Reverse Mortgage Loans: A Quantitative Analysis*

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Abstract

Reverse mortgages allow elderly homeowners with limited income or financial wealth to borrow against their housing wealth without downsizing or moving out and becoming a renter. Although the proportion of eligible older homeowners using reverse mortgages has been increasing rapidly, that proportion is only 1.4 percent at present. In this paper, we analyze reverse mortgage loans in a rich structural life-cycle model of retirement. Our model can replicate the low take-up rate with a reasonable calibration. When the model is calibrated to match the observed take-up rate, the welfare gain from introducing reverse mortgages is sizable at $510 per household in the economy. Our model indicates that one-third of reverse mortgage borrowers use them for medical expenses, while remaining in their home. Through counterfactual experiments, we identify that, conditional on the existing RML contracts, bequest motives, moving shocks, and house price fluctuations all contribute to the observed low take-up rate, and that if households expect a housing boom, reverse mortgage demand increases, consistent with the data. However, the interest and insurance costs of reverse mortgages are important determinants of demand as well. Finally, the addition of the HECM Saver, a recently-introduced reverse mortgage contract with lower upfront costs designed to boost demand for reverse mortgages, fails to create that boost.

JEL classification: D91, E21, G21, J14
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1 Introduction

Reverse mortgage loans (RMLs) allow elderly 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 change the contract to make it more appealing to borrowers, little research has been done on reverse mortgages. This paper is intended to fill the void.

In previous work, Nakajima and Telyukova (2012) find that elderly homeowners become severely borrowing-constrained as they age, as it becomes very costly to access their home equity, and that these constraints force many homeowners to sell their homes, when faced with large expense shocks. In this environment, it seems that an equity borrowing product targeted toward the elderly would be able to relax that constraint, and hence benefit many homeowners. Empirical studies have come to similar conclusions. For example, Rasmussen et al. (1995) argue, using 1990 U.S. Census data, that almost 80 percent of homeowner households of age 69 or above should benefit from reverse mortgages. Using a more conservative approach, Merrill et al. (1994) find that about 9 percent of homeowner households over age 69 could benefit from reverse mortgage loans.[1] Despite the apparent benefits, only about 1.4 percent of elderly homeowners were using reverse mortgages in 2009, although this represents the highest level of demand to date, as the take-up of reverse mortgages increased dramatically between 2000 and 2009.

In this paper, we want to answer three key questions about reverse mortgages. First, we want to understand who benefits from reverse mortgages, and how large are welfare gains from introducing RMLs. Second, we ask, given the current available RML contract, what prevents retirees from taking the loans more frequently. Here we focus on retirees' environment, such as the nature of uncertainty that they face, and motivations, such as their bequest motives, which in previous work we established to be strong. Third, we want to understand what about the nature of the contract itself may prevent retirees from borrowing, and how this contract can be changed to make the RML more beneficial to retirees and this increase the take-up rate. We are motivated here by the frequently-advanced argument that the low take-up rate in the data is due to the high upfront fees of RMLs.

To answer these questions, we use a rich structural model of housing and saving/borrowing decisions in retirement based on Nakajima and Telyukova (2012), and study reverse mortgage loans through the lens of this model. 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 uncertainty in their life span, health, medical expenses, and house prices. The model is estimated to match life-cycle profiles of net worth, housing and financial assets, homeownership rate, and home equity debt. Into this model, we introduce reverse mortgages, to understand who takes RMLs and to quantify welfare gains to different types of households, and

[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 mortgage loans. 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 (specifically those who have no moved for the last 10 years) and who own their house free and clear benefit from reverse mortgages.

then conduct counterfactual experiments to answer the questions we posed above.

There are five key findings. First, the model can replicate the observed low take-up rate (1.4 percent) with a reasonable calibration. The households who use reverse mortgages tend to be low-income, low-wealth and poor-health households. Second, the ex-ante expected welfare gain from introducing RMLs into a world where they do not exist is sizable – equivalent to 510 dollars of one-time transfer for all households at age 65. Third, our model indicates that one-third of RML borrowers use reverse mortgages to pay for medical expenses while allowing them to remain in their home, where the alternative in the world without RMLs would have been to sell the house. Fourth, through counterfactual experiments, we identify that bequest motives, moving shocks, and house price fluctuations are the features of the environment that particularly discourage the elderly from using RMLs. Episodes of housing price booms, like the most recent one, can also boost demand for RMLs which parallels the boost we observe in the data. We also find that eliminating some of these environment features changes the dominant reasons for why homeowners take up RMLs; without bequest motives, for example, retirees not only take RMLs much more frequently, but also use them overwhelmingly for non-medical consumption. Fifth, on the contract side, we find that reducing flow costs of insurance against house price drops increases demand for RMLs. Strikingly, we find that retirees do not value the insurance component of RMLs, due to low borrowed amounts and availability of government-provided programs such as Medicaid, so that eliminating altogether this insurance against house price fluctuation increases RML demand by 43 percent. Thus, the oft-heard claim that large contract costs suppress RML demand is supported by our model. However, the HECM Saver loan, which was designed to respond to this claim by lowering the upfront cost of insurance in exchange for lowering the amount of equity accessible to the elderly, reduces demand for reverse mortgages in our model, so that adding it to already existing RML contracts is not likely to boost demand.

Our paper is related to four branches of the 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. Redfoot et al. (2007) explore better design of reverse mortgage loans 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 moving shocks and finds that, in spite of the benefits, many households would suffer from using reverse mortgages because of involuntary moving shocks. Our model can provide more realistic estimates of the share of beneficiaries of reverse mortgages, and the size of their welfare gains, by modeling various kinds of shocks that elderly households face, such as health status, medical expenditures, moving, and price of their house. Moreover, by taking the initial type distribution of elderly households from the data, our model can also predict the take-up rate and what types of households benefit from availability of reverse mortgage loans. Finally, we model the popular option of a line of credit reverse mortgage loan, while she assumes that borrowers have to borrow the maximum amount at the time of the closing. We find that this distinction in the form of the contract matters.

The second relevant strand of literature addresses saving motives for the elderly, or solving 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, 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. In out previous work, Nakajima and Telyukova (2012) emphasize the role of housing and collateralized borrowing in shaping the retirement saving, and find that bequest motives and homeownership motives are key in accounting for the retirement saving puzzle, in addition to medical expense uncertainty.

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

Finally, since one of the characteristics of the reverse mortgage loans is the availability of the tenure option, which is equivalent to annuitizing one's house, the paper is related to the "annuity puzzle" literature, although we do not treat the tenure option explicitly, since it is not prevalent in the data. Since the seminal work by Yaari (1965), many explanations for the low demand of annuities are proposed. Dushi and Webb (2004) argue that individuals already have significant amount of annuitized wealth in the form of Social Security and Defined Benefits pension plans. Mitchell et al. (1999) find that annuity prices are too high compared with actuarially fair prices in the U.S. data. Lockwood (forthcoming) find importance of bequest motives and the inability of annuitized wealth to be bequeathed. Turra and Mitchell (2004) study the role of medical expenditure risks. A recent paper by Pashchenko (2004) investigates the relative importance of the existing explanations of the annuity puzzle.

The remainder of the paper is organized as follows. Section 2 provides an overview of the reverse mortgages. Section 3 develops the structural model that we use for experiments. Section 4 discusses the calibration of the model. In Section 5, we use the model to analyze the demand for reverse mortgages through a number of counterfactual experiments. Section 6 concludes.

2 Reverse Mortgage Loans: An Overview

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

[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).

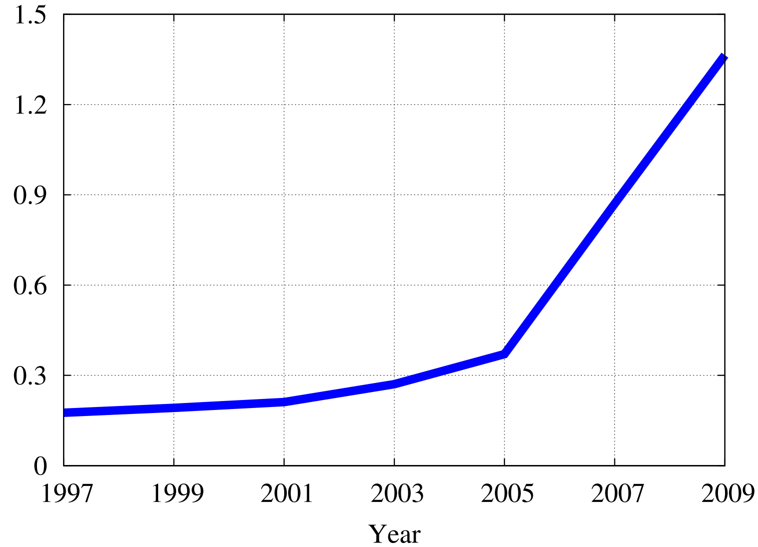


Figure 1: Percentage of Elderly (age≥65) Homeowners with Reverse Mortgages. Source: American Housing Survey, Various Waves.

The number of households with reverse mortgages is growing rapidly. Figure 1 shows the proportion of homeowner households of age 65 or above that had reverse mortgages between 1987 and 2009. Both the government-administered HECM loans and private mortgage loans are included. As the figure shows, the use of reverse mortgages was limited before 2000. In 2001, the share of eligible homeowners who had reverse mortgages was about 0.2 percent. This share increased rapidly since then, reaching 1.3 percent in 2009. Although the level is still low, the growth is all the more impressive if one considers that the popularity of reverse mortgages continued to rise even though the housing market and mortgage markets in general have been stagnating since the beginning of the ongoing housing market downturn.

Reverse mortgages differ from conventional mortgages in six major ways. First, as the name suggests, a reverse mortgage loan 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. That is why RMLs are targeted to older households.

Second, government-administered reverse mortgages (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] Finally, borrowers must have repaid all or almost all of their other mortgages at the time they take out a reverse mortgage. On the other hand, reverse mortgage loans do not have income or credit history requirements, because repayment is promised not based on the borrower's income but solely on the value of the house the borrower already owns. According to Caplin (2002), reverse mortgage loans are beneficial for elderly homeowners since

[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.

many of them fail to qualify for conventional mortgage loans because of income requirements.

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

Fourth, there is no pre-fixed due date; repayment of the borrowed amount is due only when the house is sold and all the borrowers move out, or when all the borrowers die. As long as at least one of the borrowers continues to live in the same house, there is no need to repay any of the loan amount. There is no gradual repayment with a fixed schedule, as with a conventional mortgage loan or line of credit; repayment is made in a lump sum from the proceeds from the sale of the house.

Fifth, HECM loans are non-recourse; borrowers are insured against substantial drops in house prices. Borrowers (or their heirs) can repay the loan either by letting the reverse mortgage 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, where the house value cannot cover the total costs of the loan, the borrowers are not liable for the remaining amount. The mortgage lender does not have to absorb the loss either, because the loss is covered by insurance, with the premium included as a part of a HECM loan cost structure.

Finally, there are various ways to receive payments from the RML. Borrowers can choose one of five options, and these can be changed during the life of the loan, at a small cost. The options are:

- **Tenure**: Borrowers continue to receive a fixed amount as long as one of the borrowers continues to live in the same house.
- **Term**: Borrowers receive a fixed amount for a fixed length of time.
- **Line of credit**: Borrowers can flexibly draw cash, up to a limit, during a pre-determined drawing period.
- **Modified tenure**: Combination of the tenure option and the line of credit option.
- **Modified term**: Combination of the term option and the line of credit option.

Of the payment options listed, the line of credit option has been the most popular. HUD reports that the line of credit plan is chosen either alone (68 percent) or in combination with the tenure or term plan (20 percent). In other words, it appears that older homeowners use reverse mortgages mainly to flexibly withdraw cash out of accumulated home equity.

How much can one borrow using a reverse mortgage? Let's start with the case in which borrowers receive a one-time cash payment under a reverse mortgage. The starting point is the appraised value of the house, but there is a federal limit for a government-administered HECM loan. Currently, the limit is 625,500 dollars for most states.[6] The less of the appraised value and the limit is called the

[6]The limit was raised in 2009 from 417,000 dollars as part of the Housing and Economic Recovery Act of 2008. The 625,500 limit is valid until December 2011.

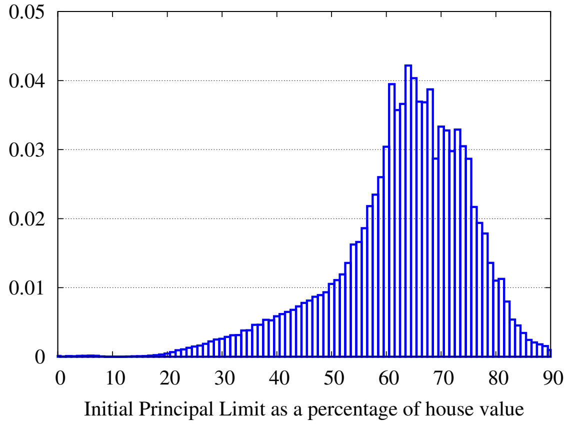


Figure 2: Initial Principal Limit Distribution. Source: Shan (2011).

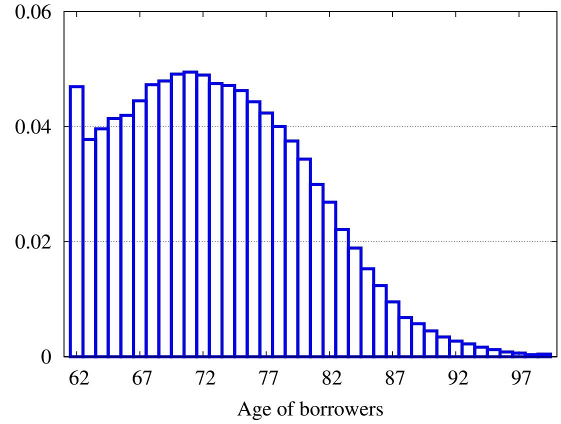


Figure 3: Age at Reverse Mortgage Origination. Source: Shan (2011).

Maximum Claim Amount (MCA).[7] Reverse mortgage borrowers cannot receive the full amount of the MCA because there are various costs that have to be paid from the house value as well. There are two types of costs: non-interest costs and interest costs. Moreover, if borrowers have outstanding mortgages, part of the new mortgage loan will be used to pay off the outstanding balance of other mortgages. 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 percent of the appraised value of the house (or the limit if the value is above the limit) initially and 1.25 percent 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 plus margin charged by the mortgage lender, and there is typically 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. The Net Principal Limit is calculated by subtracting various upfront costs from the IPL.

The IPL, which is the amount available for reverse mortgage borrowers at the time of closing, is thus larger the larger the house value, the lower the outstanding mortgage balance, the older the borrower, and the lower the interest rate. Figure 2 shows the distribution of the initial principal limit as a percentage of the house value against which mortgage loans are borrowed. It is clear that many homeowners can borrow around 60 to 70 percent of the appraised house value using reverse mortgages. If the term option is chosen, the total loan amount is divided depending on the number of times the borrower receives cash. With the tenure option, the amount of cash payment per period is determined by the number of times the borrowers are *expected* to receive cash.

To understand who the reverse mortgage borrowers are, Shan (2011) looked at the characteristics of areas with more reverse mortgage borrowers and investigated how those characteristics changed

[7]Private mortgage lenders offer jumbo reverse mortgage loans, which allow borrowers to cash out more than the federal limit. However, 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 percent to 1.25 percent in October 2010.

over time. She found that areas with more reverse mortgage borrowers tend to have lower household income, higher house value, relatively higher homeowner costs, and lower credit scores. The median house value among reverse mortgage borrowers was $222,000$ dollars in 2007, which was about 25 percent higher than the median house value of all older homeowners ($175,000$ dollars). Figure 3 shows the age distribution of borrowers at the time of mortgage origination, during 2003-2007. Observe that there is a spike at age 62, which is the first eligibility age. Shan (2011) also showed that the distribution is shifting to the left over time, implying that reverse mortgage borrowers got younger, with the spike at age 62 becoming more pronounced.

3 Model

We set up the decision problem of retired homeowners and renters, based on our previous work (Nakajima and Telyukova (2012)). Renters face a simple decision of consumption, savings, and the size of the house to rent each period, subject to several types of uninsurable idiosyncratic uncertainty. Renters are subject to idiosyncratic shocks to health status (including mortality), medical expenditures, and the house price. We do not allow renters to buy a house and become homeowners. This assumption is motivated by our data (Health and Retirement Study), in which the proportion of retired households switching from renting to owning is small.

Homeowners choose how much to consume and save, and whether to stay in their house or move out and become a renter. Homeowners face the same set of shocks as renters, and, in addition, may exogenously be forced to move out of their house. This shock is intended to capture the possibility of moving involuntarily into a nursing home as a result of deteriorating health. In addition, homeowners can borrow against their home equity using traditional mortgage arrangements, but this collateral constraint is age-dependent, and tightens with age, as we found in our previous work.

Into this benchmark, we introduce reverse mortgage loans for homeowners, which we model as a line of credit, since this is the most frequently used option. 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 life-of-credit 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, it seems that 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, in which case the tenure option can be roughly replicated by the line-of-credit option as well. Homeowners utilizing different types of reverse mortgages face different constraints over the life-cycle. In addition, homeowners who use reverse mortgages cannot also borrow using a traditional mortgage, which mirrors the restriction in the data.

We will characterize the problem recursively. The set of state variables for a household is consists of its age i, pension income b, health status m, medical expenditures x, house price p, house size h, and financial asset holdings a. In addition, homeowners also have as state variables the moving shock n and the reverse mortgage indicator k. Specifically, $n = 1$ means a homeowner is hit by a moving shock and is forced to move out of his house. $n = 0$ means the homeowner is not hit by such shock. $k = 0$ means a homeowners does not own a reverse mortgage, while $k = 1$ means the homeowner owns a reverse mortgage. Following convention, we use a prime to denote a variable in the next period.

3.1 Renters

We start with the renter's decision problem, the simpler of the two household types, since renting is the absorbing tenure state (remember a renter cannot become a homeowner by assumption). In order to save notation, we use $h = 0$ to represent a renter. $h > 0$ means that the household is a homeowner with a house size of h. The renter's problem is as follows:

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

subject to:

$$\tilde{c} + a' + x\chi_i + r_h \tilde{h} = (1 + r)a + b\chi_i \tag{2}$$

$$c = \begin{cases} \max\{\underline{c}\chi_i - r_h \tilde{h}, \tilde{c}\} & \text{if } a' = 0 \\ \tilde{c} & \text{otherwise} \end{cases} \tag{3}$$

Naturally a renter has no house ($h = 0$), and no reverse mortgage ($k = 0$). A renter, taking the states as given, chooses consumption (c), savings (a'), and the size of the house to rent ($\tilde{h}$). (m, x, p) are the shocks. $\tilde{h}$ is chosen from a discrete set $H = \{h_1, h_2, ..., h_{\overline{H}}\}$, where h_1 is the smallest and $h_{\overline{H}}$ is the largest house available. a' is assumed to be non-negative. In other words, only home equity borrowing is available in the model. This choice is motivated by the data, where holdings of unsecured debt among retirees are small.[9] $\pi^{m}_{i,m,m'}$, $\pi^{x}_{i+1,m',b,x'}$, and $\pi^{p}_{p,p'}$ denote the transition probabilities of (m, x, p), respectively. $m > 0$ indicates health levels, with a higher m for better health. The transition of m also includes mortality risk; $m' = 0$ implies that the renter does not survive to the next period. Note that health shocks are age-dependent, and medical expense shocks depend on the current health, age and income of the household. Both are motivated by the data.

The current utility of the renter depends on non-housing consumption c, services generated by the rental property (which are assumed to be linear in the size of the rental property $\tilde{h}$), and tenure status o. Age i in the utility captures the adjustment we make by the age-specific average household size factor, which weights utility of couples differently from utility of single households. This factor captures the fact that a younger retired household is more likely to be a couple, and we include couples as well as singles in our data sample.

$o = 1$ represents ownership, while $o = 0$ indicates renting. The tenure status in the utility function is intended to capture the additional private value of owned housing. The continuation value is discounted by the subjective discount factor β. Following De Nardi (2004), we assume 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'), rent payment with the rental rate r_h, and medical expenditures x,

[9] We discuss many of our model assumptions in more detail in Nakajima and Telyukova (2012)

which are multiplied by age-specific average household size factor χ_i discussed above. The right-hand side includes financial asset holdings and interest income $(1+r)a$ and pension income b, again modified by the age-specific household size factor χ_i. Equation (3) represents the consumption floor, which is provided by the government net of the rental payment. If the sum of $\tilde{c}$ implied in the budget constraint (2) and the rent payment $r_h\tilde{h}$ is lower than the consumption floor ($\underline{c}$) multiplied by the age-specific household size factor, the household can consume $\underline{c}\chi_i$, net of the rent payment, with the support from the government, if the household runs down its savings ($a' = 0$). This model feature represents Medicaid in the data.

3.2 Homeowners Without a Reverse Mortgage

First we describe the problem of a homeowner without a reverse mortgage ($k = 0$). If the homeowner is hit by a moving shock ($n = 1$), he has to sell the house and move out, i.e. become a renter in the language of the model (V_0). Otherwise ($n = 0$), he can choose whether to stay in the same house (V_1), stay in the house and take out a reverse mortgage (V_2), or sell the house and become a renter (V_0). These two scenarios are represented by the following two expressions:

$$V(i,b,m,x,p,n=1,k=0,h,a) = V_0(i,b,m,x,p,k=0,h,a) \quad \text{(Move out involuntarily)} \tag{4}$$

$$V(i,b,m,x,p,n=0,k=0,h,a) = \max \begin{cases} V_0(i,b,m,x,p,k=0,h,a) & \text{(Move out)} \\ V_1(i,b,m,x,p,k=0,h,a) & \text{(Stay)} \\ V_2(i,b,m,x,p,k=0,h,a) & \text{(Stay, take RML)} \end{cases} \tag{5}$$

The component value functions are defined below. For an owner with no reverse mortgage, who decides to move out, or is forced to do so,

$$V_0(i,b,m,x,p,k=0,h,a) = \max_{a' \geq 0} \Bigg\{ u(i,c,h,1) + \beta \sum_{m'>0} \pi^m_{i,m,m'} \sum_{x'} \pi^x_{i+1,m',b,x'} \sum_{p'} \pi^p_{p,p'} V(i+1,b,m',x',p',k=0,h=0,a') + \beta \pi^m_{i,m,0} v(a') \Bigg\} \tag{6}$$

subject to:

$$\tilde{c} + a' + x\chi_i + \delta h = (1-\kappa)hp + (1+\tilde{r})a + b\chi_i \tag{7}$$

$$c = \begin{cases} \max\{\underline{c}\chi_i, \tilde{c}\} & \text{if } a' = 0 \\ \tilde{c} & \text{otherwise} \end{cases} \tag{8}$$

$$\tilde{r} = \begin{cases} r + \iota^m & \text{if } a < 0 \\ r & \text{otherwise} \end{cases} \tag{9}$$

Compared to the problem of the renter, the new features here are that the owner, in the current period, has to pay a maintenance cost δ to keep the house from depreciating, and pay the selling cost κ. In addition, if the homeowner is in debt at the time of house sale, the interest rate has a mortgage premium ι^m on it, as defined in (9), but going forward he can no longer borrow. Finally, the consumption floor does not include a rental payment in the current period because the owner still lives in his 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

$$V_1(i,b,m,x,p,k=0,h,a) = \max_{a' \geq (1-\lambda_i^m)h} \Big\{ u(i,c,h,1)$$
$$+ \beta \sum_{m'>0} \pi^m_{i,m,m'} \sum_{x'} \pi^x_{i+1,m',b,x'} \sum_{p'} \pi^p_{p,p'} \sum_{n'} \pi^n_{i+1,m',n'} V(i+1,b,m',x',p',n',k=0,h,a')$$
$$+ \beta \pi^m_{i,m,0} \sum_{p'} \pi^p_{p,p'} \upsilon((1-\kappa)hp' + a') \Big\} \quad (10)$$

subject to:

$$c + a' + x\chi_i + \delta h = (1+\tilde{r})a + b\chi_i \quad (11)$$
$$\tilde{r} = \begin{cases} r + \iota^m & \text{if } a < 0 \\ r & \text{otherwise} \end{cases} \quad (12)$$

The differences from previous equations are that this homeowner can borrow on a traditional mortgage with the age-dependent collateral constraint λ_i^m, and in the event of death, the estate includes the value of the house, net of the selling cost to liquidate it ($\kappa hp'$). In addition, the continuation value for this homeowner includes the probability $pi^n_{i+1,m',n'}$ of the involuntary moving shock, which depends on age and health. It is natural to assume that the involuntary moving shock depends on age and health status since it is intended to capture the incident of involuntary moving into a nursing home. Finally, as long as the household remains a homeowner, he does not utilize the consumption floor. In other words, we assume no homestead exemption.[10] Next is the problem of a homeowner who stays in the house and takes out a reverse mortgage going forward:

$$V_2(i,b,m,x,p,k=0,h,a) = \max_{a' \geq (1-\lambda^r)h} \Big\{ u(i,c,h,1)$$
$$+ \beta \sum_{m'>0} \pi^m_{i,m,m'} \sum_{x'} \pi^x_{i+1,m',b,x'} \sum_{p'} \pi^p_{p,p'} \sum_{n'} \pi^n_{i+1,m',n'} V(i+1,b,m',x',p',n',k=1,h,a')$$
$$+ \beta \pi^m_{i,m,0} \sum_{p'} \pi^p_{p,p'} \upsilon(\max\{(1-\kappa)hp' + a', 0\}) \Big\} \quad (13)$$

subject to:

$$c + a' + x\chi_i + \delta h + (\nu^i + \nu^r)h = (1+\tilde{r})a + b\chi_i \quad (14)$$
$$\tilde{r} = \begin{cases} r + \iota^m & \text{if } a < 0 \\ r & \text{otherwise} \end{cases} \quad (15)$$

[10] In Nakajima and Telyukova (2012), we model the homestead exemption as the consumption floor is meant to capture Medicaid. In that paper, we find that Medicaid is not a quantitatively important reason for homeowners to stay in their homes – i.e. unless they are in a very advanced age, homeowners do not stay in their homes just to qualify for Medicaid. In addition, in the data, relatively few owners 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. Thus in this model, we abstract from the exemption.

The collateral constraint of this household obtaining a reverse mortgage is λ^r, which does not depend on age. 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.

3.3 Homeowners With a Reverse Mortgage

If a household already has a RML ($k = 1$), and is hit by a moving shock ($n = 1$), he has to sell the house and move out. Otherwise ($n = 0$), he can choose whether to stay in the same house, or sell and become a renter.

$$V(i, b, m, x, p, n = 1, k = 1, h, a) = V_0(i, b, m, x, p, k = 1, h, a) \quad \text{(Move out involuntarily)} \tag{16}$$

$$V(i, b, m, x, p, n = 0, k = 1, h, a) = \max \begin{cases} V_0(i, b, m, x, p, k = 1, h, a) & \text{(Move out)} \\ V_1(i, b, m, x, p, k = 1, h, a) & \text{(Stay, keep RML)} \end{cases} \tag{17}$$

The homeowner with a reverse mortgage who chooses to sell solves

$$V_0(i, b, m, x, p, k = 1, h, a) = \max_{a' \geq 0} \Big\{ u(i, c, h, 1) + \beta \sum_{m'>0} \pi^m_{i,m,m'} \sum_{x'} \pi^x_{i+1,m',b,x'} \sum_{p'} \pi^p_{p,p'} V(i + 1, b, m', x', p', k = 0, h = 0, a') + \beta \pi^m_{i,m,0} v(a') \Big\} \tag{18}$$

subject to:

$$\tilde{c} + a' + x\chi_i + \delta h = \tilde{r}a + b\chi_i + \max\{(1 - \kappa)hp + a, 0\} \tag{19}$$

$$c = \begin{cases} \max\{\underline{c}\chi_i, \tilde{c}\} & \text{if } a' = 0 \\ \tilde{c} & \text{otherwise} \end{cases} \tag{20}$$

$$\tilde{r} = \begin{cases} r + \iota^i + \iota^r & \text{if } a < 0 \\ r & \text{otherwise} \end{cases} \tag{21}$$

Here, the only new feature is the max operator in the budget constraint, which captures that moving out entails repayment of the reverse mortgage, as per current legislation. Notice that current RML borrowers 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. In addition, the interest rate payment for the loan includes flow interest and insurance costs that have accumulated during the term of the loan. Finally, the homeowner with a reverse mortgage who chooses to stay in his house solves the following problem:

$$V_1(i, b, m, x, p, k = 1, h, a) = \max_{a' \geq -(1-\lambda^r)h} \Big\{ u(i, c, h, 1) + \beta \sum_{m'>0} \pi^m_{i,m,m'} \sum_{x'} \pi^x_{i+1,m',b,x'} \sum_{p'} \pi^p_{p,p'} \sum_{n'} \pi^n_{i+1,m',n'} V(i + 1, b, m', x', p', n', k = 1, h, a') + \beta \pi^m_{i,m,0} \sum_{p'} \pi^p_{p,p'} v(\max\{(1 - \kappa)hp' + a', 0\}) \Big\} \tag{22}$$

subject to:

$$c + a' + x\chi_i + \delta h = (1 + \tilde{r})a + b\chi_i \tag{23}$$

$$\tilde{r} = \begin{cases} r + \iota^i + \iota^r & \text{if } a < 0 \\ r & \text{otherwise} \end{cases} \tag{24}$$

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 reverse mortgage loan balance in the model as capturing the co-existence of the inability to pay down the RML with saving in a financial asset. However, we are thus possibly understating the cost of RML borrowing, because the interest rates earned on saving are typically lower than interest and insurance costs of reverse mortgages, a spread that our model does not capture.

4 Calibration

We perform the baseline calibration on the version of the model without reverse mortgages, and then add RMLs to this calibrated benchmark to understand the role that reverse mortgages play for retirees, as well as the nature of demand for them. Calibration of parameters associated with RMLs is discussed in Section 4.3. To calibrate the baseline case, we use a two-stage estimation procedure. In the first stage we calibrate all the parameters that we can directly observe in the data, while in the second stage, we estimate the rest of the parameters to match relevant age profiles of asset holdings that we construct in the data. Section 4.1 covers the first stage, and Section 4.2 is associated with the second stage. We base the second-stage estimation on cross-sectional age profiles, rather than cohort life-cycle profiles as in our past work. The cost of doing this is that we cannot account for cohort effects in the data, because our model lacks them due to stationarity. However, we gain the ability to characterize the entire life cycle in the data, which is not possible in the HRS for a single cohort, since it has only about 14 years (8 waves) of usable data at this point. We construct the cross-sectional age profiles of homeownership rates, net worth, housing versus nonhousing assets, and home equity debt among retirees from the 2006 wave of the Health and Retirement Study (HRS), which is a biennial panel survey of households of age 50 and above. Since our sample of interest is retirees, we focus on those in the data who are age 65 and above, and self-report as retired, and we include both couples and single households.

To match the HRS, the model period is set to two years. Households are born in the model at age 65, and can live up to 99 years of age. Table 1 summarizes the calibrated parameter values. The first panel of the table covers the parameters estimated in the first stage, while the second panel covers the parameters estimated in the second stage. The third panel of table 1 covers the parameters associated with reverse mortgage loans, which will be discussed in Section 4.3.

Table 1: Calibration Summary: Model Parameters

Parameter	Description	Value
First-Stage Estimation		
r	Saving interest rate[1]	0.040
ι_m	Mortgage interest premium[1]	0.016
δ	Maintenance cost[1]	0.017
κ	Selling cost of the house	0.066
ρ_p	Persistence of house price shock[1]	0.811
σ_p	Standard deviation of house price shock[1]	0.142
Second-Stage Estimation		
β	Discount factor[2]	0.922
η	Consumption aggregator	0.724
σ	Coefficient of RRA	2.068
ω_1	Extra-utility from ownership	4.676
γ	Strength of bequest motive	3.926
ζ	Curvature of utility from bequests	13.248
$\underline{c}$	Consumption floor per adult[2]	13.681
λ_{65}	Collateral constraint for age-65	0.396
λ_{75}	Collateral constraint for age-75	0.789
λ_{85}	Collateral constraint for age-85	0.968
λ_{99}	Collateral constraint for age-99	1.016
RML-Related		
ν_r	Upfront cost of RML	0.096
ν_i	Upfront cost of RML insurance	0.020
ι_r	Interest margin for RML[1]	0.016
ι_i	RML insurance premium[1]	0.013
λ_r	Collateral constraint for RML	0.200

[1] Annualized value.
[2] Biennial value.

4.1 First-Stage Estimation

4.1.1 Preferences

Households use discount factor β to discount future value. The following period utility function with constant relative risk aversion is used.

$$u(i,c,h,o) = \frac{\left(\left(\frac{c}{\psi_i}\right)^{\eta}\left(\frac{\omega_o h}{\psi_i}\right)^{1-\eta}\right)^{1-\sigma}}{1-\sigma} \tag{25}$$

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 attached to owning a house. For renters ($o = 0$), ω_0 is normalized to unity. For a homeowner ($o = 1$),

Table 2: Income Levels[1]

Group	Group 1	Group 2	Group 3	Group 4	Group 5
Income	8,028	14,517	21,330	30,273	48,920

[1] Annualized after-tax income in 2000 dollars. Source: HRS 2006 wave.

$\omega_1 > 1$ 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_i is the age-specific adjustment factor for household size. It is constructed by computing the family equivalence scale associated with the average proportion of single and couple households at each age.[11]

A household gains utility from leaving bequests. When a household dies with the consolidated wealth of a, the household's utility function takes the form:

$$v(a) = \gamma \frac{(a+\zeta)^{1-\sigma}}{1-\sigma}. \tag{26}$$

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

4.1.2 Nonfinancial Income

We use five levels of nonfinancial income. Table 2 summarizes five nonfinancial income bins. Our definition of nonfinancial income includes Social Security, pension, disability, annuity, and government transfer income. Because some of our retirees are only partly retired, we also include labor income in this measure. However, labor income plays a small role in our sample, constituting on average about 6 percent of total income. We compute the nonfinancial income of households of age between 63 and 67 in 1996 HRS sample, sort them, allocate them into five bins equally, and compute the median income in each quintile. Recall that we adjust the nonfinancial income using household size adjustment factor χ_i in the budget constraint of the model. χ_i is constructed using the fact that income of couples is 1.5 times larger, on average, than that of single households.[12]

4.1.3 Health Status and Mortality Risk

As in Nakajima and Telyukova (2012), we group the five self-reported health status categories in the HRS into three categories: excellent, good, and poor. We also add death as one of the health states. Then we compute the transition probabilities across health states, including probability of death, using HRS sample pooled across all waves. Table 3 shows the resulting transition probabilities for people of age 65, 75, 85, and 95. It is easy to see that (1) mortality rate is higher for older and less healthy households, (2) health status is generally persistent, but (3) the persistence weakens with age as the health deteriorates gradually (shifting to worse health status) and (4) the mortality rate increases.

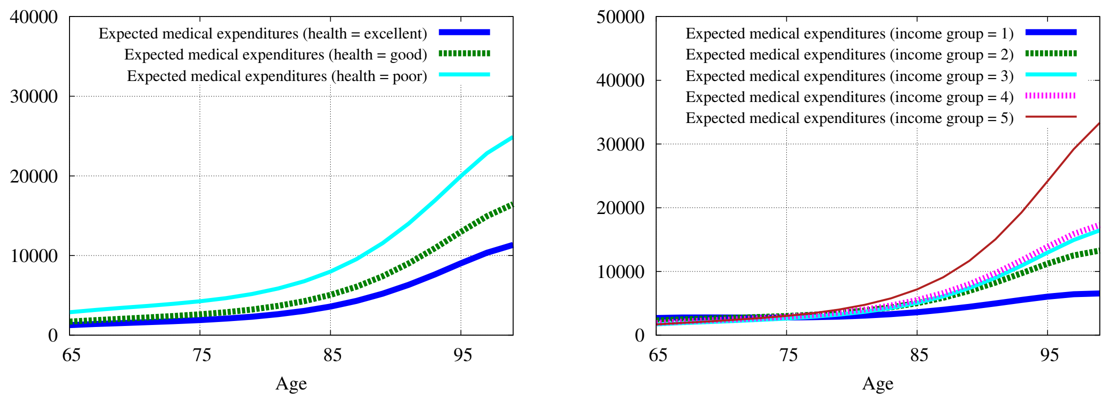
[11] Specifically, ψ_i is computed as $\psi_i = 1.34 s_i + 1(1-s_i)$, where s_i is the proportion of single households conditional on age$-i$, and 1.34 is the household equivalence scale for two-adult household (Fernández-Villaverde and Krueger (2007)).

[12] Specifically, χ_i is computed as $\chi_i = 1.5 s_i + 1(1-s_i)$, where s_i is the proportion of single households conditional on age$-i$.

Table 3: 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	25.3

Source: HRS.



(a) Mid-Income, by Health (b) Good Health, by Income

Figure 4: Expected Mean OOP Medical Expenditure

4.1.4 Medical Expenditures

We estimate the distribution of log-out of pocket (OOP) medical expenditures by age, health, income quintile and household size from a pooled 1996-2006 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 the expected mean and standard deviation of level medical expenses. Figure 4 reproduces expected mean medical expenses, for single households in the middle income bin by health, and in good health by income bin. As we would expect, people in worse health pay higher expenses, as do those with higher income. Recall that in the household budget constraint, the medical expenses of each age group are adjusted by the same household size adjustment factor as for income, χ_i.

Table 4: Probability of Moving to Nursing Home (Percent)

	Health status		
Age	Excellent	Good	Poor
65	0.13	0.16	0.60
75	0.41	1.19	1.89
85	3.99	5.96	8.31
95	22.76	18.28	15.83

Source: HRS.

4.1.5 Involuntary Nursing Home Moves

Using the pooled HRS sample from 1996-2006, we compute the 2-year probability that an individual moves into a nursing home *and* simultaneously stops being a homeowner, conditional on the household's age and health status. Table 4 shows the probabilities for age 65, 75, 85, and 95. We interpret the event of moving into a nursing home with loss of homeownership as compulsory moves out of the house, which are important when considering a reverse mortgage loan that depends critically on how long a household stays in the house. Not surprisingly, the probability is generally higher for older and less healthy individuals. There are two caveats to these estimates. First, not all elderly move into nursing homes involuntarily. If we take into account that some of the moves are voluntary, the probability that a household is forced to move out is 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. Since the data limit how well we can identify these events, our estimates of the moving shock are the best they can be.

4.1.6 Housing and Interest Rate

We create 10 house size bins, by sorting house values of all homeowners of age 63-67 in 2006 HRS sample, equally allocating them into 10 bins, and computing the median value of each bin. Housing requires maintenance, whose cost is a fraction δ of the house value. δ is set at 1.7 percent 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 sales price, has to be paid. The selling cost of a house (κ) is set at 6.6 percent 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 percent of the value of the house.

The interest rate is set at 4 percent per year (8 percent biennially). For conventional mortgage loans, we assume a borrowing premium (ι_m) of 1.6 percent annually. This is the average spread between 30-year conventional mortgage loans and Treasury bills of the same maturity between 1977 and 2009. Rent is the sum of maintenance costs (δ) and the conventional mortgage interest rate ($r + \iota_m$).

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. Contreras and Nichols (2010) estimate the AR(1) process of house prices for nine Census regions as well as the U.S. as a whole

Table 5: **Selected Characteristics of the Initial Distribution, Age 65, 2006**

Health status		Tenure status		Financial asset position	
1 (excellent)	0.46	Homeowner	0.88	Saver	0.79
2 (good)	0.32	Renter	0.12	Borrower	0.21
3 (poor)	0.22				

Source: HRS.

Their estimate of the persistence parameter associated with the Census regions varies between 0.704 and 0.940. Their estimate for the national sample is 0.811, which we use as our persistence parameter. Their estimates for the standard deviation of the shocks from Census regions varies between 6.5 percent and 9.3 percent, while the estimate from the national sample is 7.9 percent. On the other hand, Flavin and Yamashita (2002) estimate the standard deviation of individual house prices using Panel Study of Income Dynamics (PSID) and obtain the standard deviation of 14.2 percent. We use 14.2 percent as our standard deviation to house price shocks, since the shock in our model is associated with individual house value. The AR(1) process is discretized into a first-order Markov process. Since one period in the model spans two years, while the house price shocks constructed above are at annual frequency, we square the obtained Markov process to make it into a biennial process.

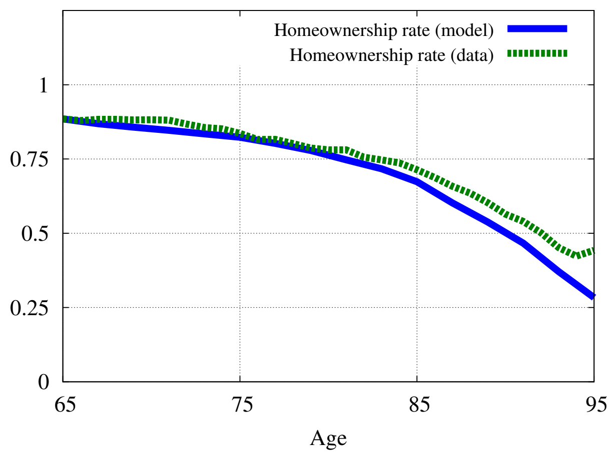
4.1.7 Initial Type Distribution

The type distribution of age-65 households is constructed using the HRS 2006 wave. Table 5 exhibits the dimensions of the initial distribution that we have not already discussed. Half of the households are in excellent health. Homeownership rate is close to 90 percent. All retirees in our sample are net savers; however, in the language of the model, the financial asset position includes secured debt. That is, the net financial position does not include the value of the house. By this measure, 79 percent of our sample are in net positive financial position at age 65 and remaining 21 percent are in net negative financial position at age 65.

4.2 Second-Stage Estimation

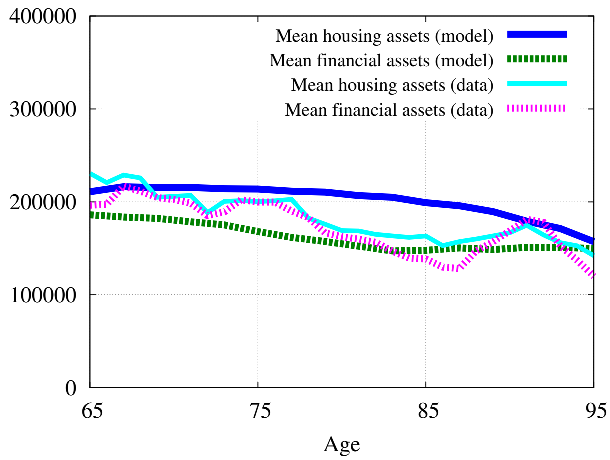
In the second-stage estimation, we match the cross-sectional age profiles of the homeownership rate, mean total, housing and financial asset holdings, and the proportion of retirees in debt. Again, we do this in the baseline model that does not have reverse mortgages in it. Hence the debt here is traditional mortgage debt. Figure 5 shows the model fit. First, it is valuable to examine the data profiles – dashed green lines in the figure. The homeownership rate is 88 percent at age 65, and declines smoothly to about 40 percent by age 95. Mean total assets show a similarly smooth, but slow, decline, from about $375,000 to about $200,000. This high mean amount even at age 95 is the statement of the classic "retirement saving puzzle" We analyze in detail the reasons for the lack of dissaving in this model in Nakajima and Telyukova (2012); there we show that housing plays a crucial role in the flatness of this profile.

Financial asset holdings do not decline much over the life-cycle for two of reasons. First, many households sell their house towards the end of life, as seen in panel (a), which increases financial asset holdings at the expense of housing asset holdings. Second, there is a mortality bias; those with

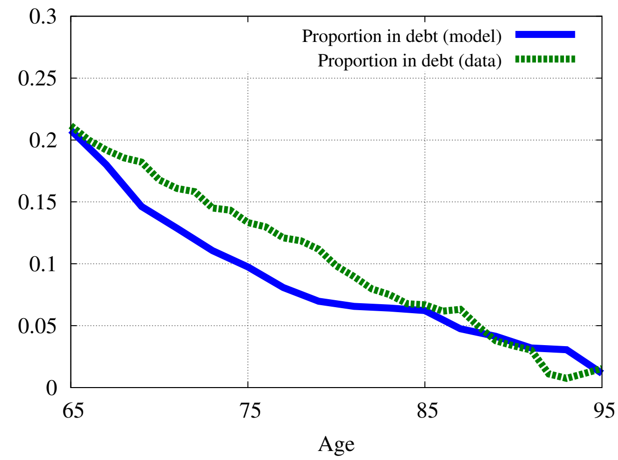


(a) Homeownership rate

(b) Mean total assets



(c) Mean housing and financial assets



(d) Proportion in debt

Figure 5: Model Fit – Age Profiles without RML, Model and Data

relatively lower wealth die earlier. Therefore, if we look at the average asset holdings of surviving households (balanced panel), the bias tends to push the life-cycle profiles upwards. This bias exists both in the data and in the model, since the correlation of health and wealth is built in to the initial conditions, which we calibrate to the data.

Finally, the proportion of households in debt declines smoothly from 20 percent at age 65 to nearly 0 at age 95, as households repay the existing collateralized loans or sell their house and become renters. This profile is what primarily pins down the age-specific collateral constraint on traditional mortgages in the model.

The age profiles implied by the model, solid blue lines in the figure, fit the data profiles well. The model slightly underpredicts the homeownership rate toward the end of life, and predicts a smoother mean housing asset profile than appears in the data. The proportion of agents in debt is matched perfectly at later stages of life, but slightly underpredicted by the model in the earlier years of retirement. The fit presented here yields the smallest sum of weighted squared residuals

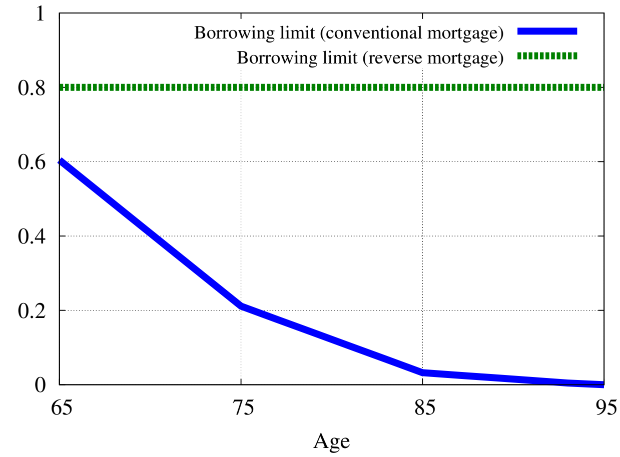


Figure 6: Borrowing Limit as a Proportion of House Value.

from the moment condition that compares the model and data moments, with equal weights.

Based on this distance criterion, the model produces the following parameter estimates, in the second panel of table 1. The estimated discount factor β is 0.92 in biennial terms, which is within the accepted range of estimates in models of this kind, particularly models that account for debt rates in the data. The coefficient of relative risk aversion is just above 2, which is in the middle of the spectrum in the literature. The extra utility from homeownership, at 4.68, suggests that homeownership yields nearly five times the utility benefit of renting in retirement. Again, this estimate captures both financial and nonfinancial benefits of ownership. In Nakajima and Telyukova (2012), we modeled the housing boom and some tax benefits of ownership, absent in this model, explicitly, such as capital gains taxation if one sells the house. In that model, this parameter was lower at 2.5, giving an indication that financial benefits of ownership are significant. The strength of the bequest motive is 3.92, and the preference shifter ζ, measured in thousands of dollars, is 13.25. The consumption floor $\underline{c}$ supported by the government through various welfare programs is estimated to be $13,681$ in 2006 dollars, which aligns well with empirical estimates of such program benefits (Hubbard et al. (1994)), once adjusted for inflation.

The age-dependent collateral constraint for conventional mortgages is characterized by $\{\lambda_i\}$. We pin down λ_i for ages 65, 75, 85, and 99 and linearly interpolate the values between these ages, with the upperbound of 1.0. Our estimates are 0.40, 0.79, 0.97, and 1.02, respectively. The profile implies that the collateral constraint tightens quickly for the elderly, which should not be taken literally as a continuously expanding downpayment requirement, for example. In our model, λ_i simply captures overall costs of borrowing in a parsimonious way, and the estimates are consistent with the fact that retired households fail income requirements inherent in most traditional mortgage contracts (Caplin (2002)).

4.3 Calibration of RML-Related Parameters

To conduct our experiments, into the baseline calibrated above, we introduce reverse mortgage loans. In order to calibrate parameters that characterize reverse mortgage loans, we rely as much as possible on the terms of reverse mortgage contracts in the data. The upfront and per-period costs associated with insurance against house price shocks are $\nu_i = 0.02$, and $\iota_i = 0.0125$ per year, respectively. The reverse mortgage is further characterized by the triplet $\{\lambda_r, \iota_r, \nu_r\}$, which captures the collateral constraint, the interest premium, and the upfront cost. First, we set the interest premium of the reverse mortgage loans to be the same as the conventional mortgages; $\iota_r = 0.016$ annually. Next, we set the borrowing limit at $\lambda_r = 0.2$, implying that any elderly household can borrow up to 80 percent of the value of their house through reverse mortgage loans. This is in line with the equity limits we see in the data. According to AARP, a 65-year-old RML borrower can take a loan of up to 50 percent of their home value, while a 90-year old borrower can access up to 75 percent. These numbers do not include interest and insurance costs, while in the model, households pay these costs using the proceeds of the loan. Therefore, our borrowing constraint, which is not age-dependent, is set slightly below the borrowing limit for a 90-year old, under the assumption that the expected interest cost for a 90-year old borrower is not too big. Figure 6 compares the borrowing limit of conventional and reverse mortgage loans in the model. It is easy to see that reverse mortgage loans allow homeowners, especially the older ones, to borrow more out of the value of their house, at various additional costs.

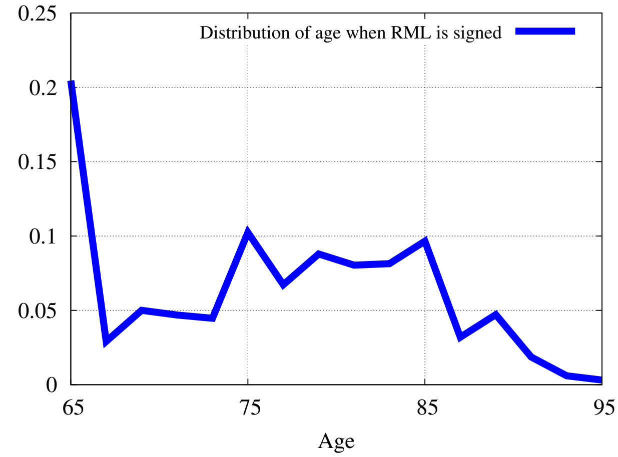
Finally, the upfront cost is calibrated such that the model replicates the empirical take-up rate in 2009, which is 1.36 percent of homeowners. The procedure yields $\nu_r = 0.096$. This is the sum of the origination fee and the closing cost. The upfront cost of 9.6 percent of house value might be on the higher side. In data, terms of reverse mortgage loans vary, but typical upfront cost appear to be around 5 percent of house value. The origination fee is typically 2 percent of the house value up to $200,000$ dollars and 1 percent above it, with the cap of $6,000$ and the floor of $2,500$. Considering that most house values in the model are below $200,000$, but half of the houses are below $100,000$, where the floor of $2,500$ dollars binds, 2.5 percent 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 percent as well. Therefore, we interpret the calibrated upfront cost $\nu_r = 0.096$ as including both the monetary costs of obtaining a reverse mortgage loans and other costs that are not explicitly modeled. Three examples come to mind. First, reverse mortgages in the model are more flexible than in the data in that borrowers can adjust the balance flexibly; in particular, they can prepay in order to avoid interest and insurance premium flow costs for the balance that they have already taken out. This kind of prepayment appears restricted in the data. Second, the model ignores the high costs of learning about reverse mortgages; for example, in order to qualify for an RML, potential borrowers are required to attend an informational seminar. The additional upfront costs in our calibration capture these information costs. Third, there might be a psychological or stigma cost attached to obtaining an RML. Later, we show results based on $\nu_r = 0.05$ instead of the baseline value of $\nu_r = 0.096$. The take-up rate of reverse mortgages associated with this lower upfront interest cost can be interpreted as the size of the pool of *potential* beneficiaries from reverse mortgage loans.

5 Results

5.1 Distribution of Reverse Mortgage Borrowers

Figure 7 shows two aspects of the age distribution of households who hold a reverse mortgage loan in the model. In particular, Panel (a) shows the distribution of the *current age* of reverse mortgage borrowers. Not surprisingly, it is hump-shaped; many of the households who have signed a reverse mortgage earlier survive up to age 70s and 80s. Between age 85 and 95, the proportion declines as households with a reverse mortgage die or sell their house, voluntarily or involuntarily, and become

(a) Age Distribution of RML Borrowers



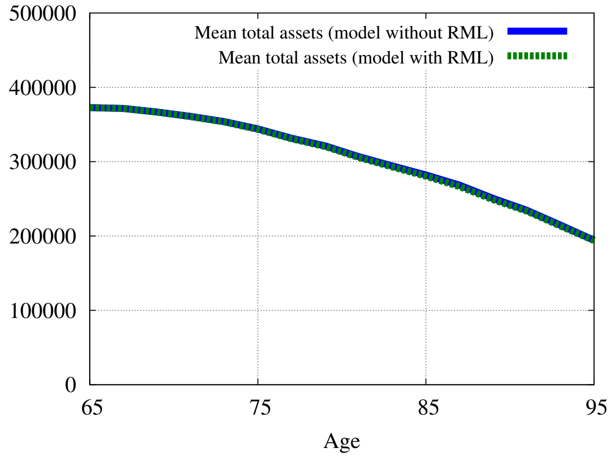
(b) Age Distribution at RML Origination

Figure 7: Distribution of RML Borrowers

a renter. Panel (b) is the distribution of *age at which a reverse mortgage loan is signed*, among all households who currently hold a reverse mortgage loan. This figure is a direct counterpart of Figure 3. Four points stand out in the comparison. First, the levels are different, partly due to different age bins in the model and data. Each point in Panel (b) of Figure 7 captures two years of age, while each bar in Figure 3 captures only one year of age. Second, the general shape of the distribution – initial spike and a hump shape after the initial spike – is quite similar between the two figures. Third, the initial spike in the data is at age 62, while it is at age 65 in the model. This is obviously because the initial age in the model corresponds to 65 years old, while reverse mortgage loans become available when a household (to be more precise, the youngest member of it) becomes 62 years old. The initial age in the model is not set at 62 because a large proportion of households is still working and earning labor income, and thus is not fit for our sample of retirees. Fourth, our model correctly predicts the drop-off of households who take a reverse mortgage later in their life. However, in the model, the peak of the distribution after the initial spike is between age 75 and 85, while the peak is around age 67 to 77 in the data. Some of this mismatch is mechanical and due to the missing ages 62-64 in the model. This necessarily shifts the graph to the right.

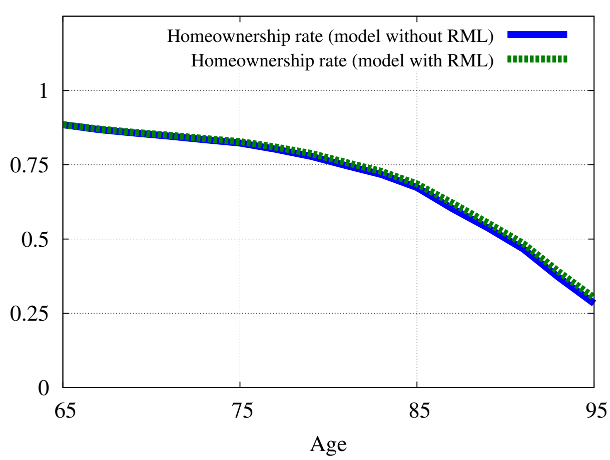
5.2 Life-Cycle Profiles in Model with Reverse Mortgages

Figure 8 shows the life-cycle profiles discussed previously, in the model with reverse mortgages relative to the benchmark without. The aggregate effect for mean assets, be it total (panel (a)), financial or housing (panel (b)), is small, which is to be expected given the low take-up rate of reverse mortgages (1.36 percent of retired homeowners). Notice that reverse mortgages enable people to stay in their house longer, which very slightly raises the homeownership rate in the model with RMLs (panel (c)). The most observable difference between the two models is in the proportion of households who are in debt (panel (d)): this proportion is clearly higher in the model with reverse mortgages, where retirees acquire a relatively flexible, if costly, means of borrowing against their home equity, compared with the more restrictive forward mortgage contracts that have income requirements usually failed by retirees.

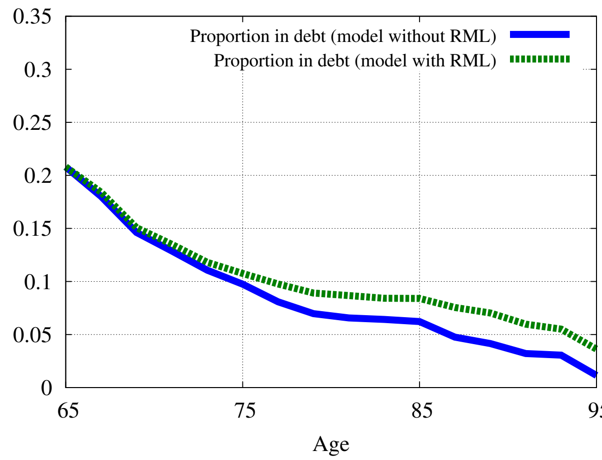


(a) Mean total assets

(b) Mean housing and financial assets



(c) Homeownership rate



(d) Proportion in debt

Figure 8: Age Profiles in Models with and without RMLs

5.3 Benefits of Reverse Mortgage Loans

Table 6 compares the take-up rate of reverse mortgages in the model and the data. As a result of our calibration strategy, which directly targets the take-up rate of reverse mortgages by homeowners, the model perfectly matches this rate, which is 1.36 percent of retired homeowners in the data. The table also shows the breakdown of household types to analyze which households are more likely to take a reverse mortgage. Reverse mortgages are far more popular among homeowners with outstanding mortgages (8 percent take-up rate, versus 0.11 percent among households with no mortgage debt), low income (5.4 percent versus 0.3 percent for highest income group), and in poor health (1.7 percent against 1 percent for households in excellent health). These characteristics of RML borrowers are qualitatively consistent with the data, although it is hard to get comparable numbers in the data since we do not have micro-data on reverse mortgages. For example, Redfoot et al. (2007) find that households are likely to use RMLs to repay outstanding mortgage debt and to pay for medical expenses, when their income is insufficient to cover these needs in other ways.

Table 6: Take-up Rate of RMLs, Share of Homeowners

	Take-up rate (percent)
Data[1]	
All homeowners	1.36
Model	
All homeowners	1.36
No outstanding mortgages	0.11
With outstanding mortgages	8.02
Low income	5.38
Medium income	0.64
High income	0.31
Poor health	1.72
Good health	1.38
Excellent health	1.04

[1] 2009 American Housing Survey.

Table 7: Welfare Gain from Reverse Mortgages, All Households

	Welfare gain[1]	Proportion with gain
All households	510	0.863
No outstanding mortgages	437	0.844
With outstanding mortgages	788	0.935
Low income	883	0.712
Medium income	449	0.926
High income	169	0.920
Poor health	588	0.837
Good health	513	0.862
Excellent health	467	0.878

[1] Welfare gain is measured by the one-time income at age 65 which would make expected life-time utility of those with access to reverse mortgages equal to expected life-time utility without. Measured in 2006 dollars.

Table 7 quantifies the expected welfare gain from the availability of reverse mortgages. The welfare gain is measured as the one-time transfer at age 65, in 2006 U.S. dollars, that would make households in the economy without reverse mortgages indifferent, in expected terms, to being in the

Table 8: **Impact of Uncertainty and Bequest Motives on RML Demand**

	Take-up rate, homeowners	Welfare gain, all households[1]
Baseline model	1.36	510
No medical expense risks	0.91	314
No medical expenses	0.85	308
No moving shocks	1.65	749
No house price shocks	1.61	303
Expected house price boom	5.99	4161
No bequest motive	12.94	7188
No house price shocks, no medical expenses	1.40	200
No moving shocks, no medical expenses	1.13	454
No bequest motive, no medical expenses	20.02	8545

[1] See note 1 of Table 7.

economy with RMLs. Note that no household in the model is worse off by having the option to buy a reverse mortgage. Moreover, only homeowners gain from the introduction of reverse mortgages. However, these numbers are computed by averaging the welfare gain across all households, owners and renters, in the economy. The welfare gain to households of living in a world with reverse mortgages is equivalent to one-time transfer of $510 per person, and 86 percent of all the retirees (i.e. almost all the homeowners) value, ex-ante at age 65, the option of taking out a reverse mortgage at some point in the future, though most do not, ex-post. The welfare gain is higher among those who have outstanding traditional mortgages ($788 per person), because the RML gives them the ability to keep borrowing against the value of their house, after they have to repay their conventional mortgage debt (i.e., the borrowing limit associated with conventional mortgages tightens). Low-income households value the option more than high-income households, and those in poor health more than those in excellent health; in both cases, the ability to take a reverse mortgage at some point in the future is valuable for the purpose of relieving liquidity constraints, either due to low income or to large medical shocks. The percent of those who gain, ex-ante, from introduction of RMLs in each line of the table reflects the proportion of homeowners in each group.

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

In this section, we investigate which elements of the retirees' environment and behavior contribute to the low RML take-up rate. In particular, we focus on the role of different types of uncertainty that retirees face, and then on the role of bequest motives. Since the main role of reverse mortgages is to relax the borrowing constraint of homeowners in retirement, the demand for reverse mortgages crucially depends on various elements that determine retirees saving and dissaving behavior. Table 8 shows the take-up rate among homeowners in the model with several counterfactual experiments, as well as the associated welfare gains for all households, measured as before. First, we evaluate the model without medical expenditure shocks; to do this, we assume that all households have to pay the mean of the medical expenditure distribution, conditional on the current household type (age, income, and health status), in the baseline specification. In this case, the take-up rate drops to 0.91 percent, all other things equal. If we shut off medical expenditures altogether, even fewer households take a reverse mortgage (0.85 percent). These experiments demonstrate that in the baseline specification, many households (about one-third of the total number) use reverse mortgages to pay for medical expenses, especially larger ones, while staying in their homes. As a result, without medical expense risk, the welfare gain from RMLs falls to \$314 per household.

If the compulsory moving shocks are turned off, the take-up rate of reverse mortgages rises to 1.7 percent of homeowners. This result echoes the result in Michelangeli (2010). The worst outcome for RML borrowers is to face the compulsory moving shock shortly after paying the large upfront cost of a reverse mortgage, but before utilizing the line of credit. This outcome is eliminated if moving shocks are turned off, which makes reverse mortgages more attractive as a way of relieving possible liquidity constraints while staying in the house longer. In this case, the welfare gain rises to \$749 per household.

Similarly, if house price shocks are turned off, the take-up rate increases to 1.6 percent of homeowner households. This increase might seem counterintuitive at first, because one of the benefits of RMLs is their non-recourse nature. However, temporary house price shocks work in the same way as moving shocks. If a household observes a temporary increase of the house value, it may want to sell the house for the capital gain, even though holding on to the house gives extra utility. This implies that the expected duration of tenure as a homeowner is shorter with house price shocks, and thus the value of reverse mortgages is lower. If the house price shocks are eliminated, homeowners can be certain to remain in their house longer, which makes reverse mortgage more attractive. The welfare gain in the world without house price shocks is \$303 per household, reflecting a reduction of risk.

Next, we add to the model the expectation of deterministic house price growth of 4.5 percent per year, which is the average real house price appreciation rate between 1996 and 2006. In this experiment, the take-up rate rises to 6 percent. This is intuitive: when households expect house price growth, they want to front-load consumption by borrowing more, which can be achieved by taking reverse mortgages. In this case, the welfare gains for RML borrowers rise significantly, to \$4161 per household. This experiment suggests that the observed fast increase in the take-up rate in the period 2000-2009, shown in Figure 1, might be the result of expected house price appreciation.

Finally, we recompute the model without the bequest motive, setting $\gamma = 0$. In this scenario, the RML take-up rate increases tenfold, to about 13 percent of homeowners. It is intuitive that bequest motives significantly dampen RML demand. Without bequest motives, many households decumulate assets substantially more quickly, and reverse mortgages allow them to do so without moving out of the house. Notice that in this case, the magnitude of the welfare gain to households from the availability of reverse mortgages is also very large compared to the benchmark case, at \$7188 per household.

In the last set of experiments, we investigate in more detail how households in the model use reverse mortgages. As we established, in the model many homeowners use RMLs to pay for medical expenses. However, we also showed that some features of the environment dampen RML demand significantly. We want to evaluate to what extent, without these features, homeowners increase the

Table 9: Reverse Mortgage Loans with Alternative Terms

	Take-up rate, homeowners	Welfare gain, all households[1]
Baseline model	1.36	510
HECM Saver[2]	1.18	611
Lower (0.5%) flow insurance premium	1.59	614
No insurance (recourse)	1.93	873
Lower (5%) upfront cost	2.12	1000

[1] See note 1 of Table 7.

[2] Upfront cost is lowered to 0.01 percent of the house value but the borrower can access to up to 65 percent (instead of 80 percent) of the home equity.

use of reverse mortgages for non-medical consumption. In the last three rows of table 8 , we answer this question by shutting off medical expenses in the model without house price shocks, moving shocks, and bequest motives. In the world without moving shocks, 1.1 percent of homeowners use RMLs for non-medical consumption; without house price shocks, 1.4 percent do. The dramatic result comes in the world without bequest motives: here, 20 percent of households use RMLs for non-medical consumption. This explains the large welfare gains from RML loans that we documented above. Notice also that this take-up rate is higher than in the model without bequest motives but with medical expenses. This happens because medical expense shocks create a precautionary motive, which dampens RML demand even if bequest motives are absent; households decumulate assets more slowly in anticipation of large medical expense shocks.

In sum, our model suggests that, conditional on the existing RML contract, low demand for reverse mortgages is in part an expression of the retirement saving puzzle: households do not take out reverse mortgages for the same reasons that they do not decumulate their assets rapidly in retirement. Of course, this is subject to the costs of RMLs; we turn to the investigation of these costs next.

5.5 The Impact of Reverse Mortgage Terms on RML Demand

In this section, we explore how the demand for reverse mortgage loans is affected by their current terms, in response to the popular claim that the high costs of RMLs are to blame. Table 9 summarizes the results. First, we consider the impact of a change in RML terms introduced in October 2010 by the Federal Housing Administration. The FHA introduced a new type of RML known as the HECM Saver. In order to reduce the oft-criticized upfront costs of reverse mortgage loans, the HECM Saver only requires upfront insurance premium of 0.01 percent of house value, down from 2 percent. However, since a lower insurance premium exposes the government to larger house price risk, the amount of equity that a borrower can extract using HECM Saver has been lowered as well. The AARP states that this amount decreases by 10-18 percent, depending on the borrower age.

We consider RML demand in a counterfactual model economy where the HECM Saver, instead of the regular reverse mortgage, is available. To do this, we make two changes to reverse mortgages in the model: first, the upfront insurance premium is reduced to $\nu_i = 0.0001$; second, reverse mortgage borrowers can extract 15 percent less than in the baseline case, reflecting the AARP estimate and the fact that the tightest constraint must be on the youngest borrowers, who are expected to live the longest. The first two rows of Table 9 compare the baseline model and the counterfactual model with HECM Saver RMLs. We find that the take-up rate of reverse mortgage loans actually falls, from 1.4 percent to 1.2 percent of homeowners. The model thus predicts that homeowners value access to additional equity more than lower insurance costs upfront. On the other hand, interestingly, the average welfare gain of having the option to purchase the HECM Saver is higher ($611) than the welfare gain in the model with the standard RML ($510). This implies that those who utilize the HECM Saver reverse mortgages benefit more than from the standard RML through the lower upfront insurance premium.

It is important to keep in mind that this result does not mean that the HECM Saver is hurting retired homeowners, because the Saver is available on top of the standard reverse mortgages in reality, while it replaces the regular reverse mortgage loans in the model. But the lower take-up rate in the model with the HECM Saver suggests that providing it in addition to the standard reverse mortgage loans would not create a substantial increase in the demand for reverse mortgage loans in general.

We also evaluate the impact of lowering the flow insurance cost. In the second counterfactual experiment, we lower the mortgage insurance premium to 0.5 percent per year from 1.25 percent in the baseline. This comparison evaluates, in reverse, the increase in the premium introduced in October 2010, which resulted from falling house prices and the perceived increase in RML risk. As can be seen in the third row of Table 9, a lower insurance premium boosts the take-up rate slightly, to 1.6 percent, other things equal. Preliminary information suggests that the market for reverse mortgage loans has been shrinking since 2010. Our model suggests that the increase in the premium might be one of the triggers.

As we discussed, reverse mortgages offer a combination of benefits. First, borrowers can access more of their home equity. Second, with mandatory insurance, reverse mortgage loans offer insurance against house price declines, through their non-recourse nature. In the next experiment, we disentangle the relative magnitude of the benefits by shutting off the insurance part of the reverse mortgage loans. We do so by, first, setting insurance costs (ι_i and ν_i) to zero, and second, making the RML a *recourse* loan. That is, we change the terms so when the borrower dies or moves out and the RML is consolidated, the borrower is liable for any excess loan amount. One point to note in this experiment is that households can always 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 as well.

The fourth row of Table 9 shows the take-up rate in the counterfactual model economy where only recourse reverse mortgage loans are available. Here, the take-up rate rises by 43 percent, to 1.9 percent of homeowners. Notable also is the increase in the welfare gain from making RMLs recourse loans: it rises to $873 per household. This suggests that, in our model, reverse mortgage borrowers do not value the 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. This feature of the model is consistent with the data. Second, borrowers have access to the publicly provided consumption floor, which captures welfare programs such as Medicaid. This makes the additional insurance in the RML contract less valuable to elderly households. Third, since we do not model the big swings in housing prices that has been observed since mid-2000s, we could be underestimating the house price risk that households face.

Finally, we discuss in Section 4.3 that the calibrated upfront interest cost (9.4 percent of the house value) is higher than the observed monetary upfront cost of obtaining a reverse mortgage (around 5 percent). Although we believe that the 9.4 number correctly captures some of the costs of RMLs that are not explicitly in the model, we run an experiment where we assume that the upfront interest cost is 5 percent. We interpret the difference between the observed take-up rate and the take-up rate in the model with the 5 percent cost as one of many possible measures of the *market potential* of reverse mortgage loans. As we discussed in Section 1 and footnote 1, Rasmussen et al. (1995) and Merrill et al. (1994) each compute the proportion of homeowners who would benefit from having the RML option, and get 80 percent and 9 percent, respectively. Although these and other studies estimate a broad range of numbers for this market potential, all seem to agree that the market for reserve mortgages can be substantially larger than the 1.36 percent take-up rate in 2009. It is often argued that one of the main reasons of such difference is that households do not know or do not know enough about reverse mortgages. The result of our last experiment (last row of Table 9) suggests that even when all households understand the benefits of RMLs, and the upfront costs are substantially lowered, the take-up rate less than doubles, to just 2.2 percent of eligible homeowners.

6 Conclusion

In this paper, we analyze reverse mortgage loans using a calibrated structural model of life in retirement where elderly households make decision of consumption, savings, housing, and reverse mortgages. When the modal is calibrated to match the observed take-up rate, the expected welfare gain of introducing reverse mortgages is sizable – equivalent to 500 dollars of one-time transfer for all households, and even higher for homeowners. Our model indicates that under the current environment and RML terms, reverse mortgages are used by about one-third of the borrowers to pay for medical expenses, while allowing them to remain their home. Not surprisingly, we also find that RMLs are particularly popular among lower-income and lower-wealth households, and households in poor health.

Through counterfactual experiments, we identify that, conditional on the RML contract as it exists in the data, bequest motives, involuntary nursing home moving shocks, and house price fluctuations all dampen RML demand to various degrees. However, not surprisingly, we also find that the costs of the RML contract are an important determinant of demand as well. In particular, the insurance costs inherent in the current RML contract dampen RML demand, because households do not value this insurance, due to relatively low borrowed amounts and government-provided insurance such as Medicaid. Along these lines, the model predicts a substantial increase in demand if the reverse mortgage were made a recourse loan. In addition, the HECM Saver loan of 2010, which lowers the upfront insurance costs in exchange for lowering the total amount of equity accessible to the borrower, actually lowers RML demand among homeowners, which suggests that adding this option to the already-existing RML contract is not likely to boost demand significantly. Finally, lowering only the upfront interest cost expands RML demand to only 2.2% of borrowers. One possible interpretation of these results is that given the risk that lenders have to take on to offer the

RML, the resulting contract is too expensive to be desirable to the vast majority of retirees. This may mean that given the costs of the reverse mortgage, many homeowners are better off selling their homes in the event of needing to liquidate their home equity, as in Nakajima and Telyukova (2012).

We also find that if households expect a housing boom, that increases demand for reverse mortgages because households would want to front-load consumption by borrowing, then repay from the capital gains. This may account for the rapid rise in demand for RMLs in 2000-2009. This suggests the question of what we may expect to happen to demand for reverse mortgages going forward. The take-up rate of reverse mortgage loans could drop as the expected house price growth rate tapers off after the Great Recession. At the same time, some homeowners might use reverse mortgages more extensively in response to the downturn, to relax the borrowing constraint that they face. Our model cannot be used to formally evaluate these possibility, because we do not model changes in house price growth rates. We leave this issue for future research.

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