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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 growth in this market, only 2.1% of eligible homeowners had RMLs in 2011. In this paper, we analyze reverse mortgages in a calibrated life-cycle model of retirement. The average welfare gain from RMLs is $885 per homeowner. Our model implies that low-income, low-wealth, and poor-health households benefit the most, consistent with empirical evidence. Bequest motives, nursing-home-move risk, house price risk, and loan costs all contribute to the low take-up. The Great Recession may lead to increased RML demand, by up to 30% for the 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, while insuring them against significant drops in house prices. Research on reverse mortgages is not extensive, despite potentially large benefits to older individuals, many of whom want to stay in their houses as long as possible, frequent coverage in the media, and attempts by the Federal Housing Administration, which administers RMLs, to change the contract to increase the appeal to borrowers. 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 expense shocks. 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 number is nearly 80%.[1] Despite the apparent benefits, RMLs were held by just 2.1% of older homeowners in 2011, which represents the highest level of demand to date.

In this paper, we study determinants of demand for reverse mortgages and its future post-Great Recession in the face of complex trade-offs 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 the loans. Here we focus on retirees' environment, such as the magnitude of risk that they face, and preferences, such as their bequest and precautionary 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 changed to make the RML more attractive. Finally, we study how reverse mortgage demand may change as a result of the Great Recession, which will have both short-run and long-run impacts on financial security and the incomes of future retirees.

To answer these questions, we use a rich structural model of housing and saving/borrowing decisions in retirement based on the model developed in 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 idiosyncratic uninsurable uncertainty in their life span, health, spouse's mortality, medical expenses, and house prices, and no aggregate uncertainty. Bad health may force older individuals into nursing homes, which we capture with an idiosyncratic 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. Into this model, we introduce reverse mortgages, study their use and value to different household types, and conduct counterfactual experiments to answer the questions posed above.

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[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 a 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.

The model predicts that the ex-ante welfare benefit of reverse mortgages is equivalent to providing a lump-sum transfer of $885 per retired homeowner at age 65, which amounts to 4.9% of median annual after-tax income in this group. The welfare gains are much larger, for example, for low-income retirees who are more likely to use RMLs. Nearly all homeowners value, ex-ante, the option of being able to tap their equity some time during their retirement; however, ex-post, only 1.67% of eligible retirees use RMLs, which is close to the data average of 1.46% for 2006-2011, appropriate for our HRS sample. 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.

The Great Recession is likely to affect the RML market in different ways in the short and 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, most retired homeowners will be less likely to take a reverse mortgage, as their home equity has fallen. However, the most vulnerable retired homeowners — those in the lowest-income quintile in their 80s and 90s — will have to rely increasingly on RMLs to finance their expenses. In this part of the distribution, demand for RMLs may increase by 30%. This raises important policy trade-offs 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.

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 large medical expenses in particular. While the aggregate take-up rate is less than 2%, it is over 5% for the lowest-income quintile and 17% for low-income households of age 90 and above. A predominant reason to take out a reverse mortgage is a large medical expense shock; however, once they have an RML, households use it to smooth consumption more generally as well. Bequest motives not only dampen RML demand, but also change the way homeowners use RMLs; without these motives, retirees are 3.5 times more likely to take RMLs and use them overwhelmingly for nonmedical consumption. On the contract side, we find that eliminating up-front costs of the loan nearly doubles demand for RMLs. In addition, reverse mortgages are nonrecourse 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 increase RML demand by 73%. 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 up-front 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.

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, as well as 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 can quantify demand, welfare gains, and effects of the Great 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) investigates empirically 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-move 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, homeownership, 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. We find that this distinction in the form of the contract matters.

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), estimating the relative strength of the bequest motives and public care aversion, 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. In a previous work, Nakajima and Telyukova (2013) emphasize the role of housing in shaping retirement saving, finding that housing and homeownership motives are key in accounting for the retirement saving puzzle, in addition to bequest motives and medical expense uncertainty. In the current 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), and 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 the most popular choice, we do not focus on the tenure option in this paper.

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 equilib-

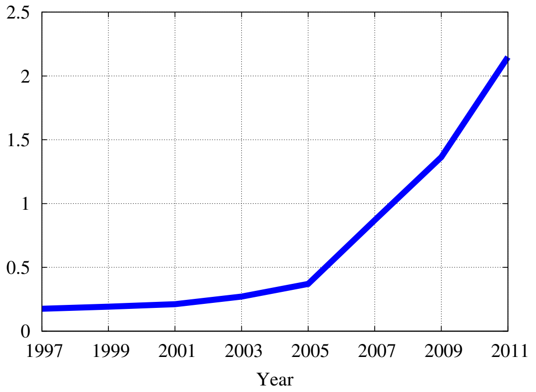

Figure 1: Percentage of Older Homeowners with Reverse Mortgages. Source: AHS.

rium 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. 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, are 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 2000. In 2001, the share of eligible homeowners with reverse mortgages was about 0.2%. This share has 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 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

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[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).

were 26.8 million households headed by individuals of age 65 and over 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 over. 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 requirements different from 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 repay 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 based not 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 an 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 nonrecourse. 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 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 predetermined 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 has been 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

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[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.

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 noninterest 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. Noninterest 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 (NPL) is calculated by subtracting various up-front costs from the IPL.

The IPL is thus larger the greater 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 (see Shan (2011)). In October 2013, HUD instituted a HECM reform that has made the borrowing limits tighter while changing the up-front insurance cost structure to make it lower for those with low initial balances, but higher for others. We will discuss and evaluate this reform in an experiment in Section 5.

3 Model

We set up the decision problem of retirees that extends our previous work (Nakajima and Telyukova (2013)). Time is discrete and finite, and there is no aggregate risk. All households are either single or couples, and face uninsurable idiosyncratic risk in health status, mortality, household size (spouse mortality), and medical expenses. 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 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

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[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.

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, compared to conventional mortgages, reverse mortgages offer different (just age-dependent) collateral constraints and cost structure. 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 an 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

$$V(i, b, s, m, x, p, k = 0, h = 0, a) = \max_{\tilde{c}, \tilde{h} \in H, a' \geq 0} \Bigg\{ u(s, c, \tilde{h}, 0)$$

$$+ \beta \sum_{s'} \pi^{s}_{i,s,s'} \sum_{m'>0} \pi^{m}_{i,m,m'} \sum_{x'} \pi^{x}_{i+1,b,s',m',x'} \sum_{p'} \pi^{p}_{p,p'} V(i+1, b, s', m', x', p', 0, 0, a') + \beta \pi^{m}_{i,m,0} v(a') \Bigg\} \tag{1}$$

subject to

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

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

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 the tilde indicates consumption before consumption floor is applied), savings (a'), and the size of the

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[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 it 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 include them as part of the renters' state variable to keep the set of state variables the same for renters and owners.

house to rent ($\tilde{h}$). $\tilde{h}$ 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. $a' \geq 0$ 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 explicitly 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, households never choose to hold simultaneously risk-free bonds and mortgage loans. Therefore, without loss of generality, we can assume that a household holds either 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. The household qualifies for this program if it runs down its savings ($a' = 0$) and, if net of its rent and medical expenses, 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 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

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[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.

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 an RML ($V_2(i, b, s, m, x, p, k = 0, h, a)$).[13]

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

$$V_0(i, b, s, m, x, p, k = 0, h, a) = \max_{\tilde{c}, a' \geq 0} \Bigg\{ u(s, c, h, 1)$$

$$+ \beta \sum_{s'} \pi^s_{i,s,s'} \sum_{m'>0} \pi^m_{i,m,m'} \sum_{x'} \pi^x_{i+1,b,s',m',x'} \sum_{p'} \pi^p_{p,p'} V(i+1, b, s', m', x', p', 0, 0, a') + \beta \pi^m_{i,m,0} v(a') \Bigg\} \tag{5}$$

subject to:

$$\tilde{c} + a' + x + \delta h = (1 - \kappa) hp + (1 + r + \mathbb{1}_{a<0} \iota^m) a + b \chi_s \tag{6}$$

$$c = \begin{cases} \max\{\underline{c}\chi_s, \tilde{c}\} & \text{if } a' = 0 \\ \tilde{c} & \text{otherwise.} \end{cases} \tag{7}$$

Compared to the problem of the renter, the new features are that the owner, in the current period, (1) may have a different utility function as represented by $o = 1$ in the function $u(i, c, h, 1)$, (2) has to pay a maintenance cost δh to keep the house from depreciating, and (3) receives the proceeds from selling her house hp net of the selling cost κhp. In addition, if the homeowner is in debt at the time of the house sale, the interest rate has a mortgage premium ι^m, and all debt must be repaid. 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 her house and does not take out a reverse mortgage in the next period is

$$V_1(i, b, s, m, x, p, k = 0, h, a) = \max_{c, a' \geq -\lambda^m_{i,b,s,m,p} hp}$$

$$\Bigg\{ u(s, c, h, 1) + \beta \sum_{s'} \pi^s_{i,s,s'} \sum_{m'>0} \pi^m_{i,m,m'} \sum_{x'} \pi^x_{i+1,b,s',m',x'} \sum_{p'} \pi^p_{p,p'} V(i+1, b, s', m', x', p', 0, h, a')$$

$$+ \beta \pi^m_{i,m,0} \sum_{p'} \pi^p_{p,p'} v((1 - \kappa) hp' + a') \Bigg\} \tag{8}$$

subject to

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

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 (hp'), net of the selling cost to liquidate it

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[13] 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 or from their children. Exploring the model with intergenerational transfer decisions is out of the scope of this paper.

($\kappa hp'$). 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.[14]

We formulate the collateral constraint for a conventional forward mortgage, $\lambda^m_{i,b,s,m,p}$, to capture the idea that, as 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 household 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 household can borrow in the next period. $\lambda^m_{i,b,s,m,p}$ is solved backwards, starting from the last period of life, when the DTI constraint implies $\lambda^m_{i,b,s,m,p} = 0$ since the borrower cannot pay anything in the following period.

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

$$\begin{aligned} V_2(i,b,s,m,x,p,k=0,h,a) = \max_{c,a' \geq -\lambda^r_i hp} \\ \Bigg\{ u(s,c,h,1) + \beta \sum_{s'} \pi^s_{i,s,s'} \sum_{m'>0} \pi^m_{i,m,m'} \sum_{x'} \pi^x_{i+1,b,s',m',x'} \sum_{p'} \pi^p_{p,p'} V(i+1,b,s',m',x',p',1,h,a') \\ + \beta \pi^m_{i,m,0} \sum_{p'} \pi^p_{p,p'} v(\max\{(1-\kappa)hp' + a', 0\}) \Bigg\} \quad (11) \end{aligned}$$

subject to

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

There are three new features. First, the collateral constraint of the reverse mortgage borrower is λ^r_i, which depends only on age.[15] In contrast with conventional mortgages, RMLs are secured purely by

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[14] Many states allow homeowners to keep their house, below a threshold value, and still qualify for Medicaid. Nakajima and Telyukova (2013) 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.

[15] 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.

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 next section. Second, in order to take out a reverse mortgage, the household pays up-front costs and an 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 nonrecourse nature of the reverse mortgage; if the borrower dies and the consolidated balance of housing assets and reverse mortgage $((1-\kappa)hp' + a')$ turns out to be negative, the heirs of the borrower are not liable for the loss.

3.3 Homeowners with a Reverse Mortgage

Similar to the household without an RML, a household with an 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 an RML holder, of moving out and becoming a renter and of staying and keeping the reverse mortgage, respectively.

The homeowner with a reverse mortgage who chooses to sell solves

$$V_0(i,b,s,m,x,p,k=1,h,a) = \max_{\tilde{c},a' \geq 0} \Bigg\{ u(s,c,h,1)$$

$$+ \beta \sum_{s'} \pi^s_{i,s,s'} \sum_{m'>0} \pi^m_{i,m,m'} \sum_{x'} \pi^x_{i+1,b,s',m',x'} \sum_{p'} \pi^p_{p,p'} V(i+1,b,s',m',x',p',0,0,a') + \beta \pi^m_{i,m,0} v(a') \Bigg\} \tag{14}$$

subject to

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

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

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 nonrecourse nature of the loan, where the lender cannot recover more than the value of the house at the time of repayment. Next, the interest payment for the loan includes the reverse mortgage premium (ι^r) and insurance premium (ι^i).

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

$$V_1(i,b,s,m,x,p,k=1,h,a) = \max_{c,a' \geq -\lambda^r_i hp}$$

$$\Bigg\{ u(s,c,h,1) + \beta \sum_{s'} \pi^s_{i,s,s'} \sum_{m'>0} \pi^m_{i,m,m'} \sum_{x'} \pi^x_{i+1,b,s',m',x'} \sum_{p'} \pi^p_{p,p'} V(i+1,b,s',m',x',p',1,h,a')$$

$$+ \beta \pi^m_{i,m,0} \sum_{p'} \pi^p_{p,p'} v(\max\{(1-\kappa)hp' + a', 0\}) \Bigg\} \tag{17}$$

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 age 65 and over, so 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 five-year age bins. Thus, age-65 households in our sample are of ages 63 to 67, and each household appears in up to five bins, of its actual age plus or minus two years.

To match the HRS, the model period is set to two years. Model households are born at age 65 and can live up to 99 years of age. Households have constant relative risk aversion period utility and use discount factor β:

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

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.

A household gains utility from leaving bequests. When a household dies with the consolidated wealth of a, the household's utility function takes the following form, with the strength of the bequest motive γ and marginal utility of bequests ζ:[16]

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

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.

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

Table 1: Calibration Summary: Model Parameters

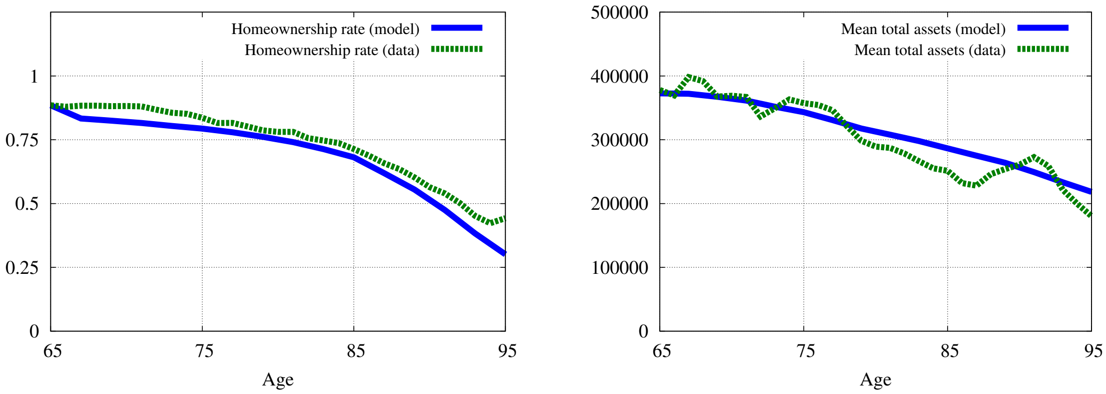
Parameter	Description	Value
First-Stage Estimation		
ψ_2	Consumption equivalence for two-adult HHs	1.340
χ_2	Income multiplier for two-adult HHs	1.480
ρ_p	Persistence of house price shock	0.811
σ_p	Standard deviation of house price shock	0.142
r	Saving interest rate[1]	0.040
ι^m	Margin for conventional mortgage[1]	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
Second-Stage Estimation		
β	Discount factor[2]	0.921
η	Consumption aggregator	0.736
σ	Coefficient of RRA	2.586
ω_1	Extra utility of homeownership	8.614
γ	Strength of bequest motive	6.576
ζ	Curvature of utility from bequests[2]	15,354
$\underline{c}$	Consumption floor per adult[2]	11,124
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[1]	0.017
ι^i	RML insurance premium[1]	0.013
λ_i^r	RML collateral constraints	See text

[1] Annualized value.

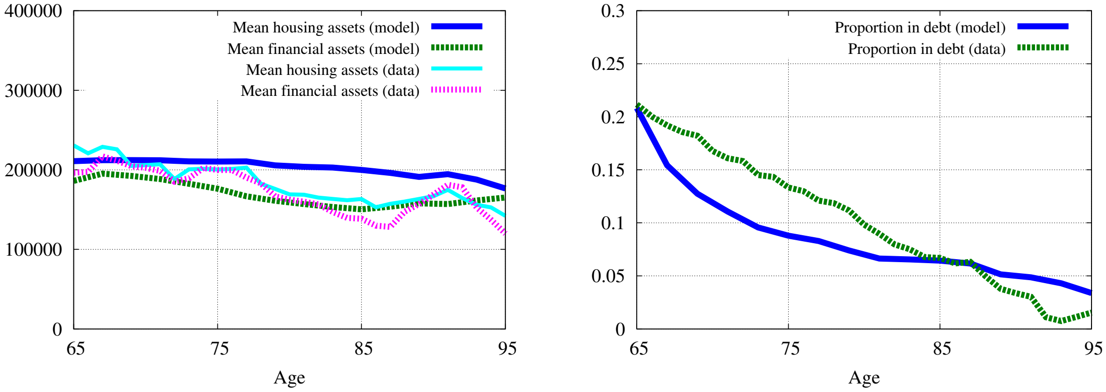
[2] Biennial value.

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. First, parameters in the first panel of Table 1 are calibrated using various sources. Consumption equivalence scale is normalized to one for single households, and we set $\psi_2 = 1.34$ for two-adult households, as estimated by Fernández-Villaverde and Krueger (2007). The income multiplier for two-adult households, χ_2, is set at 1.48, which is the median estimate in the HRS. Persistence (ρ_p) and standard deviation (σ_p) of house price shocks are calibrated based on empirical estimates of house price fluctuations. The annual saving interest rate is fixed at 4%. Mortgage interest premium ι^m is set at 1.7% per year, which is the average spread between 30-year conventional mortgages and the 10-year Treasury bond 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



(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

and Kennedy (2007)).

Next, we estimate stochastic processes of (s, m, x, n) using a pooled HRS sample of 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. We calibrate household health status and probability of health shocks conditional on age and current health. We also calibrate the distribution of household size by age, and the probability of transitioning from a couple to a single household (i.e., the loss of a spouse), conditional on age. We estimate survival probabilities and nursing-home-move shocks, conditional on age and health, and medical and nursing-home expenditure distribution, conditional on household size, income, age, and health.

Finally, in the first stage, we calibrate the initial distribution of 65-year-old retirees, along the dimensions of our state space — income, health, household size, medical expenses, housing, and financial wealth — using just the 2006 cross-section from the HRS. We use only the 2006 cross-section because using the pooled sample for this cross-section would mask a significant nonstationary trend in housing and financial wealth that makes 65-year-olds of different cohorts look different from each other, in a way that our stationary model cannot account for.

4.2 Second-State Estimation

In the second stage, we estimate the rest of the parameters to match relevant age profiles of asset holdings that we construct only from the 2006 wave of the HRS. We use cross-sectional age profiles, rather than cohort life-cycle profiles as in our past work, because this allows us to characterize the entire life cycle in the data, which is not yet possible for a single cohort with just 14 years (eight waves) of usable HRS data. We use just the 2006 wave, because pooling all the waves would, again, mask significant nonstationarity in the data arising from housing and asset market booms in the 1996-2006 period that our stationary model cannot capture.[17]

In this stage, 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. Figure 2 shows the model fit. First, it is valuable to examine the data profiles — the dashed green lines in the figure. The homeownership rate is 88% at age 65 and declines to about 40% by age 95. Mean total assets show a similarly smooth, but slow, decline, from about \$375,000 to about \$200,000, 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 toward 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 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 conditions, and agents in the model die with the same probability as in the data. Finally, the proportion of households in debt declines smoothly from 20% 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 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 compulsory shock. In turn, households sell the house for one of several reasons: to realize capital gains when a high house price shock is realized, to pay for medical expenses when a high medical expense shock hits and the trade-off works in favor of selling instead of an RML, or to dissave for life-cycle reasons. The model slightly underpredicts the homeownership rate, which may be due to an overestimate of compulsory-move probabilities, especially late in life. The model predicts a smoother mean housing asset profile than in the data. The proportion of agents in debt is matched well at later stages of life, but underpredicted in the earlier years of retirement. The fit presented here yields the smallest sum of weighted squared residuals from the moment condition 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. 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 2.59, which is in the middle of the spectrum in the literature. The extra utility from homeownership, at 8.61, suggests that homeownership yields, in financial and nonfinancial benefits not explicit in the model, over eight 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 \$11,124 in 2000 dollars, per adult per two years, which aligns with empirical estimates of such program benefits (Hubbard et al. (1994)), once

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[17] The cost of using cross-sectional age profiles is that we cannot account for cohort effects in the data, because our model lacks them due to stationarity, but these cohort effects are not central to our question.

adjusted for inflation. The strength of the bequest motive is 6.58, and the preference shifter ζ is 15,354 in biennial 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 upper end of the bequest distribution. For example, the mean and median realized bequest for singles in the model are \$238,000 and \$163,000, 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 \$493,000 in the model and \$536,000 in the data. They are fairly close. However, the proportion of singles who leave no bequests is 25% in the data, while it is less than 4% in the model.[18] In our 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 holdings toward the end of life.[19]

Most of these parameter values are similar to the estimates from our previous and related model in Nakajima and Telyukova (2013) . We discuss the comparison of parameter values in the two models in Appendix B.2 and the sensitivity of our results to these parameter estimates in Appendix D.

4.3 Reverse Mortgages

We do not include reverse mortgages in the benchmark model even though the debt measurements in the HRS include them. The reason is that we cannot observe reverse mortgages separately from other equity loans in the survey. This precludes us from calibrating, for example, the initial distribution to include reverse mortgages explicitly. However, this does not matter for our results, because in 2006 the RML take-up rate was just around 0.6% of eligible households, so reverse mortgages in the sample would have no influence on any of the 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 up-front cost is about 5% of house value. RML interest premium (annual 1.7%) is set to be the same as for conventional mortgages. The up-front 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 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, in both the data and 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

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[18] In Ameriks et al. (2011), households pay for medical expenses 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 model, the timing of medical expense shocks is thus not synchronized.

[19] De Nardi et al. (2010) compute the threshold wealth level for leaving a positive amount of bequest in the last period of life, implied by the parameters of their model. Their estimated parameter values imply that the threshold is about \$36,000, compared to our threshold value of \$7,400. Our implied threshold value is closer to that of Ameriks et al. (2011), which is \$7,300.

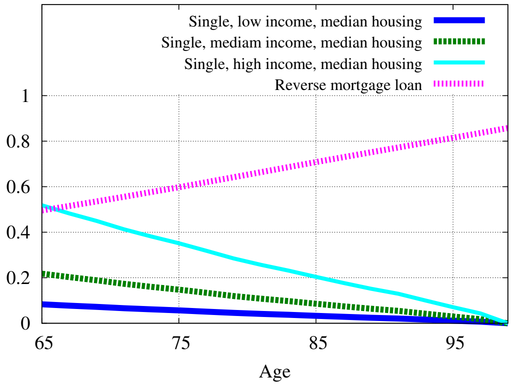

Figure 3: Collateral Constraints, Conventional and Reverse Mortgages

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.[20]

Figure 7 compares the collateral constraints for RMLs and conventional mortgages for a single household with a median house, for different income levels. While the collateral constraint associated with conventional mortgages tightens with age, RMLs offer a collateral constraint that relaxes with age. The difference is more striking for homeowners with lower incomes and larger houses.

5 Results

In this section, we study the take-up rate of RMLs and the welfare and distributional implications of reverse mortgages. Then we turn to counterfactual experiments to quantify how risk, bequest motives, and the terms of the current RML contracts affect demand for reverse mortgages, as well as what we expect to result from the recent HECM reform and what we expect demand for RMLs to be in the future as a result 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 groups of households. 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. 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 all welfare gains for homeowners only.[21] We also show the welfare gain as a share of household's average net worth.

The calibrated model implies the RML take-up rate of 1.67% of retired homeowners. Since we are working with the 2006 sample of initial retirees, we take as our empirical benchmark the average RML take-up rate from the period 2006-2011, as this gives us the best current estimate of a relevant "long-term average" take-up rate for this cohort. This average take-up rate is 1.46% in the data. Notice that we leave the RML take-up rate free in calibration — none of the parameters target it. Thus, the model implication for RML demand being very close to the data's is a significant success

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

[21] General equilibrium effects are abstracted, but considering the low take-up rate, the general equilibrium effects would be small.

Table 2: RML Take-Up Rates and Welfare Gains

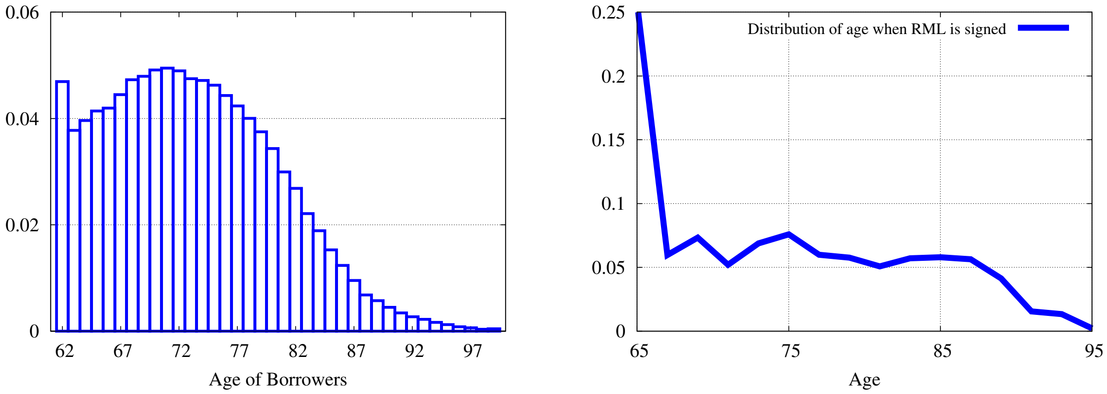
	% Holding (take-up rate)	Welfare Gain, 2000 US\$[2]	Welfare Gain, % of Wealth
Data[1]			
All homeowners	1.46		
Model			
All homeowners	1.67	885	0.216
No outstanding mortgages	0.01	889	0.180
With outstanding mortgages	10.82	871	0.666
Single	2.46	868	0.260
Couple	0.92	894	0.199
Low income	5.45	1,435	0.418
Medium income	0.85	814	0.226
High income	0.25	260	0.047
Poor health	2.19	719	0.283
Good health	1.67	865	0.240
Excellent health	1.24	983	0.188
With smallest house	0.35	43	0.073
With largest house	2.64	3,785	0.297

[1] American Housing Survey, 2006-2011.

[2] 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$.

of our model. The ex-ante mean welfare gain from having the RML option is $885 per homeowner; this translates to 4.9% of median annual after-tax income, or 0.22% of homeowners' net worth. Clearly, the gain is much larger ex-post for those who do obtain the reverse mortgage.

Reverse mortgages are far more popular among homeowners with outstanding mortgages (10.8% take-up rate versus 0.01% of those with no mortgage debt), those with low income (5.5% versus 0.25% for the highest income group), those who are single (2.5% versus 0.9%), and those in poor health (2.2% against 1.2% for households in excellent health). Many households in the model take out RMLs at the time when they are hit with high medical expenses, which can be seen if we look at the types of households that obtain an RML in a given period, and from the correlation with health. Those with larger houses are much more likely to take out RMLs, since they have far more equity to tap into. The expected welfare gains correspond to the take-up rates. The welfare gains normalized by wealth are slightly higher among those who have outstanding conventional mortgages (0.67% versus 0.18%), because the RML gives them the ability to keep borrowing against the value of their house while the collateral constraint on a conventional mortgage would tighten with age. Low-income households value the option more than high-income households (0.42% of average wealth versus 0.05%); the ability to take a reverse mortgage at some point in the future is valuable for the purpose of relieving liquidity constraints resulting from large medical expense shocks, which are more likely for low-income households. Poor-health households benefit more from RMLs than



(a) Data from Shan (2011)

(b) Model

Figure 4: Age Distribution of Borrowers at RML Origination

those in excellent health (0.28% versus 0.19%) since they are more likely to take out RMLs ex-post. 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 houses have a welfare gain of \$3,785, or 0.3% of net worth.

Our results are qualitatively consistent with data findings in the literature, although we lack the necessary micro-data on reverse mortgages to compute direct comparisons. Shan (2011) finds that areas with more RML borrowers tend to have lower household income and credit scores, but 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.

5.2 Age Distribution of Reverse Mortgage Borrowers

Figure 4 shows the age distribution of households *at the time of RML signing* among all households who currently hold a RML, in both the data (Shan (2011)) and the model. Like the data, our model correctly predicts an 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. The model take-up rate at 65 of 25% slightly overpredicts the level of take-up for ages 62 to 65 in the data (17%). Thereafter, the model correctly predicts a drop-off in the rate of RML signing and a tapering to zero at age 95, although the tapering in the model is more gradual than in the data.

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. Table 3 shows the take-up rate and welfare gains among homeowners in the model based on 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 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 1.69%, all else equal. There are two effects here: On the one hand, we remove a source of expense shocks, which is a key reason to take out a reverse mortgage — this would decrease demand. On the other hand, we remove a source of risk, which may encourage more RML demand, as one

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

		Take-Up Rate, Homeowners	Welfare Gain, 2000 US ^{1,2}	Welfare Gain, % of Wealth
1	Baseline model	1.67	885	0.216
2	No medical expense risks	1.69	852	0.208
3	No medical expenses	2.01	825	0.201
4	No moving shocks	1.94	1,248	0.305
5	No house price shocks	2.82	725	0.177
6	Expected house price boom (+4.5%)	10.41	8,856	2.163
7	Expected house price drop (−4.5%)	0.22	51	0.012
8	No bequest motive	5.85	4,850	1.185

[1] See note 2 in Table 2.

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

precautionary reason for holding off borrowing is removed. The latter dominates slightly, though the associated welfare gain from reverse mortgages also declines slightly. If we shut off medical expenditures altogether, we see a larger increase in RML demand, to 2%.

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 1.94% of homeowners, similar to the finding by Michelangeli (2010). The worst outcome for RML borrowers is to face a compulsory moving shock shortly after paying the large up-front 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. In this case, the welfare gain rises to $1,248 per homeowner. Removing idiosyncratic house price uncertainty increases the take-up rate by 68%, to 2.82% of retired homeowners, because absent temporary increases of the house value, households lack unexpected opportunities to sell the house for capital gain. This significantly increases expected years of homeownership and in turn encourages more RML demand.

Next, we add to the model an expectation of deterministic and permanent house price growth of 4.5% per year, which is the average real house price appreciation rate between 1996 and 2006. The result is a more than sixfold increase in demand, to 10.4%. 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 $8,856 per household, more than 2% of their net worth. 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, by 4.5% per year. This has the opposite effect of the expected housing boom, dampening the demand for reverse mortgages to 0.22%. The reason is that, faced with a predicted decline in prices, many households will choose to sell their house in the current period. However, some households will still use reverse mortgages for medical or nonmedical consumption. 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 recent collapse of the housing

Table 4: RML Demand with Alternative Loan Terms

		Take-Up Rate, Homeowners	Welfare Gain, 2000 US ^{1,2}	Welfare Gain, % of Wealth
1	Baseline model	1.67	885	0.216
2	2013 HECM reform	0.99	805	0.197
3	Lower (0.5%) up-front ins. premium[3]	1.88	1,047	0.256
4	Tighter (−15pp) borrowing limit	0.86	669	0.163
5	No insurance (recourse)	2.89	1,512	0.369
6	Zero up-front cost	3.16	1,850	0.452

[1] See note 2 of Table 2.

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

[3] If borrowing is less than 60% of the maximum amount that can be borrowed in the first year; up-front cost rises to 2.5% if initial disbursement exceeds the threshold.

market was predicted by homeowners, and expectations matter greatly for this result. Indeed, house prices stopped declining around 2009.[22] 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.

Finally, we recompute the model without the bequest motive ($\gamma = 0$). In this scenario, the RML take-up rate increases 3.5 times, to 5.85% 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. 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 $4,850 per homeowner.

In sum, the model suggests that, conditional on the existing RML contract, RML demand is low for the same reasons that retirees do not rapidly spend down assets: the precautionary motives in the face of risks that they face and the bequest motive. These factors affect not only demand for reverse mortgages, but also their purpose: Under the current environment, high medical expense shocks are a key reason to take out a reverse mortgage, though subsequently it is used to smooth consumption as well. In the absence of those risks or bequest motives, households would use RMLs more freely for nonmedical consumption. Next we examine the RML contract itself.

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. 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 into a 15-percentage-point reduction in the borrowing

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

limit for all households. In accordance with the new rules, the initial insurance cost decreases from 2% to 0.5%, unless the household's initial RML balance exceeds 60% of the maximum loan amount, in which case it pays an up-front 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 RML take-up rate falls, from 1.67% to 1% (row 2) of homeowners, and the expected welfare gain falls as well. To understand the reason, we separately change only the up-front insurance cost, then only the borrowing limit, in the next two lines. These experiments reveal that the amount of equity that retirees can access is more important than the decrease in the up-front cost for those with lower balances: Demand increases 13% if the up-front cost is changed in isolation (row 3), but keeping up-front costs the same, tightening the borrowing limit decreases demand by 50% (row 4), so this force dominates. In sum, our model suggests that the recent reform will dampen demand for reverse mortgages, all else equal.

As we discussed, reverse mortgages offer several benefits. First, borrowers can access their home equity for non-housing consumption while staying in the house. Second, RMLs offer (mandatory) insurance against house price declines, through their nonrecourse 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 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 a recourse loan boosts the take-up rate by 73%, to 2.89% of homeowners. Notable also is the resulting increase of 70% in the welfare gain from reverse mortgages. These results suggest that retirees 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. 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 big swings in housing prices that have been observed since the mid-2000s, we are abstracting from downward aggregate house price risk that households face and hence may be underestimating the insurance benefit from reverse mortgages.

Finally, in row 6 in the table, we arbitrarily reduce the up-front 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 claim that high up-front costs deter RML demand. In this case the take-up rate nearly doubles relative to the benchmark, to 3.16% of retired homeowners, with an associated gain in welfare, demonstrating that high up-front costs do play a quantitatively significant role.

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. While the overall take-up rate is just 1.67%, it is 5.5% for the lowest-income quintile, compared to 0.8% for those with median income and just 0.25% for the highest quintile. Similarly, the take-up rate for older households is highest: e.g., it is 17.4% for the lowest-income homeowners in their

Table 5: RML Demand Distribution and the Great Recession

		% Take-Up				Welfare Gain, % of Wealth
		All Ages	71-79	81-89	91-99	
1	**Baseline**					
	All	1.67	1.56	3.02	7.94	0.21
	Bottom income quintile	5.45	6.56	9.71	17.44	0.42
	Median income	0.84	0.57	1.48	6.02	0.23
	Top income quintile	0.25	0.30	0.29	0.66	0.05
2	**Post-recession retirees (65 in 2010)**					
	All	1.19	1.06	2.55	5.57	0.17
	Bottom income quintile	4.53	4.32	12.51	22.61	0.55
	Median income	0.76	0.72	1.09	5.58	0.16
	Top income quintile	0.04	0.01	0.08	0.63	0.03
3	**Long-run: 5% drop in income**					
	All	1.82	1.75	3.17	8.33	0.22
	Bottom income quintile	5.50	6.78	9.32	18.47	0.36
	Median income	1.02	0.72	1.91	6.40	0.24
	Top income quintile	0.35	0.42	0.44	0.61	0.06
4	**Post-recession retirees with 5% income drop**					
	All	1.29	1.20	2.80	5.72	0.18
	Bottom income quintile	5.08	4.85	14.38	25.46	0.57
	Median income	0.84	0.95	1.27	4.68	0.17
	Top income quintile	0.05	0.02	0.08	0.63	0.03

90s, compared to just 6.6% for those in their 70s. The interpretation of these results is that those with the lowest incomes are most likely to become constrained and require the additional equity to meet their expenditure needs, but they have the most restricted access to conventional mortgages due to the debt-to-income requirement of such mortgages. Similarly, as households age, they are much more likely to need a reverse mortgage: Partly, this is due to the correlation of age with large medical expense shocks, as well as to the fact that older households are more likely to run down their financial wealth.

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 Great Recession. This cross-section of new retirees differs from the benchmark 2006 cross-section chiefly in their wealth: The 2010 mean housing wealth is 22% below the 2006 mean, and the mean financial wealth is 10% lower.[23]

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 felt most by households currently in their 20s and 30s, through the effects on earnings of prolonged unemployment or un-

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[23] 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.

deremployment 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.[24]

Finally, in a third experiment, we reduce the wealth 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 29% decline in RML demand relative to the baseline, from 1.67% to 1.2% of retirees. This is because, for the majority of households, the majority of wealth lost is in their home equity, which lowers the propensity to borrow through a reverse mortgage. This decline in RML demand holds for all age groups and through most of the income distribution, though the extent is heterogeneous. However, for older homeowners in the bottom quintile of the income distribution, there is a second effect owing to their low income: The wealth shock makes them more likely to be pressed against their budget constraint, while they have the fewest options outside of the reverse mortgage market. The impact is significant. While among low-income homeowners in their 70s demand still decreases, from 6.6% to 4.3% of the group, low-income homeowners in their 80s and 90s increase their demand by about 30%, from 9.7% and 17% to 12.5% and 22.6%, respectively, for the age groups.

In contrast, the long-term effect of the recession of a uniform drop in incomes increases RML take-up across the income distribution and across almost the entire age distribution. While wealth is not changed, households' income is more likely to be insufficient to cover their nondiscretionary expenses, such as house maintenance and medical or nursing-home expenses. While high-income households are still much less likely to borrow than low-income households, they also experience the largest medical expense shocks and have larger houses to maintain. Their RML demand increases more in percentage terms than that of low-income households'. For example, the share of low-income households in their 70s with reverse mortgages increases by 3.5%, from 6.6% to 6.8%, while the share of high-income households in this age group increases by 42%, from 0.3% to 0.42%.

Finally, in combining the 5% income decrease with the less wealthy 2010 retiree sample, we see that the overall RML demand decreases, such that the impact of decreased equity dominates for most of the income distribution. The lowest-income households in their 80s and 90s are a notable exception, where, with the loss of both wealth and income, the increase in RML demand is nearly 50% relative to benchmark.

The last column shows ex-ante welfare gains from reverse mortgages for homeowners in each group, evaluated as a percent of average wealth, which is useful since wealth 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 0.42% to 0.55% of net worth. Ex-ante welfare gains increase slightly in the income drop experiment for all but the low-income households (panel

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[24] 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.

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.[25] We can expect these retirees to use reverse mortgages much more in the future, all else equal. This has policy implications for both the 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 following 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

In this paper, 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 the average expected welfare gain of reverse mortgages is equivalent to \$885, or nearly 5% of median annual after-tax income, in a one-time transfer to retired homeowners. Our model indicates that, under the current environment and RML terms, reverse mortgages are taken out at a time of a large medical expense shock, allowing borrowers to meet their obligations while remaining in their homes. The model also predicts 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. The take-up rate among the lowest-income quintile is 5.5%, and it is over 17% for the lowest-income households of age 90 and above.

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-move risk, as well as house price fluctuations, all dampen RML demand. However, not surprisingly, we also find that the costs of the RML contract are an important determinant of demand. In particular, the insurance costs inherent in the current contract reduce RML demand because households do not value this insurance, due to relatively low borrowed amounts and government-provided insurance such as Medicaid. The model predicts a 73% increase 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 up-front insurance cost for those with lower balances, will decrease RML take-up by 60%, all else equal. In addition, lowering the up-front cost to zero increases demand for the loan to just over 3% of retirees. One possible interpretation of these results is that, given the risk that lenders have to take on in order to offer the RML, and given retiree preferences and risks, the resulting contract is too expensive to be desirable to the majority of homeowners. Many homeowners are better off selling their homes in the event of needing to liquidate their home equity.

The Great Recession, however, may drive up demand for reverse mortgages over time, particularly among the more vulnerable low-income and older households. This highlights important trade-offs between access and portfolio risk that should 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,

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

which decreases their desire to borrow against it. However, for homeowners over age 80 in the lowest-income quintile, the loss of wealth, combined with low income, drives up demand for reverse mortgages by 30%. Moreover, 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 the 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 in 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 $\pi^s_{i,2,2}$, the couple household remains a couple. We assume that a single household remains single with probability one, i.e., $\pi^s_{i,1,1} = 1$, 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 assume that the age (i) and the health status (m) of a couple household is represented by the age of the head of the household and the health status of the head's spouse. Naturally, since the husband and the wife can have a different health status, we split each couple household in the HRS data into two households in the model and assign the 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.

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 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, which we estimate separately for singles and couples. The distribution of medical expense shocks also depends on household size s.

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. 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 ages 65, 75, 85, and 95. As with other shock processes, we assume that the household size transition probabilities

Table 6: Household Size Transition (Percent)

	Current Period: Two-Adult		Current Period: One-Adult	
Age	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.

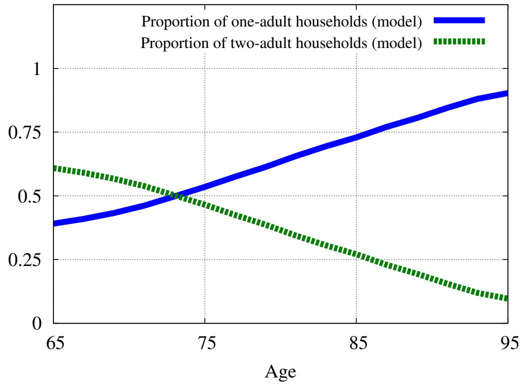


Figure 5: Household Size Distribution

are time-invariant and we 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 their low occurrence 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., they are involuntary. That is, we assume away divorce, which is rare in our sample. Figure 5 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 one-adult and two-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 estimated 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 ages 65, 75, 85, and 95. As expected, the mortality rate is higher for older and less healthy households. Health status is generally persistent, but the

Table 7: Health Status Transition (Percent)

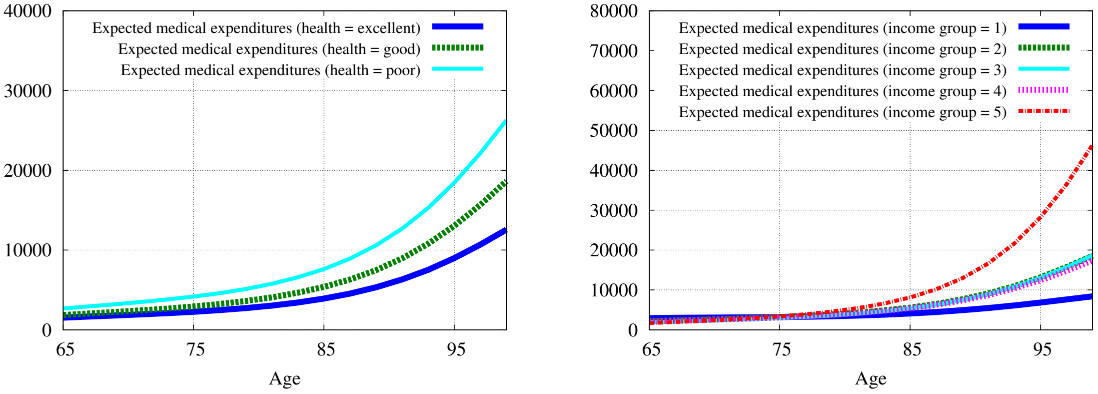
Health Status Transition (Age 65)	Dead	Excellent	Good	Poor
Excellent	1.3	72.8	21.5	4.4
Good	2.2	25.8	53.3	18.7
Poor	9.6	6.1	20.7	63.7

Health Status Transition (Age 75)	Dead	Excellent	Good	Poor
Excellent	3.9	60.1	26.9	9.2
Good	6.6	21.1	46.9	25.4
Poor	16.3	3.8	17.6	62.3

Health Status Transition (Age 85)	Dead	Excellent	Good	Poor
Excellent	10.5	46.8	27.1	15.6
Good	14.7	17.0	37.8	30.5
Poor	28.8	5.1	13.2	52.9

Health Status Transition (Age 95)	Dead	Excellent	Good	Poor
Excellent	28.5	29.5	19.8	22.3
Good	32.9	12.9	26.8	27.5
Poor	56.9	4.2	13.6	25.3

Source: Constructed based on HRS, 1996-2006.



(a) Median Income, by Health

(b) Good Health, by Income

Figure 6: 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 health care 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 6 reproduces expected mean medical expenses, for single households in the middle income bin by health (panel (a)) and those in good health by income bin (panel (b)). As we would expect, people in worse health have higher expenses, as do

Table 8: Probability of Permanent Nursing-Home Move (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: Constructed based on HRS, 1996-2006.

those with higher incomes, 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 (two-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 two 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 an individual moves into a nursing home *and* simultaneously stops being a homeowner, conditional on the individual'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 ages 65, 75, 85, and 95. Not surprisingly, the probability is higher for less healthy individuals and grows rapidly in old 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 upward biased. 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 value. δ is set at 1.7% per year, which is the average depreciation rate of residential structures in the 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% of the value of the house. This is the estimate obtained by Greenspan and Kennedy (2007). Grueber and Martin (2003) report a median selling cost of 7.0% of the value of the house.

The interest rate is set at 4% per year. For conventional mortgage loans, we assume a borrowing

Table 9: Income Levels[1]

Group	Group 1	Group 2	Group 3	Group 4	Group 5
Income	6,858	12,403	17,948	25,948	42,722

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

premium (ι^m) of 1.7% annually. This is the average spread between 30-year conventional mortgage loans and 10-year Treasury bonds between 1996 and 2006.[26] 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 ratio. First is the front-end DTI ratio, which is applied only to mortgage and other housing-related expenses, such as 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 not likely to pay for student loans, and they carry a relatively small balance of credit card debt, we model only equity debt and choose $\alpha = 0.35$.

See Figure 7 for the resulting collateral constraints $\lambda^m_{i+1,b,s',m',p'}$ 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. Contreras and Nichols (2010) estimate the AR(1) process of house prices for the U.S. as a whole, obtaining the persistence value of 0.811, which we use as our persistence parameter. Flavin and Yamashita (2002) estimate the standard deviation of *individual* house prices using the Panel Study of Income Dynamics (PSID). We use their estimate of 14.2% as our standard deviation for house price shocks, since the shock in our model is associated with individual house values. The AR(1) process is discretized into an annual first-order Markov process, which we then square to obtain a biennial process for the model.

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. 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 ages 63 to 67 in the 2006 HRS sample, 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

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

Table 10: 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, 2006.

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 and putting it 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. Half of the households are in excellent health. The 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 the households in our sample are in a net negative position.

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

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

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 (0.74 here, 0.81 previously), coefficient of relative risk aversion σ (2.59 versus 2.93 previously), strength of bequest motive (6.58 versus 7.19), and consumption floor per adult $\underline{c}$ (\$11,124 in 2000 dollars versus \$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 0.92 in biennial terms in the current model and was 0.96 in our previous one. This implies less patient households and affects household saving and debt. The difference likely stems from the fact that, in the current paper, we are more explicit about modeling conventional mortgages using an empirically motivated debt-to-income requirement as opposed to a reduced-form age-specific collateral constraint, and we have a reverse mortgage present in the model as well. We then use the debt rate in the retiree population as a target but, given the significant differences in the model, the discount factor estimates are likely not to be the same, as the parameters show.

The most dramatic difference in the two models is in the parameter ω_1, which measures the extra utility of homeownership relative to renting. In the current model, it is 8.6, while in our previous model it was 2.6. This is because there are substantial differences in the models pertaining to the dynamics of housing prices. In Nakajima and Telyukova (2013), we modeled the 1996-2006 housing

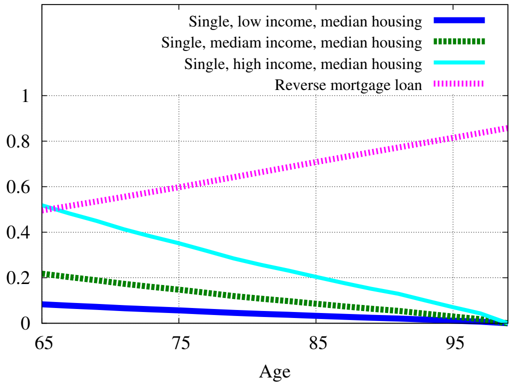


Figure 7: Collateral Constraints, Conventional and Reverse Mortgages

boom and some tax benefits of ownership, such as capital gains taxation if one sells the house, which are absent in the current model, and which, by encouraging homeownership, lower the value of ω needed to match the homeownership rate. Instead, 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, both of which drive the needed ω up. Both sets of differences imply a higher value of ω needed in the current model. 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.

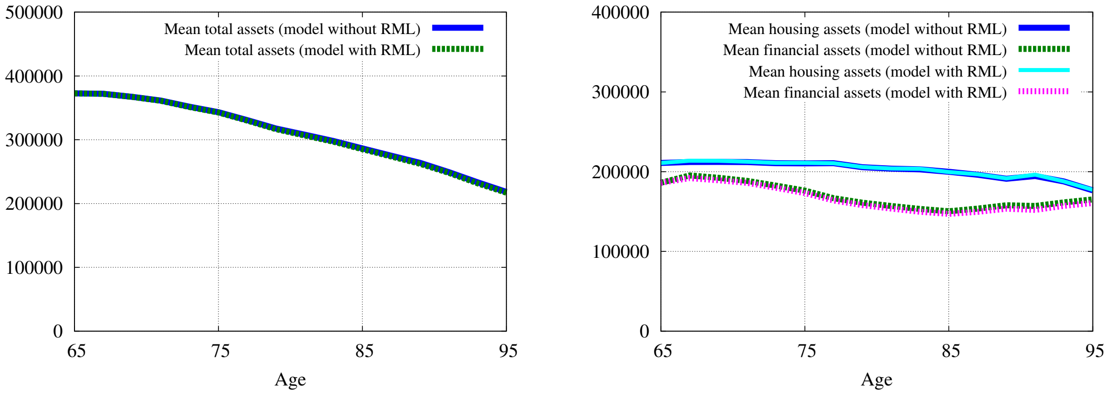
The luxury bequest parameter ζ is smaller in this model (15,354) relative to our previous model (45,714). The reason lies in the difference of the targets: Because of our previous interest in studying the retirement saving puzzle itself, in the previous model we matched net worth profiles by income bin. The luxury parameter in that model is higher than in the current model in order to match the steep dissaving of lower-income groups late in life.

B.3 Third Stage: Calibration of Reverse Mortgage Parameters

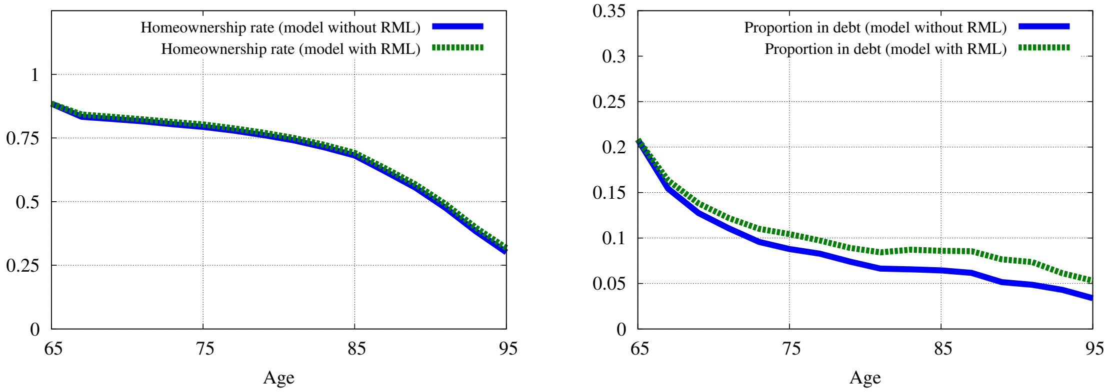
To conduct our experiments, we now introduce reverse mortgages into the calibrated baseline. In order to calibrate parameters that characterize RMLs, we rely on the terms of reverse mortgage contracts in the data. The up-front and per-period costs associated with insurance against house price shocks are $\nu^i = 0.02$ and $\iota^i = 0.0125$ 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 up-front cost. We set the interest premium of reverse mortgages to be the same as conventional mortgages; $\iota^r = 0.017$ annually.

The up-front cost in the data appears to be about 5% of the house value. The origination fee is typically 2% of the house value up to $200,000 and 1% above it, with a cap of $6,000 and a floor of $2,500. Considering that most house values in the model, as in the data, are below $200,000 but half are below $100,000, where the floor of $2,500 binds, 2.5% is reasonable. The closing cost is typically around $2,000 to $3,000. Dividing the amount by the median house value in the sample, we get 2.5% as well. Adding these together, we get $\nu^r = 0.05$.

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



(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

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 7. 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 incomes and larger houses.

C 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. Given the low take-up rate of reverse mortgages, the aggregate effect of reverse mortgages is small. Reverse mortgages enable people to stay in their houses longer, which slightly raises the homeownership rate relative to the benchmark model while increasing the proportion of homeowners in debt.

Table 11: Alternative Calibration and Results

Parameter	Description	Model with $\sigma = 3.81$
β	Discount factor[1]	0.902
η	Consumption aggregator	0.744
σ	Coefficient of RRA	**3.810**
ω_1	Extra-utility from ownership	9.826
γ	Strength of bequest motive	4.859
ζ	Curvature of utility from bequests	19,831
$\underline{c}$	Consumption floor per adult[1]	14,360
Results:	Take-up rate, among homeowners	1.93
	Welfare gain, all households	1,073
	(% of average wealth)	0.288
	Welfare gain, all homeowners	1,213
	(% of average wealth)	0.296

[1] Biennial value.

D Sensitivity Analysis

The results presented above are all subject to the benchmark model calibration. One of the key mechanisms by which retirees decide how much to save or borrow in retirement is the interplay of the precautionary motive and the bequest motive. The identification of the relevant parameters (σ and γ) is difficult to ascertain formally in this setting, as emphasized by Ameriks et al. (2011) and discussed extensively in Nakajima and Telyukova (2013). This is a shortcoming of most life-cycle models with a warm-glow bequest motive.[27] Thus, in this section we perturb the calibration to demonstrate the sensitivity of our results.

In this experiment, we change our estimated coefficient of relative risk aversion from our value of 2.59 to 3.81, which is the point estimate from a life-cycle model of retirement similar to ours but crucially without housing, in De Nardi et al. (2010). Then, we reestimate the model to match the same targets we use in the benchmark. The fit of this model, measured by the weighted squared distance between data and model moments, deteriorates relative to the benchmark, particularly for the age profile of the homeownership rate, but still produces reasonable age profiles. With this parameter specification, we have a decline in the strength of the bequest motive γ. The result of this perturbation is a slightly higher reverse mortgage take-up rate of 1.9%, which is comforting given that we do not target the empirical take-up rate in the calibration process. Consistent with the higher take-up rate, the welfare gain of having RMLs for homeowners increases from \$885 (0.22% of average wealth at age 65) to \$1,213 (0.30% of average wealth at age 65). By forcing a higher σ, the relative strength of saving motives in retirement shifts from bequest motives to precautionary motives against medical expense risks, but its effect on the demand for RMLs is found to be limited. In other perturbations of the model parameters, we have found the main model implications to be similarly robust.

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[27] Ameriks et al. (2011) overcome the identification problem by using novel survey data.