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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 rapid growth in this market, only 1.9% of eligible homeowners had RMLs in 2013. In this paper, we analyze reverse mortgages in a calibrated life-cycle model of retirement. The average welfare gain from RMLs is $252 per homeowner, and $1,770 per RML borrower. Bequest motives, uncertainty about health and expenses, and loan costs account for low demand. According to the model, the Great Recession's impact differs across age, income, and wealth distributions, with a threefold increase in RML demand for lowest income and oldest households.

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

In Nakajima and Telyukova (2013), we find that older homeowners become borrowing-constrained as they age and these constraints force many retirees to sell their homes when faced with large medical expenses. In this environment, it seems that an equity borrowing product targeted toward older homeowners may be able to relax that constraint, and hence potentially benefit many owners later in life. Empirical studies suggest a similar possibility, though estimates range widely. For example, while Merrill, Finkel, and Kutty (1994) suggest that about 9% of homeowner households over age 69 could benefit from RMLs, Rasmussen, Megbolugbe, and Morgan (1995) argue, using 1990 U.S. Census

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data, that this number is nearly 80%.[1] Despite the apparent benefits, however, just 1.9% of older homeowners held RMLs in 2013, down slightly from its all-time high of 2.1% in 2011.

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

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

The model predicts that the ex ante welfare benefit of reverse mortgages is equivalent to providing a lump-sum transfer of \$252 per retired homeowner at age 65, which amounts to 0.84% of median annual after-tax income for this group. The welfare gains are of course much larger for eventual borrowers, amounting to \$1,770 per borrower or 5.1% of median annual income. All homeowners value, ex ante, the option of being able to tap their equity some time during their retirement; however, ex post, only 0.89% of eligible retirees use

[1] Rasmussen, Megbolugbe, and Morgan (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, Finkel, and Kutty (1994) assume that households with housing equity between \$100,000 and \$200,000, income of less than \$30,000 per year, a strong commitment to stay in the current house (i.e., had not moved over the previous 10 years), and who own their house free and clear benefit from reverse mortgages.

RMLs in our model, which is close to the long-term data average of 0.84% between 1997 and 2013. Reverse mortgage demand is dampened by a combination of substantial risks that households face late in life—such as health, medical expense and long-term care risks, and house price uncertainty—as well as bequest motives, and significant costs of the contract. We find that the 2013 RML reform is likely to further dampen demand going forward, stemming from its tighter borrowing limit for most retirees, and in spite of lowered costs for some borrowers.

More specifically, we find that retirees who use reverse mortgages tend to have low income, low wealth, and poor health, and those who use them do so primarily to support consumption expenditure in general, or in some cases large medical expenses. While the aggregate take-up rate is less than 1%, it is 2.2% for the lowest income quintile and 3.9% for low-income households aged 90 and above. Bequest motives not only dampen RML demand, but also change the way homeowners use RMLs; without a desire to bequeath, retirees are over 17 times more likely to take RMLs, even without being pushed to do so by a medical expense shock, and use them overwhelmingly for nonmedical consumption. On the contract side, we find that eliminating up-front costs of the loan more than triples demand for RMLs. In addition, reverse mortgages are nonrecourse loans, which means 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 would remove substantial insurance premia from the cost of the loan, would triple RML demand. In this sense, the oft-heard claim that large contract costs suppress RML demand is supported by our model. The FHA's 2013 RML reform, in contrast, dampens demand in spite of a lower up-front insurance cost for some retirees, because it also significantly tightens the borrowing limit for most homeowners and raises insurance costs for the most heavily indebted.

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

This paper makes three key contributions to the literature. We are the first, to our knowledge, to model reverse mortgages in a standard life-cycle environment that incorporates both key sources of risk that retirees face and aspects of older households' preferences previously shown to be important, 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, because our model allows for rich distributional analysis, we quantify demand, welfare gains, and effects of the Great Recession for different types of households and across the income and age distributions.

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

Our paper is also related to the literature that addresses saving motives for the elderly, or the so-called "retirement saving puzzle." Hurd (1989) estimates the life-cycle model with mortality risk and bequest motives and finds that the intended bequests are small. Ameriks et al. (2011) estimate the relative strength of bequest motives and public care aversion, and find that both are significant. De Nardi, French, and Jones (2010) estimate out-of-pocket (OOP) medical expenditure shocks using the HRS, and find that large OOP medical expenditure shocks are the main driving force for retirement saving, such that bequest motives no longer matter. Venti and Wise (2004) study how elderly households reduce home equity, and Yogo (2016) studies portfolio choice decision in retirement. In Nakajima and Telyukova (2013), we emphasize the role of housing in shaping retirement saving and find that housing and homeownership motives are key in accounting for the retirement saving puzzle, in addition to bequest motives and medical expense uncertainty. In this paper, we model mortgages and mortgage choice in more detail, with a 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 a large literature on retirement saving products, such as life insurance and annuities. Some examples are Yaari (1965), Mitchell, Poterba, and Warshawsky (1999), Dushi and Webb (2004), Turra and Mitchell (2004), Inkmann, Lopes, and Michaelides (2011), Pashchenko (2013), Lockwood (2012), and Koijen, van Nieuwerburgh, and Yogo (2016). Our paper is related to this literature because reverse mortgages, in their tenure form, can be seen as a way of annuitizing home equity. However, because line-of-credit RMLs are by far the most popular choice, we do not focus on the tenure option in this paper.

The third literature that our paper is related to is that on mortgage choice using structural models. This literature is growing in parallel with developments in the mortgage markets. Chambers, Garriga, and Schlagenhauf (2009) construct a general equilibrium model with a focus on the optimal choice between conventional fixed-rate mortgages (FRMs) and newer mortgages with alternative repayment schedules. Campbell and Cocco (2003) and van Hemert, Koijen, and van Nieuwerburgh (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 I provides an overview of reverse mortgages. Section II develops the structural model that we use for experiments. Section III discusses model calibration and model fit, including implications for the distribution of debt. In Section IV, we use the model to analyze the demand for reverse mortgages through a number of counterfactual experiments. Section V concludes. Many details on the calibration of the model, as well as sensitivity analysis, are relegated to the Internet Appendix, which is published online with this article.[2]

I. RMLs: 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.[3] The government-administered reverse mortgage is called a home equity conversion mortgage (HECM). According to Shan (2011),

[2] The Internet Appendix may be found in the online version of this article.

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

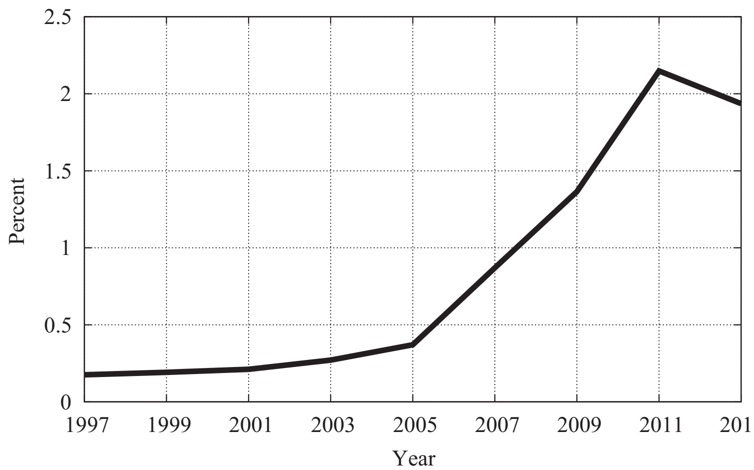

Figure 1. Percentage of older homeowners with reverse mortgages. This figure shows the proportion of all homeowners aged 65 and above that have RMLs. The data are constructed using various years of the AHS.

HECM loans represent over 90% of all reverse mortgages originated in the U.S. market.[4]

The number of households with reverse mortgages has been growing in recent years. Figure 1 shows the proportion of homeowner households aged 65 and above that had reverse mortgages between 1997 and 2011, based on data from the American Housing Survey (AHS). As the figure shows, the use of reverse mortgages was limited before 2005. In 2001, the share of eligible homeowners with reverse mortgages was about 0.2%. This share had increased rapidly since then, however, reaching 2.1% in 2011. This recent growth motivates our 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 that it implies is nontrivial and is expected to grow. In particular, with 26.8 (46) million households with heads aged 65 and above in 2012 (projected by 2030), a 2.1% take-up rate implies 563,700 (966,000) RMLs outstanding among this age group, if the take-up rate were to stay constant at its current level.

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

[4] Many other reverse mortgage products, such as Home Keeper mortgages offered by Fannie Mae or the Cash Account Plan offered by Financial Freedom, were recently discontinued as the HECM market has expanded. See Foote (2010).

Second, government-administered HECM loans have different requirements from conventional mortgage loans. These mortgages are available only to borrowers aged 62 or older who are homeowners and live in their house.[5,6] Moreover, borrowers must have repaid their other mortgages at the time they take out a reverse mortgage. RMLs do not have income or credit history requirements, because repayment is made not based on the borrower's income but rather 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 an HUD-approved counselor in order to qualify for an 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 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 does not cover the total costs of the loan, the borrowers are not liable for the remaining amount, and thus they are insured 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 the 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 by far the most popular, with HUD indicating that the line-of-credit plan is chosen alone 68% of the time, and in combination with the tenure or term plan 20% of the time. It thus appears that older homeowners have used reverse mortgages mainly to flexibly withdraw funds out of accumulated home equity.

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

[6] 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.

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 an HECM loan. Currently, the limit is \$625,500 for most states.[7] The lesser of the appraised value and the limit is the Maximum Claim Amount (MCA).[8] Reverse mortgage borrowers cannot receive the full amount of the MCA because there are both 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.[9] 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 the 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.[10] The Net Principal Limit is calculated by subtracting various up-front costs from the IPL.

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

II. Model

To set up the decision problem of retirees, we extend our previous work (Nakajima and Telyukova (2013)). Time is discrete. All households are either

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

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

[9] The annual mortgage insurance premium was increased from 0.5% to 1.25% in October 2010.

[10] The lender computes, based on the borrower's current age and life expectancy, how much interest and other costs a loan will accumulate over 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.

single or couples, and face uninsurable idiosyncratic risk in health status, mortality, household size (spouse mortality), and medical expenses; there is no aggregate uncertainty. Household size in the model affects the income, consumption, and medical expenses of the household; including it allows us to consider both couples and single households in our data sample. Internet Appendix Section I 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, 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 RMLs for homeowners, which we model as lines of credit, as this is by far the most frequently used option.[11] As we specify later, reverse mortgages offer different (i.e., age-dependent) collateral constraints and cost structure from conventional mortgages. Finally, as 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 the household's age i, pension income b, household size s, health status m, medical expenditures x, house price p, reverse mortgage indicator k ($k = 0$ means a homeowner does not have an RML, while $k = 1$ means that she does),[12] house size h ($h = 0$ means the household is a renter), and financial asset holdings a. Following convention, we omit time subscripts and use a prime to denote a variable in the next period ($t + 1$).

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

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

A. 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 tilde indicates consumption before the consumption floor is applied), savings a', and the size of the house to rent $\tilde{h}$, where $\tilde{h}$ is chosen from a discrete set $H = \{h_0 = 0, h_1, h_2, ..., h_{\overline{H}}\}$, with h_1 and $h_{\overline{H}}$ denoting the smallest and largest house available, respectively. The constraint $a' \geq 0$ implies that renters cannot borrow using financial assets; in other words, only home equity borrowing is available in the model, as the data show that the holdings of unsecured debt among retirees are small. The quantities $\pi^{s}_{i,s,s'}$, $\pi^{m}_{i,m,m'}$, $\pi^{x}_{i,b,s,m,x}$, and $\pi^{p}_{p,p'}$ denote the transition probabilities of the shocks (s, m, x, p), respectively, and $m > 0$ 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 varies 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, nonhousing consumption c, services generated by the rental property (assumed linear in the size of the rental property $\tilde{h}$), and tenure status o, where $o = 1$ represents ownership, and $o = 0$ indicates renting. Tenure in the utility function captures different private values of owned versus rented housing, due to financial and nonfinancial benefits of ownership that are not explicit in the model. Household size s differentiates the utility of couples from 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 the rent payment with rental rate r_h. We assume that rents are constant; adding realistically mild rent fluctuations does not affect the results. The right-hand side includes financial assets and interest income $(1+r)a$ plus 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.[13] Moreover, since both bonds and mortgage loans are risk-free, and mortgage interest rates are higher than the interest rate on savings, households never choose to hold risk-free bonds and mortgage loans simultaneously. 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.[14] The household qualifies for this program if it runs down its savings ($a' = 0$) and if, net of its rent, the household cannot afford the consumption floor $\underline{c}$ multiplied by the household size factor χ_s.

B. *Homeowners without a Reverse Mortgage*

The choice of a homeowner with no reverse mortgage ($k = 0$) is characterized as follows:

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

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; 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 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 ($V_2(i, b, s, m, x, p, k = 0, h, a)$).[15]

[13] In the HRS, 29% of retirees hold stocks or mutual funds and 49% 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.

[14] Hubbard, Skinner, and Zeldes (1994) and De Nardi, French, and Jones (2010).

[15] 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 their children upon death. If their children have sufficient liquid assets, the amount of the inheritance is below the estate tax exemption, the savings 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 from an RML and borrowing from their children. Exploring the model with intergenerational transfer decisions is outside the scope of this paper.

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

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

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

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

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

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

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 collateral constraint characterized by $\lambda^m_{i,b,s,m,p}$. In the event of death, the estate includes the value of the house ($p'h$) net of the selling cost to liquidate it ($\kappa p'h$). Again, it is not possible for a household to have positive mortgage debt and positive financial assets at the same time, 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.[16]

We formulate the collateral constraint for a conventional forward mortgage, $\lambda^m_{i,b,s,m,p}$, to capture the idea that, as in practice, 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 DTI 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:

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

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

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

For comparison purposes, Yogo (2016) assumes, following Sinai and Souleles (2008), that homeowners can borrow up to 50% of their house value, regardless of age. Although this implies a looser collateral constraint than ours, especially

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

for older homeowners, his calibrated model replicates the observed life-cycle pattern on home equity borrowing. However, crucial differences are that Yogo (2016) focuses on single households, who decumulate assets more quickly in the data, and thus fewer households have an incentive to borrow against home equity.[17] Moreover, in his model, housing assets are significantly more liquid than in our model, and there is no renting. Both of these features imply that homeowners reduce housing assets gradually, with less need to borrow against home equity.

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

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

subject to

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

There are three new features. First, the collateral constraint of the reverse mortgage borrower is characterized by λ_i^r, which depends only on age.[18] In contrast with conventional mortgages, RMLs are secured purely by the value of housing and thus reverse mortgage lenders do not conduct income and credit checks, so the collateral constraint does not depend on other household characteristics. We discuss further the nature of these constraints in the section below. Second, in order to take out a reverse mortgage, the household pays up-front costs and insurance premium proportional to the value of the house, ν^r and ν^i. Finally, there is a max operator in the utility from bequests. This captures the nonrecourse nature of the reverse mortgage; if the household dies, and the consolidated balance of housing assets and reverse mortgage $((1-\kappa)p'h + a')$ turns out to be negative, the heirs of the household are not liable for the loss.

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

[18] Notice that we model both conventional forward mortgages, including home equity lines of credit (HELOCs), and RMLs as a 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.

C. 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 $\pi^n_{i,m}$:

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

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 the values to an RML holder of moving out and becoming a renter, voluntarily or involuntarily, and of staying and keeping the reverse mortgage, respectively.

The homeowner with a reverse mortgage who chooses to sell solves

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

subject to

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

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

The max operator in the budget constraint (15) reflects 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 flow 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

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

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 can save in financial assets at the same time they borrow against an RML, which in our model is ruled out. Thus, we think of the flexible adjustment of the RML balance in the model as capturing this missing additional saving channel. However, we may be understating the cost of RML borrowing, because the interest rates earned on savings are typically lower than the interest and insurance costs of reverse mortgages, a spread that our model does not capture for equity borrowers.

III. Calibration

We first calibrate the baseline version of the model without reverse mortgages. We 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 HRS, which is a biennial panel survey of older households. We focus only on retirees aged 65 and above, so that we do not have to account for labor supply decisions. We use self-reported retirement status, and include both couples and single households. To make data cells sufficient in size, given the richness of our state space, we pool households into five-year age bins. Thus, age-65 households in our sample comprise ages 63 to 67, and each household appears in up to five bins, that of its actual age plus/minus two years.

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

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

where η is the Cobb-Douglas aggregation parameter between nonhousing consumption goods c and housing services h, σ is the risk aversion parameter, and 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. Finally, ψ_s is the household consumption equivalence scale.

Table I

Calibration Summary: Model Parameters

This table presents calibrated parameter values from the baseline model. All parameter values are annual, except for ρ_p and σ_p, which are biennial.

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

Households get utility from leaving bequests. When a household dies with wealth a, its utility function takes the following form, with bequest motive strength γ and bequest marginal utility ζ[19]:

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

Table I 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.

A. *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

[19] De Nardi, French, and Jones (2010) also use the same risk aversion parameter σ for utility from bequests.

description of our first-stage calibration in Internet Appendix Section II.A. Consumption equivalence scale is normalized to one for single households, and we set $\psi_2 = 1.34$ for two-adult households, as computed by Fernández-Villaverde and Krueger (2007). The income multiplier for two-adult households, χ_2, is set at 1.48, which is the median in the HRS. The annual real saving interest rate is fixed at 2.58% per year. This is the average real interest rate on the 10-year Treasury bond during our sample period, 1996 to 2006, deflated using CPI. The mortgage interest premium ι^m is set at 1.69% per year, which is the difference between the average real mortgage interest rate during this period of 4.27% and the risk-free rate. The maximum DTI ratio is set at 35%, which is the common value in the data. The annual maintenance cost is calibrated to be 1.7%, based on the depreciation rate of residential capital. House selling cost is 6.6% of house value (Greenspan and Kennedy (2007)).

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

We treat house price dynamics as a persistent but stationary shock, which we model as an AR(1) process. We use a mean-reverting AR(1) process, even though our sample spans the years 1996 to 2006 with a house price boom, because in this paper we are interested in long-run reverse mortgage demand and we are agnostic about future house price trends. We estimate the biennial AR(1) process for idiosyncratic house price shocks based on monthly ZIP code-level CoreLogic housing price index (HPI) data for the period 1976 to 2015. The CoreLogic HPI is a proprietary monthly ZIP code-level home price index, based on repeat sales of single-family homes. The sample includes data for 7,142 ZIP codes. We deflate the house prices by the CPI prior to running the estimation. The estimation yields a biennial persistence of house prices of $\rho_p = 0.859$ and a standard deviation of $\sigma_p = 0.125$. The resulting house price shocks are large, with possible realizations between 29% below and 41% above the median house price, thus introducing significant house price uncertainty into the model. The shocks are also persistent: for instance, when the house value is 41% above median, the expected duration of staying at that level is 6.7 years. Thus, the mean-reversion aspect of the AR(1) does not greatly affect the extent of individual house price uncertainty. Further details of the estimation are in Internet Appendix Section II.A.5.

Finally, we calibrate the initial distribution of 65-year-old retirees along our state space dimensions—income, health, household size, medical expenses, housing wealth, and financial wealth—using the 2006 cross-section from the HRS. We use only the 2006 cross-section because using a pooled sample would mask time effects in housing wealth and financial wealth that make 65-year-olds from different survey waves differ from each other in a way that our stationary model cannot account for.

B. Second-Stage Estimation

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

Figure 2 shows the model fit. First, it is useful to examine the data profiles given by the dashed lines in the figure. The homeownership rate is 88.5% at age 65, and declines to just over 40% by age 95. Mean total assets show a similarly smooth, but slow, decline, from about \$375,000 to about \$250,000, while the housing asset profile is essentially flat. Financial asset holdings do not decline much over the life-cycle for two reasons. First, many homeowners sell their house toward the end of life, as seen in Panel A, which just substitutes housing assets with financial assets. Second, there is a mortality bias—those with relatively lower wealth die earlier. This bias pushes the life-cycle profiles upwards and exists both in the data and in the model, since the correlation of health and wealth is built into the initial type distribution and agents in the model die with the same probability as in the data. Finally, the proportion of households in debt declines smoothly from 21% at age 65 to nearly zero at age 95, as homeowners repay existing collateralized loans or sell their house and become renters.

The age profiles implied by the model, given by solid lines in the figure, fit the data profiles very well. In the model, the homeownership rate declines when households either choose to sell the house (the majority of moves) or are forced to move into a nursing home by a moving shock. In turn, households sell

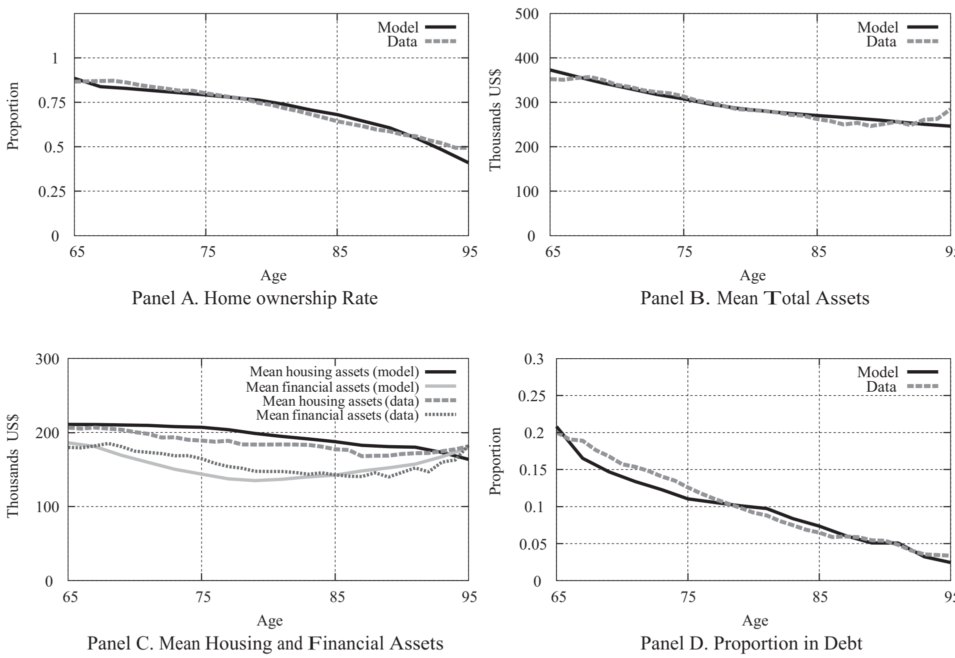

Figure 2. Model fit: age profiles of the baseline model. The figures compare key asset age profiles from the calibrated baseline model to those in the data. The data counterparts are age profiles based on age-year regressions using HRS data pooled over the period 1996 to 2006.

the house to realize capital gains when a high house price shock is realized, to dissave for life-cycle reasons, or as discussed in Section II, to pay for medical expenses when a high medical expense shock hits or another shock that impacts the collateral constraint is realized. The model matches the empirical homeownership rate very closely, as well as the mean net worth, housing asset and financial asset age profiles, and overall proportion in debt. The fit presented here yields the smallest sum of weighted squared normalized errors comparing the model and data moments, with equal weights.

Based on this distance criterion, the model produces the parameter estimates in the second panel of Table I, presented in annualized terms. The estimated discount factor β is 0.91 in annual terms, which is within the accepted range of estimates in models of this kind. The coefficient of relative risk aversion is 2, which is in the middle of the spectrum in the literature.[20] The extra utility from homeownership, at 4.9, suggests that homeownership yields, in financial and nonfinancial benefits not explicit in the model, nearly five times the utility benefit of renting in retirement. The consumption floor $\underline{c}$ supported by the government through welfare programs such as Medicaid is estimated

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

to be $13,919 in 2000 dollars per adult per year, which aligns with empirical estimates of such program benefits (Hubbard, Skinner, and Zeldes (1994)), once adjusted for inflation. The strength of the bequest motive is 20.5, and the preference shifter ζ is 7,619 in annual terms. The aggreation parameter of housing and nonhousing consumption is estimated to be 0.76.

The bequest motive in this model is primarily identified by the asset profiles of older households: it affects (dis)saving decisions of older retirees, while precautionary motives affect younger retirees more. Our parameter estimates imply that our model overestimates the realized bequests for the lower end of the distribution, but matches quite well the middle and upper end of the bequest distribution, without targeting any of these quantities in estimation. For example, the mean and median realized bequest for singles in the model are $234,000 and $175,000, respectively. According to Ameriks et al. (2011), corresponding numbers in the data are $234,000 and $114,000. The realized bequest for the 90th percentile is $470,000 in the model and $536,000 in the data. However, the proportion of singles who leave no bequests is 25% in the data, while it is about 1% in the model, although the bottom quintile of the model's single households leaves only 3% of all bequests.[21] 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 and low level of indebtedness toward the end of life.

A number of these parameter values are similar to the estimates from our model in Nakajima and Telyukova (2013), while other parameter values have changed since the models are different in significant ways. We provide a comparison of parameter values in the two models in Internet Appendix II.B.

C. Additional Implications for Distribution of Debt and Portfolio Allocation

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

Figure 3 compares mean and median debt among debtors, in the model and data. Both median and mean profiles in the model exhibit initial drops in debt as some homeowners immediately sell their houses in the model, contrary to the data, where the decumulation is more gradual. The difference is more noticeable in the mean profiles; after the initial drop, the slope of the profile exactly matches that of the data. The model matches the median profile of debt quite well, notwithstanding the noise in the data resulting from small cell sizes in late years of life. The initial drop in debt profiles occurs because, in the data,

[21] In Ameriks et al. (2011), households pay for medical expenses just before they die, which helps better match the low tail of bequests, since it is known that a large portion of medical expenses is spent just before death. In our model, the timing of medical expense shocks is not synchronized this way, as households make savings decision every two years.

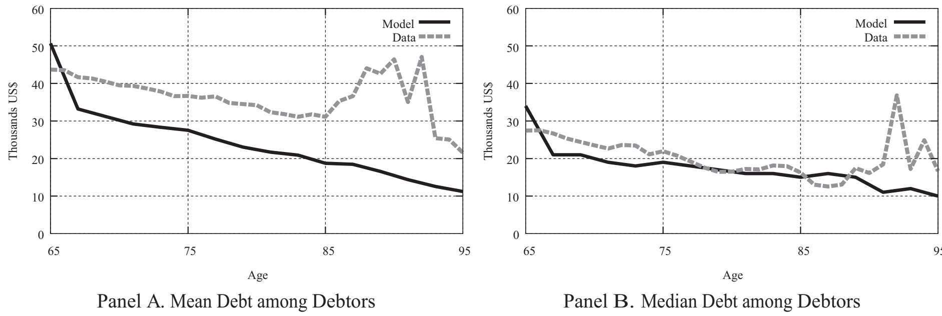

Figure 3. Model versus data: distribution of debt. The figures compare mean and median age profiles of debt from the calibrated baseline model to those in the data. The data counterparts are age profiles based on age-year regressions using HRS data pooled over the period 1996 to 2006.

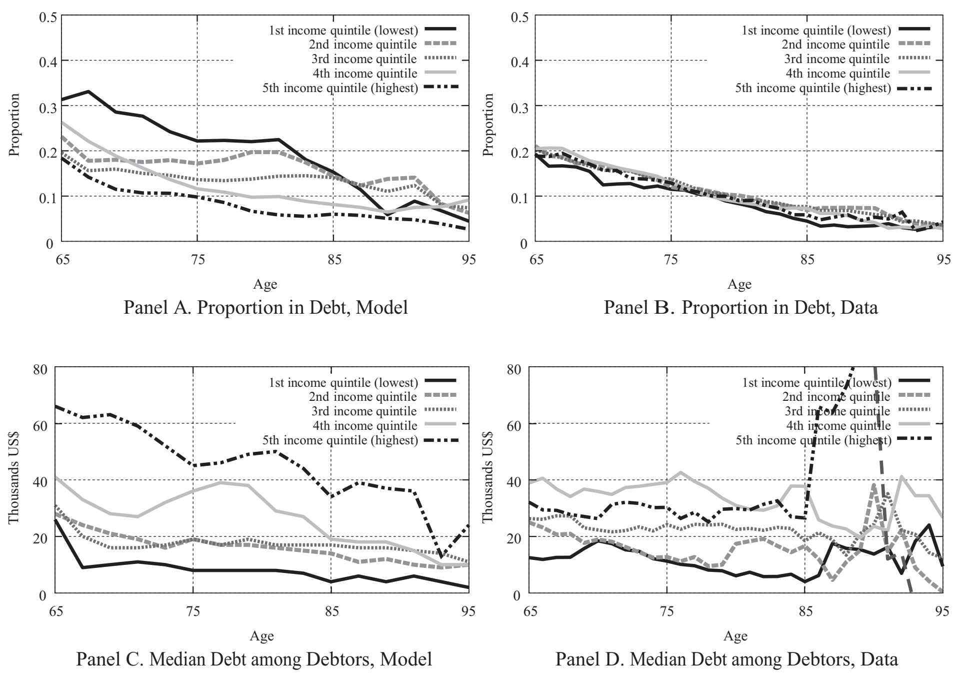

Figure 4. Model versus data: distribution of debt for each income quintile. The figures compare the proportion of homeowners in debt and median debt among debtors by income quintile, from the calibrated baseline model to the same profiles in the data. The data counterparts are age profiles based on age-year regressions using HRS data pooled over the period 1996 to 2006.

some households have a significant amount of debt initially and are forced either to sell their house or repay a part of their debt. This is the impact of our parsimonious modeling of the collateral constraint based on the DTI ratio.

Figure 4 compares debt rates, as well as median debt profiles, *by income quintile* in the model and data. The model matches well the empirical pace

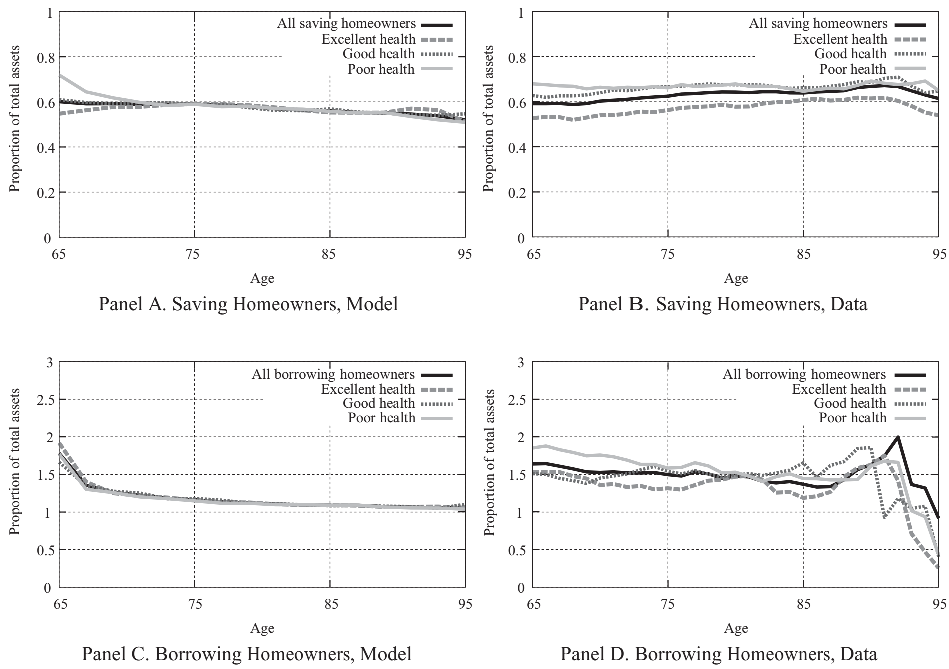

Figure 5. Model versus data: proportion of housing assets over total assets. The figures compare the proportion of housing to total assets by age for all homeowners, as well as homeowners by health status, from the calibrated baseline model to the same profiles in the data. The data counterparts are age profiles based on age-year regressions using HRS data pooled over the period 1996 to 2006.

of indebtedness decline with age. Note that the model profiles imply larger dispersion of debt rates across income groups than the data. We observe this pattern repeatedly in the graphs that follow, as it results by construction. We use the empirical distribution of debt in 2006 as the model initial conditions, as discussed above. The counterpart age profiles in the data are the result of extracting the age effects from the age-year regressions. The resulting initial conditions differ in the model and data, causing some persistent difference in dispersion in the model versus the data. Even with that caveat, the model matches all income groups' profiles well, although the top income group's debt amount, which is initially higher in the model than the data, drops at a faster pace in the model.

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

D. Reverse Mortgages

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

The third panel of Table I summarizes the parameter values associated with RMLs; the details are in Internet Appendix II.C. 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. The RML interest premium (annual 1.7%) is set to be the same as that for conventional mortgages. The upfront insurance premium (2%) and flow insurance premium (1.23%) are fixed for HECM loans. Finally, the collateral constraint for RMLs is taken from AARP (2010). The amount of loan given, unlike conventional mortgages, depends on the age of the borrower and indeed grows with age, because the older the borrower, the lower the expected interest costs and the smaller the future house price risks. In reality, while the borrowing limit is less tight for older borrowers, it does not change after a homeowner takes out a RML. In other words, the age-dependent borrowing limit in the model corresponds to "refinancing" the RML each period. We use this setup as it captures the loosening of the RML borrowing limit with age, without further complicating the model.[22]

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

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

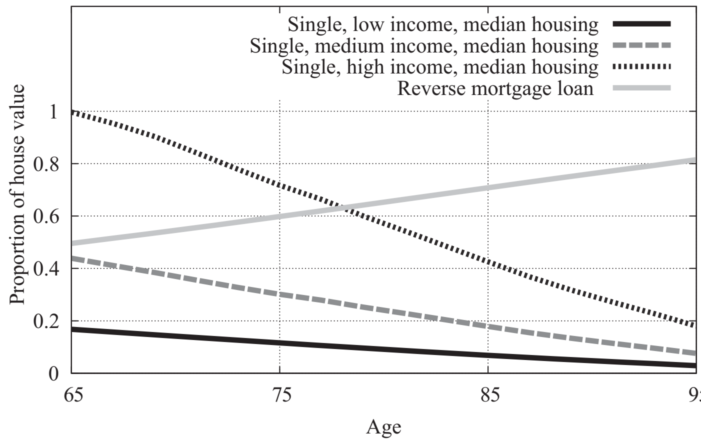

Figure 6. Collateral constraints: conventional and reverse mortgages. This figure compares collateral constraints, measured as the maximum allowed debt amount as a proportion of house value, for conventional and reverse mortgages. For the former, collateral constraints vary with household characteristics because they are based on household income. In the figure, conventional mortgage collateral constraints are shown for households in good health in three income quintiles. These collateral constraints are downward-sloping since they depend on future income to be used to repay the debt. For reverse mortgages, the collateral constraint depends only on age, in particular, it is increasing in age.

IV. Results

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

A. Take-Up and Benefits of Reverse Mortgages

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

Table II

RML Take-Up Rates and Welfare Gains

This table summarizes the impact of RMLs in the baseline model. The first column shows the share of homeowners that obtain an RML. The second column shows the welfare gain of introducing an option to purchase RMLs, measured by a one-time payment at age 65, which would make the expected life-time utility of those with access to RMLs equal to the expected life-time utility without, measured in 2000 US$. The third column shows this welfare gain measured as a percentage of household income at age 65. Panel A shows the RML take-up rate among all homeowners aged 65 and above in the United States, for three different time periods. The data are from the AHS. Panel B shows the take-up rate and welfare gains for all retired homeowners, as well as for subsets of homeowners by household characteristic.

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

of reverse mortgages, so we compute welfare gains for homeowners only.[23] We also show the welfare gain as an average share of income at age 65.

The calibrated model implies an RML take-up rate of 0.89% of retired homeowners. Since the model produces a long-term average RML take-up rate in a stationary world, the rate of 0.84% for the period from 1997 to 2013 is an appropriate data benchmark. Alternatively, since we are working with the 2006 sample of initial retirees, the observed average RML take-up rate between 2007

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

and 2013 can also be considered relevant; this rate is 1.34% in the data. Since we do not target the RML take-up rate in our calibration, and we use the terms of RMLs as observed in the data, the model rate of RML demand being close to that in the data is a significant success of our model.

The RML take-up rate varies significantly across types of households. For example, the take-up rate is higher for older homeowners (2.4% among households in their 90s versus 0.9% among those in the 70s), homeowners with outstanding mortgages at age 65 (5.4% take-up rate), low-income homeowners (2.2% versus 0.2% for the highest income group), single-person households (1.3% versus 0.5% among two-person households), and homeowners in poor health (1.1% versus 0.7% for homeowners in excellent health). It is not surprising that the take-up is higher among older and less healthy households, since they are more likely to see tight conventional mortgage constraints and are more likely to have high medical expenses, both of which can make a reverse mortgage attractive.

Our results are qualitatively consistent with empirical findings in the literature, although we lack 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, and higher house values and homeowner costs. Redfoot, Scholen, and Brown (2007) find that RMLs are likely to be used to repay outstanding mortgages and for medical expenses when household income is insufficient.

According to our model, the ex ante mean welfare gain from having the RML option is $252 per homeowner; this translates to, on average, 0.84% of annual after-tax income at age 65. The gain is much larger for those who obtain the reverse mortgage ex post, at $1,770 or 5.13% of household income. The welfare gain also varies across household types. For example, low-income households value the option more than high-income households ($369 or 2.22% versus $40 and 0.04%), as the ability to take a reverse mortgage at some point in the future is valuable for the purpose of relieving liquidity constraints, which are more likely for low-income households. Welfare gains are also increasing in the value of the house, which is not surprising since a more expensive house entails more equity for the potential borrower; those with the largest house have a welfare gain of $1,415 or 3.61% of income. Interestingly, the ex ante welfare gain is slightly higher for healthier homeowners at age 65, even though the take-up rate is higher among those with poor health. This is because households with poor health tend to be older and are more likely to incur large medical expenses, while healthier homeowners tend to live longer and thus are more likely to need a reverse mortgage late in life.

B. Age Distribution of Reverse Mortgage Borrowers

Figure 7 compares the age distribution histograms of households *at the time of RML signing*, among all households who currently hold an RML, in the data

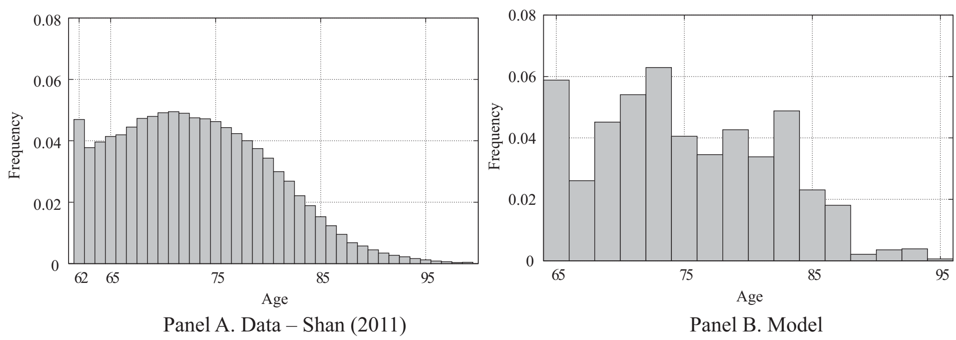

Figure 7. Age distribution of borrowers at RML origination. These figures plot empirical and model histograms of the age distribution of RML borrowers when they first obtain RMLs. Panel A shows the profile in the U.S. data constructed by Shan (2011), while Panel B is the corresponding output of the calibrated baseline model. Since one period is two years in the model, while one bar represents one year in Panel A, we adjust the model output by dividing by two, so that the levels are annualized and comparable between the two figures.

(Shan (2011)) and in the model, the latter adjusted to annual terms.[24] The model replicates the distribution of age origination very well, including the initial spike in demand: many homeowners take up the RML as soon as they can, at age 62 in the data and at age 65 in the model. Both the model and the data exhibit a hump shape after the initial spike, and taper to zero toward the end of life. This age distribution of take-up rates is another significant success of the model.

C. 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 factors determine how households (dis)save in retirement more generally. In Internet Appendix V, we present life-cycle profiles that result in alternate economies in these experiments. Table III shows the take-up rate and welfare gains among homeowners in the model with several counterfactual experiments. First, we evaluate the model without medical expenditure shocks. To do so, we assume that all households have to pay the mean of the medical expenditure distribution, conditional on household age, income, and size but not on health, which itself is a source of uncertainty. In this case, the take-up rate increases slightly to 1.03%, all else equal. There are two opposing effects at work here. On the one hand, we remove large expense shocks, whose realization is one reason to take out a reverse mortgage—this would decrease demand. On the other hand, we remove a source of risk, which increases RML demand for other purposes, as one precautionary reason for delaying borrowing is removed. The latter effect

[24] We thank Hui Shan for making the data used to construct the figure available to us.

Table III

Impact of Uncertainty and Bequest Motives on RML Demand

This table summarizes the impact of RMLs when aspects of the baseline model are changed. The first column shows the take-up rate of RMLs among homeowners. The second and third columns show the welfare gains of introducing an option to purchase RMLs. See the notes of Table II for the definition of welfare gains. The first row corresponds to the baseline model. The other rows report results for alternative models.

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

dominates. For the same reason, if we shut off medical expenditures altogether, we see a larger increase in RML demand, to 1.21%.

Nursing home move risk dampens demand for reverse mortgages, as does house price risk, because both reduce the expected duration of homeownership. Removing compulsory nursing home move shocks increases the RML take-up rate to 0.95% of homeowners, similar to 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 using the line of credit. Eliminating this possibility makes these loans more attractive as a way of relieving possible liquidity constraints while staying in the house longer. Removing idiosyncratic house price uncertainty increases the take-up rate to 1.22% of retired homeowners, because absent temporary increases in house value, households lack unexpected opportunities to sell the house for a capital gain, which would shorten the expected duration of an RML. This increases expected years of homeownership and in turn encourages more reverse mortgage borrowing. Interestingly, while in this case the uptake of RMLs increases, the welfare gain falls relative to benchmark. This is because, in the presence of house price uncertainty, reverse mortgages serve as an option allowing smoothing in low house price states but an occasional opportunity to sell in high-price states. Absent that uncertainty, the insurance benefit of reverse mortgages is removed.

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

We also run the symmetric experiment of assuming that households expect house prices to drop, deterministically, at 4.5% per year. This has the opposite effect of the expected housing boom, bringing RML demand to zero. The reason is that the amount of equity against which homeowners can borrow is declining, which makes borrowing more costly. This result may seem to contradict the rise in RML demand after 2007. The clue lies partly in the predictable nature of the decline in the model: it is hard to argue that the collapse of the housing market in the last recession was predicted by homeowners, and expectations matter greatly for this result. Indeed, house prices stopped declining around 2009.[25] 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 impact of the Great Recession in more detail below.

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

To summarize so far, the model suggests that, conditional on the existing RML contract, reverse mortgage demand is low for the same reasons that retirees do not rapidly spend down assets: due to precautionary motives given the risks that they face and due to the bequest motive. These factors affect not only demand for reverse mortgages, but also their purpose. Under the current environment, absent constrained states or spending emergencies, households prefer not to be in debt. In the absence of risks or bequest motives, however, households would use RMLs more freely for general consumption.

Finally, we conduct an experiment in which we introduce idiosyncratic interest rate uncertainty. This experiment captures the fact that interest rates for conventional mortgages are usually fixed, while other interest rates, including those on reverse mortgages, fluctuate over time, a consideration that may affect demand for RMLs. In constructing the interest rate shock, we fit an AR(1) process to the time series of real interest rates, measured as the 10-year

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

Treasury rate net of the CPI inflation rate. We then discretize the estimated AR(1) process into a first-order Markov process. As a result, the annualized interest rate fluctuates between 0.52% and 4.49%, instead of staying at the 2.58% benchmark level, with a two-year persistence of 0.71. In other words, the interest rate is expected to remain the same for 6.8 years on average. This model variant requires the addition of another state variable. For computational tractability, we assume that the interest rate shock is *idiosyncratic* to households, instead of affecting all households in the same way as aggregate shocks do, so that the overall household distribution remains stationary. Therefore, our results should be interpreted as the time-series average when interest rates fluctuate over time.

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

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

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

In this section, we explore how demand for reverse mortgages is affected by their current terms, in response to the popular claim that high costs of RMLs are to blame for low demand. Table IV summarizes the results. First, we evaluate the October 2013 reform in the HECM program. In this reform, 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 DTI requirement), and changed the insurance cost structure (see HUD (2013)). In the language of our model, this translates

Table IV

RML Demand with Alternative Loan Terms

This table summarizes the impact of RMLs when the terms of the RML contract are changed in the baseline model. The first column shows the take-up rate of RMLs among homeowners. The second and the third columns shows the welfare gains of introducing an option to purchase RMLs. See the notes of Table II for the definition of welfare gains. The first row corresponds to the baseline model. The other rows report results for models with alternative RML terms.

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

to a 15 percentage point reduction in the borrowing limit for all households. In accordance with the new rules, the initial insurance cost decreases from 2.0% to 0.5%, unless the household's initial RML balance exceeds 60% of the maximum loan amount, in which case it pays an up-front cost of 2.5%.

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

As we discussed, reverse mortgages offer several potential benefits. First, borrowers can access their home equity for nonhousing 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 or her heir is liable for any excess loan amount. One point to note is that households can accumulate the RML balance and then default, using the consumption floor, when they sell the house and 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 IV shows that changing the RML to be a recourse loan triples the take-up rate to 2.71% of homeowners. Notable also is the resulting near-tripling of the welfare gain from reverse mortgages. These results suggest that retirees do not value this insurance aspect of the RML. There are three reasons for this. First, most RML borrowers in the model carry relatively small balances of reverse mortgages when the loans become due, and thus the probability of being unable to repay is small. Second, borrowers have access to the publicly provided consumption floor. This makes the additional insurance in the RML contract less valuable to older households. Third, since we do not model the aggregate swings in housing prices that have been observed since the mid-2000s, we are abstracting from the aggregate downward 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 an RML to zero without making the borrowers pay for it in other ways. This experiment aims to evaluate, albeit in an extreme way, the significance of the often-mentioned high up-front costs for RML demand. In this case, all else equal, the take-up rate increases even higher relative to the benchmark, to 3.24% of retired homeowners, with an associated large gain in welfare.

E. Distribution of Reverse Mortgage Demand and the Great Recession

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

We perform three stylized experiments to assess the impact of the Great Recession on future RML demand. 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 the 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 and somewhat in their income: the 2010 mean housing wealth is 22% below the 2006 mean, and the mean financial wealth is 10% lower. Median income in the 2010 initial distribution is 2.3% lower than in 2006. The homeownership rate in 2010 is two percentage points above the 2006 rate, while the indebtedness rate is two percentage points higher.[26]

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

Table V

RML Demand Distribution and the Great Recession

This table shows how RML take-up rate and welfare gains are affected by the Great Recession, given its short-run and long-run impact on household wealth and income. The first four columns show RML take-up rates among all homeowners aged 65 and above, and among homeowners of ages 71 to 79, 81 to 89, and 91 to 99. The last column shows the welfare gain. See the notes of Table II for the definition of welfare gains. Panel A corresponds to the baseline model. In Panel B, the initial age-65 household type distribution used in the model is from the 2010 wave of the HRS, instead of the baseline 2006 distribution. In the Panel C, household income is lowered by 5%. In Panel D, the 2010 household type distribution and 5% reduction in income are combined. Each panel shows the take-up rate and welfare gains for all income groups, as well as for three income quintiles.

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

In the second experiment, we speculate on the long-run impact of the Great Recession. Butrica, Johnson, and Smith (2012) estimate that the long-run impact of the Great Recession will be most felt by households that are currently in their 20s and 30s, through effects of prolonged unemployment or underemployment spells early in their careers on earnings. Endogenous response to such shocks notwithstanding, they estimate that these households will arrive at retirement with incomes that are about 4.8% lower than those of current retirees. Thus, in our second experiment we drop the incomes of our 2006 retirees by 5% across the board, while holding their wealth constant.[27]

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

Table V presents the results of these experiments. Overall, for all ages and all incomes, we see that the short-run loss in wealth for current entrants into retirement results in a decline in RML demand of 20% relative to the baseline, from 0.89% to 0.71% of retired homeowners. However, the effect varies across the income distribution. The most significant decreases in RML uptake are seen among the highest income individuals, who likely lost the most equity in their homes during the crisis, but are least constrained in other ways, which discourages borrowing. In contrast, in the bottom income quintile of homeowners, the model predicts an increase in RML demand, with the size of the impact increasing in age. While these households still have the majority of their wealth in home equity, they are also most likely to be impacted by other adverse wealth effects pushing them against their liquidity constraint, which in turn induces higher RML borrowing. The increase in RML uptake is 12% for low-income homeowners in their 70s, but rises more than threefold (from 3.9% to 12.9%) for those in their 90s, as the oldest households have the fewest options outside the reverse mortgage market.

In contrast, the long-term effect of a uniform 5% drop in incomes increases RML take-up across the income distribution and across almost the entire age distribution, although the magnitude of the impact is less dramatic than in the first experiment. The overall take-up increases by 12%, from 0.89% to 1.00%. 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.[28]

Finally, in combining the 5% income decrease with the less-wealthy 2010 retiree sample, we see that although the overall take-up rate declines slightly from 0.89% to 0.83%, it rises among median- and low-income households. Reverse mortgage demand is lower for high-income households, for whom the decrease in equity dominates the decrease in income in terms of impact. For all but the oldest households of low and mid-income groups, the increase in

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

[28] We also conducted an experiment in which we reduced income by 10%, for a more dramatic long-run income effect. We found that the effects moved in the expected direction.

RML demand is larger in this experiment than in the previous two, showing a combined effect from decreases in income and wealth.

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

These experiments suggest that the effect of the Great Recession, while small for reverse mortgage demand in aggregate, does have significant effects for more vulnerable retirees, namely low-income and older households.[29] All else equal, we can expect these retirees to use reverse mortgages more in the future, particularly as the housing market recovers. This has policy implications for both the demand and the supply sides. The RML is a way to ensure financial security in retirement for the most vulnerable retirees while diminishing their dependence on social programs. At the same time, this selection of the borrower pool suggests that the riskiness of the HECM portfolio held by HUD may increase in the future. It is important that future evaluations of HECM regulations in the vein of the 2013 reform strike the right balance to ensure program viability while giving those that need it most access to their home equity.

V. Conclusion

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

Through counterfactual experiments, we show that, conditional on the existing RML contract in the data, bequest motives and precautionary motives in the face of medical expense and nursing home moving risk as well as house

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

price fluctuations dampen RML demand, while adjustable interest rates on reverse mortgages can increase demand slightly. We also find that the costs of the RML contract are an important determinant of demand. In particular, the mandatory insurance costs inherent in the current contract decrease RML demand, because households do not value this insurance due to relatively low borrowed amounts and government-provided insurance alternatives such as Medicaid. The model predicts a tripling in demand if the reverse mortgage were made a recourse loan. In contrast, the recent 2013 HECM reform by HUD, which tightens borrowing limits for all future borrowers but decreases the upfront insurance cost for those with lower balances, will decrease RML take-up slightly, all else equal. One possible interpretation of these results is that given the risk that lenders have to take to offer RMLs, and given retiree preferences and risks, the resulting contract is too expensive to be desirable to the majority of homeowners, so that many homeowners are better off selling their homes if they need to liquidate some home equity.

The Great Recession, however, may drive demand for reverse mortgages up over time, particularly among the more vulnerable low-income and older households. This highlights important trade-offs between access and portfolio risk to be considered in future redesigns of the HECM program. We find that the *short-run* effect of the recent crisis is to lower reverse mortgage demand in aggregate, because the majority of households suffered a large loss to home equity, which decreases homeowners' desire and ability to borrow against it. However, for homeowners above age 90 in the lowest income quintile, the loss of wealth combined with lower income triples demand for reverse mortgages. 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 show in additional experiments that these dynamics, and expectations regarding them, can significantly impact RML demand as well. We leave a deeper analysis of this issue to future research.

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Supporting Information

Additional Supporting Information may be found in the online version of this article at the publisher's website:

Appendix S1: Internet Appendix