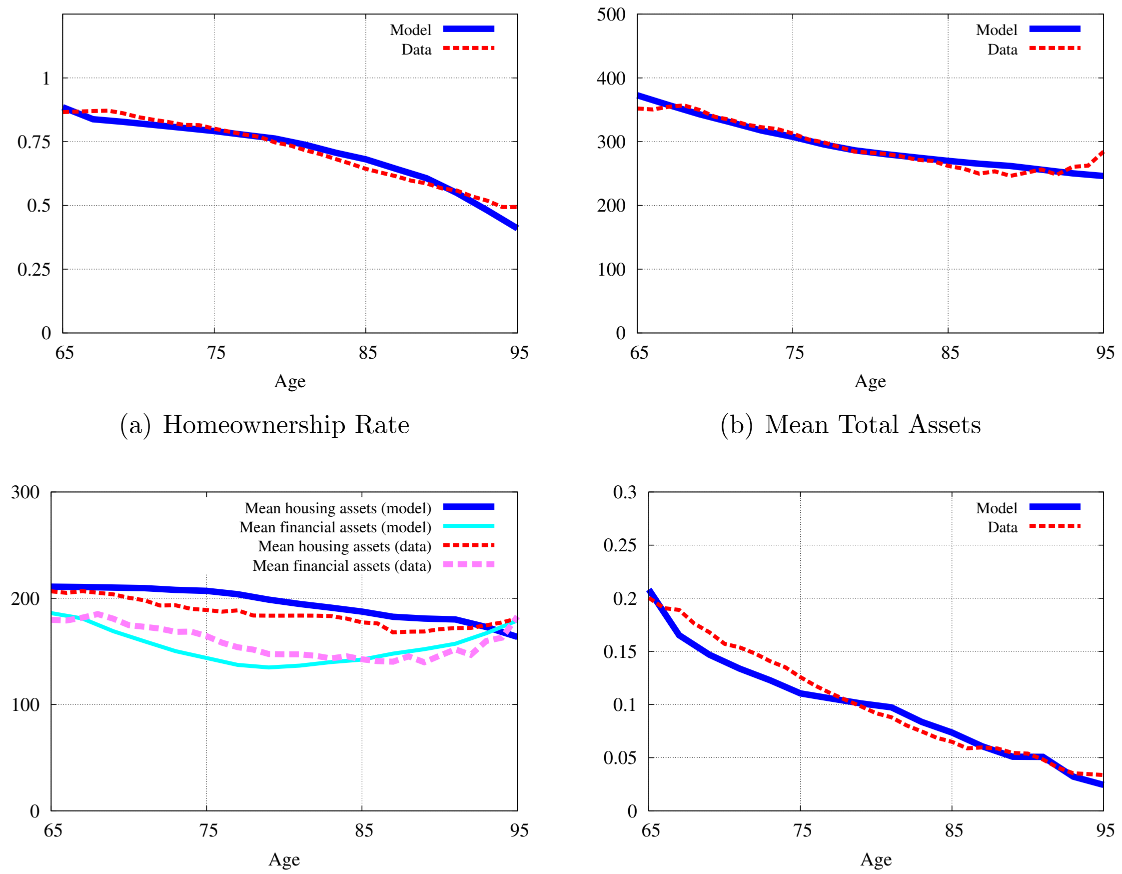
4.1 First-Stage Estimation

In the first stage we calibrate all the parameters that we can directly observe in the data, using the HRS and other sources. We provide a very detailed description of our first-stage calibration in appendix B.1. Consumption equivalence scale is normalized to one for singe households, and we set $\psi_2 = 1.34$ for two-adult households, as computed by Fernández-Villaverde and Krueger (2007). The income multiplier for two-adult households, χ_2 is set at 1.48, which is the median in the HRS. The annual real saving interest rate is fixed at 2.58% per year. This is the average real interest rate on the 10-year Treasury bond during our sample period, 1996-2006, deflated using CPI. The mortgage interest premium ι^m is set at 1.69% per year, which is the difference between the average real mortgage interest rate during this period of 4.27% and the risk-free rate. Maximum DTI ratio is set at 35%, which is the common value in the data. Annual maintenance cost is calibrated to be 1.7%, based on the depreciation rate of residential capital. House selling cost is 6.6% of house value (Greenspan and Kennedy (2007)).

We estimate all the stochastic processes for shocks that affect households, (s, m, x, n), using a pooled HRS sample from 1996-2006, because we found these quantities and probabilities to be stationary over this period, while the pooling of the sample provides larger sample sizes. First, we estimate transition probabilities of household size, conditional on age. We assume single households remains single, based on our finding in the HRS that single-to-couple transitions are rare in retirement, and compute age-dependent probabilities of loss of a spouse. Second, we estimate transition probabilities of household health status, conditional on age and current health of each of the spouses. We estimate mortality risk, i.e. the transition probability from any health status to death, as part of the health transition. We find that health status is generally persistent, though persistence weakens with age as health deteriorates. Third, we estimate parameters of the distribution of out-of-pocket medical expenses, conditional on age, current health status, household size, and income quintile. Not surprisingly, OOP medical expenses tend to be higher for older, less healthy, and higher-income households. Fourth, we estimate probabilities of moving into a nursing home, i.e. compulsory moving shocks for homeowners, conditional on age and health. These probabilities rise with age, and for less healthy households. Further details are in appendix B.1

We treat house price dynamics as a persistent, but stationary, shock which we model as an AR(1) process. We use a mean-reverting AR(1) process, even though our sample spans the years of 1996-2006 with a house price boom, because in this paper we are interested in long-run reverse mortgage demand, and we are agnostic about future house price trends. We estimate the biennial AR(1) process for idiosyncratic house price shocks based on monthly ZIP code-level CoreLogic housing price index (HPI) data for the period 1976-2015. The CoreLogic HPI is a proprietary monthly ZIP code-level home price index, based on repeat-sales single-family homes. The sample includes data for 7,142 ZIP codes. We deflate the house prices by CPI prior to doing the estimation. The estimation yields biennial persistence of house prices of $\rho_p = 0.859$, and standard deviation $\sigma_p = 0.125$. The resulting house price shocks are large, with possible realizations between 29% below, and 41% above, median house price, thus introducing significant house price uncertainty into the model. The shocks are also persistent: for instance, when the house value is at 41% above median, the expected duration of staying at that level is 6.7 years. Thus the mean reversion aspect of the AR(1) does not greatly affect the extent of individual house price uncertainty. Further details of the estimation are in appendix B.1.5.

Finally, we calibrate the initial distribution of 65-year-old retirees, along our state space dimen-



(a) Homeownership Rate

(b) Mean Total Assets

(c) Mean Housing and Financial Assets

(d) Proportion in Debt

Figure 2: Model Fit: Age Profiles without RML, Model and Data

sions – income, health, household size, medical expenses, housing and financial wealth – using the 2006 cross-section from the HRS. We use only the 2006 cross-section because using a pooled sample would mask time effects in housing and financial wealth that make 65-year-olds from different survey waves differ from each other, in a way that our stationary model cannot account for.

4.2 Second-Stage Estimation

In the second stage, we estimate the rest of the parameters to match age profiles of the homeownership rate, mean total, housing and financial asset holdings, and the proportion of retirees in debt. We construct these age profiles from the 1996-2006 waves of the HRS. In order to take the aforementioned time effects out of the resulting profiles, we run age-year regressions on each of the target variables, averaged by age and wave. Then, we use the estimated age effects together with 2006 time effects to construct the target age profiles in 2006, and compare them to the corresponding outputs of the model. We choose age-time regressions instead of age-cohort regressions because in the short period of time that our sample covers, asset price trends created strong time effects that are more salient than cohort effects.

Figure 2 shows the model fit. First, it is valuable to examine the data profiles – dashed red lines in the figure. The homeownership rate is 88.5% at age 65, and declines to just over 40% by age

95. Mean total assets show a similarly smooth, but slow, decline, from about \$375,000 to about \$250,000, and the housing asset profile is essentially flat. Financial asset holdings do not decline much over the life-cycle for two reasons. First, many households sell their house towards the end of life, as seen in panel (a), which just substitutes housing assets with financial assets. Second, there is a mortality bias; those with relatively lower wealth die earlier. This bias pushes the life-cycle profiles upwards, and it exists both in the data and in the model, since the correlation of health and wealth is built in to the initial type distribution, and agents in the model die with the same probability as in the data. Finally, the proportion of households in debt declines smoothly from 21% at age 65 to nearly 0 at age 95, as households repay existing collateralized loans or sell their house and become renters.

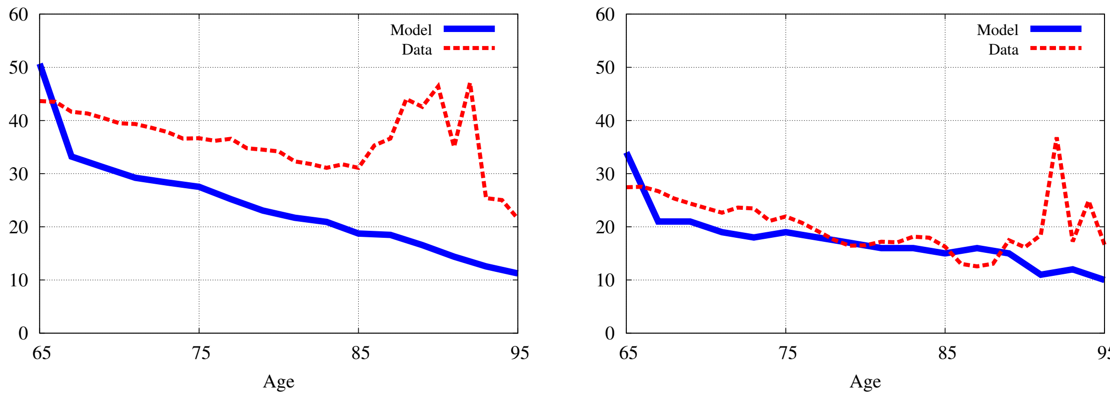
The age profiles implied by the model, solid blue lines in the figure, fit the data profiles very well. In the model, the homeownership rate declines when households either choose to sell the house (the majority of moves), or are forced to move into a nursing home by a moving shock. In turn, households sell the house either to realize capital gains when a high house price shock is realized, to dissave for life-cycle reasons, or as discussed in the model section, to pay for medical expenses when a high medical expense shock hits, or another shock that impacts the collateral constraint is realized, and the trade-off works in favor of selling instead of a RML. The model matches the empirical homeownership rate very closely, as well as the mean net worth, housing and financial asset age profiles, and the overall proportion in debt. The fit presented here yields the smallest sum of weighted squared normalized errors comparing the model and data moments, with equal weights.

Based on this distance criterion, the model produces the parameter estimates in the second panel of table 1, presented in annualized terms. The estimated discount factor β is 0.91 in annual terms, which is within the accepted range of estimates in models of this kind. The coefficient of relative risk aversion is 2, which is in the middle of the spectrum in the literature.[19] The extra utility from homeownership, at 4.9, suggests that homeownership yields, in financial and nonfinancial benefits not explicit in the model, nearly five times the utility benefit of renting in retirement. The consumption floor $\underline{c}$ supported by the government through welfare programs such as Medicaid is estimated to be \$13,919 in 2000 dollars, per adult per year, which aligns with empirical estimates of such program benefits (Hubbard et al. (1994)), once adjusted for inflation. The strength of the bequest motive is 20.5, and the preference shifter ζ is 7,619 in annual terms.

The bequest motive in this model is primarily identified by the asset profiles of older households: it affects (dis)saving decisions of older retirees, while precautionary motives affect younger retirees more. Our parameter estimates imply that our model overestimates the realized bequests for the lower end of the distribution, but matches quite well the middle and upper end of the bequest distribution, without targeting any of these quantities in estimation. For example, the mean and median realized bequest for singles in the model are \$234,000 and \$175,000, respectively. According to Ameriks et al. (2011), corresponding numbers in the data are \$234,000 and \$114,000. The realized bequest for the 90th percentile is \$470,000 in the model and \$536,000 in the data. However, the proportion of singles who leave no bequests is 25% in the data, while it is about 1% in the model, although the bottom quintile of model's single households leaves only 3% of all bequests.[20] In our

[19] In related work discussed above, Yogo (2016) uses Epstein-Zin preferences and estimates elasticity of intertemporal substitution to be 0.5, which is consistent with our estimate of $1/\sigma$, but risk aversion in his model is 5, to match the observed small share of stocks in retirees' portfolio.

[20] In Ameriks et al. (2011), households pay for medical expenses just before they die, which helps better match the low tail of bequests, since it is known that a large portion of medical expenses is spent just before death. In our



(a) Mean Debt among Debtors

(b) Median Debt among Debtors

Figure 3: Model vs. Data: Distribution of Debt

model, bequest motives, especially for the lower part of the wealth distribution, are estimated to be strong in order to match the high level of housing asset holding and low level of indebtedness towards the end of life.

A number of these parameter values are similar to the estimates from our previous, related, model in Nakajima and Telyukova (2013), and some parameter values have changed, since the models are different in significant ways. We discuss the comparison of parameter values in the two models in appendix B.2.

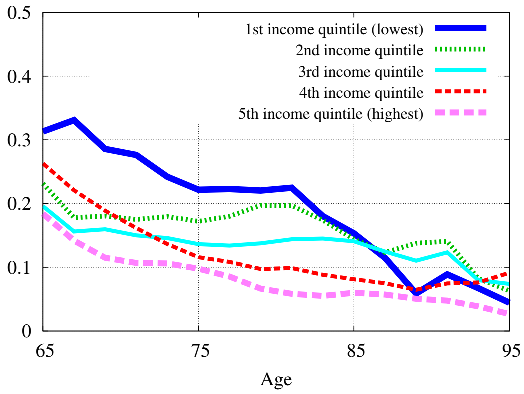
4.3 Additional Implications for Distribution of Debt and Portfolio Allocation

In addition to the model fit along the dimensions that we target in estimation, in this section we assess what the model implies for the *distribution* of debt, as well as for household portfolio allocation. These quantities are not targeted in model calibration, but shed light on and give confidence in the model performance and its mechanisms.

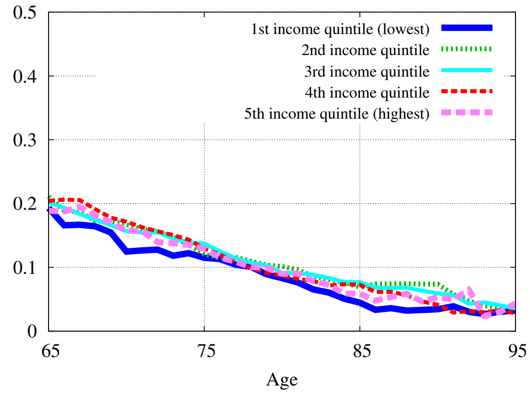
Figure 3 compares mean and median debt among debtors, in the model and data. Both median and mean profiles in the model exhibit initial drops in debt as some homeowners immediately sell their houses in the model, contrary to the data, where the decumulation is more gradual. The difference is more noticeable in the mean profiles; after the initial drop, the slope of the profile exactly matches that of the data. The model matches the median profile of debt quite well, notwithstanding the noise in the data resulting from small cell sizes in late years of life. The initial drop in debt profiles occurs because, in the data, there are households with significant amount of debt initially, and they are either forced to sell the house or repay a part of their debt. This is the impact of our parsimonious modeling of the collateral constraint based on the debt-to-income ratio.

Figure 4 compares debt rates, as well as median debt profiles, *by income bin* in the model and data. The model matches well the empirical pace of indebtedness decline with age. Note that the model profiles imply larger dispersion of debt rates across income groups than the data. We observe this repeatedly in the graphs that follow, and this results by construction. We use the empirical distribution of debt in 2006 as the model initial conditions, as discussed above. The counterpart age profiles in the data are the result of extracting the age effects from the age-year regressions.

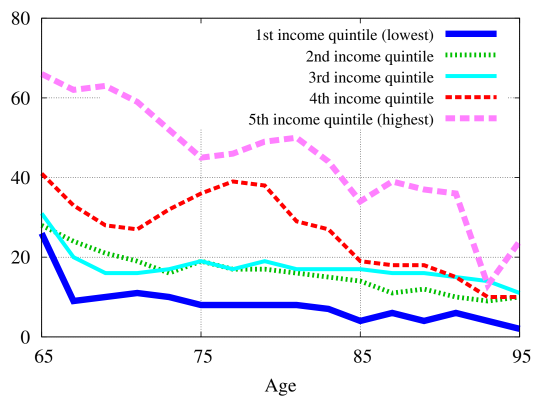
model, the timing of medical expense shocks is not synchronized this way, as households make saving decision every two years.



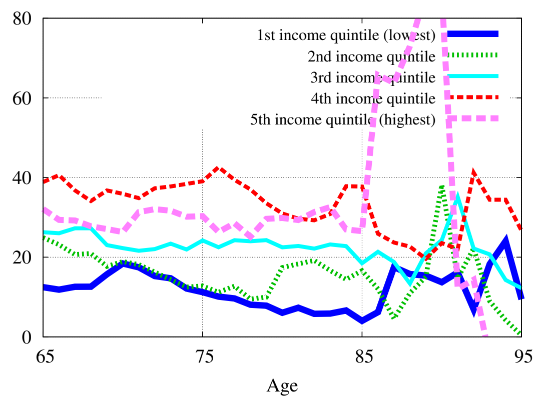
(a) % of Homeowners in Debt



(b) % of Homeowners in Debt



(c) Median Debt among Debtors

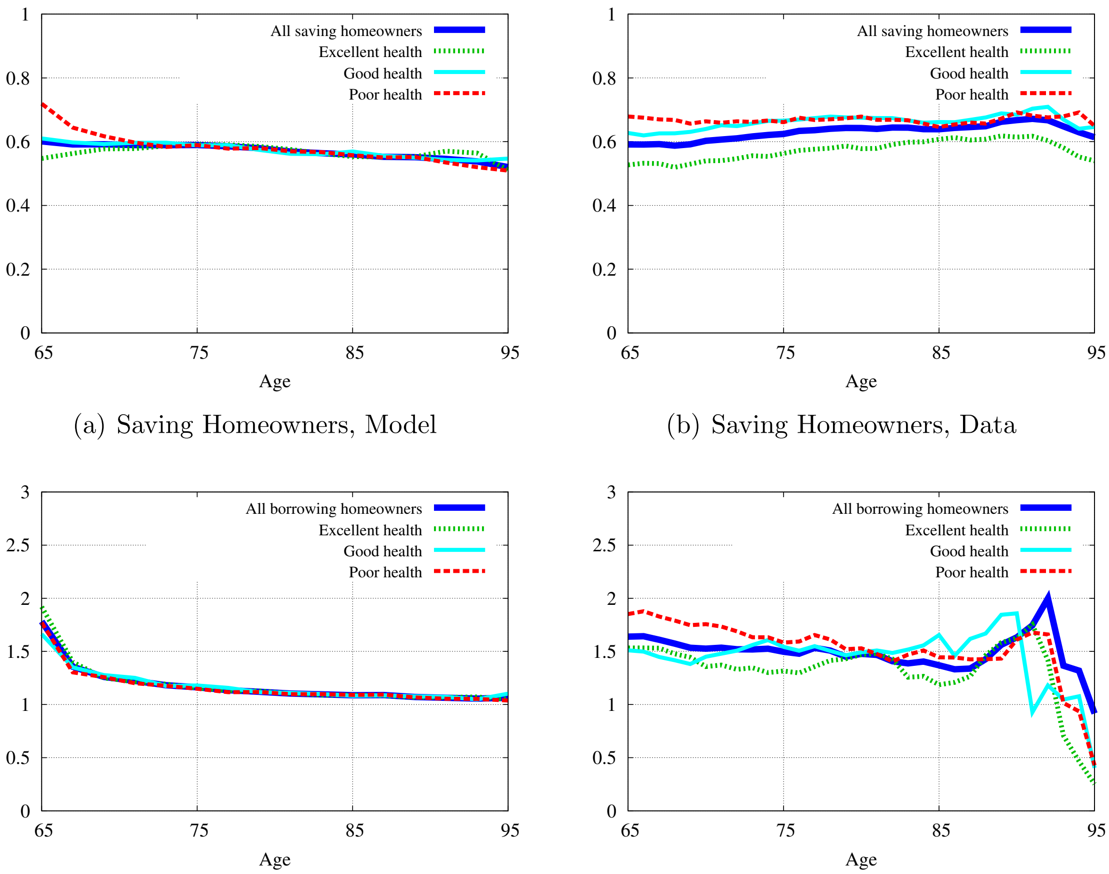


(d) Median Debt among Debtors

Figure 4: Model (left) vs. Data (right): Distribution of Debt for Each Income Bin

The resulting initial conditions differ in the model and data, causing some persistent difference in dispersion in the model vs. data. Even with that caveat, the model matches all income groups' profiles well, although the top income group's debt amount, higher initially in the model than the data, drops at a faster pace in the model.

Next, we turn to portfolio allocation between housing and financial assets. Figure 5 compares the proportion of housing assets in net worth, between the model (left) and the data (right). The top two panels compare the profiles for saving homeowners, while the bottom panels compare the numbers among borrowing homeowners. For each figure, the proportion for all homeowners in the group, as well as proportions for each of three health categories, are shown. The model matches the empirical levels and fairly flat slopes of housing shares over the life cycle. There is an initial decline of housing asset shares among borrowing households in the model, while the data feature a decline towards the end of life. The former is again due to the initial reduction of borrowing among heavily-indebted homeowners, as discussed above. The latter is affected by small data sample sizes at later ages. The model captures the negative correlation between health and housing shares among young saving households, which Yogo (2016) also finds.



(a) Saving Homeowners, Model (b) Saving Homeowners, Data

(c) Borrowing Homeowners, Model (d) Borrowing Homeowners, Data

Figure 5: Model vs. Data: Percent of Assets Held in Housing

4.4 Reverse Mortgages

We do not include reverse mortgages in the benchmark model even though the debt measurements in the HRS include them, because we cannot observe them separately from other equity loans in the survey. However, this does not matter for our results, because in the period 1996-2006, the RML take-up rate reached just 0.6% of eligible households, so reverse mortgages in the sample would have little, if any, influence on parameter estimates.

The third panel of table 1 summarizes the parameter values associated with RMLs, and the details are in appendix B.3. In general, we calibrate all the reverse mortgage parameters and age-dependent collateral constraints based on the existing RML contract. According to AARP (2010), the upfront cost is about 5% of house value. RML interest premium (annual 1.7%) is set to be the same as for conventional mortgages. The upfront insurance premium (2%) and flow insurance premium (1.23%) are fixed for HECM loans. Finally, the collateral constraint for RMLs is taken from AARP (2010). Depending on the age of the borrower, the amount of loan given is different, and unlike conventional mortgages, it grows with age, because the expected interest costs are lower and future house price risks are smaller, the older the borrower. This setup corresponds to the data's, as long as the borrower does not max out her credit line at the time of signing: in that case, the credit line will grow over time as the expected costs fall with age, both in the data and

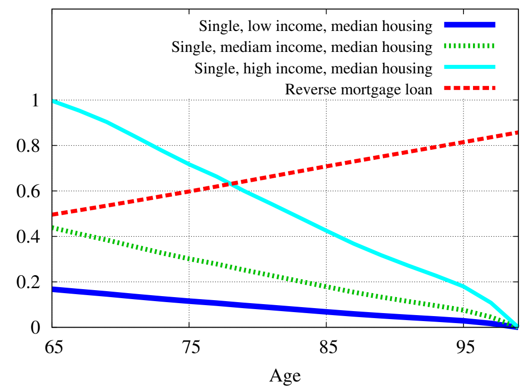


Figure 6: Collateral Constraints, Conventional and Reverse Mortgages

the model. The only difference between the model and the data happens if the borrower were to borrow to the maximum at the start of the loan: in that case, the borrower in the data cannot borrow more the following period, unless she refinances; in our model, borrowers can "refinance" every period. However, in the model, as in the data, borrowers do not, for the most part, max out their RML credit line at the time of signing.[21]

Figure 6 compares collateral constraints for RMLs and conventional mortgages for a single household with a median house, by income level. While the collateral constraint associated with conventional mortgages tightens with age, RMLs offer a collateral constraint that relaxes with age, and that is looser at all ages for low- and medium-income households, and above age 70 for high-income households. In general, the older, lower-income and less healthy the household, the tighter the collateral constraint of the conventional mortgage, and the more attractive the reverse mortgage.

5 Results

In this section, we first introduce RMLs into our calibrated model, and study the take-up rate, and welfare and distributional implications of reverse mortgages. The life-cycle profiles in the model with RMLs are similar to those of the baseline model without RMLs; therefore, we present the profiles in appendix D. Then we turn to counterfactual experiments to quantify how risks, bequest motives, and the terms of the current RML contracts affect demand for reverse mortgages, what we may expect as a result of recent HECM reform, and what to expect for demand for RMLs in the future, as a result of short-term and long-term effects of the recent crisis.

5.1 Take-Up and Benefits of Reverse Mortgages

Table 2 shows the take-up rate of reverse mortgages, as well as expected welfare gains from availability of reverse mortgages, for different types of homeowners. The welfare gain is measured as a one-time transfer at age 65, in 2000 U.S. dollars, that would make households in the economy without reverse mortgages indifferent, in expected terms, to being in the economy with RMLs. By construction, no household in the model is worse off by having the option to take a reverse mortgage, and only homeowners gain from the introduction of reverse mortgages, so we compute welfare gains

[21]We also found that the RML take-up rate is not significantly affected by the age slope of the RML constraint.

Table 2: **RML Take-Up Rates and Welfare Gains**

	% Holding (take-up rate)	Welfare Gain, 2000 US$[1]	Welfare Gain, % of Income[2]
Data[3]			
All homeowners – 1997–2013	0.84		
1997–2007	0.35		
2007–2013	1.34		
Model[4]			
All homeowners	0.89	252	0.84
Eventual RML borrowers	–	1,770	5.13
Age: 70s	0.92	–	–
Age: 80s	1.87	–	–
Age: 90s	2.44	–	–
No outstanding mortgages	0.00	273	0.94
With outstanding mortgages	5.39	185	0.51
Single	1.28	222	1.03
Couple	0.52	269	0.73
Low income	2.19	369	2.22
Medium income	0.54	256	0.54
High income	0.18	40	0.04
Poor health	1.12	142	0.51
Good health	0.93	240	0.88
Excellent health	0.66	317	0.97
With smallest house	0.00	1	0.01
With median house	0.96	116	0.61
With largest house	2.78	1,415	3.61

[1] Welfare gain is measured by a one-time payment at age 65, which would make expected life-time utility of those with access to RMLs equal to expected life-time utility without, measured in 2000 US$.
[2] Measured as percent of household income at age 65.
[3] American Housing Survey.
[4] Among homeowners.

for homeowners only.[22] We also show the welfare gain as an average share of income at age 65.

The calibrated model implies the RML take-up rate of 0.89% of retired homeowners. Since the model produces a long-term average RML take-up rate in a stationary world, the rate of 0.84% for the period 1997-2013 is an appropriate data benchmark. Alternatively, since we are working with the 2006 sample of initial retirees, the observed average RML take-up rate from the period 2007-2013 can also be considered relevant; this rate is 1.34% in the data. Since we did not target the RML take-up rate in our calibration, and used the terms of RMLs as observed in the data, the

[22] We abstract from the general equilibrium effects, but considering the low take-up rate, the general equilibrium effects would be small.

model rate of RML demand being close to the data's is a significant success of our model.

The RML take-up rate varies significantly across different types of households. For example, the take-up rate is higher for older homeowners (2.4% among households in their 90s, versus 0.9% among those in the 70s), those with outstanding mortgages (5.4% take-up rate), low income (2.2% versus 0.2% for highest income group), single households (1.3% against 0.5% among couple households), and in poor health (1.1% against 0.7% for households in excellent health). It is not surprising that the take-up is higher among older and less healthy households, since they are more likely to see tight conventional mortgage constraints, and since they are more likely to have high medical expenses, both of which can make a reverse mortgage attractive.

Our results are qualitatively consistent with data findings in the literature, although we lack necessary micro-data on reverse mortgages to compute direct comparisons. Shan (2011) found that areas with more RML borrowers tend to have lower household income and credit scores, and higher house values and homeowner costs. Redfoot et al. (2007) find that RMLs are likely to be used to repay outstanding mortgages and for medical expenses, when household income is insufficient.

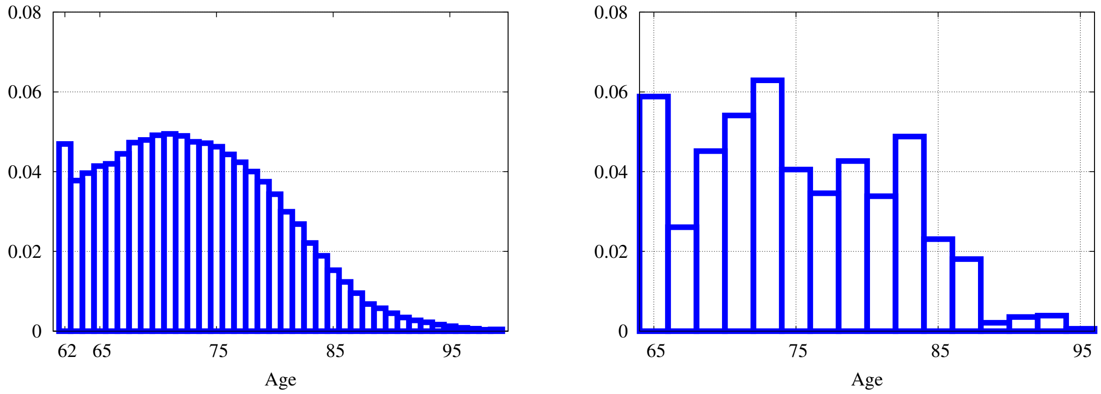
According to our model, the ex-ante mean welfare gain from having the RML option is \$252 per homeowner; this translates to, on average, 0.8% of annual after-tax income at age 65. Clearly, the gain is much larger for those who do obtain the reverse mortgage ex-post; it is \$1,770, or 5.13% of household income. The welfare gain also varies with household types. For example, low-income households value the option more than high-income households (\$369 or 2.2% vs. \$40 and 0.04%); the ability to take a reverse mortgage at some point in the future is valuable for the purpose of relieving liquidity constraints, which are more likely for low-income households. Welfare gains are also increasing in the value of the house, which is not surprising, since a more expensive house entails more equity for the potential borrower; those with the largest house have welfare gain of \$1,415 or 3.6% of income. Interestingly, the ex-ante welfare gain is slightly higher for healthier homeowners at age 65, even though the take-up rate is higher among those with poor health. This is because households with poor health tend to be older, and are more likely to incur large medical expenses. In contrast, healthier homeowners tend to live longer and thus are more likely to need a reverse mortgage late in life.

5.2 Age Distribution of Reverse Mortgage Borrowers

Figure 7 compares the histogram of age distribution of households *at the time of RML signing*, among all households who currently hold an RML, in the data (Shan (2011)) and in the model, the latter adjusted to annual terms. The model replicates the distribution of age origination very well, including the initial spike in demand: many homeowners take up the RML as soon as they can, at age 62 in the data, and at age 65 in the model. Both the model and the data exhibit a hump-shape after the initial spike, and taper to zero towards the end of life. This age distribution of take-up rates is another significant success of the model.

5.3 The Role of Bequest Motives and Uncertainty for Reverse Mortgage Take-Up

In the first set of experiments, we investigate how the risks that retirees face, as well as bequest motives, affect RML take-up, since these are the factors that determine more generally how households (dis)save in retirement. In appendix E, we show life-cycle profiles that result in the alternate economies in these experiments. Table 3 shows the take-up rate and welfare gains among homeowners in the model with several counterfactual experiments. First, we evaluate the model without medical expenditure shocks; to do this, we assume that all households have to pay the mean of the



(a) Data – Shan (2011) (b) Model

Figure 7: Age Distribution of Borrowers at RML Origination

Table 3: Impact of Uncertainty and Bequest Motives on RML Demand

		Take-Up Rate, Homeowners	Welfare Gain, 2000 US $[1,2]	Welfare Gain, % of Income[1]
1	Baseline model	0.89	252	0.84
2	No medical expense risk	1.03	269	0.92
3	No medical expenses	1.21	274	0.98
4	No moving shocks	0.95	272	0.90
5	No house price shocks	1.22	61	0.12
6	Expected house price boom (+4.5%)	13.21	7,899	24.02
7	Expected house price drop (−4.5%)	0.02	0	0.00
8	No bequest motive	17.17	9,789	20.28
9	Model with interest rate risk	0.98	341	1.11

[1] See notes 1, 2 in Table 2.

[2] Welfare gain is averaged across *all homeowners*.

medical expenditure distribution, conditional only on household age, income, and size, but not on health, which itself is a source of uncertainty. In this case, the take-up rate increases slightly, to 1.03%, all else equal. There are two opposing effects at work here. On the one hand, we remove large expense shocks, whose realization is one reason to take out a reverse mortgage – this would decrease demand. On the other hand, we remove a source of risk, which encourages more RML demand for other purposes, as one precautionary reason for holding off borrowing is removed. The latter dominates. For the same reason, if we shut off medical expenditures altogether, we see a larger increase in RML demand, to 1.21%.

Nursing home move risk dampens demand for reverse mortgages, as does house price risk, because both reduce the expected duration of homeownership. Removing compulsory nursing home move shocks increases the RML take-up rate to 0.95% of homeowners, similarly to Michelangeli (2010). The worst outcome for RML borrowers is to face a compulsory moving shock shortly after paying the large upfront cost of a reverse mortgage, but before utilizing the line of credit.

Eliminating this possibility makes these loans more attractive as a way of relieving possible liquidity constraints while staying in the house longer. Removing idiosyncratic house price uncertainty increases the take-up rate to 1.22% of retired homeowners, because absent temporary increases of the house value, households lack unexpected opportunities to sell the house for capital gain, which would shorten the expected duration of an RML. This increases expected years of homeownership, and in turn encourages more reverse mortgage borrowing. Interestingly, while the uptake of RMLs in this case increases, the welfare gain falls relative to benchmark. This is because in the presence of house price uncertainty, reverse mortgages serve as an option, allowing smoothing in low house price states, with an occasional opportunity to sell in high-price states. Absent that uncertainty, the insurance benefit of reverse mortgages is removed.

Next, in a stylized housing market boom experiment, we add to the model an expectation of deterministic and permanent house price growth of 4.5% per year, while keeping the idiosyncratic house price shocks in place. We chose the 4.5% growth rate because it is the average real house price appreciation rate between 1996 and 2006, our baseline sample period. The result is a very significant increase in demand for reverse mortgages, to over 13%. The increase is intuitive: when households expect house price growth, they want to front-load consumption by borrowing more. In this case, the welfare gains for RML borrowers rise dramatically, to $7,899 per household, or 24% of income at age 65. This result is qualitatively consistent with the observed rapid increase in the RML take-up rate in the period 2000-2007, shown in figure 1.

We also run the symmetric experiment of assuming that households expect house prices to drop, deterministically, at 4.5% per year. This has the opposite effect of the expected housing boom, bringing RML demand to zero. The reason is that the amount of equity against which homeowners can borrow is declining, which makes borrowing more costly. This result may seem to contradict the rise in RML demand after 2007. The clue lies partly in the predictable nature of the decline in the model: it is hard to argue that the collapse of the housing market in the last recession was predicted by homeowners, and expectations matter greatly for this result. Indeed, house prices stopped declining around 2009.[23] In addition, the housing market bust coincided with a wider recession that is not in the model, forcing more households to rely on reverse mortgages for consumption than the model predicts, and countering the dampening effect described above. We analyze the Great Recession in more detail below.

In the next experiment, we recompute the model without the bequest motive ($\gamma = 0$). In this scenario, the RML take-up rate increases to 17% of homeowners. It is intuitive that bequest motives dampen RML demand, since retirees want to keep their wealth in order to pass it on to heirs; without bequests, retirees are more likely to use home equity to supplement consumption generally, rather than just in constrained states. Notice that in this experiment, the magnitude of the welfare gain to households from the availability of RMLs is also very large compared to the benchmark case, at $9,789 per homeowner. The asset age profiles that result in this economy shed further light on relevant mechanisms; see appendix E.

In sum, the model suggests that, conditional on the existing RML contract, reverse mortgage demand is low for the same reasons that retirees do not rapidly spend down assets: due to precautionary motives in the face of risks that they face, and to the bequest motive. These factors affect not only demand for reverse mortgages, but also their purpose: under the current environment, ab-

[23]According to S&P Case-Shiller 20-City Home Price Index, the timing of the trough varies between 2009 and 2011, depending on the source.

sent constrained states or spending emergencies, households prefer not to be in debt. In the absence of risks or bequest motives, households would use RMLs more freely for general consumption.

Finally, we conduct one more experiment, in which we introduce idiosyncratic interest rate uncertainty. This experiment captures the fact that interest rates for conventional mortgages are usually fixed, while other interest rates, including those on reverse mortgages, fluctuate over time, a consideration that may affect demand for RMLs. In constructing the interest rate shock, we fit an AR(1) process to the time series of real interest rates, measured as the 10-year Treasury rate net of the CPI inflation rate. Then we discretize the estimated AR(1) process into a first-order Markov process. As a result, the annualized interest rate fluctuates between 0.52% and 4.49%, instead of staying at the 2.58% benchmark level, with a two-year persistence of 0.71. In other words, the interest rate is expected to remain the same for 6.8 years on average. This model variant requires the addition of another state variable. For computational tractability, we assume that the interest rate shock is *idiosyncratic* to households, instead of affecting all households in the same way as aggregate shocks do, so that the overall household distribution remains stationary. Therefore, our results should be interpreted as the time series average when interest rates fluctuate over time.

We assume that both the saving rate and the borrowing rate on reverse mortgages are affected by the interest rate shock, while the borrowing rate on conventional mortgages remains fixed. This could make conventional mortgage loans more attractive relative to RMLs. Moreover, we assume that rental costs are not affected by interest rate fluctuations either, motivated by the observation that rent moves little compared with interest rates in the data.

We find that the take-up rate and the ex-ante welfare gain of reverse mortgages are not very different from our baseline results. In this sense, our main results are robust to adding interest rate shocks. Surprisingly, the take-up rate increases (from 0.89% to 0.98%) with the addition of this type of uncertainty, and the welfare gain rises as well. It is true that additional interest rate risk associated with RMLs works to lower RML demand, but this effect turns out to be dominated by the role of RMLs as an interest rate option. In essence, it benefits households to have the additional choice between a fixed-rate loan and an adjustable-rate loan. The reason is that while demand for RMLs when the interest rate is high is slightly dampened, there are households whose RML demand is not price sensitive, and take-up is significantly higher than in the baseline model when the interest rate is low. More households take advantage of a cheaper loan when rates are low; since the interest rate shock is persistent, and retired households are of an advanced age with high discount rates, they are less concerned with the risk of future interest rates increasing. This experiment implies that demand for reverse mortgages would go up when interest rates are low, and are not expected to rebound quickly, as in the current U.S. environment.

5.4 The Impact of RML Terms and the 2013 HECM Reform on Demand

In this section, we explore how demand for reverse mortgages is affected by their current terms, in response to the popular claim that high costs of RMLs are to blame for low demand. Table 4 summarizes the results. First, we evaluate the October 2013 reform in the HECM program. In this reform, in order to protect the viability of the program in the face of rising insurance payouts, the FHA imposed more stringent borrowing limits, instituted mandatory credit checks for borrowers (though no debt-to-income requirement), and changed the insurance cost structure (see HUD (2013)). In the language of our model, this translates to a 15 percentage point reduction in the borrowing limit for all households. In accordance with the new rules, the initial insurance cost decreases from 2.0% to 0.5%, unless the household's initial RML balance exceeds 60% of the

Table 4: RML Demand with Alternative Loan Terms

		Take-Up Rate, Homeowners	Welfare Gain, 2000 US $[1]	Welfare Gain, % of Income[1]
1	Baseline model	0.89	252	0.84
2	2013 HECM reform	0.82	287	0.92
3	Lower (0.5%) up-front ins. premium[2]	1.27	351	1.13
4	Tighter (−15pp) borrowing limit	0.57	216	0.71
5	No insurance (recourse)	2.71	700	2.25
6	Zero up-front cost	3.24	985	3.28

[1] See notes 1,2 of Table 2.

[2] If initial disbursement is greater than 60% of maximum loan amount, upfront cost rises to 2.5%.

maximum loan amount, in which case it pays an upfront cost of 2.5%.

The first two rows of table 4 compare the baseline model and the counterfactual model with the 2013 reform built in. We find that the aggregate effect of this change is very small: RML take-up rate falls very slightly, from 0.89% to 0.82% (row 2) of homeowners, while the expected welfare gain rises. Clearly there are two opposing effects: a lower initial borrowing cost may encourage more loan demand, but a tighter collateral constraint may act in the opposite direction. We examine these two effects by changing separately only the upfront insurance cost, then only the borrowing limit. The experiments reveal that the two effects nearly cancel each other out: demand increases by 43% if the upfront cost is lowered in isolation (row 3); keeping upfront costs the same, tightening the borrowing limit decreases demand by 36% (row 4), with the latter force slightly dominating on the demand side, although not on the welfare side. In sum, our model suggests that the recent reform is going to slightly dampen uptake of reverse mortgages.

As we discussed, reverse mortgages offer several potential benefits. First, borrowers can access their home equity for non-housing consumption while staying the house. Second, RMLs offer (mandatory) insurance against house price declines, through their non-recourse nature, but at a higher cost. In the next experiment (row 5), we shut off the insurance part of reverse mortgages. We do so by setting insurance costs (ι^i and ν^i) to zero, and making the RML a *recourse* loan, by changing the terms so that when the borrower dies or moves out and the RML is consolidated, she or her heir is liable for any excess loan amount. One point to note is that households can accumulate the RML balance and then default, using the consumption floor, when they sell the house; hence the loan cannot be made a perfect recourse loan. However, this likely mirrors the possibility of default in the data.

Row 5 in table 4 shows that changing the RML to be a recourse loan triples the take-up rate, to 2.71% of homeowners. Notable also is the resulting near-tripling of the welfare gain from reverse mortgages. These results suggest that retirees do not value this insurance aspect of the RML. There are three reasons for this. First, most RML borrowers in the model carry relatively small balances of reverse mortgages when the loans become due, and thus the probability of being unable to repay is small. Second, borrowers have access to the publicly provided consumption floor. This makes the additional insurance in the RML contract less valuable to older households. Third, since we do not model the aggregate swings in housing prices that have been observed since mid-2000s, we

Table 5: RML Demand Distribution and the Great Recession

		% Take-Up				Welfare Gain,
		All Ages	71-79	81-89	91-99	% of Income[1]
1	**Baseline**					
	All	0.89	0.92	1.87	2.44	0.84
	Bottom income quintile	2.19	2.71	5.14	3.87	2.22
	Median income	0.54	0.58	1.17	1.01	0.54
	Top income quintile	0.18	0.23	0.29	0.36	0.04
2	**Post-recession retirees (65 in 2010)**					
	All	0.71	0.80	1.42	2.13	0.71
	Bottom income quintile	3.01	3.04	9.05	12.87	2.27
	Median income	0.58	0.81	0.68	2.82	0.30
	Top income quintile	0.01	0.02	0.00	0.00	0.01
3	**Long-run: 5% drop in income**					
	All	1.00	1.04	2.01	2.88	0.91
	Bottom income quintile	2.75	3.34	6.48	5.12	2.31
	Median income	0.69	0.81	1.31	1.98	0.63
	Top income quintile	0.23	0.32	0.34	0.27	0.06
4	**Post-recession retirees with 5% income drop**					
	All	0.83	0.94	1.64	2.29	0.77
	Bottom income quintile	3.11	3.39	9.39	11.86	2.40
	Median income	0.66	0.84	0.98	2.77	0.34
	Top income quintile	0.04	0.02	0.13	0.00	0.01

[1] See notes in Table 2.

are abstracting from aggregate downward house price risk that households face, and hence may underestimate the insurance benefit from reverse mortgages.

Finally, in row 6 in the table, we arbitrarily reduce the upfront cost of a RML to zero, without making the borrowers pay for it in other ways. This experiment is to evaluate, albeit in an extreme way, the significance of the oft-mentioned high upfront costs for RML demand. In this case, all else equal, the take-up rate increases even higher relative to the benchmark, to 3.24% of retired homeowners, with an associated large gain in welfare.

5.5 Distribution of Reverse Mortgage Demand and the Great Recession

We now use our model to understand in more detail how reverse mortgage demand differs across the income and age distribution, and then to assess the impact of the Great Recession on retirees' demand for reverse mortgages going forward, both in the short and the long run. The first panel of table 5 shows the overall take-up rate, but also the rates for different income and age groups, in the benchmark model, as discussed above.

We perform three stylized experiments to assess the impact of the Great Recession on future RML demand. In the first, we use a new initial distribution of 65-year-old retirees from the 2010 wave of the HRS, to evaluate the impact of the crisis on RML demand of households entering retirement just after the Recession. This cross-section of new retirees differs from the benchmark

2006 cross-section chiefly in their wealth, and somewhat in their income: the 2010 mean housing wealth is 22% below the 2006 mean, and the mean financial wealth is 10% lower. Median income in the 2010 initial distribution is 2.3% lower than in 2006. The homeownership rate in 2010 is two percentage points above the 2006 rate, while the indebtedness rate is two percentage points higher.[24]

In the second experiment, we speculate on the long-run impact of the recession. Butrica et al. (2012) estimate that the long-run impact of the Great Recession will be most felt by households that are currently in their 20s and 30s, through effects on earnings of prolonged unemployment or underemployment spells early in their careers. Endogenous response to such shocks notwithstanding, they estimate that these households will arrive at retirement with incomes that are about 4.8% lower than the current retirees'. Thus, we run a second experiment, in which we drop the incomes of our 2006 retirees by 5% across the board, while holding their wealth constant.[25]

Finally, in a third experiment, we reduce the pension income of the 2010 cohort of entrants into retirement by 5%, as a proxy for an intermediate generation of retirees that may suffer both a loss of wealth and some labor market effects on their income.

Table 5 presents the results of these experiments. Overall, for all ages and all incomes, we see that the short-run loss in wealth for current entrants into retirement results in a decline of RML demand by 20% relative to the baseline, from 0.89% to 0.71% of retired homeowners. However, the effect is heterogeneous across the income distribution. The most significant decreases in RML uptake are seen among the highest-income individuals; these are households who likely lost the most equity in their homes during the crisis, while being least constrained in other ways, which discouraged borrowing. In contrast, in the bottom income quintile of homeowners, the model predicts an increase in RML demand, with the size of the impact increasing in age. While these households still have the majority of their wealth in home equity, they were also most likely to be impacted by other adverse wealth effects pushing them against their liquidity constraint, which in turn induced higher RML borrowing. The increase in RML uptake is 12% for low-income homeowners in their 70s, but more than threefold (from 3.8% to 12.9%) for those in their 90s; the oldest households have the fewest options outside the reverse mortgage market.

In contrast, the long-term effect of the recession of a uniform 5% drop in incomes increases RML take-up across the income distribution and across almost the entire age distribution, although the magnitude of the impact is less dramatic than in the first experiment. The overall take-up rises by 12%, from 0.89% to 1.00%. While wealth is not changed, households' income is more likely to be insufficient to cover their non-discretionary expenses, such as house maintenance and medical or nursing home expenses.[26]

[24]Clearly, one response to the recession would be to postpone retirement, so there is a selection effect that we are not taking a stand on. Also, asset prices have at this point generally recovered to their pre-recession levels, so the effects of the recessionary drop in wealth may be mitigated somewhat over time.

[25]Clearly, this experiment does not allow for the potential endogenous adjustment of saving in response to a lowered income. However, quantifying and determining the direction of this endogenous response is impossible without a full life-cycle model. Another important long-run trend is the transition from defined-benefit to defined-contribution plans that may play a role in the wealth levels of future retirees as well. However, the long-run impact of this transition requires a large number of assumptions and is hard to quantify succinctly for the purposes of our experiments. Poterba et al. (2007) estimate, for example, that for the majority of households, the transition from DB to DC pension plans will actually result in an increase in pension savings, though there is heterogeneity through the income distribution similar to our 2010 experiment.

[26]We also conducted the experiment of dropping income by 10%, for a more dramatic long-run income effect, and

Finally, in combining the 5% income decrease with the less-wealthy 2010 retiree sample, we see that, although the overall take-up rate slightly declines from 0.89% to 0.83%, it rises among median- and low-income households. Reverse mortgage demand is lower for high-income households, for whom the decrease in equity dominates in impact the fall in income. For all but the oldest households of low and mid-income groups, the increase in RML demand is larger in this experiment than in the previous two, showing a compounded effect from income and wealth decreases.

The last column shows ex-ante welfare gains from reverse mortgages for homeowners in each income group, evaluated as percent of income, which is useful since income levels change from experiment to experiment. In accordance with the take-up results, the short-run (i.e., due to change in wealth) impact of the Great Recession is to lower welfare gains from RMLs, except for the low-income households, whose welfare gain rises from 2.22% to 2.27% of average income. Ex-ante welfare gains slightly increase in the income drop experiment for all households (panel 3), and decrease for all but the low-income in the combined experiment (panel 4).

These experiments suggest that the effect of the Great Recession, while small for reverse mortgage demand in aggregate, does have significant effects for more vulnerable retirees – the low-income and older households.[27] We can expect these retirees to use reverse mortgages more in the future, all else equal, particularly as the housing market recovers. This has policy implications for both demand and supply sides: the RML is a way to ensure financial security in retirement for the most vulnerable retirees while diminishing their dependence on social programs. At the same time, this selection of the borrower pool suggests that the riskiness of the HECM portfolio held by HUD may increase in the future. It is important that future evaluations of HECM regulations in the vein of the 2013 reform strike the right balance to ensure program viability while giving those that need it most access to their home equity.

6 Conclusion

We analyze reverse mortgage loans using a calibrated structural model of retirement where older households make decisions about consumption, saving, housing, and reverse mortgages. We find that although the average expected welfare gain of reverse mortgages is equivalent to just $252, or 0.84% of median annual after-tax income, in a one-time transfer to retired homeowners, the welfare gains are much larger for those in the lower tail of the income distribution and the oldest households. Our model indicates that RMLs are particularly popular among lower-income and lower-wealth households, single households, and households in poor health, which is consistent with RML use in the data. As compared to the average RML take-up rate of 0.89%, the take-up rate among the lowest income quintile is 2.2%, and it is 3.9% for lowest-income households of age 90 and above, with associated much larger welfare gains.

Through counterfactual experiments, we identify that, conditional on the existing RML contract in the data, bequest motives and precautionary motives in the face of medical expense and nursing home moving risk, as well as house price fluctuations, all dampen RML demand, while adjustable interest rates on reverse mortgages can slightly raise demand. We also find that the costs of the RML contract are an important determinant of demand. In particular, the mandatory insurance costs inherent in the current contract decrease RML demand, because households do not value this

found that the effects moved in the expected direction. We omit this experiment here for space considerations.

[27] Notice that this experiment might underestimate the heterogeneous effects, since the decline in income might not be uniform, unlike the assumption here. If income declines more for lower-income households, the demand for RMLs by lower-income households would increase even more.

insurance, due to relatively low borrowed amounts and government-provided insurance alternatives such as Medicaid. The model predicts a tripling in demand if the reverse mortgage were made a recourse loan. In contrast, the recent 2013 HECM reform by HUD, which tightens borrowing limits for all future borrowers, though decreasing the upfront insurance cost for those with lower balances, will decrease RML take-up slightly, all else equal. One possible interpretation of these results is that given the risk that lenders have to take on to offer the RML, and given retiree preferences and risks, the resulting contract is too expensive to be desirable to the majority of homeowners, so that many homeowners are better off selling their homes if they need to liquidate some home equity.

The Great Recession, however, may drive demand for reverse mortgages up over time, particularly among the more vulnerable low-income and older households. This highlights important tradeoffs between access and portfolio risk to be considered in future redesigns of the HECM program. We find that the *short-run* effect of the recent crisis is to lower reverse mortgage demand in aggregate, because the majority of households suffered a large loss to home equity, which decreases their desire and ability to borrow against it. However, for homeowners above age 90 in the lowest income quintile, the loss of wealth, combined with lower income, drives demand for reverse mortgages up threefold. One *long-run* effect of the recent crisis may be a loss of income at retirement age as a result of prolonged unemployment spells for younger households. As a result of this income loss, we foresee an increase in reverse mortgage demand for all income quintiles and nearly all age groups. This evaluation is done in a model without aggregate house price dynamics; we do show in additional experiments that these dynamics, and expectations regarding them, can significantly impact RML demand as well. We leave a deeper analysis of this issue to future research.

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APPENDIX

A Household Size Dynamics in the Model

We introduce household size in the model, since existing research on housing decisions in retirement, such as Venti and Wise (2004), finds that death of a spouse is often a trigger for selling the house and downsizing. At the same time, we model household size transition as parsimoniously as possible, in order to make our model manageable. In particular, it is infeasible to keep track of the health status of both spouses in a couple household. Specifically, a household is either single ($s = 1$) or a couple ($s = 2$). Household size changes following a Markov transition probability $\pi^s_{i,s,s'}$. For an age-i couple household, the probability of losing a spouse and becoming single is $\pi^s_{i,2,1}$. With probability $\pi^s_{i,2,2} = 1-\pi^s_{i,2,1}$, the couple household remains a couple. We assume that a single household remains single with probability one, i.e. $\pi^s_{i,1,1} = 1, \forall i$, in order to avoid consolidation of wealth when two singles get married, and because our HRS data shows that remarriage in retirement is rare. We also assume that when a household in the model dies, both spouses die. Since the probability of losing a spouse is lower than the probability of death for the majority of relatively younger households, couple households are more likely to become single before dying.

When we convert the type distribution in the HRS data to a model input, we assign the age (i) and the health status (m) to a couple household as follows. Since the husband and the wife can differ in both age and health, we split each couple household in the HRS data into two households in the model, and assign the age and health status of one of the spouses to each of the two households. Each of the two model households is then assigned one-half of the sample weight of the original household.

Household size s affects households in the following ways:

1. Pension income is multiplied by χ_s. For a single household, $\chi_1 = 1$. For a couple household, χ_2 is calibrated to be 1.48, which is the median value in the HRS data (see appendix B.1.6 below). Consumption floor is also multiplied by the same income multiplier.

2. For a couple household, consumption is shared but the consumption equivalence scale $\psi_2 = 1.34$ is below 2, implying that there is a positive externality of being a couple. Moreover, $\psi_2 < \chi_2$, implying that, everything else (including per-adult pension income) equal, per-adult consumption is higher for couple households.

3. Medical expenses in the model (x) represent household-level total medical expenses. Naturally, we assume that the distribution of medical expense shocks depends on household size s and estimate the parameters characterizing the distribution accordingly.

B Calibration in Detail

B.1 First-Stage Estimation

In the first-stage estimation, we set values of parameters that can be directly observed from the data, and for the most part, our data source is the Health and Retirement Study.

B.1.1 Household Size

Table 6 shows the two-year transition probabilities of household size, conditional on age 65, 75, 85, and 95. As with other shock processes, we assume that the household size transition probabilities

Table 6: **Household Size Transition (Percent)**

Age	Current Period: Two-Adult		Current Period: One-Adult	
	One-adult	Two-adult	One-adult	Two-adult
65	3.38	96.62	100.00	0.00
75	8.00	92.00	100.00	0.00
85	13.41	86.59	100.00	0.00
95	21.85	78.15	100.00	0.00

Source: Constructed based on HRS, 1996-2006.

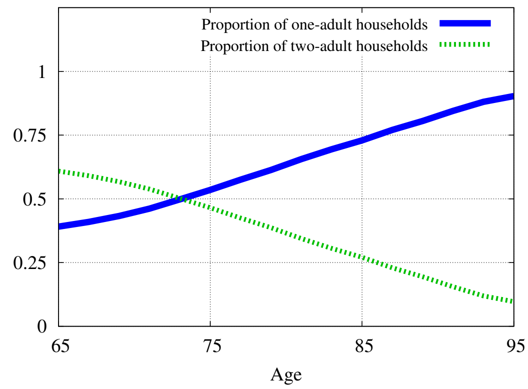


Figure 8: Household Size Distribution

are time-invariant and estimate them from the pooled 1996-2006 sample of the HRS. As can be seen in the last two columns of the table, we abstract from remarriages, based on low occurrence of these among retirees in our data; thus, a single retired household cannot become a couple again. We also 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 is rare in our sample. Figure 8 presents the resulting proportions of two-adult and one-adult households conditional on age. The proportion is constructed using the initial (age-65) distribution of 1-adult and 2-adult households in HRS 2006, and applying the transition probabilities shown in table 6. The proportion of couples is approximately linearly decreasing with age, while the proportion of single households is, correspondingly, increasing.

ψ_s is the household consumption equivalence scale, capturing the positive externality enjoyed by couple households. We normalize $\psi_1 = 1$ and set $\psi_2 = 1.34$ for two-adult households, as computed by Fernández-Villaverde and Krueger (2007).

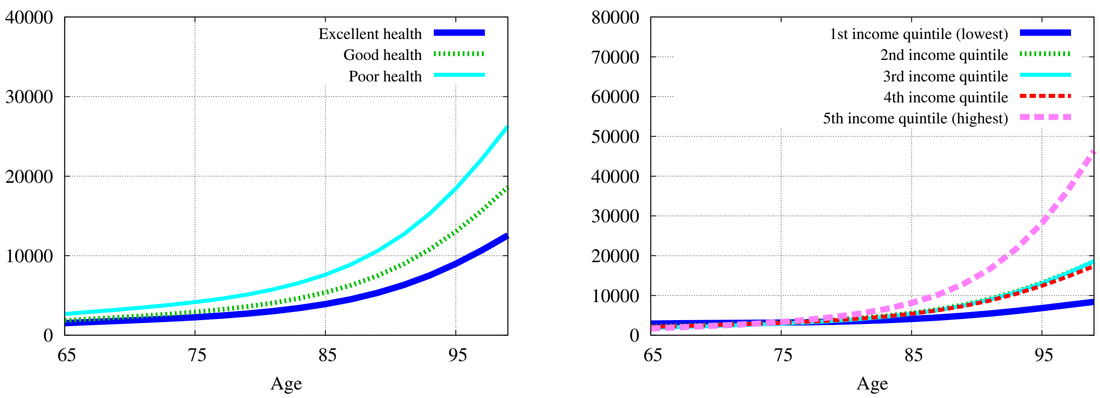
B.1.2 Health Status and Mortality Risk

We group the five self-reported health states in the HRS into three categories: excellent, good, and poor. We also add death as one of the health states. Then we compute two-year transition probabilities across health states, including probability of death, using a pooled 1996-2006 HRS sample, after observing that these probabilities are constant over this period. Table 7 shows the resulting transition probabilities for people of age 65, 75, 85, and 95. As expected, mortality rate is higher for older and less healthy households. Health status is generally persistent, but the

Table 7: **Health Status Transition (Percent)**

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	25.2

Source: Constructed based on HRS, 1996-2006. Rows represent the current health status. Columns represent the health status (including death) in the next period.



(a) Median Income, by Health

(b) Good Health, by Income

Figure 9: Expected Mean OOP Medical Expenditure, Single Households, 2000 US$

persistence weakens with age as health deteriorates on average.

B.1.3 Medical Expenditures

Our measure of out-of-pocket (OOP) medical expenses in the data includes both healthcare and long-term care (LTC) expenses, and we utilize the exit waves of the HRS to include end-of-life medical and LTC expenses, as in De Nardi et al. (2010). We estimate the distribution of log-OOP medical expenses as a function of age, health, household size, and income quintile, from the pooled HRS sample of retirees. The mean, standard deviation and probability of zero expenses are estimated as quartics in age, and include interaction terms between age and the other three variables. Under the assumption of log-normality of medical expenses, we then compute expected mean and standard deviation of medical expenses in levels. The probability of zero medical expenses is used to ensure that the types of households that do not pay OOP in the data are not incorrectly allocated OOP shocks in the model. Figure 9 reproduces expected mean medical expenses, for single households in the middle income bin by health (panel (a)), and in good health by income

Table 8: Probability of Permanent Nursing-Home Move (Percent)

Age	Health Status		
	Excellent	Good	Poor
65	0.08	0.14	0.18
75	0.42	0.42	1.04
85	1.50	2.41	4.83
95	8.43	8.43	16.50

Source: Constructed based on HRS, 1996-2006.

bin (panel (b)). As we would expect, people in worse health have higher expenses, as do those with higher income, and OOP expenses grow dramatically with age, especially for higher-income individuals. The implication of our calibration is that a single individual of age 91, with median income and in poor health, has a 5.6% chance of spending $102,506 out of pocket per (2-year) period, in 2000 dollars. A similar individual of age 95 has a 5.5% chance of spending $154,650, while her high-income counterpart would have a 6% chance of spending $337,610 in 2 years. These numbers are in line with the findings in Ameriks et al. (2011).

B.1.4 Compulsory Nursing Home Moves

Using the pooled HRS sample from 1996-2006, we compute the two-year probability that a homeowner moves into a nursing home *and* simultaneously stops being a homeowner, conditional on the household's age and health status. This probability is important to consider, since moving out of the house requires selling the house and repaying the reverse mortgage. To measure this, in the data we consider only *permanent* moves to nursing homes concurrent with loss of homeownership, using the panel dimension to identify them, and interpret them as involuntary moves. Table 8 shows these probabilities for age 65, 75, 85, and 95. Not surprisingly, the probability is higher for less healthy individuals, and grows rapidly with age. There are two caveats to these estimates. First, not all permanent moves into nursing homes are involuntary in the data. This implies that our measure of the probability that a household is forced to move out is biased upward. In turn, this bias causes the estimate for extra-utility of homeownership to be upward biased. On the other hand, some older retirees might move to their children's homes instead of a nursing home. This consideration implies that the probability of a moving shock might be underestimated. The data limit how well we can identify these events; our estimates of the moving shock are the best that the data allow.

B.1.5 Housing, Conventional Mortgages, and Interest Rates

We allocate self-reported house values in our 2006 sample of 65-year-olds equally into 11 bins, and compute the median value of each bin to create a discrete house value distribution. Housing requires maintenance, whose cost is a fraction δ of the house size. δ is set at 1.7% per year, which is the average depreciation rate of residential structures in National Income and Product Accounts (NIPA). When a household sells the house, the sales cost, which is a fraction κ of the house value, has to be paid. The selling cost of a house (κ) is set at 6.6% of the value of the house. This is the estimate obtained by Greenspan and Kennedy (2007). Grueber and Martin (2003) report the median selling cost of 7.0% of the value of the house.

The interest rate is set at 2.58% per year. For conventional mortgage loans, we assume a borrowing premium (ι^m) of 1.69% annually. This is the average spread between 30-year conventional mortgage loans and 10-year Treasury bonds between 1996 and 2006.[28] Following the arbitrage condition standard in the literature, we assume that rent is the sum of maintenance costs and the conventional mortgage interest rate: $r_h = \delta + r + \iota^m$.

The collateral constraint for conventional mortgage loans is computed based on equation (10), which states that the expected debt service obligation never exceeds the share α of the household's income. In the data, mortgage lenders impose two types of debt-to-income (DTI) ratio. First is the front-end DTI ratio, which is applied only to mortgage and housing related expenses, such as mortgage, insurance, and property tax payments. The front-end DTI ratio is typically around 30-35%. The second is the back-end DTI ratio. The back-end DTI ratio includes not only payments included in the front-end ratio, but also payment of unsecured debt, student loans, and the like. The back-end DTI ratio is typically 43%. Since households in the model are retirees and are not likely to pay for student loans, and they carry relatively small balance of credit card debt, we model only equity debt and choose $\alpha = 0.35$.

See figure 6 for the resulting collateral constraints $\lambda^m_{i,b,s,m,p}$ in the model. They imply that households with lower income, and older households, have more restricted access to conventional mortgages; this aligns well with the findings of, e.g., Caplin (2002), who points out that most retirees fail the income requirements of conventional mortgage contracts, and thus are unable to borrow in that way.

To calibrate idiosyncratic house price shocks, we assume that the house price is normalized to one in the initial period, and follows an AR(1) process thereafter. To estimate the AR(1) process, we use CoreLogic HPI, which is a proprietary and confidential monthly ZIP code-level home price index. While this is not individual house price data, ZIP code-level granularity is sufficiently rich for our purposes, absent data on individual house prices over time. The CoreLogic HPI is a monthly repeat-sales single-family house price index, available from January 1976 to March 2015. For each ZIP code, the index is normalized to 100 in January 2000. Since we use all sales transactions, including distressed sales, short sales, and REO, we have house price data for 7,142 ZIP codes available.[29] According to CoreLogic, the index covers 57.3% of U.S. population. Since one period is two years in our model, we first construct biennial data by simple averaging after deflating the data using CPI. Then we run the following regression with the ZIP code-level biennial data:

$$\log p'_i = \bar{p} + \rho_p \log p_i + \epsilon \tag{21}$$

where $\epsilon \sim N(0, \sigma_p^2)$ and i indicates the ZIP code. $\bar{p}$ takes care of the average level of house prices. ρ_p is the persistence of the real house price index. σ_p is the standard deviation of the house price innovation. With the regression, we obtain $\rho_p = 0.859$ and $\sigma_p = 0.125$. These are the parameter values that we use for our calibration of the idiosyncratic house price shock. Adjusted R^2 is 0.764. In order to translate this estimation into the model, we discretize the AR(1) process into a biennial first-order Markov process. The resulting shocks are large, fluctuating between -29% and 41% of the median house value. The shocks are also persistent. For example, when the house price is 41% above the median level, the expected duration of staying at the level is 6.7 years.

Table 9: Income Levels[1]

Group	Group 1	Group 2	Group 3	Group 4	Group 5
Income	6,858	12,404	17,948	25,918	42,722

[1] Annualized after-tax income, 2000 US$. Source: HRS, 2006.

Table 10: Selected Characteristics of the Initial Distribution, Age 65, 2006

Health Status		Tenure Status		Financial Asset Position	
1 (excellent)	0.445	Homeowner	0.885	Saver	0.792
2 (good)	0.323	Renter	0.115	Borrower	0.208
3 (poor)	0.231				

Source: HRS, 2006.

B.1.6 Nonfinancial Income

We group nonfinancial income into five bins, summarized in table 9. We define nonfinancial income to include Social Security, pension, disability, annuity, and government transfer income, but net of taxes. Because some of our retirees are only partly retired, we also include labor income in this measure. However, labor income plays a small role in our sample, constituting on average 6% of total income. We compute the nonfinancial income of households aged 63-67 in the 2006 HRS sample ("age 65" in our calibration), allocate them into five quintiles, and compute the median income in each quintile. Finally, recall that we adjust nonfinancial income b using household size adjustment factor χ_s in the budget constraint of the model. We measure χ_s from the fact that in the median in our sample, the income of a couple household is 1.48 times larger than the same household's income after one spouse dies; the standard deviation of this number is 0.8.

B.1.7 Initial Type Distribution

The type distribution of age-65 retired households is constructed using the HRS 2006 wave. By taking the initial distribution directly from the data into the model, we capture empirically relevant correlations across household characteristics, e.g. the correlations between income, housing and financial wealth, health, household size and homeownership. Table 10 exhibits the dimensions of the initial distribution that we have not already discussed. 45% of the households are in excellent health. Homeownership rate is close to 90%. All retirees in the sample are net savers; however, in the language of the model, the financial asset position includes secured debt. By this measure, 21% of our sample are in net negative position.

B.2 Second-Stage Estimation: Comparison to Previous Estimates

Since in our previous work we used a model that was related to the model used in this paper, in this section we compare the parameter estimates between the two models.

[28] We use 10-year Treasury bonds because the average life of a 30-year mortgage in the U.S. is 7-10 years.

[29] We also run our regression excluding distressed sales, short sales, and REO and found that our regression results change little.

There are significant differences both in the current model, compared to that in Nakajima and Telyukova (2013), and in the data sample that we use to estimate the model. These differences are very likely to produce some differences in parameter estimates in the second-stage estimation. Nevertheless, many of the estimated parameters are similar in the two models. The consumption aggregator parameter η (0.76 here, 0.81 previously), coefficient of relative risk aversion σ (2.01 vs. 2.93 previously), consumption floor per adult $\underline{c}$ (\$13,919 in 2000 dollars vs. \$8,981 in 1996 dollars) are all quite close to each other, considering the underlying differences in the focus, features and methods in the two models.

The discount factor β is 0.91 in annual terms in the current model, and was 0.98 in our previous one. This implies less patient households, and affects household saving and debt. The difference likely stems from substantial differences in the models pertaining to the dynamics of housing prices. In particular, in Nakajima and Telyukova (2013), we modeled the 1996-2006 housing boom as the constant house price growth perfectly predicted by households. When households know that house price is rapidly growing, the high discount factor is needed to prevent households from overborrowing, relative to the data, in order to front-load the capital gains of housing price appreciation.

The differences of how we model house price dynamics, as well as financial benefits of homeownership, also generate the difference in the estimate of parameter ω_1, which measures the extra utility of homeownership relative to renting. In the current model, it is 4.9, while in our previous model it was 2.5. In addition to the trend house price growth in our previous work, in our previous work we explicitly modeled some tax benefits of ownership, such as capital gains taxation if one sells the house, which are absent in this model. These features encourage homeownership, even with a relatively low value of ω_1 in our previous work. Moreover, in the present model we have idiosyncratic house price shocks and nursing home move shocks, which create the impetus for selling the house whenever a high price shock is realized, or moving out involuntarily in the case of a move shock, and both of which drive the needed ω_1 up. The difference between the two parameter values indicates that the omitted financial forces, as well as idiosyncratic price and move shocks, play quantitatively important roles.

The most dramatic difference in the two models is in the calibration of the bequest motives. The parameter γ, which measures the strength of the bequest motive, is nearly three times higher in the current model relative to previous one, at 20.5 vs. 7.2, At the same time, the luxury bequest parameter ζ is significantly smaller in this model (7,619) relative to our previous model (45,714), counteracting the difference in γ. The reason lies in part in the difference of the targets, and hence identification strategies: because of our previous interest in studying the retirement saving puzzle itself, in the previous model, we matched net worth profiles by income bin. The bequest parameters in that model had to match the steep dissaving of lower income groups late in life, which both decreased the strength of the bequest motive, and increased the luxury bequest parameter. The distributions of debt, as well as bequests, are discussed in the text of this paper; we do not target the dissaving behavior of the low tail, which accounts for the changes of the bequest parameters.

B.3 Third Stage: Calibration of Reverse Mortgage Parameters

To conduct our experiments, into the calibrated baseline we now introduce reverse mortgages. In order to calibrate parameters that characterize RMLs, we rely on the terms of reverse mortgage contracts in the data. The upfront and per-period costs associated with insurance against house price shocks are $\nu^i = 2.0\%$, and $\iota^i = 1.25\%$ per year, respectively. Reverse mortgages are further characterized by the triplet $\{\lambda_i^r, \iota^r, \nu^r\}$, which captures the collateral constraint, the interest premium, and the upfront cost. We set the interest premium of reverse mortgages to be the same as conventional mortgages; $\iota^r = 1.69\%$ annually.

The upfront cost in the data appears to be about 5.0% of the house value. The origination fee is typically 2.0% of the house value up to $200,000 and 1.0% above it, with the cap of $6,000 and the floor of $2,500. Considering that most house values in the model, as in the data, are below $200,000, but half of the houses are below $100,000, where the floor of $2,500 binds, 2.5% is reasonable. The closing cost is typically around $2,000-3,000. Dividing the amount by the median house value in the sample, we get 2.5% as well. Adding these together, we get $\nu^r = 5.0\%$

We calibrate the age-dependent collateral constraint λ_i^r for reverse mortgages from the HUD schedules of HECM credit line growth, given our assumed mortgage interest rate of 5.7% (see e.g. AARP (2010)). These schedules imply that at age 65, a household can borrow 49.6% of the house value; by age 95, that number is 81.5%. The collateral constraint slackens with age because the remainder of home equity is reserved by the lender for repayment of expected interest and insurance cost that accumulates through the life of the loan; thus, the older the borrower is at the time of withdrawal from the credit line, the more credit she has access to. The entire collateral constraint schedule is the dashed pink line in figure 6. It is easy to see the benefits of RMLs. While the collateral constraint associated with conventional forward mortgages tightens up with age, RMLs offer collateral constraint that relaxes with age. The difference is more striking for homeowners with lower income and larger house.

C Additional Baseline Model Characteristics: Debt Distribution

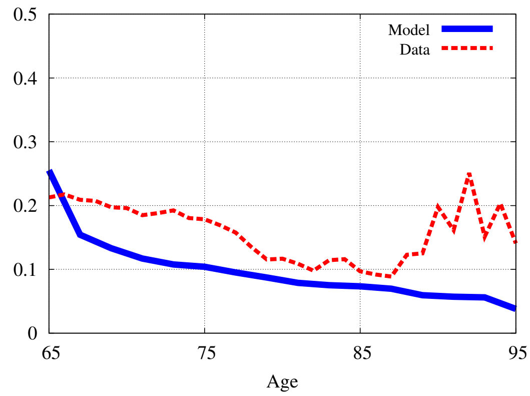
Figure 10 compares the median loan-to-value (LTV) ratios, as well as the distribution of LTV ratios, i.e. shares of households with LTV ratio above 10, 30, 50, 70 and 90 percent, between the model and the data. The LTV ratio is just the level of debt as a share of house value. The median LTV ratio is decently matched by the model, although as we discussed before, the model predicts faster initial decumulation of debt than its empirical counterpart. This is also true when we look at the proportion of households with LTV ratios above 10, 30, 50, 70 and 90%; the model implies that most households pay down debt faster than they do in the data, suggesting that the borrowing constraints are tighter in the model than the data. For example, over 30% of data households of age 75 have more than 30% LTV ratios, while that share in the model is around 5%. At age 85, around 60% of households have LTV ratios greater than 10%; in the model, that share is about 30%.

Figure 11 compares the median LTV ratios for each of the five income groups. They are consistent overall in the model and data, in the sense that dispersion of life-cycle profiles of the LTV ratios across income groups is not that large, and the profiles have similar slopes for the majority of the life cycle. The LTV profiles are somewhat flatter in the data, due to a notable initial decline in the model that is not mirrored in the data.

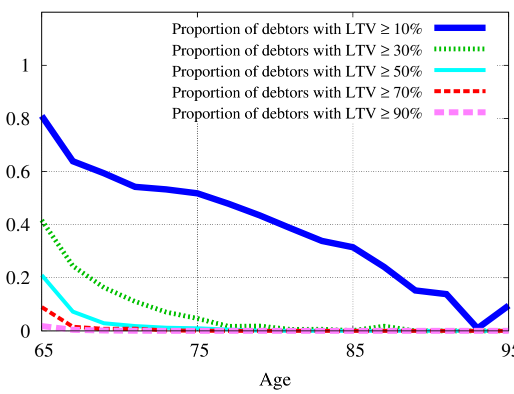
Figures 12 and 13 further break down the LTV distribution, by showing households with each LTV ratio (higher than 10, 30, 50, 70, 90 percent, respectively) by income bin. As we would expect given the above discussion, the model predicts faster decumulation of debt than the data for all levels of LTV.

D Age Profiles in Model with Reverse Mortgages

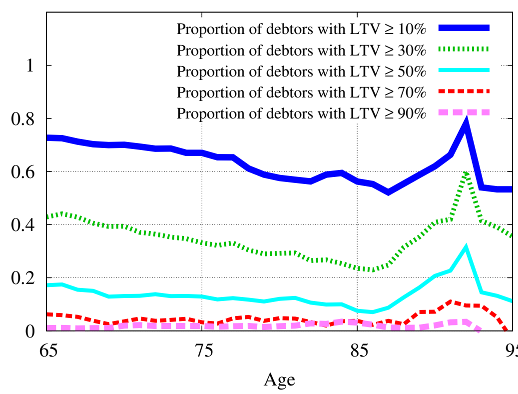
Figure 14 shows the age profiles discussed previously, in the model with reverse mortgages relative to the benchmark without. Given the low take-up rate of reverse mortgages, the aggregate effect



(a) Median LTV Ratio

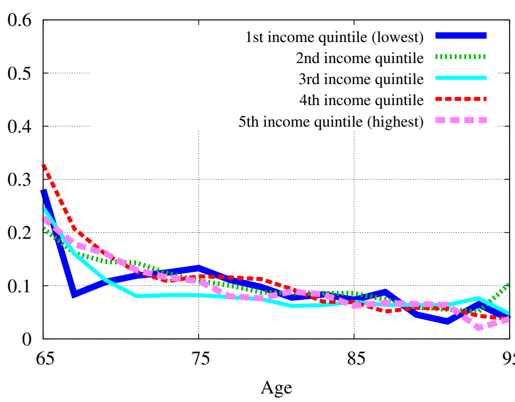


(b) Distribution of LTV Ratio, Model

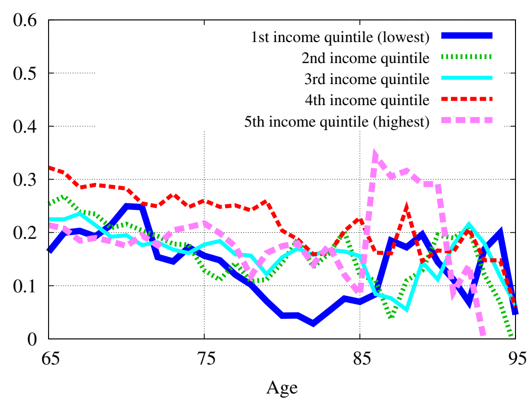


(c) Distribution of LTV Ratio, Data

Figure 10: Model vs. Data: Distribution of LTV Ratio



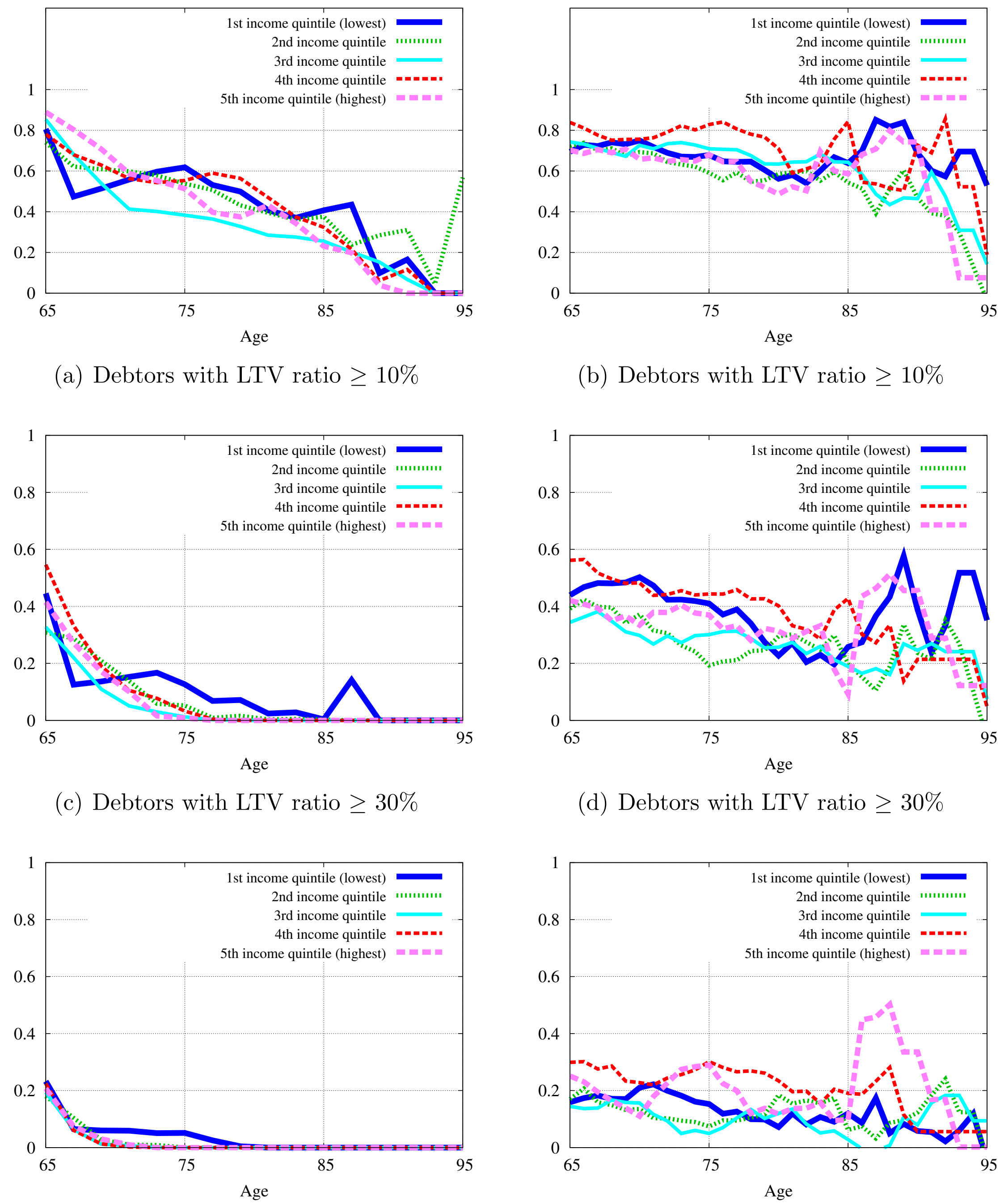
(a) LTV Ratio, Model



(b) LTV Ratio, Data

Figure 11: Model vs. Data: LTV Ratio, Median by Income Bin (1=Highest Income, 5=Lowest Income)

of reverse mortgages is small. Reverse mortgages enable people to stay in their house longer, which slightly raises the homeownership rate relative to the benchmark model, while increasing the



(a) Debtors with LTV ratio $\geq$ 10%

(b) Debtors with LTV ratio $\geq$ 10%

(c) Debtors with LTV ratio $\geq$ 30%

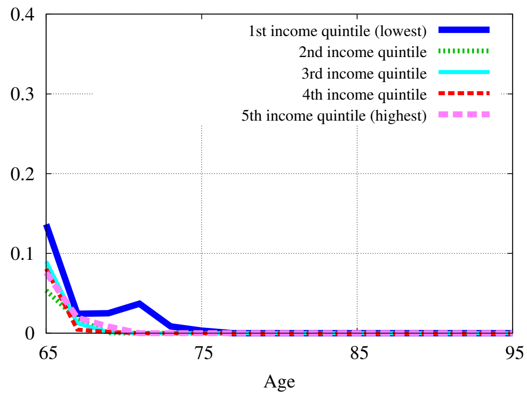
(d) Debtors with LTV ratio $\geq$ 30%

(e) Debtors with LTV ratio $\geq$ 50%

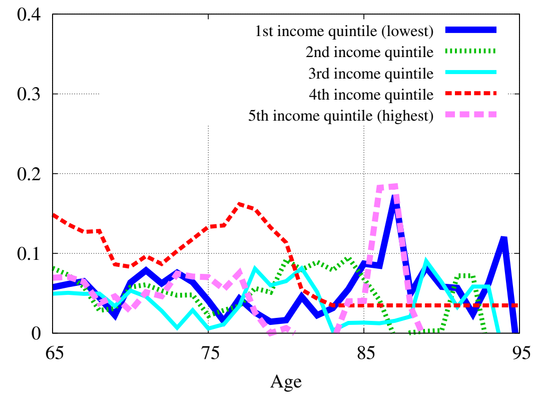
(f) Debtors with LTV ratio $\geq$ 50%

Figure 12: Model (Left) vs. Data (Right): LTV Ratio Distribution by Income Bin (1=Highest Income, 5=Lowest Income)

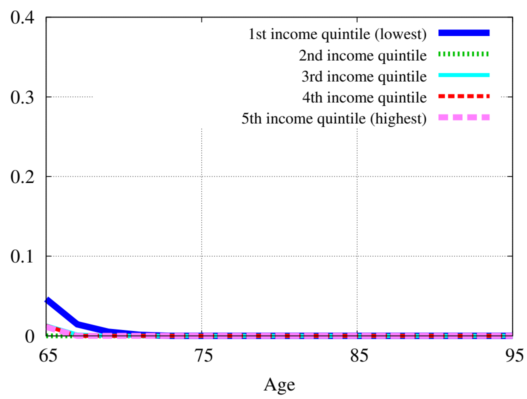
proportion of homeowners in debt, and thus slightly decreasing mean housing and financial assets.



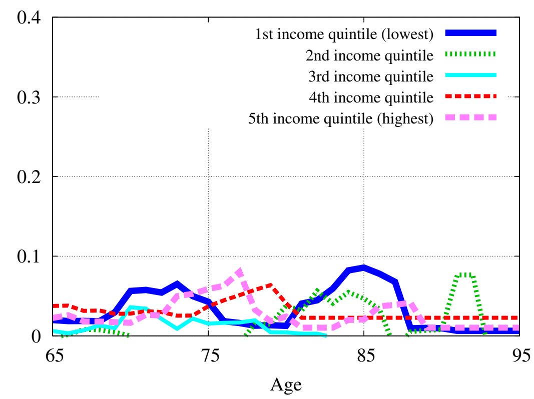
(a) Debtors with LTV ratio $\geq 70\%$



(b) Debtors with LTV ratio $\geq 70\%$



(c) Debtors with LTV ratio $\geq 90\%$



(d) Debtors with LTV ratio $\geq 90\%$

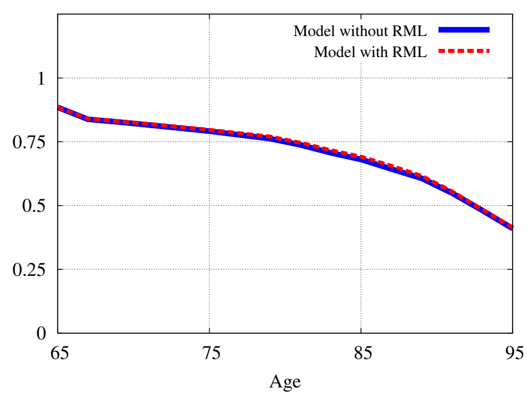
Figure 13: Model (Left) vs. Data (Right): LTV Ratio Distribution by Income Bin, Continued (1=Highest Income, 5=Lowest Income)

E Age Profiles in Experiment Economies

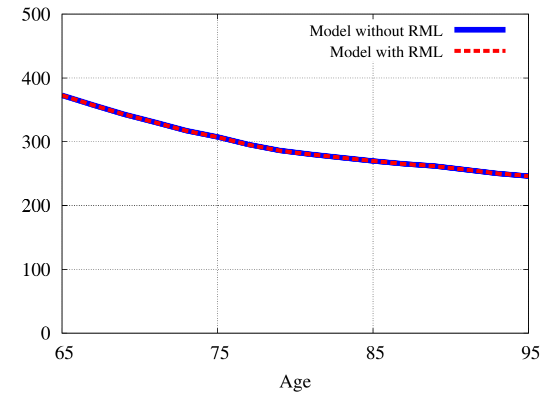
In this section, we include the age profiles that result from alternative economies in section 5.3, where we investigate the impact of various risks and bequest motives in the baseline economy.

Figure 15 demonstrates the age profiles in alternative models, where we shut down, in the benchmark model, bequest motives, house price shocks, medical expense risk and nursing home moving shocks. The most notable difference comes from the model without bequest motives. As we previously described, the bequest motive is the strongest motivation for saving late in life, including through homeownership. Absent the bequest motive, the homeownership rate declines nearly to zero, in spite of the fact that the utility parameter on homeownership does not change. In parallel, while they own their homes, homeowners borrow against reverse mortgages significantly more, with the borrowing activity peaking between ages 75 and 77. As a result, we also see a smooth decline in mean total assets and its components. A second notable difference comes from the economy with no nursing home moving shock. Not surprisingly, the absence of this shock means that retirees stay in their homes much later in life, with the homeownership rate profile becoming much flatter late in life. Consequently, the borrowing rate also increases, particularly at later ages.

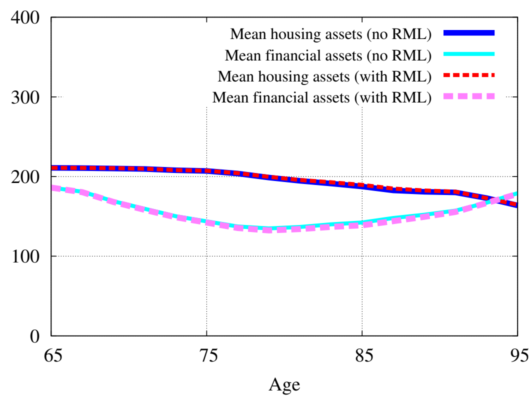
Figure 16 describes the effect of house price growth on the model's age profiles. With perpetually



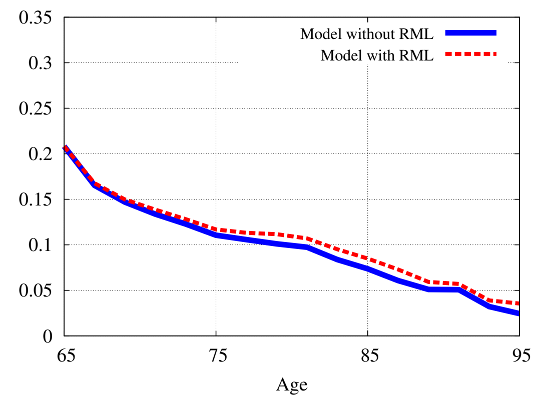
(a) Homeownership Rate



(b) Mean Total Assets



(c) Mean Housing and Financial Assets

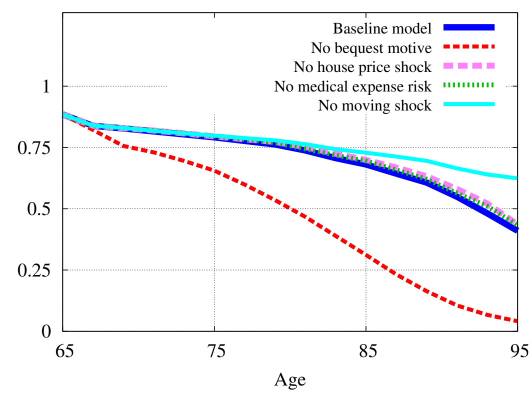


(d) Proportion in Debt

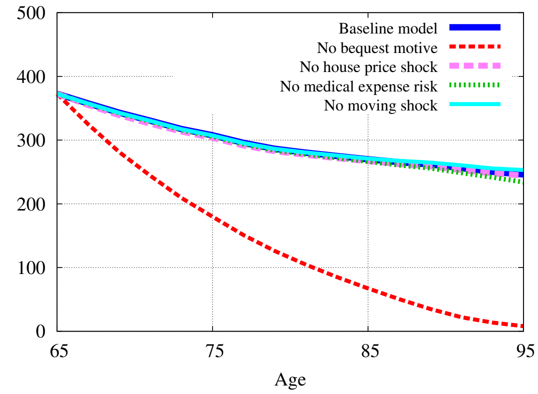
Figure 14: Age Profiles in Models with and without RMLs

rising house prices, homeowners are encouraged to borrow against their homes earlier in life, in part to finance more consumption up-front. However, many homeowners sell their house later in life, because the collateral constraint for conventional mortgages do not adjust with house price growth. At some point, homeowners decide to tap into the (appreciated) house value by selling their house, when the collateral constraint, which depends purely on repayment ability of homeowners and not house value, starts binding. As a result, in this economy, there is less debt and financial assets are higher later in life, and the overall net worth profile stays flat, buoyed by this reduction in borrowing and ever-increasing house prices for those that stay owners. On the other hand, when house prices are perpetually falling, homeowners borrow less to back-load consumption. Homeownership rate remains higher in this economy because homeowners borrow less, which make them less likely to be forced to sell their house in face with a large medical expense shock. Mean total asset, however, is lower than in the baseline, reflecting capital loss from house price depreciation.

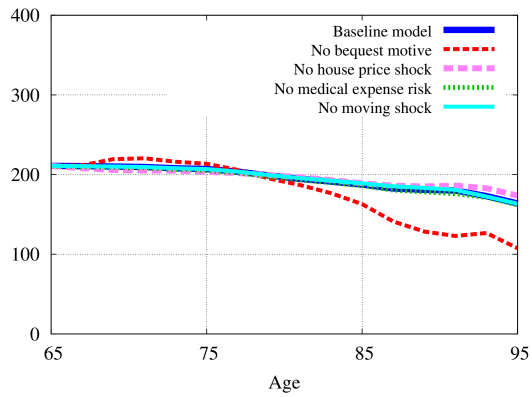
Figure 17 shows the life-cycle profiles of the alternative economy with interest rate risk. We find that adding this idiosyncratic shock does not alter the life-cycle profiles relative to the baseline model in a significant way.



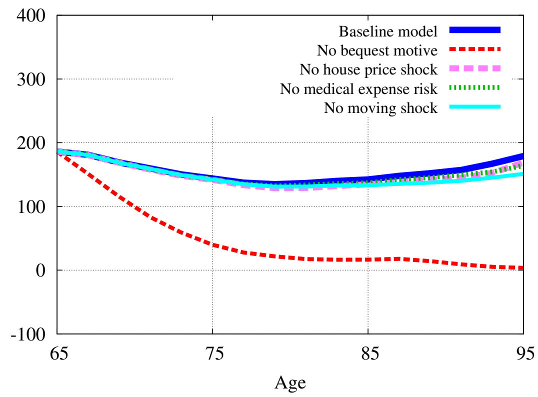
(a) Homeownership Rate



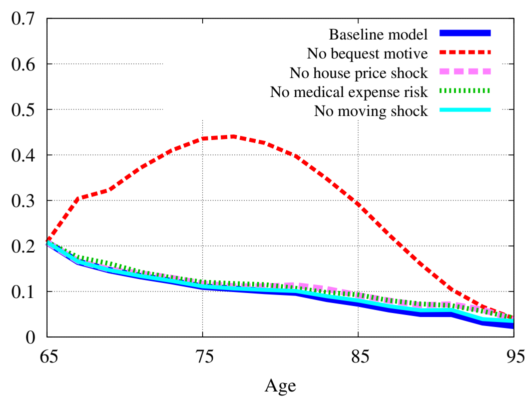
(b) Mean Total Assets



(c) Mean Housing Assets

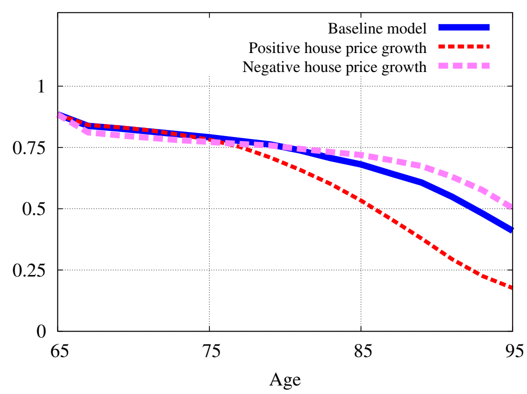


(d) Mean Financial Assets

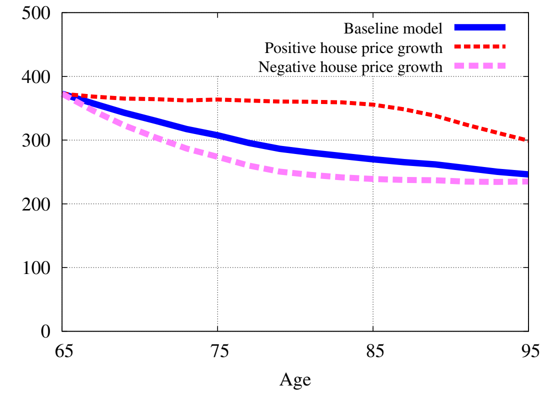


(e) Proportion in Debt

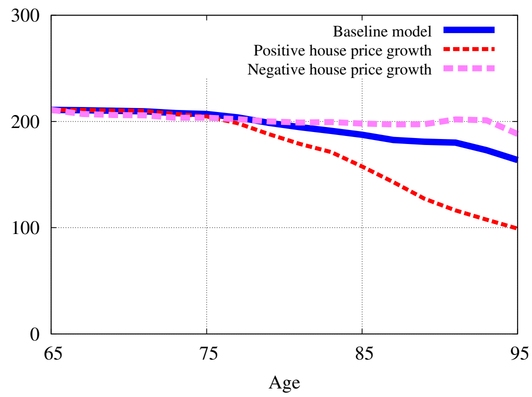
Figure 15: Effects of Uncertainty on Benchmark Age Profiles



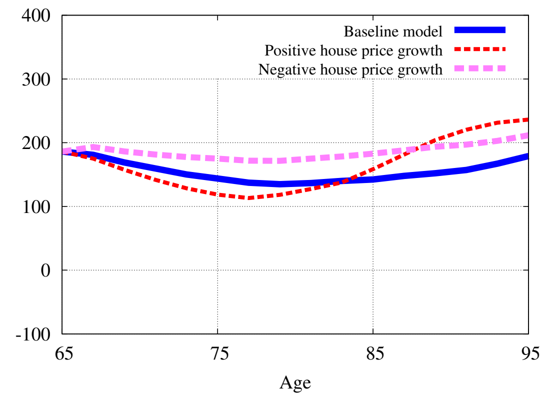
(a) Homeownership Rate



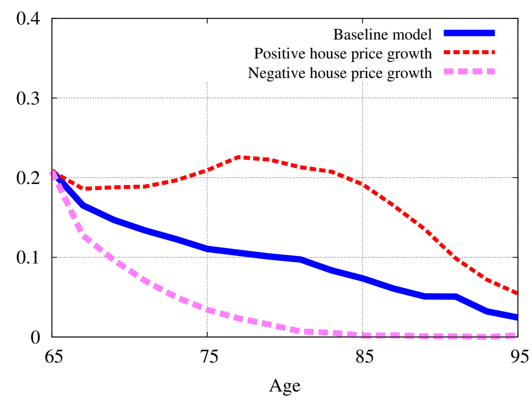
(b) Mean Total Assets



(c) Mean Housing Assets

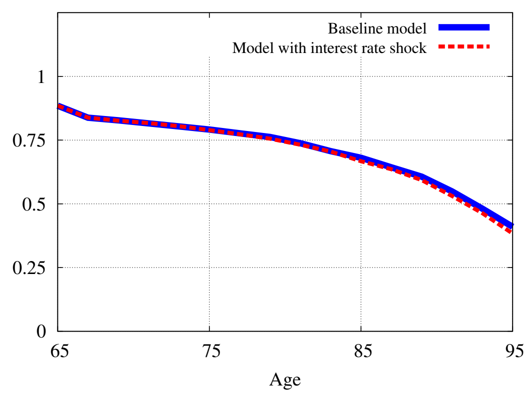


(d) Mean Financial Assets

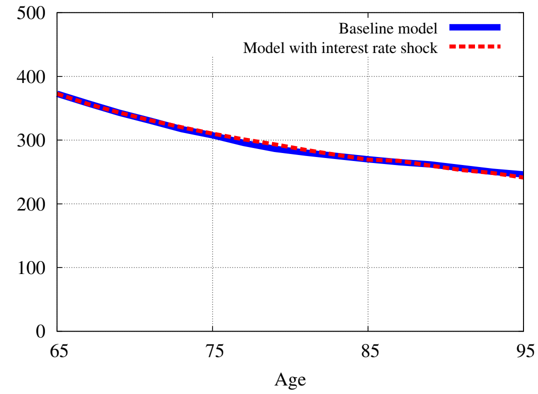


(e) Proportion in Debt

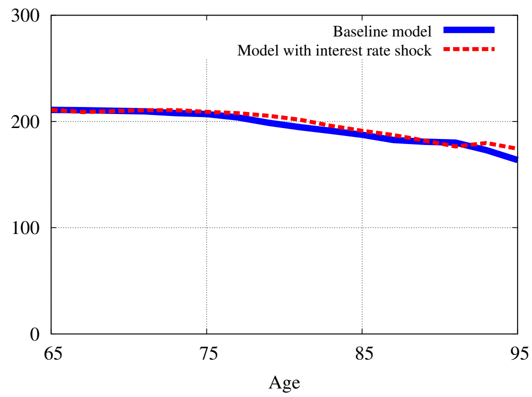
Figure 16: Effects of House Price Growth



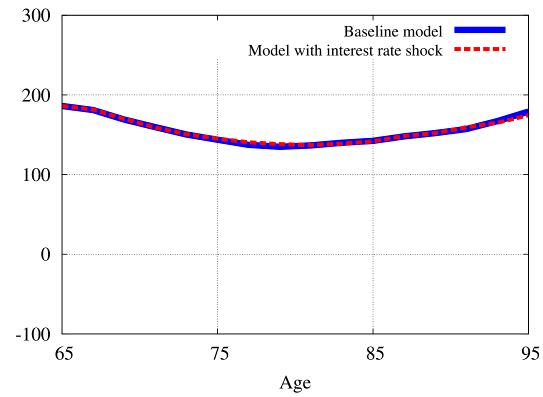
(a) Homeownership Rate



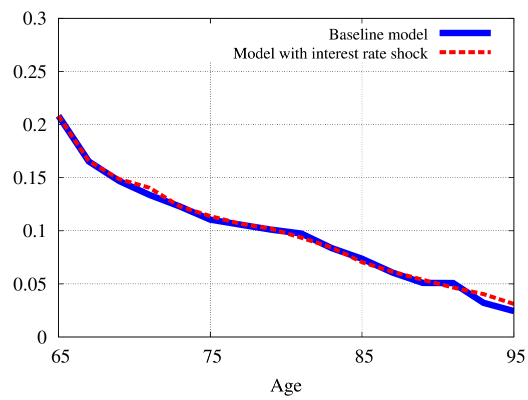
(b) Mean Total Assets



(c) Mean Housing Assets



(d) Mean Financial Assets



(e) Proportion in Debt

Figure 17: Age Profiles in Model with Interest Rate Shock