Aging in Place, Housing Maintenance and Reverse Mortgages*

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ABSTRACT

We study the role of housing wealth in financing retirement consumption. In our model retirees: (i) derive utility benefits from remaining in their home (aging in place); and (ii) choose in each period whether to maintain their house. The evidence that we present shows that these features are important in explaining the saving decisions of the elderly. The costs and the maintenance requirement of reverse mortgages reduce (or eliminate) the benefits of the loans for retirees who wish to do less maintenance. We evaluate the impact of different loan features on retirees' utility, cash-flows to lenders and to the government agency that provides mortgage insurance. We show that combining reverse mortgages with insurance against a forced home sale (e.g. due to a move to a nursing home) is Pareto improving and can lead to increased demand for the loans due to product complementarities.

JEL classification: G21, E21.

Keywords: retirement, housing wealth, precautionary savings, aging in place, property maintenance.

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1 Introduction

In many countries, the government provides a pension to retirees through the social security system. However, there have been increasing concerns about the sustainability of these (mainly unfunded) social security systems and the adequacy of households' private retirement savings (Banks, Blundell, Tanner, 1998, Kotlikoff, 2001, Scholz, Seshadri, and Khitatrakun, 2006). At the same time, homeownership rates are particularly high among U.S. households and for most of them housing assets constitute the single most important component of their wealth (Bertaut and Starr-McCluer, 2002). We study the role of housing wealth in financing retirement consumption.

Retirees could release their home equity by downsizing, by moving into rental accommodation, or by using financial products such as reverse mortgages (RMs). However, in spite of its potentially large relevance, the existing empirical studies do not find strong support for housing wealth being used to finance non-housing retirement consumption. Retirees do not appear to purchase a house of lower value or to discontinue homeownership. The few that discontinue homeownership do so only late in life (after age 75 or so, as documented by Venti and Wise, 2004, Poterba, Venti, and Wise, 2011a). To date, the demand for RMs has been limited (Caplin, 2002, Davidoff, 2015, Shan, 2011).

The explanations that have been proposed in the literature for why older individuals do not wish to dissave could in principle also explain why they do not wish to tap into their home equity. Those which have received more attention are bequest motives (important early references include Abel, 1985, Hurd, 1989 and Bernheim, 1991) and precautionary saving motives arising from uncertain life span and risky medical expenditures (Hubbard, Skinner, and Zeldes, 1994, Palumbo, 1999, De Nardi, French, and Jones, 2010, Ameriks, Caplin, Laufer, Van Nieuwerburgh, 2011). If retirees do not wish to dissave, they may not want to sell their house or borrow against it. It may also be re-assuring for retirees to know that if they remain homeowners they have a hedge against future house price fluctuations (Sinai and Souleles, 2005).

In order to investigate these explanations we build a model of the consumption and housing choices of retired homeowners. Retirees derive utility from housing, from non-durable consumption and from leaving a bequest. They are subject to several sources of risk, including an uncertain life span, health risk, medical expenditure shocks, interest rate risk and house price fluctuations. Our model has two additional features. The first is that retirees derive utility benefits from living in the same house that they retired in, which increase with the number of years in the residence. Such benefits are at the center of the concepts of "place attachment" and of "aging in place." Place attachment is a key concept in environmental psychology.[1] It refers to a set of feelings that emotionally bind a person to a given place. Rubinstein and Parmelee (1992) argue that the concept is especially significant for older people, as one way of keeping the past alive, maintaining a sense of continuity and fostering identity. Venti and Wise (2004) discuss the importance of these psychological benefits when analyzing the housing decisions of the elderly.

The second model feature is that in each period, retirees choose whether to maintain their property. The possibility of cutting back on housing maintenance may be particularly important for older homeowners, as a way of dissaving and of having more cash available to meet medical and other expenditures. Davidoff (2005) uses the American Housing Survey (AHS) to provide evidence that older homeowners reduce housing maintenance and that this reduction has an impact on the sale price of the houses when they are eventually transacted.

The model calibration shows that both the benefits of aging in place and maintenance choice are important model features for explaining the homeownership age profiles, maintenance expenses and wealth decumulation of the elderly. Bequest and precautionary savings motives are also important, and they lead individuals to remain homeowners until a later age. However, without the aging in place benefits, the model predicted decline in homeownership rates with age is too large compared with the data. The fundamental economic reason is simple: Even though precautionary savings and bequest motives lead retirees to save more, housing is not an asset that is particularly suitable for this purpose, since it is lumpy and risky. As retirees age, as they are hit by health and medical expenditure shocks, and as house prices and interest rates fluctuate, in the absence of aging in place benefits, the likelihood that at all points in time the value of each retiree's house matches the amount that he/she wishes to consume of housing and to save is fairly small, so too many decide to sell. Both the utility from aging in place and maintenance choice features of our model have implications for RMs.

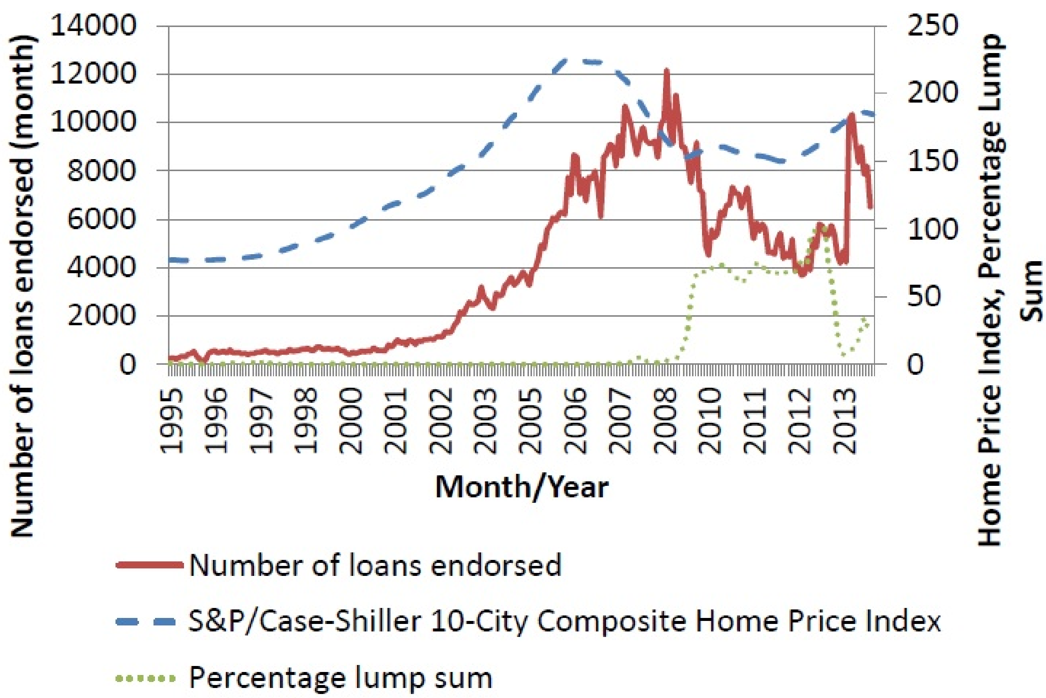
RMs allow retired homeowners to borrow against their home equity without moving and to make partial withdrawals which may help them choose a savings level that better matches their desired level. Borrowers do not have to make any payments on the loan before

[1] When applying the concept of place attachment to the elderly, a common concept used in policy circles is that of "aging in place." The Centers for Disease Control defines this as the "the ability to live in ones own home and community safely, independently, and comfortably, regardless of age, income, or ability level." Survey data shows that the majority of older individuals do want to remain in their current residence. When asked whether they agreed or disagreed with the following statement "What I would like to do is stay in my current residence as long as possible," an overwhelming majority of 91% (95%) of individuals in the 65-74 (75 and older) age group answered that they strongly agreed or somewhat agreed (Kochera, Straight, and Guterbock (2005)).

termination: any interest due is simply rolled into the outstanding loan balance. When the retiree dies or sells the house, the loan is terminated and it becomes due. If at termination the outstanding loan amount is higher than the value of the house, neither the retiree nor the heirs are responsible for any shortfall. Therefore, from the point of view of retirees, RMs combine the right to borrow against their house with a put option, or the right at loan termination to give the house to the lender instead of repaying the outstanding loan amount (Davidoff, 2015). In the U.S. most loans are insured by the government, through the Federal Housing Administration (FHA), which bears the losses if house values decline.

Figure 1 plots the number of RM loans endorsed by the FHA and the S&P/Case-Shiller 10-City Composite Price Index over the last two decades. The number of new RMs increased considerably over this period, to a monthly maximum of 12,000 just before the onset of the recent financial crisis. In spite of the large increase, the number of loans is relatively small when compared to the number of potential borrowers (only two to three percent of eligible borrowers take out a RM).[2]

Figure 1: **Number of reverse mortgage loans**



Our calibrated model generates limited demand for RMs. Even though they could be

[2] The figure also plots the percentage of loans that are of lump-sum type. We discuss the types of products in the next section.

beneficial for retirees who derive utility benefits from remaining in the same house, the large product costs and the requirement that homeowners maintain the property in the same condition significantly reduce or eliminate the loan benefits for retirees who wish to do less maintenance. In our model, retirees value (and exercise) the option to cutback on property maintenance, an option which is no longer available if a RM is used to borrow against the house.[3]

Retirees in our benchmark model do not benefit from RMs. However, the model predicts that the products are beneficial for individuals who have a weaker bequest motive, for those with low levels of financial wealth (and pension income) relative to housing wealth, and for those who have considerable levels of other pre-existing debt. These model predictions are consistent with the empirical evidence that to date, it has been primarily the poor and those with large housing wealth relative to the other components of wealth who have made use of RMs (Davidoff, 2014, Shan, 2011, Warshawsky and Zohrabyan, 2016). For these cases, our model shows that the expected present value of the cash-flows received by the insurance agency are negative, meaning that the government is effectively subsidizing RMs. This is an important point also made by Davidoff (2015) and Lucas (2016), who use simulation results in a continuous time setting to illustrate the risks of the program to the government.

In the last part of the paper, we use our calibrated model to carry out several experiments. We show that the elimination of the maintenance requirement can make the products more appealing to a wider set of retirees, but that it increases the expected government losses. In a second experiment, we evaluate the effects of removing the government insurance, and show that it would have to be accompanied by a reduction in borrowing limits to allow lenders to break even. In a final experiment we focus on product design. One of the risks that retirees in our model face is that they may be forced to sell their house. We interpret this as a forced move to a nursing home and use HRS data to parameterize the probability of this event. The probability of a forced sale makes dissaving using a RM less appealing (as in Michelangeli, 2010). We show that the loans and the insurance against a forced sale act as complements, and we quantify the complementarities.[4]

Our paper is related to the previously mentioned large literature on the motives for dissaving during retirement. Our main contribution to this literature is that we explicitly

[3]Even though in reality lenders may not always enforce the maintenance requirement, many older borrowers may not wish to violate the loan conditions and find themselves in a situation in which they might face foreclosure, especially if they derive benefits from aging in place. In addition this is a feature of the product that retirees may find difficult to understand (Davidoff, Gerhard and Post, 2017).

[4]Our objective is to investigate the benefits and disadvantages of certain RM features, in the context of a realistically parameterized model. We do not try to solve for the optimal RM contract among the set of all possible contracts (Piskorski and Tchistyi, 2010).

model housing. Early important contributions in the RMs literature include Mayer and Simons (1994) and Caplin (2002). Mayer and Simons (1994) analyze the potential of RMs to increase liquid wealth and the income of households, by identifying those with relatively high levels of housing equity. They estimate that over six million homeowners could use RMs to increase their monthly income by at least 20%: a large number compared to the overall size of the RM market. Caplin (2002) analyzes the economic forces that might explain this gap, and he identifies, among others, transaction costs, moral hazard, and psychological factors. We explicitly model some of these factors, and we quantitatively evaluate the impact of RM costs on demand for these mortgages.

More recent papers include Davidoff (2015), Hanewald, Post and Sherris (2016) and Lucas (2016). Our paper differs from these in its quantitative focus and in trying to match the patterns observed in the HRS data. In this respect our paper is closer to that of Nakajima and Telyukova (2017), studying RM demand in a model parameterized using the HRS data, and to that of Nakajima and Telyukova (2013), studying home equity in retirement in a model without RMs and with deterministic house prices.

Our paper differs from their work in several important dimensions. First, our model captures the benefits of aging in place, with the additional utility that the retired homeowner derives increasing with the number of years in the home. Second, we model the retiree's choice regarding whether to maintain the property, provide evidence that it declines with age, and use this evidence to calibrate the model. We show that this model feature is important in allowing retirees to decumulate housing wealth in old age. It also reduces the benefits of RMs. Third, we model RMs as long-term debt contracts and allow for strategic use of the product. Nakajima and Telyukova (2017) model RMs as a series of rolling one-period loans which, in the presence of house price risk, underestimates the insurance benefits of RMs, that arise from the option that borrowers (and their heirs) have to give the house to lenders in lieu of payment. Davidoff (2015) and Lucas (2016) show that the value derived from the put option, and its strategic use by borrowers, is high. In our paper, retirees can make strategic use of the product, but the costs and maintenance requirement of RMs reduce (or eliminate) their benefits. Finally, we derive implications for the financial position of lenders and the government agency, and for product design.

The paper is structured as follows. In section 2 we describe the U.S. RM products. Section 3 sets up the model and section 4 describes the parameterization. Section 5 reports the model results. Section 6 focuses on several experiments. The final section concludes.

2 Description of products

In the U.S., homeowners have access to several financial products designed to release their home equity. Among them are the traditional home equity loans and lines of credit that require future monthly payments, adequate income and credit scores. For this reason, they are not accessible to many older retired individuals who do not meet the affordability criteria. An alternative product is a RM. These loans do not require regular interest or principal repayments since the monthly interest is simply added to the previously outstanding loan balance.

In the U.S. RM market, the vast majority of the contracts are originated under the Home Equity Conversion Mortgage (HECM) program insured by the FHA. Such a program insulates lenders against the risk of house price declines at a cost that is passed on to borrowers under the form of an insurance premium. Under the HECM program, homeowners are allowed to borrow up to a fraction of the value of their house in the form of a line of credit or an up-front lump-sum. We will designate these two alternatives by *drawdown* and *lump-sum*, respectively.[5] The drawdown is adjustable-rate and the lump-sum is fixed-rate (Consumer Financial Protection Bureau, 2012).

The loan becomes due when the borrower sells the house, dies, or moves out. If at this time the proceeds from the house sale are lower than the outstanding loan balance, the FHA insurance will cover the difference, so that lenders still receive the outstanding balance. The retiree or the heirs are not liable for any shortfall, but they are entitled to the positive difference between the proceeds from the house sale and the loan balance. Therefore, from the point of view of borrowers, RM loans combine the right to borrow against the house with a put option to give the house to the lender at loan termination, instead of repaying the outstanding loan balance. This is shown clearly in Davidoff (2015).

RM loans have several requirements and costs. The most significant requirements are that retirees pay property insurance and taxes, and that they maintain the property in the same state of repair as it was at loan initiation. If they fail to do so the loan may become due, and in case of no repayment, the lender has the right to foreclose. The initial loan fees include an origination fee, a mortgage insurance fee and other closing costs. There are ongoing loan servicing fees. In addition, borrowers have to pay a loan interest rate that is higher than the reference index rate. It includes the lender's margin and an annual mortgage insurance premium paid to the FHA. The loan rate is the rate at which the interest on the outstanding loan balance accrues (it is also known as the accrual rate).

[5] Other less common alternatives are a monthly fixed payment or an annuity.

The HECM program specifies the loan borrowing limit at the time when the loan is initiated. It depends on the assessed house value, the borrower's age (or the age of the youngest co-borrower), and the expected loan rate at mortgage initiation. For the drawdown, the expected loan rate is equal to the 10-year risk-free interest rate plus the lender's margin. For the lump-sum option, it is simply equal to the initial loan rate (excluding the mortgage insurance premium). One important feature of the program is that if borrowers do not exhaust the borrowing limit at loan initiation, the amount that they are allowed to draw down increases over time (i.e. the credit limit grows). Over the years, there have been a number of changes to the program. We discuss them in Appendix A.

3 The Model

We model the decisions of single retirees who are homeowners at the beginning of retirement, the risks that they face, and the benefits that they derive from RMs.[6] Retirees are heterogeneous in their pension income and assets, among other dimensions. We take this heterogeneity into account in the empirical implementation of the model, but in the model description, to simplify notation, we drop the subscript that denotes the retiree. Our model is real and the variables should be interpreted accordingly.

3.1 Preferences and health

Survival probabilities. Retired individuals live for a maximum of T periods, but they face mortality risk. We let p_{t+1} denote the probability that the retiree is alive at date $t+1$, conditional on being alive at date t. We follow De Nardi, French and Jones (2010) in choosing the functional form for these conditional survival probabilities, so that we model them as a logistic function of a cubic in age, gender, gender interacted with age, health status (h_t), permanent income rank (Y_t denotes permanent income), permanent income rank squared, and permanent income rank interacted with age.

Per-period preferences. The retiree discounts the future exponentially, with discount factor β. She derives utility from the consumption of housing services (S_t) and non-durable goods (C_t). The per-period preferences are given by a constant elasticity of substitution (CES) function:

[6] We focus on singles for tractability.

$$U(C_t, S_t) = \frac{\{[\theta^{\frac{1}{\epsilon}} C_t^{\frac{\epsilon-1}{\epsilon}} + (1-\theta)^{\frac{1}{\epsilon}} (\omega_t S_t)^{\frac{\epsilon-1}{\epsilon}}]^{\frac{\epsilon}{\epsilon-1}}\}^{1-\frac{1}{\sigma}}}{1-\frac{1}{\sigma}} \tag{1}$$

where θ is the expenditure share in non-durable consumption, ϵ is the intra-temporal elasticity of substitution which measures the degree of substitutability between the two goods, and σ is the intertemporal elasticity of substitution. We assume that housing services are linear in the size of the property (H_t). The size of the house should be interpreted broadly as reflecting not only the physical size, but also its quality.

The parameter ω_t captures the aging in place benefits or the additional utility that the retiree derives from remaining the homeowner of the *specific* house that she had at the beginning of retirement, where she has lived for a number of years. We assume that these benefits increase with the number of years in place (denoted A_t) according to:

$$\omega_t = exp(\alpha A_t). \tag{2}$$

When $\alpha = 0$ it follows that $\omega_t = 1$, $\forall t$ and there are no aging in place benefits. Rubinstein and Parmelee (1992) argue that remaining in their home becomes more important for individuals as they grow older, since it allows them to keep the past alive, maintain a sense of continuity, and strengthen identity. The chosen functional form for the aging in place benefits allows for the possibility that they become increasingly important as individuals grow older in their home. It distinguishes our model from those which have modeled a preference for owning relative to renting (e.g. Fisher and Gervais, 2011).[7]

Bequest motive. In the event of death, the retiree derives utility from bequeathed wealth (W_{t_d}) according to:

$$v(W_{t_d}) = b\frac{(W_{t_d} + \kappa)^{1-\frac{1}{\sigma}}}{1-\frac{1}{\sigma}} \tag{3}$$

where t_d denotes the time of death, b measures the intensity of the bequest motive and κ the extent to which bequests are a luxury good. Bequeathed wealth is equal to financial wealth plus housing wealth net of debt outstanding.

Health risk and medical expenditures. Retirees face health and medical expenditure risks. In each period their health status can be good or bad, with $h_t = 1$ ($h_t = 0$) for

[7] The functional form that we use implies that the marginal utility of non-durable consumption depends on the number of years the retiree has lived in his/her home.

good (bad) health, and transition probability matrix $\Pi[h_t, h_{t+1}](t, Y_t, \ell)$.[8] These transition probabilities depend on age, permanent income, and a vector ℓ of other parameters. Out-of-pocket medical expenditures, $ME(t, Y_t, \ell, h_t)$, are also a function of these variables and of health status. Medical expenditures are subject to persistent shocks. For tractability, we only model two health states and we use a small number of points to approximate the medical expense shocks. We give more details in the data section and in the appendix.

3.2 Pension income, financial assets and taxation

Pension income. In each period t that she is alive, the retiree receives a constant real pension $Y_t = Y$, for $t = 1, ..., T$. This is a measure of her permanent income. Its source may be an inflation-indexed government or private (annuitized) pension that the retiree has accumulated during her lifetime.

Financial assets. We assume that the individual starts retirement with (non-annuitized) financial assets or cash-on-hand of X_1. In the baseline model, we assume that there is no pre-existing debt outstanding or, alternatively, the initial cash-on-hand X_1 can be interpreted as being net of the cash used to prepay any pre-existing mortgage debt. We assume that non-consumed financial assets are invested in a one-period bond.[9]

For some retirees, the interest received on their financial savings is an important source of income, and fluctuations in interest rates are an important source of risk. In our model, interest rates are stochastic. Let r_{1t} denote the log gross real return on a one-period bond, so that $r_{1t} = \log(1 + R_{1t})$. We assume that it follows an $AR(1)$ process:

$$r_{1t} = \mu_r(1 - \phi_r) + \phi_r r_{1,t-1} + \varepsilon_t, \tag{4}$$

where ε_t is a normally distributed white noise shock with mean zero and variance σ_ε^2.

Taxation and government transfers. Pension and interest income are taxed at rate τ. Bequeathed wealth above an exemption level E is taxed at τ_e. For individuals who have low financial assets, government and social security transfers (TR_t) provide a consumption floor. The level of these transfers is such that individuals are able to consume $\underline{C}$ of non-durable

[8] Yogo (2016) develops a life-cycle model of portfolio choice, in which agents face stochastic health depreciation and must choose consumption, health expenditures and portfolio allocation. To simplify, similar to Palumbo (1999) and others, we take health expenditures to be exogenous, and use HRS data to parameterize them. See also Koijen, Van Nieuwerburgh, and Yogo (2016), who develop risk measures for the universe of health and life insurance products.

[9] We do so to be able to model with more realism the risks that retirees face and the features of RMs.

goods and to rent a house of size $\underline{H}$. The taking out of a RM or the selling of the house, to the extent that it affects retirees' financial savings, may also affect their eligibility to receive these government transfers.

3.3 Housing

Housing and property maintenance choices. The individual starts retirement as a homeowner of a given house of size H_1, in which she has lived for A_1 years. The initial price per unit of housing is P_1^H, so that initial house value is $P_1^H H_1$. In each period the house depreciates by a constant proportional amount d_p. The homeowner must decide whether to maintain the property (binary choice). The maintenance counteracts property depreciation, so that house size evolves according to:

$$H_{t+1} = H_t - (d_p - m_t)H_t \tag{5}$$

where m_t denotes maintenance incurred as a proportion of house size (and value). When $m_t = d_p$, house size remains fixed from one period to the next. In addition, we model a minimum level of maintenance that retirees must incur:

$$m_t \geq \underline{m}. \tag{6}$$

This minimum level captures the fact that some maintenance may be required to keep the house in a livable condition. When $\underline{m} > 0$, the homeowner's choices are whether to incur this minimum level or to set m_t equal to d_p. Maintenance expenses (in dollar terms, denoted M_t) are equal to:

$$M_t = m_t P_t^H H_t \tag{7}$$

where P_t^H is the period t price per unit of housing. Homeowners must pay annual insurance costs and property taxes equal to a proportion τ_p of house value. For those who decide to remain in place $A_{t+1} = A_t + 1$.

In each period, retired homeowners decide whether to sell their house and move into rental accommodation, in which case they must also decide the size of the house to rent. If they do so, they no longer derive the additional utility benefits from remaining in their home, so that ω_t is equal to one for renters. To capture the illiquid nature of housing, we assume that a house sale is associated with a monetary cost equal to a proportion λ of the current house value.

For tractability, we do not allow homeowners to sell and buy a house of a different size, nor do we allow transitions from renting to homeownership. The purchase of a smaller house would be an alternative channel, other than neglected maintenance, for retirees to downsize while remaining homeowners. However, in a model in which retirees derive utility benefits from aging in place, doing so may be less attractive than letting the house depreciate. The empirical evidence presented in the next section shows that retired homeowners tend to spend less in property maintenance as they age (consistent with the evidence shown by Davidoff, 2005) and that only a small proportion of them sell their house to buy a smaller one (consistent with the evidence shown by Venti and Wise, 2004).

The rental cost of housing RC_t is a proportion of current house value, equal to the user cost of housing, plus a rental premium, φ. For a house of size H_t it is given by:

$$RC_t = [R_{1t} - \mathrm{E}_t[(\exp(\Delta p^H_{t+1}) - 1] + \tau_p(1-\tau) + d_p + \varphi]P^H_t H_t, \tag{8}$$

where $\Delta p^H_{t+1} = log(P^H_{t+1}) - log(P^H_t)$. Thus, renting exposes retirees to fluctuations in the cost of housing. Setting rents equal to the user cost of housing is a natural benchmark which is used in several papers in the literature (e.g. Bajari, Chan, Krueger and Miller, 2013). However, this may expose renters to too much risk if in reality rents fluctuate less than house prices.

House prices. House prices fluctuate over time. Recall that P^H_t denotes the date t price per unit of housing, so that a house of size H_t is worth $P^H_t H_t$ at t. The price of other consumption goods (the numeraire) is fixed and normalized to one. We assume that changes in the log price of housing follow a random walk with drift:

$$\Delta p^H_{t+1} = \mu_H + \eta_{t+1}, \tag{9}$$

where μ_H is the mean log house price growth and η_{t+1} is a shock that is assumed to be i.i.d. and normally distributed with mean zero and variance σ^2_η.

Forced house sale. In each period, with a certain probability, homeowners are forced to sell their house, in which case they move into rental accommodation for the remainder of the horizon and choose the size of the house to rent (for which they must pay the rental cost). The probability of a forced sale (p^{fs}_t) depends on age and health status. The event is meant to capture, in a simplistic manner, the risk that retirees might be forced to sell their house and move to a nursing home. The rental cost that they must pay is in addition to the previously described medical expenditures. Furthermore, the forced sale event comes with an additional one-off medical expenditure of ME^{fs}. Michelangeli (2010) emphasizes the implication of the forced sale shock for RMs.[10]

We would like to be able to model the forced sale shock in a more realistic manner, but the large number of state variables required for the other model features (and for the RMs in particular) makes it difficult to do so. Nevertheless our model captures the fact that for a retiree who derives utility benefits from aging in place, the forced sale shock is a particularly bad event; it means that the individual will no longer obtain those benefits. The higher medical expenditure makes the event even worse, and as we will see has important implications for the design of reverse mortgages.

3.4 Drawdown reverse mortgages

Retirees in our model can access home equity by selling their house and moving into rental accommodation, but they can also do so while remaining in their house by borrowing against it using a drawdown RM. For tractability, we do not consider other forms of home equity borrowing. Retirees decide at the initial date (model period 1) whether to set up the RM loan, and if they do so, in each period they choose the amount of additional funds to draw, provided that the outstanding loan balance is lower than the borrowing limit. Therefore, we model drawdown RMs as long-term debt contracts. This is important since, as Davidoff (2015) and Lucas (2016) have shown, the put component of the product, i.e. the fact that retirees (and their heirs) can give the house to lenders in lieu of payment (if the value of the house at loan termination is lower than the outstanding debt), has potentially large insurance benefits for retirees. The longer the time horizon, the higher the value of the put component.

In spite of maximizing the benefits of the put option, our model is not as general as one in which the retiree decides in each period whether to set up the long-term debt contract (if she has not done so before). In a more general model such as this, the solution would require two additional state variables, the initial borrowing limit and interest rates in the period in which the loan is set up. In our analysis these are simply model parameters. However, we are able to use our model to evaluate the benefits of RMs for different initial conditions and time horizons (e.g. by varying survival probabilities).

Loan fees. The loan has several fees and costs. We let the parameters (f_1, f_a, ψ, l_1) denote the initial loan arrangement and valuation fees, the annual service costs, the interest rate

[10] Michalengeli (2013) studies the effects of purchasing longevity insurance on the consumption and homeownership decisions of the elderly.

premium and the loan limit as a proportion of initial house value, respectively. The loan arrangement and valuation fees are added to the loan balance. They include an origination fee, other closing costs, and an initial insurance premium payable to the government (denoted f_{1A}). The annual service costs are assumed to be a fixed dollar amount.

Loan interest rates and credit limit. The loan interest rate is equal to the one-period interest rate plus the spread ψ (or $R_{1t} + \psi$). The loan interest rate determines the rate at which the interest on outstanding debt accrues. The loan spread includes the lender's margin and the annual mortgage insurance premium paid by the lender to the government agency (denoted ψ_L and ψ_A, respectively, with $\psi = \psi_L + \psi_A$). A second interest rate that is relevant is the *expected* loan interest rate. It is equal to the ten-year risk-free rate at the time that the mortgage begins ($R_{10,1}$) plus the lender's margin.

To model long-term interest rates, we assume that the log expectation hypothesis holds. That is, we assume that the log yield on a long-term n-period real bond, $r_{nt} = \log(1 + R_{nt})$, is equal to the expected sum of successive log yields on one-period real bonds which are rolled over for n periods plus a constant term premium, ξ:

$$r_{nt} = (1/n) \sum_{i=0}^{n-1} E_t[r_{1,t+i}] + \xi. \tag{10}$$

This model implies that excess returns on long-term bonds over short-term bonds are unpredictable, even though changes in short rates are partially predictable.

The initial borrowing limit (B_1) is a proportion (l_1) of the house value at the initial date that depends on the retiree's age and on the expected loan rate. This rate is also the rate at which the borrowing limit grows over time:

$$B_{t+1} = B_t(1 + R_{10,1} + \psi_L). \tag{11}$$

Borrowers who do not exhaust the credit limit at the initial date will be able to borrow additional funds in subsequent periods.

Loan balance. We let D_t^S denote the outstanding loan amount at the beginning of period t, and D_t^C the additional amount that the homeowner borrows in that period (the superscript S denotes state and C denotes choice). The equation describing the evolution of outstanding debt is:

$$D_{t+1}^S = (D_t^S + D_t^C + f_a)(1 + R_{1t} + \psi). \tag{12}$$

with $D_1^S = f_1$. Therefore, interest payments due are capitalized.

Maintenance requirement. The contract does not require the borrower to make any interest payments prior to termination, but it does specify that retirees must pay property insurance and taxes. In addition, it specifies that borrowers must maintain their homes. The Consumer Financial Protection Bureau makes this clear in its documentation on RMs:[11] "Reverse mortgage borrowers are obligated to pay taxes and insurance and to provide normal maintenance and upkeep of the property for the life of the loan. If taxes and insurance are not paid, or if the borrower allows the condition of the property to deteriorate without making the necessary repairs (the borrower commits "waste"), the lender may consider the borrower to be in default on the loan and the servicer could foreclose on the home." In its documentation on RMs, the New York State Department of Financial Services states: "Take good care of the house. It should be in the same condition as it was in at the time of closing." If borrowers comply with the requirements of the mortgage contract, lenders cannot force them out of the house, even if they are in a situation of negative home equity.

We assume that borrowers comply with the RM requirements, so that if they decide to take a loan $m_t = d_p \; \forall t$. If retirees have exhausted the credit line, are in a situation of negative equity, and do not have enough cash to pay the property taxes, insurance, and maintenance, they are forced to default.

Loan termination. If at date t the retiree sells the house (or dies), the value of D_t^S is deducted from the proceeds of the sale. In this mortgage product, retirees retain homeownership and benefit/suffer from any increases/decreases in the value of their house (unless there is negative home equity). Furthermore, they retain the option to discontinue homeownership in the future. The mortgage loan is non-recourse: if at loan termination there is negative home equity, the lender seizes the house, but the borrower or her heirs are not liable for any shortfalls, even if there are other financial assets.

In essence, from the point of view of retirees, RMs allow them to borrow against their house, and live in it without having to make any interest or principal loan repayments before loan termination. In addition, borrowers have a put option: at loan termination, they (or their heirs) can give the house to the lender instead of repaying the outstanding loan amount. These rights come with several fees, costs and requirements as described above. We simplify the problem by not considering the possibility of loan refinancing.

[11] The document is available at: https://files.consumerfinance.gov/f/documents/102016_cfpb_Reverse MortgageServicingExaminationProcedures.pdf.

3.5 Timing and laws of motion for cash-on-hand

The retiree starts the model in period 1 (age 65) as an owner of a house of a certain size (H_1), in which she has lived for A_1 years, and with a level of financial wealth (initial cash-on-hand) of X_1. In addition there are initial levels of health (h_1) and medical expenditures (ME_1).[12] At the initial date retirees decide whether to take out a RM. If they do so the (initial) borrowing limit depends on the level of the initial risk-free interest rate ($R_{10,1}$), the loan premium and the initial house value.

Retirees who decide to remain homeowners must decide how much to consume of non-durable goods, and if they decide to take out a RM, how much cash to withdraw using the loan. In addition they incur maintenance and other housing related expenditures. The equation describing the evolution of cash-on-hand for those who decide to remain homeowners is:

$$X_{t+1} = [X_t - C_t - M_t - \tau_p(1-\tau)P_t^H H_t + D_t^C][1+R_{1t}(1-\tau)] + (1-\tau)Y_{t+1} - ME_{t+1} + TR_{t+1}, \quad (13)$$

where M_t denotes the dollar value of the maintenance expenses incurred in period t. For homeowners without a RM the additional debt drawn is $D_t^C = 0$. At the beginning of the following period, the new values for the house price, interest rate, health status and medical expenditures are realized. Cash-on-hand is equal to savings from the previous period and interest, plus pension income (net of taxes) and government transfers, minus medical expenditures. Before any decisions for the period are made, the forced house sale shock is realized.

For individuals who sell their house in period t and become renters the equation describing the evolution of cash-on-hand is:

$$X_{t+1} = (X_t - C_t - RC_t + MAX[(1-\lambda)P_t^H H_t - D_t^S, 0])[1+R_{1t}(1-\tau)] + (1-\tau)Y_{t+1} - ME_{t+1} + TR_{t+1}. \quad (14)$$

Individuals with a RM receive the maximum between the proceeds from the house sale (net of the proportional transaction costs λ) minus the outstanding loan balance (D_t^S) and zero. This reflects the option that at loan termination they have to give the house to the bank instead of repaying the outstanding loan balance. For those without a RM at the time of sale $D_t^S = 0$. Renters choose how much non-durable goods to consume and the size of house

[12]We model the initial cash-on-hand as being net of initial medical expenditures.

to rent, for which they pay a rental cost RC_t.

The equation describing the evolution of cash-on-hand for periods in which individuals start as renters is similar to equation (14) except that the maximum term which captures the proceeds from the house sale is not included:

$$X_{t+1} = (X_t - C_t - RC_t)[1 + R_{1t}(1-\tau)] + (1-\tau)Y_{t+1} - ME_{t+1} + TR_{t+1}. \tag{15}$$

Before any decisions for the period are made the mortality shock is realized. In the event that the homeowner dies in period t the bequeathed wealth is net of estate taxes (exemption level E):

$$W_{t_d} = X_{t_d} + MAX[(1-\lambda)P^H_{t_d}H_{t_d} - D^S_{t_d}, 0] - \tau_e MAX[X_{t_d} + MAX[(1-\lambda)P^H_{t_d}H_{t_d} - D^S_{t_d}, 0] - E, 0] \tag{16}$$

where t_d denotes the time of death. The first maximum term captures the fact that for a homeowner with a RM for whom at the time of death the outstanding loan balance is higher than the proceeds from the house sale, the heirs are not responsible for the difference. The above equation assumes that when death arrives, retirees do not have the time to go to the bank and withdraw any unused portion of the credit line. If they do have the time to do so, that would be the optimal strategy for borrowers who are in a situation of negative equity, who have not yet exhausted the credit limit, and who know that they are just about to die. Since in reality some deaths are at least (partly) predictable, we will report some results for the case in which we relax this assumption. For homeowners who die without a reverse mortgage, $D^S_{t_d} = 0$. For retirees who die as renters, the bequeathed wealth is simply the available cash-on-hand (again net of estate taxes).

3.6 The retiree's problem, choice and state variables

For renters, the choice variables are how much of non-durable goods to consume (C_t) and the house size to rent (H_t). For renters in a given permanent income group the state variables of the problem are age/time, cash-on-hand, the level of interest rates, the level of house prices, health status and medical expenditures. We let S^R_t denote this set of state variables, or $S^R_t = [t, X_t, r_{1t}, P^H_t, h_t, ME_t]$. For each permanent income group, pension income is fixed throughout, making it a model parameter and not a state variable. The retiree-renter makes choices in each period so as to maximize expected lifetime utility:

$$V_t^R(.) = MAX_{C_t,H_t}U(C_t, H_t) + \beta E_t[p_{t+1}V_{t+1}^R(.) + (1 - p_{t+1})v(W_{t+1})] \tag{17}$$

subject to the law of motion for cash-on-hand for renters (equation 15), the equations describing the evolution of the exogenous model variables, and non-negativity constraints on non-durable consumption and housing choices.

Homeowners in a given permanent income group and without a RM (denoted NoRM) decide in each period whether to sell the house and move to renting, by comparing the remaining expected lifetime utility of the two alternatives. In the event that they decide to remain homeowners, the choice variables are how much of the non-durable good to consume and how much to spend in property maintenance (M_t). The set of state variables $S_t^{H,NoRM} = [t, X_t, r_{1t}, P_t^H, h_t, ME_t, H_t]$ includes the current house size (H_t). In periods in which they decide to remain homeowners (and are not hit by the forced sale shock), they solve:

$$V_t^{H,NoRM}(.) = MAX_{C_t,M_t}U(C_t, H_t) + \beta E_t[p_{t+1}V_{t+1}^{H,NoRM}(.) + (1 - p_{t+1})v(W_{t+1})]. \tag{18}$$

Homeowners with a RM must choose whether to remain so or to sell the house and move to renting in which case the loan is terminated. If individuals decide not to sell, the choice variables are how much of the non-durable good to consume and how much additional cash to draw from the loan (D_t^C), if the outstanding loan balance is below the limit. The set of state variables $S_t^{H,RM} = [t, X_t, r_{1t}, P_t^H, h_t, ME_t, D_t^S]$ includes the currently outstanding loan balance (D_t^S). Recall that in each period, homeowners with a RM set $m_t = d_p$, so that $H_t = H_1 \; \forall t$. Thus, for these individuals H_t is a model parameter and not a state variable.

We solve the model for several alternative initial conditions, including the size of the house with which the retiree starts the model and the level of period 1 interest rates ($R_{10,1}$), which is important for the credit limit. The values for these variables are set at the initial date and are constant throughout the optimization problem. One could think of them as either initial conditions or more generally as state variables whose value is constant throughout. To simplify notation, we treat them as model parameters.

Let $V_t^{H,RM}(.)$ denote the value function for homeowners with a RM. In periods in which they decide to remain homeowners (and are not hit by the forced sale shock), they solve:

$$V_t^{H,RM}(.) = MAX_{C_t,D_t^C}U(C_t, H_t) + \beta E_t[p_{t+1}V_{t+1}^{H,RM}(.) + (1 - p_{t+1})v(W_{t+1})]. \tag{19}$$

The retiree with a RM makes consumption and debt choices subject to the law of motion for cash-on-hand, the equations describing the evolution of the exogenous model variables, the equation describing the evolution of the outstanding loan balance, the borrowing limit constraint, the constraint that she must fully maintain the property, and a non-negativity constraint on non-durable consumption.

We calculate the benefits of RMs by comparing the initial date value functions of retirees with and without a RM: $V_1^{H,RM}(.)$ and $V_1^{H,NoRM}(.)$, respectively. Retirees who are better off with a reverse mortgage choose to set up the loan at the initial date ($RM_1^C = 1$, zero otherwise), where RM_1^C is a binary variable that captures the first period loan choice.

3.7 Lump-sum reverse mortgage

For most of the analysis, we will focus on drawdown RMs, but we will also solve the model for the case of lump-sum products. In a lump-sum loan, all available funds are drawn up-front. The interest rate is equal to the ten-year risk-free interest rate at the initial date ($R_{10,1}$), plus the mortgage premium (ψ). The equation describing the evolution of the outstanding debt for periods $t > 1$ is given by:

$$D_{t+1}^S = (D_t^S + f_a)(1 + R_{10,1} + \psi), \tag{20}$$

with $D_1^S = f_1 + l_1 P_1^H H_1$. Lump-sum RMs have analogous fees and requirements to those described for the drawdown loans, which we do not repeat here. Their model solution is simpler. Since all funds are borrowed up-front there is no debt choice in periods subsequent to the first. The level of initial interest rates together with the amount borrowed and loan period determine the outstanding debt in each period, which reduces the number of state variables.

3.8 Private lenders, the insurance agency, and pricing kernel

In our baseline model, loan losses are insured by a government agency. This describes the current U.S. experience under the HECM program. However, later on we will consider the possibility that private lenders bear the risk of house price declines: in such a setting, the cash-flows of lenders and the government agency described below are consolidated.[13]

Lenders. At mortgage initiation, in period 1, the lenders' (L) cash-flows are equal to the initial funds disbursed plus the initial mortgage insurance premium paid by lenders to the government agency (f_{1A}) (but added to the outstanding loan balance):

[13] In the U.K., there is no government insurance and lenders bear house price risk. In the U.S., there are non-government insured RMs, but the size of this market is very small.

$$CF_1^L = -D_1^C - f_{1A}. \tag{21}$$

In each subsequent period t prior to loan termination, the cash-flows received by lenders are:

$$CF_t^L = -D_t^C - \psi_A D_t^S, \tag{22}$$

where ψ_A denotes the annual mortgage insurance premium payable to the government agency. It is important to note that these cash-flows do not take into account the administrative and advertising costs incurred by lenders. Their present value should be interpreted accordingly. At loan termination, in period say t', the lenders receive the debt balance outstanding:

$$CF_{t'}^L = D_{t'}^S. \tag{23}$$

The insurance agency. The insurance agency (A) collects the mortgage insurance premia in periods prior to loan termination, and at loan termination it receives:

$$CF_{t'}^A = MIN[0, (1-\lambda)P_{t'}^H H_{t'} - D_{t'}^S]. \tag{24}$$

This reflects the fact that if house values are lower than the outstanding loan balance, the government agency must compensate private lenders for the difference. Note that since borrowers are required to maintain their house, $H_{t'} = H_1$.

Pricing kernel. We will use U.S. RM data on premia and borrowing limits to parameterize the model. However, we are also interested in evaluating the extent to which the mortgage insurance is correctly priced or, in the absence of government insurance, whether mortgage margins allow lenders to achieve a positive expected present value of future cash-flows.[14] We need to specify a discount rate to calculate the present values. We report results for both the risk-free interest rate and a risk-adjusted discount rate. To calculate the latter we follow Campbell and Cocco (2015) in specifying an exogenous pricing kernel. We give details in Appendix B. The discount rates are lower for cash-flows that occur when house prices are low, so that such cash-flows are more valuable. Even though lenders do not face credit risk (which is insured by the government) the risk-adjusted discount factors are relevant for them since they face cash-flow risk that is correlated with house price movements (retirees' decisions to draw down on the loans are correlated with house prices).

[14] In order to perform these calculations, we assume that at mortgage arrangement, the insurance agency and lenders observe the relevant parameters that influence retiree survival probabilities.

Solution technique. The numerical techniques that we use to solve our model are standard (Deaton, 1991). We discretize the state space and the choice variables. We approximate the random variables using Gaussian quadrature. We solve the model backwards, selecting the optimal choices at each data using grid search, and we use the optimal policy functions to simulate the model. We give more details in Appendix B.

4 The Data

We use several data sources to parameterize the model and to provide further evidence in support of some of its features. In addition we describe the moments that we target in the calibration. Our main data source is the HRS data from 1996 to 2012. We use the Rand version of the data and combine it with information from the core and exit interviews. Following De Nardi, French, and Jones (2010) we restrict the analysis to single, retired individuals who are aged 65 or over. Furthermore, since our model is one of homeowners at the beginning of retirement we exclude those individuals who are renters at this age. We only observe those individuals who are homeowners at age 65 in 1996 (the first year in the HRS data) up to a maximum age of 81. Therefore, to generate age profiles that span the full retirement, we need to use data from other birth cohorts, corresponding to individuals who are older than 65 in 1996. The cohorts that we use are those for individuals born in 1915-19, 1920-24, 1925-29, and 1930-34. They are the cohorts with more data observations, as described in Appendix C. For each of these, we select only those individuals who are homeowners when they enter the data.

4.1 Pension income and assets

We solve the model for each of the cohorts with different starting ages and initial conditions. More precisely, we take the initial conditions for homeowners at age 65 in the cohort born in 1930-34, for homeowners at age 70 in the cohort born in 1925-29, for homeowners at age 75 in the cohort born in 1920-24, and finally for homeowners at age 80 in the cohort born in 1915-19.

We follow De Nardi, French, and Jones (2010) and calculate for each individual a measure of his/her permanent/retirement income, by averaging the annual real non-asset income over the years in which the individual appears in the data. We use this measure of permanent income (PI) to group individuals into quintiles. Table 1 reports median retirement income for two of the cohorts. It also reports, for the different permanent income groups, initial median real financial wealth (excluding housing wealth, but net of debt outstanding) and median initial house values. The dollar values that we report are real 1996 dollars.

Table 1 shows that individuals with higher permanent income tend to have higher financial wealth and higher housing wealth. Venti and Wise (1991) provide similar evidence on the relationship between the income and the housing equity of the elderly. We use the median income values to parameterize Y and median housing wealth to parameterize H_1. We make the assumption that initial house size is the same for individuals in a given cohort/permanent income group to reduce the dimensionality of the problem. Since we are calculating initial financial wealth net of outstanding debt, the values are negative for some of the groups shown in Table 1. However, their initial cash-on-hand is positive (since their income, which we add to the net initial financial assets to obtain initial cash-on-hand, is larger than the absolute value of the negative net financial assets). For each individual, we calculate the number of years she has been living in the current residence. We use the median values for this variable for each of the groups to parameterize A_1 (shown in the last column of Table 1).

Table 1: **Permanent income, assets, health status and number of years in residence.**

PI group	Income (thous.)	Financial wealth (th.)	Housing wealth (th.)	Prop. bad health	Years in resid.
		At age 65, cohort born 1930-1934			
1	5.7	2.2	48.0	0.45	16
2	8.4	-2.0	60.0	0.24	19
3	11.6	15.1	67.0	0.21	18
4	14.4	15.0	96.6	0.20	19
5	27.7	92.0	100.0	0.29	18
		At age 75, cohort born 1920-1924			
1	7.2	-0.7	41.4	0.50	25
2	9.1	7.2	91.5	0.20	26
3	11.6	18.3	62.6	0.43	24
4	14.8	36.1	79.9	0.36	23
5	20.5	262.8	144.4	0.26	25

4.2 Health status, survival probabilities and medical expenditures

Individuals in the HRS data are asked to rate their health. We use this information to construct a dummy variable that takes the value of one for retirees who report fair or poor health, and zero for individuals who report good, very good, or excellent health. The mean of this variable for those retirees aged 65 in the 1930-34 birth cohort and for those aged 75 in the 1920-24 birth cohort are shown in Table 1. The proportions of individuals who report fair or poor health are significantly higher for those in the lowest permanent income group.[15] We use this information to parameterize initial health status: we set the proportions of individuals in bad health at the initial age in the model simulation equal to those in the data.

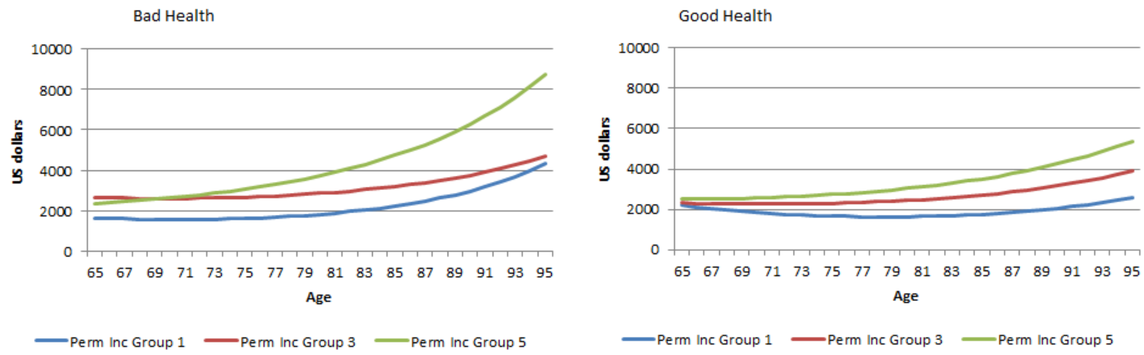
We follow De Nardi, French, and Jones (2010) in our estimation of the transition probability matrix for health status. The probability of bad health is assumed to be a logistic function of a cubic in age, gender, gender interacted with age, health status, health status interacted with age, permanent income rank, permanent income rank squared, and permanent income rank interacted with age. We use a logistic function and the same explanatory variables to estimate survival probabilities. The maximum age is ninety-five, so that the maximum number of model periods (T) is equal to thirty. We give more details in Appendix C.

We use HRS data to construct a measure of out-of-pocket medical expenditures. We model the mean of log medical expenses as a function of a quadratic in age, gender, gender interacted with age, health status, and health status interacted with age. In Figure 2, we plot the estimated age profiles for three of the permanent income groups. This figure shows that mean out-of-pocket medical expenditures increase with age and permanent income. Individuals with fair or poor health face higher medical expenses than those in good health.

The analysis of the residuals of the log medical expenditures regression shows higher variability at older ages. We take this into account by letting the variance of the medical expenditures shocks increase with age. To estimate the increase we first calculate for each age (and permanent income group) the variance of the residuals of the log medical expenditures regression, and then regress them on a second order polynomial in age. In addition, we allow for persistence in the medical expenditure shocks. The estimated first order auto regression coefficients are equal to 0.70, 0.71 and 0.73 for individuals in permanent income groups one, three, and five respectively.

[15] These patterns may in part be due to reverse causality: if there is persistence in health status, retirees in poor health will also be more likely to have had poor health in the years prior to retirement and may have accumulated lower retirement benefits (Poterba, Venti, and Wise, 2011b).

Figure 2: **Medical expenditures**



For tractability, the medical expenditure process that we use is simpler than the ones in French and Jones (2004) or De Nardi, French and Jones (2010) and the age increase that we estimate is smaller than theirs. We (partially) address these differences and incorporate medical expenditures tail risk in the model through the forced sale shock. We explain this in the next section. We give further details on medical expenditures in Appendix C.

4.3 Moving and evidence on aging in place

We study the moving decisions of retirees in the HRS data. For those who are alive in any two consecutive waves of the survey and who are homeowners in the earlier one, we create dummy variables for a house sale and move to homeownership (of a different house), to renting, and to a nursing home. We calculate the average of these dummy variables by age. The survey is biennial but we convert the estimated transition probabilities into annual values and calculate averages by five-year age group (this reduces the significant age variation due the relatively small number of observations in some cells). The results are shown in Table 2.

Early on in retirement there is a small proportion of homeowners (around 1%) who decide to sell their house and buy another one. To simplify the analysis, we have not considered this possibility in the model, so it is re-assuring to find that in the data only a small proportion of retirees do so. Furthermore, even though they are still small, as Table 2 shows, the largest moving probabilities occur later in life for individuals who sell their house to move into rental accommodation and for those who move into a nursing home. The moves into renting are captured endogenously in the model.

We parameterize the probability of a forced sale (p_t^{fs}) in the model using the data in the last two columns of Table 2. As expected, the probabilities are higher for individuals in

Table 2: **Annual moving probabilities.**

Age group	Move to renting	Move to homeownership	Move to nursing Good health	Bad health
65-69	0.013	0.011	0.001	0.001
70-74	0.011	0.013	0.000	0.001
75-79	0.015	0.009	0.002	0.006
80-84	0.019	0.007	0.003	0.009
85-89	0.018	0.009	0.012	0.027
90-94	0.025	0.001	0.018	0.060

bad health and increase with age. To parameterize the additional medical expenditures in the case of a forced sale (ME^{fs}), we calculate their value in the year in which individuals report moving to a nursing home. Their mean (median) value is 10,500 (5,945) dollars. We set ME^{fs} equal to 10,000 dollars.

A hypothesis consistent with place attachment is that retired homeowners who have lived longer in their current residence are more attached to their homes (and local communities) and are less likely to sell their houses and move. In order to test this hypothesis, we have taken the sample of single retired homeowners over the age of 65 and we have created dummy variables for a move (other than to a nursing home) and a move to a nursing home, between times $t-2$ and t (corresponding to two consecutive waves of the survey, two years apart). For each of these dummy variables, we have estimated probit models by regressing them on age, number of years in the current residence (measured at time $t-2$), and dummies for bad health (at $t-2$ and at t). The estimated marginal effects are shown in the second and third columns of Table 3.

Interestingly, we find that the longer the individual has been in his/her house, the lower the probability that he/she will move (other than to a nursing home): an additional year in place reduces the probability of a move by 12 basis points. In contrast, for explaining moves to a nursing home, the statistically (and economically) significant variables are age and health status (at t): an age increase of one year increases the probability of a move to a nursing home by 23 basis points and bad health at time t by 1.4%. The fact that bad health at $t-2$ is not statistically significant suggests that individuals move to a nursing home between times $t-2$ and t in response to a deterioration in health during this period. The small marginal effects of the explanatory variables reflect the small probability that

Table 3: **Evidence on aging in place.**

Independent variables	Move other than to nursing home	Move to nursing home
Age at t	0.000	0.002
	(-0.12)	(6.62)
Number of years in residence at t-2	-0.001	0.000
	(-5.64)	(-0.46)
Dummy for bad health at t-2	0.009	0.011
	(1.11)	(0.43)
Dummy for bad health at t	0.005	0.014
	(0.63)	(3.25)
Number of observations	4,634	4,634

individuals will move as they grow older.[16]

Another interesting piece of evidence on the benefits of aging in place can be found in Davidoff (2005). Using information on the perceived quality of the house by owners in the AHS data, he finds evidence that older homeowners tend to think more highly of similar homes than younger ones, which may result from place attachment being more important for the old.

4.4 Interest rates, house prices, and reverse mortgages

In the first panel of Table 4, we report the annual parameters that we use for the interest rate and house price processes. For interest rates we use data on U.S. 1-year treasury yields, deflated using the consumer price index. For house prices we use S&P/Case-Shiller Composite Home Price data for the 20 major U.S. Metropolitan Statistical Areas (MSAs) from 1987 to 2014. The mean log house price growth across these MSAs is 0.002. The standard deviation of each MSA varies between 4% and 14%. The median is 7.4%. These standard deviations capture the MSA-wide house price risk, but not idiosyncratic risk of specific houses within each city. This is why in our base case we use a standard deviation of 10% (we will also solve the model for alternative values).

Over the years there have been several changes to the HECM program. Therefore, we

[16] We have also estimated regressions that allow for the possibility that the number of years in the current residence and age affect moving probabilities in a non-linear way, by including the square of these variables among the regressors. The relatively small number of observations makes it hard to identify such effects and the estimated coefficients on these quadratic terms were not statistically significant.

Table 4: **Model parameters.**

Interest rates and house prices		
Mean log real rate	μ_r	0.012
Stdev of the real rate	σ_ε	0.018
Log real rate AR(1) coefficient	ϕ_r	0.825
Term premium	ξ	0.005
Mean log real house price growth	μ_H	0.002
Stdev house price return	σ_η	0.10
Reverse mortgage		
Loan origination fees		0.02
Initial mortgage ins. premium	$f_{1,A}$	0.02
Other closing costs		0.02
Initial borrowing limit	l_1	0.564
Annual servicing fees	f_a	\$420
Annual mortgage ins. premium	ψ_A	0.005
Lender's margin	ψ_L	0.0165
Tax rates and other parameters		
Income tax rate	τ	0.2
Property tax rate	τ_p	0.015
Estate tax rate	τ_e	0.4
Estate tax exemption level	E	600k
Property depreciation	d_p	0.02
Rental premium	φ	0.01
Transaction costs of house sale	λ	0.06
Lower bound on non-dur. cons., house size	$\underline{C}, \underline{H}$	4.8k, 15 units

use historical data to parameterize the RM loans that correspond to the early part of our sample. In Appendix A we give further details on the data sources, we discuss the most significant historical changes that have occurred in the program and we report parameter values for later years.

Table 4 reports the baseline parameters. The values for the loan origination fees and mortgage insurance premia (both initial and annual) are from several mortgagee letters. Other closing costs (in addition to the origination fees) include the appraisal of the property, the title insurance and inspection fees. A realistic value is 2% of the value of the property (Davidoff, 2015). The most common index for the drawdown loans is the 1-year Treasury rate. In order to obtain an estimate of lenders' margins, we have used Treasury rates data and data from the HECM Single-Family Portfolio Snapshot that includes information on loan interest rates.

The value for the initial borrowing limit is obtained from the HECM historical principal limit factor tables. These tables give us the borrowing limit as a proportion of the appraised house value[17] as a function of the age of the borrower (or the youngest borrower in joint applications) and the expected interest rate on the loan. The initial age in our model is 65 and we parameterize the initial borrowing limit accordingly. The value for the servicing fees is 420 dollars per year (35 dollars per month, mortgagee letter 98-3).

4.5 Tax rates and other parameters

The last panel of Table 4 reports other model parameters. The HRS has data for younger individuals in the 55 to 64 age group who are still working. The average housing maintenance expenses for these individuals are 0.021. We assume that this is the average annual level of maintenance expenses that exactly offsets depreciation and set d_p equal to 0.02. The remaining values of the user cost of housing and property taxes are from Himmelberg, Mayer and Sinai (2005). The transaction costs of a house sale are equal to 0.06. The tax rate τ_e is 0.40 and the estate tax exemption level is 600,000 dollars.

The consumption floor is such that the retiree is guaranteed a certain level of non-durable consumption and in addition he/she is able to rent a house of a given minimum size. We use the 1996 distribution of house values in the HRS data to parameterize this minimum house size ($\underline{H}$): we assume that it is equal to the house size corresponding to percentile 10 of the distribution of house values in this year, of fifteen thousand dollars. We can think of this as corresponding to fifteen units of housing. As house prices increase, these same fifteen units will correspond to house values larger than fifteen thousand dollars. As house and rental prices fluctuate from year to year, so does the monetary value of the (overall) floor. We set the guaranteed level of non-durable consumption at 4.8 thousand dollars. This implies an overall floor of between 5.8 and 7.1 thousand 1996 US dollars (for the realizations of house prices and rental rates during the sample period).

One can think of this consumption floor as arising from Medicaid transfers (De Nardi, French and Jones, 2016). The role of housing wealth in Medicaid is complex. Even though U.S. states need to follow Federal guidelines, each state makes Medicaid policy choices and administers its program separately, meaning that there are differences in eligibility and rules across states. However, thinking about these rules more broadly, there are some similarities between them and what happens in our model. According to Medicaid rules, the individual's

[17] Or of the maximum claim amount if it is lower than the house value. The maximum claim amount is the lesser of the property appraised value and the applicable FHA loan limit.

home is excluded when determining eligibility. Whether the individual is entitled to benefits depends on his/her income and assets other than the home. In our model, individuals receive government transfers if, in order to meet the required medical expenditures, they are left with insufficient financial assets to achieve the lower bound in consumption. Similar to what happens in the program, the likelihood that they will receive the transfers depends on their income and the level of their financial assets (excluding the home).[18]

4.6 Target moments

Our target moments are the 5-year age profiles of homeownership rates, total wealth and maintenance expenses, for the different permanent income groups. To calculate the moments we restrict the data to the same sample of single retired homeowners at the beginning of the HRS sample period in birth cohorts from 1930-34, 1925-29, 1920-24, and 1915-19 and track them over time. For each cohort and age, we calculate homeownership rates and median total wealth (which includes housing wealth). We then calculate their average over 5-year age groups (65-69, 70-74, and so on up to 90-94) and different cohorts (for the first and last age groups there are data for only one cohort). We do these calculations by permanent income group. In Table 5 we report values for permanent income groups one, three and five, spanning the income distribution.

Homeownership rates decline slowly with age and are still high late in life. As expected, total wealth is higher for higher permanent income groups at all ages. In spite of the calculation of five-year averages the last three columns of Table 5 still show significant age variability in total wealth for each income group. Increases in wealth late in life may be due to sample selection: wealthier individuals are likely to be healthier and to live longer.

Due to data limitations, to calculate the target moments for maintenance expenses we need to follow a different approach. The data are from the Consumption and Activities Mail Survey (CAMS), which is a supplementary survey to the HRS. The first wave did not take place until 2001 and it covered five thousand households selected at random from those who participated in the HRS 2000 core survey. The same households were then interviewed every two years. We have used data from seven waves up to 2013. The survey collects information on

[18]In addition, Medicaid eligibility rules do not prevent individuals from using RMs. In our model, individuals are allowed to take out a reverse mortgage and do not lose the entitlement to transfers if they do so. A house sale in our model leads to an increase in cash-on-hand (depending on the existing home equity), which reduces the likelihood of receiving government transfers. This is in the spirit of what happens in Medicaid. When the homeowner moves permanently out of the house, it is no longer a "home," it becomes a countable asset, and its equity must be spent on the homeowner's health costs. Therefore even though our model is not designed to think of many of the complicated rules regarding housing wealth in Medicaid, it captures some (not necessarily all) of its broad principles.

Table 5: **Target moments.**

Age	Homeown. rates			Maint. expenses			Total wealth (thous.)		
group	PI 1	PI 3	PI 5	PI 1	PI 3	PI 5	PI 1	PI 3	PI 5
65-69	0.99	0.99	1.00	0.017	0.018	0.017	61.6	128.1	178.2
70-74	0.96	0.97	0.99	0.014	0.015	0.014	81.2	144.1	180.7
75-79	0.92	0.92	0.96	0.014	0.016	0.014	44.5	106.2	196.4
80-84	0.87	0.83	0.91	0.012	0.014	0.012	52.4	101.8	233.2
85-89	0.77	0.77	0.79	0.012	0.013	0.012	49.0	84.5	221.1
90-94	0.70	0.73	0.77	0.007	0.009	0.007	70.8	76.4	169.1

annual spending on housing maintenance, including materials bought directly and services. We calculate maintenance expenses as a proportion of house value. To reduce the potential impact of outliers, we winsorize the variables at the one percent level.

We select the sample of single retired homeowners over the age of 65. Therefore, due to the shorter sample period and number of observations, we no longer restrict the sample to the same four cohorts as before. To calculate age profiles we regress maintenance expenses as a proportion of house value on age, cohort, and permanent income group dummies. Most of the cohort and permanent income group dummies are not statistically significant. In Table 5 we report the averages over five-year age groups of maintenance expenses. There is an age decline in such expenses from an annual average of 0.018 for the 65-69 age group to values of around 0.01 late in life (the differences between the 65-69 and 90-94 age groups are statistically significant).

We have calculated average maintenance expenses for single individuals in the 55 to 64 age group who are still working and compared them to those incurred by retired individuals in the 65 to 74 age group. The corresponding values are 0.021 and 0.015. These are significantly different from each other at the one percent level. Due to the collinearity among the variables, it is hard to separate the effects of age and retirement on maintenance expenses. However, this evidence shows that older retired homeowners spend considerably less on housing maintenance than those approaching retirement age, and they decrease housing maintenance as they age. There may be several reasons for this. One reason, captured by our model, is that retirees reduce housing maintenance as a way of dissaving from their most important asset, and of having more cash available to meet medical or other expenditures. Another possibility is that older individuals find it more difficult to deal with contractors, and therefore refrain from doing so and from maintaining their house.[19]

5 Model Results

We first briefly describe the simulated data, followed by an analysis of the model fit and the calibrated parameters, then we turn our attention to RMs.

5.1 Simulated data

We solve the model separately for individuals in each cohort and permanent income group, and use it to generate simulated data. The initial conditions (financial assets, median income, median house values and the number of years living in the residence) for each cohort and permanent income group are taken from the HRS data. To capture heterogeneity in initial financial assets, in the simulated data we set their value for each one third of the individuals to the value that corresponds to percentiles 17, 50 and 83 of the corresponding distribution of financial assets in the HRS data. Heterogeneity in income and initial house sizes is captured through the differences that exist across permanent income groups and cohorts. We set the proportion of individuals who are initially in bad health equal to those in the HRS data.

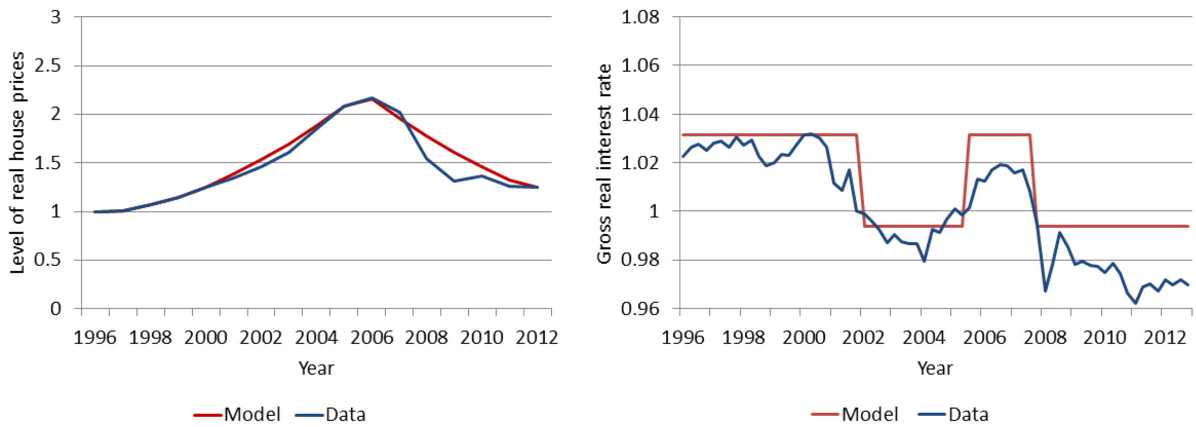
In our model, real interest rates and house price changes are stochastic, with two possible values for each of these. In the simulations, we set the values of the real interest rate equal to the values that better match the data over the 1996-2012 period (the right panel of Figure 3 compares the data and the model). For house prices, we try to match the changes in the U.S. Case-Shiller composite index. In the model, house price growth can be low or high. In the simulated data, we set the proportions of individuals who face the low/high value so that the average house price change matches the index (left panel of Figure 3). This introduces heterogeneity in the simulated data which may be interpreted as reflecting geographical differences in house price changes.

We use the policy functions to generate simulated data for each cohort/permanent income group over a fifteen year horizon. This simulated data is used to calculate homeownership rates, maintenance expenses and median total wealth for each cohort/permanent income group and age. Finally, we calculate averages first over five-year age groups and then for each age group over the different cohorts, exactly as we have done in the calculation of the target moments.[20]

[19]If older individuals bear higher non-monetary costs of maintaining their house, this would make the maintenance requirement of RMs more costly.

[20]One difference between our simulated data and the HRS data is that the former is annual whereas the

Figure 3: **House prices and interest rates.**



When calibrating the preference parameters, we assume that retirees do not have access to RMs. Even though they have been available for many years, the number of loans originated has been very small, particularly during the early part of the HRS data sample. The extent to which the calibrated parameters generate demand for RMs provides an out-of-sample test of the model.

We use a minimum distance criterion to choose among parameter values. More precisely, we solve our model and generate simulated data for different combinations of preference parameter values. For each, we calculate the weighted sum of squared difference between the model moments and the data moments. For the weighing matrix, we use the diagonal matrix with the inverse of the variance of the data moments in the main diagonal. We select the combination of preference parameter values for which the calculated weighted sum is lowest.

5.2 Calibrated parameters and model fit

Table 6 reports the calibrated parameters. Before we discuss their values, we evaluate the ability of the model to replicate the targeted moments. Figure 4 compares model and data along the income distribution (income groups one, three and five in Panels A through C, respectively). The model generates the slow age decline in homeownership rates and the age decline in maintenance expenses observed in the data. Furthermore, the model replicates relatively well the age profiles of total wealth for the different permanent income groups.

Figure 4 also plots the age profiles of median financial wealth generated by the model compared to those calculated from the HRS data (in a similar manner to total wealth).

latter is biennial. We abstract from this difference when calculating the five-year age group averages.

Table 6: **Calibrated parameters.**

Description	Parameter	Value
Discount factor	β	0.97
Intertemporal elasticity of subs.	σ	0.333
Aging in place	α	0.019
Non-durable cons exp. share	θ	0.70
Intratemporal elasticity of subs.	ϵ	1.25
Bequest motive intensity	b	12
Bequest motive curvature	κ	$6,000$
Minimum housing maintenance	$\underline{m}$	0.01

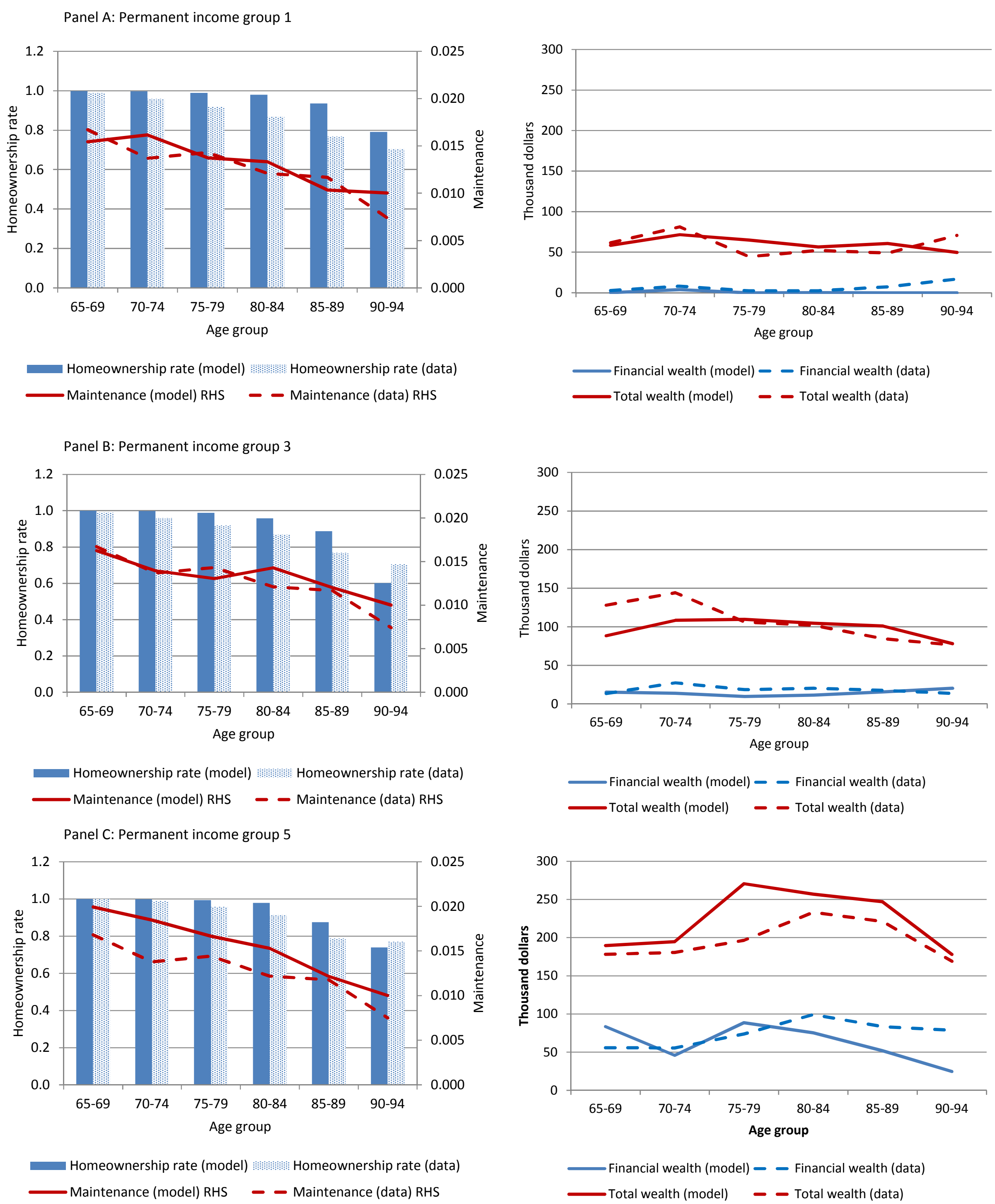
These were not directly targeted by the calibration, but again the model replicates them relatively well (with the exception of the financial wealth of the highest income group late in life, which is underestimated by the model).

Even though overall the model seems to provide a reasonably good fit, there is one aspect in which it is less successful, which we would like to highlight: it tends to overestimate homeownership rates in the 80-84 and 85-89 age groups. One possible explanation is that in reality some individuals may have reasons to sell that are not captured by the model (e.g. to be nearer to a family member).

As a further check on the model, we have calculated the predicted mean fraction of consumption expenditures in housing. For our calibrated parameters, and for permanent income groups one, three and five, they are equal to 0.22, 0.24 and 0.18, respectively. Therefore the highest income agents in our model spend a relatively smaller proportion on housing. This is mainly due to the fact that their houses are less valuable relative to their income and financial assets. We compare these values to those from the Aggregate Expenditure Share Tables provided by the U.S. Bureau of Labor Statistics (BLS).[21] The latter vary depending on whether one considers a broad definition of housing expenditures that includes (among other things) household furnishings and equipment or a narrower definition that includes only shelter. The average values for those aged 65 years and older over the 1996 to 2012 period are 0.332 and 0.174, respectively. The values predicted by our model fall in between these two. If one considers differences across income quintiles (for all age groups) in the BLS data, the values are 0.38 (housing) and 0.22 (shelter) for those in the bottom income quintile and 0.31 (housing) and 0.18 (shelter) for those in the top income quintile. Therefore, those

[21] They are available at https://www.bls.gov/cex/csxashar.htm

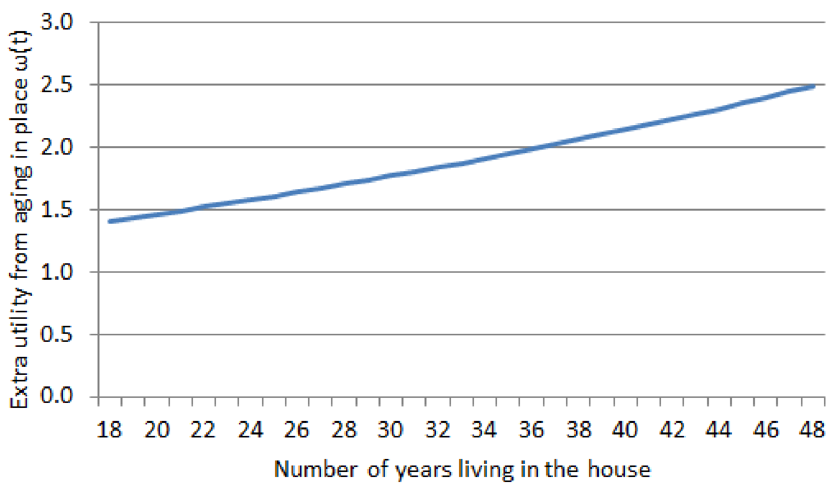
Figure 4: **Model versus data target moments.**



in the top income quintile spend less on housing than those in the bottom quintile: this is similar to what happens in our model.[22]

We now discuss the calibrated parameters. The utility benefits from aging in place are important: the calibrated value of α is 0.019 implying a value for ω_t that increases from roughly 1.5 to 2.5 for an increase in the number of years living in the home from 18 to 48 (as shown in Figure 5). Recall that ω_t is the parameter that multiplies housing services in the utility function capturing the extra utility benefits of remaining in the same house in which the individual has retired, compared to a similar size rental unit.[23] To quantitatively evaluate its effects, we have solved our model for α equal to zero (so that $\omega_t = 1\ \forall t$) while keeping the other parameters at their benchmark values.

Figure 5: **Aging in place utility benefits.**



The results are shown in the third row of each of the panels of Table 7. In order to keep the length of the paper manageable, in this table we report averages for ten-year age groups (instead of five) and for individuals in the middle quintile of the income distribution (the effects that we describe are similar for the other income groups). For comparison, the first two rows of each panel report the HRS data moments and the model generated ones for the calibrated parameters, respectively. The table shows that when we remove the benefits from aging in place, agents in the model want to sell too early compared to the data: homeown-

[22]In appendix B we investigate the extent to which our model generates bequests that are comparable to those in the HRS data.

[23]One way to interpret a value of ω_t of say two is that the individual derives as much utility from a given house where she has lived for most of her life (36 years), and which brings her good memories, as from a rented house which is twice as large to which she does not have a psychological attachment.

Table 7: **Other preference parameters and model features.**

Age group	65-74	75-84	85-94	65-74	75-84	85-94
	Homeownership rate			Maintenance		
Data	0.98	0.88	0.75	0.017	0.014	0.011
Calibrated parameters	1.00	0.97	0.74	0.015	0.014	0.011
No aging in place benefits $\alpha = 0$	0.91	0.42	0.06	0.014	0.012	0.010
No maint. choice $m = 0.02$	0.97	0.82	0.55	0.020	0.020	0.020
Minimum maint. $\underline{m} = 0$	1.00	0.99	0.85	0.013	0.009	0.003
No bequest motive $b = 0$	0.97	0.75	0.15	0.013	0.012	0.010
Bequest curvature $\kappa = 0$	1.00	0.97	0.79	0.015	0.014	0.011
Intrat. elast. subs. $\epsilon = 0.8$	0.86	0.76	0.27	0.012	0.011	0.010
	Total wealth (thous.)			Fin. savings (thous.)		
Data	136.1	104.0	80.4	20.4	19.3	15.6
Calibrated parameters	98.3	106.9	89.5	14.4	10.5	17.8
No aging in place benefits $\alpha = 0$	94.7	86.8	53.0	21.1	58.5	51.4
No maint. choice $m = 0.02$	99.8	103.9	86.3	16.3	21.2	38.7
Minimum maint. $\underline{m} = 0$	96.9	104.8	89.3	13.0	9.2	3.4
No bequest motive $b = 0$	95.0	93.4	35.1	12.8	26.4	26.3
Bequest curvature $\kappa = 0$	98.8	108.1	91.8	14.7	11.3	10.1
Intrat. elast. subs. $\epsilon = 0.8$	92.2	96.1	58.7	20.6	31.5	43.4

ership rates decline to 0.42 and 0.06 for the 75-84 and 85-94 age groups, respectively.[24] An additional interesting effect is that there is a significantly larger reduction in total wealth with age, for the same bequest motive intensity. The main reason is that since individuals sell at an earlier age, they do not benefit from the large house price increases that occurred during the sample period. Realized bequests in our model are to some extent driven by the desire to age in place and the realized house price changes.

In the next two rows of Table 7, we report the results for experiments that are aimed at understanding the role that maintenance plays in our model. We first eliminate maintenance as a choice variable and set $m_t = d_p = 0.02 \ \forall t$ (while keeping all other parameters at their calibrated values, including the benefits from aging in place). Giving the retirees the choice of cutting back on housing maintenance allows them to adjust their housing consumption and saving, and makes them want to remain homeowners until later in life: the average

[24]It is instructive to briefly consider what triggers a house sale and a move to renting in the model. As in the data, those who decide to sell earlier have lower cash-on-hand and higher house values relative to cash-on-hand. These constitute an incentive for individuals to tap into their home equity through a house sale.

homeownership rate for those in the 85-94 age group drops from 0.74 to 0.55 when we force them to always fully maintain their house. In the model, the ability to cut back on housing maintenance is an option that is particularly valuable for older retirees, as a way to release the cash needed to meet medical or other expenditures and reduce housing wealth. Davidoff (2005) presents empirical evidence that the elderly do reduce housing maintenance.

When we let agents choose whether to maintain the house but we set the minimum level of maintenance equal to zero, the model generates counterfactually low maintenance rates late in life, equal to 0.3% per year for the 85-94 age group compared to 1.1% in the data. We interpret this minimum level of maintenance as that needed to keep the house in a habitable condition.

In addition to a precautionary savings motive arising from uncertain life span and medical expenditures, the literature has proposed a bequest motive as a reason for why retirees do not run down their wealth faster during retirement (see for example Bernheim (1992) and Hurd (1989)).[25] The next two rows of Table 7 evaluate the effects of the bequest motive parameters. We first consider the case in which there is no bequest motive ($b = 0$). The results show that the bequest motive plays a role in our model. In its absence, the model generates too low homeownership rates and too little wealth accumulation late in life (although the results are not shown in the table, this is still the case if we increase the benefits from aging in place further). The next row shows the effects of setting $\kappa = 0$. When bequests are not a luxury good, individuals want to save more, particularly at lower levels of wealth. This means that they tend to remain homeowners for longer. This experiment also shows that some of the model parameters impact some of the target moments in the same direction, making it challenging to precisely identify the values of the different parameters.[26] However, in spite of these considerations, when agents in our model do not derive utility benefits from aging in place, homeownership rates late in life are always too low, even with stronger bequest and precautionary savings motives.[27]

[25] More recently, Ameriks, Caplin, Laufer, and Van Nieuwerburgh (2011) have used survey data to estimate a structural model in which they separate bequest and precautionary savings motives. Their estimates highlight the importance of public care aversion in explaining the data.

[26] For instance, benefits from aging in place lead individuals to remain homeowners until later in life, as does a stronger bequest motive (or a lower κ). Furthermore, given that our data (and model) are for homeowners at the beginning of retirement, it does not capture the behavior of the very poor, which would be useful to evaluate the extent to which bequests are a luxury good.

[27] A higher expected house price growth has also limited success in generating high homeownership rates late in life. Even though it increases the attractiveness of housing as a vehicle for saving, it also reduces its rental cost. Furthermore, as retirees age and house prices increase, there are additional incentives to tap into the higher home equity. The more realistic and comprehensive modeling of the risks that retirees face explains why in our model it is difficult to generate high rates of homeownership late in life, compared to models where fewer risks are modeled (for example Yang (2009)).

Finally, we show the effects of a lower value for the elasticity of substitution between housing and non-durable consumption. As Zevelev (2017) discusses, there is a large disparity in estimates in the literature ranging from values well below one to those well above one. When we set $\epsilon = 0.8$, agents in our model want to sell their house too early and to reduce maintenance. Our calibrated value is at the top of the range considered by Piazzesi, Schneider, and Tuzel (2007) but is significantly lower than the one estimated by Bajari, Chan, Krueger, and Miller (2013).

5.3 Reverse mortgages

5.3.1 Drawdown loans

We now introduce drawdown RMs into the model. We start by solving it for the set of calibrated preference parameters and for aggregate initial conditions that correspond to those faced by retirees in the cohort born in 1930-1934, who reach age 65 at the beginning of the HRS sample, including an initially high interest rate. The comparison of the initial age value functions of homeowners with and without a RM, i.e. $V_1^{H,RM}(.)$ and $V_1^{H,NoRM}(.)$ allows us to evaluate the benefits of the loans for retirees. More precisely, we calculate the proportion of initial cash-on-hand that they are willing to pay to have access to RMs. We focus on the welfare gains for retirees who are initially in good health (since this is the case for the majority of age 65 individuals) and face low initial medical expenditures. But we will also perform calculations for other parameters and initial conditions.

In each panel of Table 8, the first three rows report the results for retirees across the income distribution (for two levels of initial cash-on-hand corresponding to percentiles 25 (Panel A) and 50 (Panel B) of the distribution of age 65 cash-on-hand in the HRS data). The welfare gains are zero throughout. The high costs and the property maintenance requirement eliminate the loan benefits. This result is consistent with the small number of loans originated before the turn of the century, as shown in Figure 1.[28]

Even though in reality the demand for the loans was initially extremely small, it was not exactly zero, so it is instructive to investigate, within the context of our model, the nature of the parameter value changes required for the loans to become beneficial for retirees. In the next two rows of Table 8, we show that this can be achieved through a reduction in the importance of the bequest motive or in the value for the discount factor (while in each case

[28] In the model, the death shock is realized before individuals have the time to make any decisions. We have solved the model under the alternative assumption that when retirees know that they are about to die, they still have the time to drawdown any unused portion of the credit line (which is optimal in cases of negative equity). The welfare gains of the loans are still zero.

Table 8: **Drawdown loans.**

Parameterization	Welf gain of retirees	PV CF Lenders Yield	Risk-adj.	PV CF IA Yield	Risk-adj.
	Panel A: Percentile 25 of initial cash-on-hand				
Perm Inc Group 1, calibrated parameters	0.00	n/a	n/a	n/a	n/a
Perm Inc Group 3, calibrated parameters	0.00	n/a	n/a	n/a	n/a
Perm Inc Group 5, calibrated parameters	0.00	n/a	n/a	n/a	n/a
Lower discount factor ($\beta = 0.90$)	0.32	17.8	18.0	-10.4	-12.6
Weaker bequest motive ($b = 6$)	0.31	16.5	16.8	-10.3	-12.4
No aging in place ben. ($\alpha = 0$) and $b = 6$	0.00	n/a	n/a	n/a	n/a
	Panel B: Percentile 50 of initial cash-on-hand				
Perm Inc Group 1, calibrated parameters	0.00	n/a	n/a	n/a	n/a
Perm Inc Group 3, calibrated parameters	0.00	n/a	n/a	n/a	n/a
Perm Inc Group 5, calibrated parameters	0.00	n/a	n/a	n/a	n/a
Lower discount factor ($\beta = 0.90$)	0.05	16.8	17.0	-10.4	-12.5
Weaker bequest motive ($b = 6$)	0.08	15.8	16.0	-10.2	-12.2
No aging in place ben. ($\alpha = 0$) and $b = 6$	0.00	n/a	n/a	n/a	n/a

keeping all other model parameters equal to the calibrated values). To avoid increasing the length of the paper, we report results only for the middle permanent income group. Retirees who derive utility from aging in place but who do not have such strong incentives to save as retirees with the calibrated parameters, value the ability to borrow against the house, more so at lower levels of initial cash-on-hand.[29] For $b = 6$ the proportions of initial cash-on-hand are 0.31 and 0.08 for individuals with percentile 25 and percentile 50 of the distribution of initial cash-on-hand respectively.

The remaining columns of Table 8 report, for the cases for which the loans are beneficial for retirees, the present value of the cash-flows received by lenders and by the insurance agency using two different discount rates (bond yields and risk-adjusted). The present values are in thousand U.S. dollars per loan and calculated as an average across many different realizations for the aggregate and individual specific shocks. In other words, they are expected present discounted values at loan origination. The values for the insurance agency are negative. This means that the price of the insurance is too low, and that the government is subsidizing these products, a point made by Davidoff (2015) and Lucas (2016), in the context of different models, set in continuous time.

[29]The quantitative results for the other income groups (not reported) are obviously different, but the same economic intuition holds.

The cash-flows of the insurance agency are more negative when we use a risk-adjusted discount rate that captures the fact that the agency must make large payouts in states of the world with large house price declines, which are states with high marginal utility of consumption and low risk-adjusted discount rates. In contrast, the cash-flows of the lenders are positive and slightly higher when we use a risk-adjusted discount rate, even though lenders are insured against default losses. This is because borrowers are more likely to draw on the loan, which implies negative cash-flows for lenders, when house prices increase. These are states of the world with low marginal utility of consumption. It is important to note that these present values should not be interpreted as being equal to the profits of lenders, since we have not subtracted the costs of originating and servicing the loans.

The last row of Table 8 reports the results for the case of a weaker bequest motive but no aging in place benefits. The loans are no longer beneficial for retirees. They prefer to sell the house early on and rent rather than to take out a loan.

Table 9 reports the age profiles of debt drawn and debt outstanding (in thousands of dollars) for the weaker bequest motive parameterization (and for percentile 25 of initial cash-on-hand). The bulk of the borrowing takes place between the ages of 70 and 84. Late in life, the amounts drawn are smaller on average since some retirees have exhausted their debt capacity. In the model, the most common motive for loan termination is death. While alive, borrowers in a situation of negative home equity do not voluntarily exit the home and terminate the debt contract. However, there is a small proportion of retirees, equal to 3.4 percent of the total, who (involuntarily) exit the home and default on the loan while still alive, at a loss for the insurance agency.[30] These are retirees who have exhausted their debt capacity, are in a situation of negative equity, and are hit by the forced sale shock (3.2 percent) or while not being hit by the shock they are not able to meet the property tax and maintenance expenses and are forced to default (0.2 percent). Even though this is a relatively small proportion, it could be very important for lenders who are worried about the reputational risk of foreclosing on old retired homeowners.

The last row of Table 9 shows the values for different percentiles of the present value cash-flow distribution of the insurance agency. The median cash-flows (in thousands of dollars) are positive, but the agency faces significant downside risk.

[30]The loans induce moral hazard on moving out of the house while alive, since borrowing acts as a substitute for an earlier house sale.

Table 9: **Amount drawn, debt outstanding and distribution of present value of cash-flows for weaker bequest motive parameterization ($b = 6$).**

	Percentile 25 of initial cash-on-hand					
Age group:	65-69	70-74	75-79	80-84	85-89	90-94
Average annual amount drawn	0.5	2.1	3.3	2.6	1.6	1.0
Average debt outstanding	7.0	17.7	39.9	66.2	91.5	117.1
PV risk-adjusted CF, percentiles:	p5	p10	p25	p50	p75	p90
PV CF Lenders	4.2	5.3	7.7	12.5	22.3	33.8
PV CF to Insurance agency	-56.4	-43.4	-22.8	1.4	2.0	2.8

5.3.2 Lump-sum reverse mortgages

In lump-sum RMs, retirees borrow the whole amount up-front, at an interest rate that is fixed at loan initiation. We have solved our model for such a product, for the same borrowing limit and loan costs as the drawdown loans. This provides a benchmark and facilitates comparison across loans. The benefits for the calibrated parameters were always zero. And they were also zero for the weaker bequest motive parametrization with $b = 6$. It was only when we reduced the strength of the bequest motive further that the lump-sum loans became beneficial. For example, for $b = 2$ and percentile 25 of the distribution of initial cash-on-hand, the welfare gains are equal to 0.14. But even in this case the welfare benefits are lower than those of drawdown mortgages. Thus, the model has difficulty in generating demand for lump-sum mortgage products. To make them more appealing to retirees, we would need to model a motive for retirees to wish to withdraw a large amount upfront, such as the presence of pre-existing debt that is amortized using the proceeds from the lump-sum loan. We consider this possibility later on in the paper.[31]

5.3.3 Historical changes in loan terms, interest rates and house prices

There have been historical changes in loan terms, interest rates and house prices. We evaluate their effects on the benefits of drawdown RMs. To facilitate the comparison, we first use the same initial conditions as in the previous section, for individuals in the middle permanent

[31] In reality supply factors may also play a role in the loan origination process. Since in lump-sum loans the whole amount is borrowed up-front, the average debt outstanding and the cash-flows of lenders are higher than those in drawdown loans. This may incentivize them to try to sell the former to retirees. The added risk and potentially higher losses are borne by the insurance agency. Another supply factor that may affect the incentives of lenders is that it may be easier to securitize lump-sum loans than drawdown loans (again because the whole amount is borrowed up-front).

income group (including house values), and change only the loan terms and initial interest rates. Table 10 reports the two sets of changes that we evaluate, corresponding to the years 2006 and 2010.[32]

Table 10: **Historical changes to loan parameters.**

Description	Parameter	Year 2006	Year 2010
Initial borrowing limit	l_1	0.577	0.584
Annual mortgage ins. premium	ψ_A	0.005	0.013
Lender's margin	ψ_L	0.015	0.023
Real interest rate	R_{1t}	0.031	-0.006

The results in Table 11 show that for both sets of parameters, and similar to the benchmark case, RMs are not beneficial for retirees. Therefore, in addition to the changes in loan parameters, we consider the effects of changes in house values. The median ratios of housing wealth to income for retirees aged 65 or 66 in the HRS data in 2006 and in 2010 are 6.8 and 7.4, respectively. In Table 11 we report the RM benefits for two different initial house values (and sizes) relative to income (we keep income fixed to facilitate the comparison).

There are several interesting results. First, for some of the parameterizations, RMs become beneficial. Second, the benefits are generally larger for 2006 than for 2010. For the latter year they only become marginally positive at lower levels of initial cash-on-hand and when we increase the initial house value to a multiple of eight of income. These time-series patterns for the model predicted benefits of RMs roughly match the time-series patterns for the number of new loans endorsed, plotted in Figure 1.

The model provides an explanation. For individuals who derive utility benefits from aging in place, a higher house value relative to retirement income (and financial savings) makes it more attractive to use RMs to tap into home equity. This point is also highlighted in the empirical analysis of Shan (2011), who combines reverse mortgage data with county-level house price data to show that elderly homeowners are more likely to purchase reverse mortgages when the housing market is at its peak. The main reason why in the model, for a given house value relative to income, the benefits of RMs are higher in 2006 than in 2010 is the higher interest rate in the former compared to the latter year. This may seem strange since a higher interest rate usually means a higher loan cost, but for RMs a higher interest rate also means that the borrowing limit will grow faster, so that retirees who do not borrow

[32]These values come from several mortgagee letters, historical data, and papers in the literature (most notably Davidoff (2015)). We give further details in Appendix C.

Table 11: **Drawdown loans: historical changes.**

Parameterization	Welf gain of retirees	PV CF Lenders Yield	PV CF Lenders Risk-adj.	PV CF IA Yield	PV CF IA Risk-adj.
	Panel A: Percentile 25 of initial cash-on-hand				
2006 loan param.	0.00	n/a	n/a	n/a	n/a
2006 loan param., house value = 7x inc	0.32	18.0	18.2	-11.8	-14.3
2010 loan param.	0.00	n/a	n/a	n/a	n/a
2010 loan param., house value = 7x inc	0.00	n/a	n/a	n/a	n/a
2010 loan param., house value = 8x inc	0.02	26.2	26.8	-12.6	-16.0
Higher house price risk ($\sigma_\eta = 0.20$)	0.31	14.2	14.3	-11.1	-13.5
Low mean house price ret. ($\mu_H = -0.02$)	0.41	17.6	17.9	-21.9	-24.0
	Panel B: Percentile 50 of initial cash-on-hand				
2006 loan param.	0.00	n/a	n/a	n/a	n/a
2006 loan param., house value = 7x inc	0.15	17.2	17.3	-11.5	-14.0
2010 loan param.	0.00	n/a	n/a	n/a	n/a
2010 loan param., house value = 7x inc	0.00	n/a	n/a	n/a	n/a
2010 loan param., house value = 8x inc	0.00	n/a	n/a	n/a	n/a
Higher house price risk ($\sigma_\eta = 0.20$)	0.10	13.5	13.7	-11.0	-13.4
Low mean house price ret. ($\mu_H = -0.02$)	0.20	17.1	17.3	-21.7	-23.8

the full amount up front will be able to access more funds later in life (and possibly make strategic use of the put component of the product).

These two features of RMs, namely the right to borrow against the house and the option to default, are clearly explained by Davidoff (2015). In the last two rows of Table 11, we perform two experiments to illustrate them, keeping all the other parameters at their benchmark values. First, we increase the standard deviation of house price returns to 0.20. RMs become beneficial: the higher the volatility of the underlying asset and the longer the horizon the higher the value of the put option.[33] This highlights the importance of modeling RMs as long-term debt contracts. Second, we decrease the log expected house price growth to -0.02. This also increases the value of the option to default on the loan.

Although the benefits of RMs predicted by the model mirror the time-series patterns of new loans endorsed, it is important to acknowledge its limitations with respect to explaining

[33] The horizon may be longer due to a higher life expectancy. We have solved and parameterized the model for a single individual. However, the HECM program does not distinguish between singles and couples. In the case of a couple, the borrowing limit is determined using the age of the youngest co-borrower. We have evaluated the effects of the higher life expectancy of couples on the RM benefits. In Appendix C we give details on how we parameterize it. Even though the value of the put increases, the benefits of the loan for the calibrated parameters are still zero.

the total number of new loans endorsed, particularly for 2006. The model predicts that RMs are beneficial for a number of individuals larger than the total number of endorsed loans in this year.

5.4 Other assets and liabilities

Retirees have other assets and liabilities that so far we have not explicitly considered. In appendix D we give details on their prevalence using HRS data. In this section we analyze possible interactions between some of them and RMs. Throughout, we use the benchmark parameters (and the initial conditions of the 1930-1934 cohort, middle permanent income group).[34]

5.4.1 Insurance against forced house sale.

One of the risks that the retirees in our model face is that they may be forced to sell their house. For individuals who derive utility benefits from aging in place, being forced to sell one's home and move can have a large adverse utility impact. We are interested in investigating the benefits of purchasing insurance against such an event in our model.[35] Given its complexity and large number of state variables, we consider a simple form of insurance which pays the retiree a certain dollar amount in the event of and in the period of the forced house sale (and zero in all other periods). The retiree decides whether to purchase such insurance at the initial model age of 65 for a one-off payment. We solve our model for both an actuarially fair insurance and one with an 8% load.[36]

Table 12: **Welfare gain of insurance against forced sale.**

	Actuarially fair price		Load = 8%	
Parameterization/Initial cash-on-hand	Median	Perc 25	Median	Perc 25
Cash rec. when forced sale = 5,000	0.009	0.013	0.008	0.011
Cash rec. when forced sale = 10,000	0.015	0.019	0.014	0.016
Cash rec. when forced sale = 20,000	0.022	0.022	0.019	0.014

In Table 12 we report results for three levels of payout that retirees receive in the event

[34]In appendix B we expand on this analysis, and show that the model generates little annuity demand.

[35]Davidoff (2010) shows how home equity may substitute for long-term care insurance.

[36]The calculation of the insurance price requires that insurance companies can evaluate the (initial) health status of the retiree. In addition, we assume that the probability of a forced house sale is unaffected by the purchase of the insurance. We use interest rates to discount the payouts.

of a forced house sale: five, ten and twenty thousand dollars. The purchase of the insurance is beneficial for all the cases considered, but more so for retirees with higher initial cash-on-hand. Retirees with lower initial cash-on-hand are more likely to benefit from the lower bound in consumption, but less so when they have insurance against a forced house sale. This reduces the benefits of purchasing insurance for these individuals. For median levels of initial cash-on-hand, the benefits of the insurance vary between 0.8 and 1.9 percent of this initial cash-on-hand (for an 8% load). We have investigated whether an individual with median initial cash-on-hand who purchases insurance against a forced sale wants to take out a RM with a maintenance requirement, but found this not to be the case.

5.4.2 Pre-existing mortgage debt

Although the median individual at age 65 does not have any mortgage debt outstanding, a significant proportion of them do (we include details in Appendix D). This has motivated us to investigate the benefits of RMs for retirees who have pre-existing outstanding mortgage debt larger than their initial financial assets. We assume that 30,000 dollars is outstanding at age 65, that the remaining mortgage maturity is 10-years, and that the premium on this pre-existing debt is 2%. We use these assumptions to determine the annual mortgage payments that the retiree has to make over the following ten years. We solve the model and obtain the age 65 value function.

The alternative is to take out a RM and pre-pay the pre-existing mortgage debt. We assume that there are no pre-payment fees. We solve the model for the lump-sum loan and obtain the benefits of the RM by comparing the value function to that of the case in which retirees do not take out the loan. Recall that in the benchmark case, without pre-existing mortgage debt, RMs were not beneficial. For individuals with median levels of initial cash-on-hand, the loans are still not beneficial. However, when the substantial pre-existing debt is combined with lower levels of initial cash-on-hand (percentile 25 of the distribution), individuals are willing to pay 0.20 of initial cash-on-hand to have access to the loans. Therefore, in the presence of pre-existing debt, the demand for RM loans increases in general, and for lump-sum loans in particular (since individuals must borrow a substantial amount up front to pre-pay the existing debt). Nakajima and Telyukova (2017) also find that pre-existing debt increases the demand for RM loans, but they restrict their attention to short-term drawdown loans.

6 Experiments

We analyze the impact of some of the terms and features of drawdown RMs on their benefits to retirees, and on cash-flows to lenders and the government. We illustrate the effects using the parameter values for the cohort born in 1930-34 and permanent income group three. Recall that for the benchmark case, the products are not beneficial for retirees.

6.1 Maintenance requirement and government insurance

One of the requirements of RMs is that retirees maintain their house. If they fail to comply with this requirement, the lender has the right to foreclose on the property. We now relax the maintenance requirement and set annual housing maintenance equal to the minimum level of 1% of the property value. RMs are now beneficial for retirees: the welfare gains are equal to 0.26 of initial cash-on-hand (first row of Panel A.1 in Table 13). Retirees in our model (as in the data) cut down on housing maintenance in old age. This allows them to dissave and release cash for medical and other expenditures. The undesired maintenance that RMs impose reduces the benefits of the products. It explains why the benefits of RMs in our model are not as large as in Davidoff (2015).

The lower level of housing maintenance has a cost for the insurance agency. The collateral value of the property is lower, and the potential loan losses larger. In an attempt to improve the expected payoffs for the agency, we increase the annual insurance premium from the benchmark value of 0.5% to 1.5%. Perhaps surprisingly, this has a relatively small effect on the payoffs. The economic reason is simple, though. A higher premium benefits the agency in periods prior to loan termination. However, it also means that the outstanding loan amount will be higher at each point in time, not only because of the additional premium, but also because in subsequent periods lenders receive the loan margin on the higher outstanding loan balance. This makes it more likely that at loan termination outstanding loan balances will be higher than house values. As premia are increased, there is a reduction in borrower benefits, which is likely to reduce the overall demand for the products and the total expected losses of the agency. For an annual premium equal to 0.02 (not shown on the table), the products are no longer beneficial for retirees. In the third row of Panel A.1 we consider the effects of a reduction in the initial borrowing limit to 0.50 of house value, while maintaining the insurance premium at the baseline value. It leads to a decrease in the benefits for retirees, which become zero.

For all of the parameterizations that we have considered, the expected present value of the payoffs for the insurance agency are negative. They are also more negative than the benefits

Table 13: **Maintenance requirement and government insurance.**

Maintenance equal to 1% of property value for all the cases considered.

Parameterization	Welf gain of retirees	PV CF Lenders Yield	PV CF Lenders Risk-adj.	PV CF IA Yield	PV CF IA Risk-adj.
Panel A.1: High initial interest rate, pctile 25 of initial cash-on-hand					
Calibrated parameters	0.26	16.5	16.7	-15.3	-17.4
Annual insurance = 0.015	0.06	16.9	17.1	-13.4	-15.5
Borrowing limit = 0.50	0.00	n/a	n/a	n/a	n/a
No insurance, borrowing limit = 0.50	0.20	1.5	-0.2	n/a	n/a
House val.=7x inc, no ins., limit = 0.45	0.36	3.4	1.6	n/a	n/a
Panel A.2: High initial interest rate, pctile 50 of initial cash-on-hand					
Calibrated parameters	0.03	16.0	16.3	-15.2	-17.3
House val.=7x inc, no ins., limit = 0.45	0.06	3.4	1.6	n/a	n/a
Panel B.1: Low initial interest rate, pctile 25 of initial cash-on-hand					
Calibrated parameters	0.00	n/a	n/a	n/a	n/a
Annual service cost = 0	0.38	8.8	9.1	-9.3	-11.2
House val.=7x inc	0.25	18.7	19.0	-12.6	-15.1
House val.=7x inc, no ins., limit = 0.50	0.20	5.9	4.1	n/a	n/a
Panel B.2: Low initial interest rate, pctile 50 of initial cash-on-hand					
Calibrated parameters	0.00	n/a	n/a	n/a	n/a
Annual service cost = 0	0.13	8.2	8.5	-9.1	-11.0
House val.=7x inc	0.04	18.0	18.3	-12.3	-14.7
House val.=7x inc, no ins., limit = 0.50	0.01	5.4	3.6	n/a	n/a

to retirees. For instance, in the first row of Panel A.1 of Table 13 the risk-adjusted losses for the insurance agency are 17.4 thousand dollars, making them larger than the benefits to retirees of 2.5 thousand dollars (0.26 of 9.64 thousand dollars). The loan guarantees expose the government to significant downside risk, and more so when the levels of property maintenance are lower. In contrast, the payoffs for lenders are positive and large. They bear no house price risk, but the high loan margins and product fees mean that the expected present value of their cash-flows is large.

The large expected losses for the insurance agency raise the questions of whether the products would be provided in the absence of government subsidies and, if so, how loans provided solely by the private sector would differ from those currently available in the U.S.. As a first step, we note that in the U.K. there are RMs provided by private lenders without government guarantees, with a no negative home equity guarantee (so that lenders bear the losses in the event of house price declines). In Appendix A we compare the products in more detail, but one of the differences is that borrowing limits are lower in the U.K. than in the U.S..

With this in mind, we examine the removal of mortgage insurance and all of the associated costs (initial and annual). In this scenario, there is no insurance agency and lenders bear the downside risk. The first no insurance row in Panel A.1 reports results for an initial borrowing limit of 0.50 (lower than the 0.564 in the benchmark). Even though lenders break even if one uses the risk-free rate to discount their cash-flows, they do not break even on a risk-adjusted basis. When we reduce the initial loan limit further to 0.45, the loans are no longer beneficial for retirees (not shown on the table). The last row of Panel A.1 of Table 13 shows that the loan benefits to retirees and lenders are higher for the case of higher house value relative to income.

Panel A.2 shows the results (for a subset of the cases in Panel A.1) for higher initial cash-on-hand. The benefits of RMs to retirees are smaller. In Panels B.1 and B.2 we report results for an initially low interest rate, so that the borrowing limit will grow more slowly (if the agent does not borrow the full amount up-front). The relaxation of the maintenance requirement is not sufficient to make the loan attractive for agents. For that to happen, a reduction in the annual service costs is needed.[37] Alternatively, loans are also beneficial when initial house values are high relative to income. As before, the insurance agency suffers substantial losses. If we eliminate the government insurance and lenders bear the house price risk, it is possible for lenders to have positive expected cash-flows and the loans to be beneficial for retirees.[38] A larger demand for RMs may allow lenders to benefit from economies of scale.

6.2 Product design: insurance against forced sale.

One of the risks that retirees in our model face is that they may be forced to sell their house, which has a particularly large adverse utility impact due to the loss of the benefits from aging in place. It also interacts with the RM: the forced house sale triggers early loan termination and a reduction in the ex-ante benefits of taking out a loan. This point is made by Michelangeli (2010). Our contribution here is to quantitatively evaluate the benefits of combining RMs with the insurance against a forced sale. We do so for our calibrated parameters (with high initial interest rates), but with maintenance expenses equal to 1%

[37] Since RMs do not require borrowers to make payments before loan termination, the loans do not need to be serviced regularly like traditional mortgages. Therefore one might expect lower servicing costs.

[38] As previously discussed, one should not interpret a present value of cash-flows of lenders equal to zero as the level that allows them to break even, since in the calculations we have not subtracted the costs of originating the loans.

of house value, so that the loans are beneficial for retirees even in the absence of insurance against a forced sale.

The results are shown in the first panel of Table 14. The first row shows the benefits for retirees, as a proportion of their initial cash-on-hand, if lenders combine RMs with the insurance against a forced sale. The different columns report results for different values of the cash that retirees receive (five, ten and twenty thousand dollars) and for two different levels of their initial cash-on-hand (coh). Importantly, these benefits are calculated so that the present value of the risk-adjusted cash-flows of lenders and of the insurance agency are the same as in the case of reverse mortgages only (i.e. without the insurance against a forced sale). This is achieved through cash transfers at the initial date between retirees, lenders and the insurance agency so that the latter two are as well off as in the base case.

The second row reports the welfare gains for retirees for the scenario in which they have a RM but no insurance against forced sale. They correspond to the first row of Panels A.1 and A.2 of Table 13. Since there is no insurance, the benefits are the same across columns. The third row reports the results for insurance against forced sale but no RM (from Table 12). The last row of the panel shows the difference between the values in the first row and the sum of the values in the second and third rows. These are the additional gains from product bundling.

Table 14: **Product design: insurance against forced sale**

Maintenance equal to 1% of property value for all the cases considered.

Cash received when forced sale:	5k	10k	20k	5k	10k	20k
Panel A: Calibrated parameters	Hi. int. rate, p25 of coh			Hi. int. rate, p50 of coh		
1. Reverse mort. and insurance	0.290	0.296	0.321	0.048	0.063	0.082
2. Reverse mort., no insurance	0.259	0.259	0.259	0.031	0.031	0.031
3. No reverse mort., insurance	0.013	0.019	0.022	0.009	0.015	0.022
4. Additional gain from bundling	0.018	0.018	0.041	0.008	0.017	0.029
Panel B: Higher house val. (7x inc)	Hi. int. rate, p50 of coh			Low int. rate, p50 of coh		
1. Reverse mort. and insurance	0.252	0.285	0.294	0.054	0.068	0.088
2. Reverse mort., no insurance	0.236	0.236	0.236	0.038	0.038	0.038
3. No reverse mort., insurance	0.007	0.030	0.016	0.007	0.011	0.015
4. Additional gain from bundling	0.009	0.019	0.042	0.009	0.019	0.035

Interestingly, and importantly, the table shows that there are significant positive additional gains from the bundling of RMs with the insurance against a forced house sale. For individuals who derive benefits from aging in place, the state of the world in which they are forced to sell the house is particularly bad. It gives rise to a precautionary savings motive, which reduces the benefits of RMs. The insurance against a forced sale transfers resources to individuals in this state of the world, it reduces the need for precautionary savings, and it increases the benefits of the loans. This explains the product complementarities. The benefits from combining RMs with the insurance arise in spite of the fact that the it reduces the expected value of government transfers in case of a forced sale, more so for individuals with lower initial cash-on-hand. Panel B reports the results for a higher house value relative to income. We report results for high/low initial interest rates and median initial cash-on-hand. The benefits from product complementarities are larger.

7 Conclusion

We have solved a quantitative model of retirees' consumption and homeownership decisions that incorporates aging in place utility benefits and housing maintenance choice. The evidence that we provide and the model calibration show that these features play an important role in explaining the housing decisions of the elderly. In our model, the maintenance requirement of RMs together with the high product costs reduce (or eliminate) the loan benefits. We have carried out several experiments. The elimination of the maintenance requirement increases the benefits of the loans for retirees, but leads to a deterioration in the government position. The removal of the government insurance (and its associated costs) would also increase demand for the products, but the borrowing limits would have to be tightened for lenders to break even. In a final experiment, we have shown that combining RMs with insurance against a forced house sale is Pareto improving in the sense that retirees are better off, while lenders and the insurance agency are as well off as in the case in which reverse mortgages are not combined with the insurance.

The decision of whether to take out a RM in old age is likely to be influenced by factors absent from our model, such as the attitudes of retirees towards debt, retirees' ability to understand the products, their perception of how trustworthy the sellers of the products are, among others. Some of these, such as attitudes towards debt, may change in the future, as more individuals reach retirement age with significant amounts of outstanding debt. In addition, as our results have shown, higher house values relative to financial savings (and to retirement income) will create an extra incentive for homeowners to tap into their home equity to finance retirement consumption.

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