# Reverse Mortgage Design

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**ABSTRACT**

We study the role of housing wealth for the financing of retirement consumption, focusing on the design of the financial products that allow households to tap into their home equity. Our model results show that bequest and precautionary savings motives have difficulty generating the high homeownership rates late in life observed in U.S. data. The model is more successful at matching the data, including a limited demand for reverse mortgages, when: (i) retirees value property maintenance less than potential buyers of the property; (ii) for psychological reasons, retirees derive utility from remaining in the same house. We use the model to evaluate the impact of different reverse mortgage features and costs on their benefits to retirees, cash-flows to lenders and to the government agency that provides mortgage insurance.

**JEL classification**: G21, E21.

**Keywords**: Household finance, reverse mortgages, retirement, housing wealth.

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# 1 Introduction

In many countries the government, through the social security system, provides a pension to retirees. However, recently there have been increasing concerns about the sustainability of these (mainly unfunded) social security systems and the adequacy of households' private retirement savings (Scholz, Seshadri, and Khitatrakun, 2006).[1] Our paper studies the role of housing wealth for the financing of retirement consumption, focusing on the design of the financial products that allow retired households to tap into their home equity.

Our motivation for studying the role of housing wealth is straightforward: 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). Retirees could release their home equity by downsizing, moving into rental accommodation, or by using financial products such as reverse mortgages. 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, 2001, Poterba, Venti, and Wise, 2011a). To date the demand for reverse mortgages has been limited (Caplin, 2002, Davidoff, 2014).

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. The ones which have received more attention are bequest motives (Bernheim, 1991) and precautionary saving motives arising from uncertain life span and risky medical expenditures (Palumbo, 1999, De Nardi, French, and Jones, 2010). If retirees do not wish to dissave they may not want to sell their house or to borrow against it. It may also be re-assuring for retirees to know that if they remain homeowners they have an 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. In our model retirees derive utility from housing, 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 analysis is quantitative so that we use several data sources to parameterize these risks. The focus in the first part of the paper is positive. The question is whether, given the pension income and assets of retired homeowners and the

[1] This is in part due to the aging of the population: the ratio of the number of U.S. individuals aged 18 to 64 to those aged 65 or over is projected to decline from 4.84 in 2010 to 2.96 by 2030 (Source: Projections of the Population by Selected Age Groups and Sex for the United States: 2010 to 2050, U.S. Census Bureau). The U.S. Social Security trust fund assets are expected to be exhausted by 2036 (2011 OASDI Trustees Report).

risks that they face, the model can generate homeownership and saving decisions that match those of past generations of retired homeowners, observed in the Health and Retirement Study (HRS), and a limited demand for reverse mortgages.

The model results show that even though a bequest motive or a precautionary savings motive lead individuals to remain homeowners until a later age, the decline in homeownership rates with age is still 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, the likelihood that at all points in time the value of the retirees' house matches the amount that they wish to consume of housing and to save is fairly small. As a result, and in the model, many of them decide to sell their house too soon compared to the data. We show that simply making bequest or precautionary motives stronger does not address this issue. They lead to higher savings in old age, but not necessarily in housing, so that matching the composition of savings is difficult.

In an attempt to match the data, we motivate and model two alternative features. The first is that retirees value property maintenance less than potential buyers of the house, so that a reduction in maintenance expenses has a larger effect on its price than on the utility that retirees derive from it. For example, retirees may not value a new kitchen in the same way as potential buyers of the property. Davidoff (2005) provides evidence that retirees reduce housing maintenance.[2] The second is that retirees derive some utility benefits from living in the same house in which they retired, possibly because their house brings good memories or because they know their next door neighbors. These two explanations are related, in that they introduce a wedge between the utility value of the house for the retiree and its value from the perspective of a buyer of the property. But they have different cash-flow and wealth dynamics implications, that are relevant for the benefits from and the design of reverse mortgages.

Reverse mortgages allow retired homeowners to withdraw home equity without moving and to make partial withdrawals which may help them choose a savings level that better matches their desired level. They are available in several countries, including the U.S. where they benefit from government guarantees, but to date the demand for them has been limited. Figure 1 plots the number of reverse mortgage loans endorsed by the Federal Housing Administration (FHA) and the S&P/Case-Shiller 10-City Composite Price Index over the last three decades. The number of new reverse mortgages increased considerably over this period to a monthly maximum of 12,000 just before the onset of the recent financial

[2] This reduction could also be due to retirees not having the financial resources needed to maintain the property and that a reduction in maintenance is valued equally by retirees and potential buyers of the property. We also consider this possibility in the model.

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 reverse mortgage).

Our model results show that for retirees who derive utility benefits from remaining in the same house reverse mortgages can be beneficial, but for the empirically observed distributions of housing and financial wealth, and the financial terms of reverse mortgages, including both up-front and on-going costs, the model generates very limited demand for these products. And their demand is even lower among retirees who do not value property maintenance as highly as potential buyers of the property.

In the second part of the paper our focus is more normative. We use our model to investigate how the costs and terms of reverse mortgages affect their demand, how to design them so that they are more beneficial to retirees, and at the same time allowing lenders and other market participants to break-even. To be more specific, in our baseline analysis we model the features of the U.S. reverse mortgage market and in particular of those contracts that are originated under the Home Equity Conversion Mortgage (HECM) program insured by the FHA. Such 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 and of a higher interest rate. The program also imposes limits on the maximum amount that can be borrowed against the house.

Thus in our analysis we model the cash-flows received by the lenders and by the U.S. government, as well as the risks that they face. But we also consider alternative contract parameters and features. In this respect it is useful to compare them to the U.K. reverse mortgages available, which do not receive government guarantees. We evaluate the products bearing in mind their complexity and requirements, since there is evidence that retirees may find it difficult to understand the different features of reverse mortgages and feel a certain reluctance to buy them (Davidoff, Gerhard and Post, 2014).[3]

Our calculations show that the present value of the cash-flows received by the insurance agency are negative, so that the government is effectively subsidizing reverse mortgages. This is an important point also made in Davidoff (2014), who uses simulation results in a continuous time setting to illustrate the risks of the program to the government. More generally, we use our model to quantitatively evaluate the different mortgage terms, costs and features, and how they impact the demand for reverse mortgages. We show how a reduction in their requirement and costs, including a reduction in the insurance premium, accompanied by a reduction in borrowing limits, may make reverse mortgages more appealling to a wider number of individuals, while at the same time generating positive expected cash-flows for

[3]This analysis focuses on the design and the terms of reverse mortgage loans. Our objective is to investigate the benefits and disadvantages of certain reverse mortgage features, in the context of a realistically parameterized model. We do not try to solve for the optimal reverse mortgage contract among the set of all possible contracts (Piskorski and Tchistyi, 2010).

lenders and the insurance agency. Our analysis shows that a higher insurance price, without additional restrictions on loan limits, is a fairly ineffective tool for limiting the losses of the insurance agency.

Our paper is related to the previously mentioned literature on the motives for dissaving during retirement. In addition it is closely related to the papers that study reverse mortgages. Early important contributions include Mayer and Simons (1994) and Caplin (2002). More recent papers include Davidoff (2014) and Hanewald, Post and Sherris (2014). One dimension along which our paper differs from these is in trying to match the patterns observed in the HRS data. In this respect our paper is closer to that of Telyukova and Nakajima (2014). They also solve study reverse mortgage demand in a model parameterized using these data. However, we model a larger number of the risks that retirees face, and explicitly model several of the institutional features of reverse mortgage products, the different types of products available, the financial position of lenders and the insurance agency, and we use our model to study product design.

The paper is structured as follows. In section 2 we describe the reverse mortgage products available in the U.S. and compare them to those available in the U.K., including their costs. We also briefly describe some of the recent market dynamics. Section 3 sets up the model and section 4 the parameterization. Section 5 reports the model results, while section 6 focuses on the terms and features of reverse mortgages. The final section concludes.

# 2 The Products

## 2.1 The U.S. 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 affordability criteria. An alternative product is reverse mortgages. 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. reverse mortgage market the vast majority of the contracts are originated under the HECM program insured by the FHA.[4] Under the HECM program homeowners are allowed to borrow up to a fraction of the value of their house in the form of an upfront lump-sum or of a line of credit. We will designate these two alternatives by *lump-sum* and *line of credit*, respectively. The lump-sum loan is fixed-rate whereas the line of credit alternative is adjustable-rate indexed to the LIBOR.

[4] For instance, 96% of active loans in the Fiscal Year of 2011 were insured by the FHA.

For either alternative, 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 his/her 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. The most significant loan requirements are that retirees pay property insurance and taxes, and maintain the property in a good state of repair. If retirees fail to do so the loan may become due, and in case of no repayment, the lender has the right to foreclose.

The initial fees of reverse mortgages include a loan origination fee, a mortgage insurance fee and other closing costs. Panel A of Table I reports representative values for these initial costs. There are both fixed and proportional costs. The initial mortgage insurance premium (MIP) is equal to a proportion of the assessed house value and it depends on the first-year loan disbursement. It is equal to 0.5% of house value for initial loan disbursements lower than 60% of the maximum loan amount, but it increases to 2.5% of house value for initial loan disbursements higher than this threshold.[5] Panel B of Table I reports typical initial loan interest rates on both lump-sum and line of credit reverse mortgages. They include the lender's margin and an annual mortgage insurance premium of 1.25% paid to the FHA. The index used for the adjustable-rate is the 1-month LIBOR. The total loan rate determines the rate at which the interest on the outstanding loan balance accrues (it is also known as the accrual rate).[6] For comparison this table also reports the difference in interest rates between reverse mortgages and standard principal repayment mortgages.[7]

A second loan rate that is relevant is the *expected* loan rate. For the line of credit it is equal to 10-year swap rate plus the applicable margin. For the lump-sum option it is simply equal to the initial loan rate (excluding the mortgage insurance premium). The *expected* loan rate determines (together with the age of the borrower and the assessed house value) the borrowing limit. The values for this rate at the end of April 2014 are reported in the last row of Table I (it is also known as the HECM expected rate).

Figure 2 plots the borrowing limit or the principal limit factor (PLF) for the different loan types as a function of the borrower's age (or of the youngest co-borrower) at the time that the loan is initiated, for the expected loan rates reported in Table I. The limit increases with

[5] The U.S. values were obtained using the National Reverse Mortgage Lenders Association mortgage calculator. These values are representative since there is some variation in closing costs across States. The calculations were done at the end of April 2014. The calculator is available at

*http://www.reversemortgage.org/About/ReverseMortgageCalculator.aspx.*

We also use this calculator to obtain the representative interest rates and loan limits reported below.

[6] For the line of credit the loan rate is also used to determine the rate at which the unused portion of the credit limit grows over time.

[7] For the line of credit we calculate the difference relative to the 1-year ARM, and for the lump-sum mortgage we calculate the difference relative to the 30-year FRM. The mortgage data is from the Federal Reserve.

the borrower's age and it is higher for the lump-sum than for the line of credit product, since at the time the expected loan rate was lower for the lump-sum than for the line of credit. However, there is an additional restriction, that the first year loan disbursements must be smaller than the maximum between 60% of the maximum loan amount and the mandatory obligations plus 10% of the maximum loan amount.[8] Even though this maximum initial loan disbursement restriction applies to both line of credit and lump sum products, it is a more important restriction for the latter since all funds are borrowed up-front. For this reason in Figure 2 we plot the effects of this restriction on the loan limit for the lump-sum mortgage.

## 2.2 The U.K. products

In the United Kingdom reverse mortgages have also been available for a number of years. Similarly to the U.S. they are lifetime mortgages that become due when the borrower dies, sells his house or moves out, and they include lump-sum and line of credit alternatives. Although there are several differences relative to the U.S. products, the most significant is that the U.K. products do not receive government guarantees. Lenders provide borrowers with a no negative equity guarantee, so that private providers bear the risk that at loan termination the value of the house may be lower than the outstanding loan balance. In Tables I we report the initial costs and interest rates for representative U.K. products.[9] The U.K. products tend to have lower initial costs than their U.S. counterparts but higher loan interest rates, also when compared to the interest rate on standard principal repayment mortgages.

Figure 2 plots typical maximum loan-to-value (LTV) for the U.K. reverse mortgages.[10] They are considerable lower than the borrowing limits for the U.S. products, particularly so for younger borrowers. Another interesting difference is that even though in the U.K. the interest rate for the line of credit alternative is lower than for the lump-sum loan, the maximum LTV is higher for the latter. In equilibrium mortgage costs will reflect the riskiness of the loans and of the pool of borrowers who select each type of mortgage. In other words, mortgage characteristics will reflect and explain mortgage selection by heterogeneous borrowers.

[8]The mandatory obligations include initial loan costs (and HECM counseling), delinquent Federal debt, amounts required to discharge any existing liens on the property, funds to pay contractors who performed repairs as a condition of closing, and other charges authorized by the Secretary.

[9]These data are obtained from Aviva, a large publicly traded insurance company, and one of the main providers in the U.K. reverse mortgage market.

[10]The values reported are obtained from Aviva, with loan interest rates equal to those reported in Table I. In the U.K. there are small variations across lenders in maximum LTV.

## 2.3 The recent experience

With respect to mortgage characteristics and selection, it is interesting to briefly consider the recent U.S. experience. The products described above, the associated costs and borrowing limits refer to those in existence in April 2014. But over the years there have been a number of changes to the HECM program products and requirements.[11] Overall, the size of the U.S. reverse mortgage market is relatively small. Only two to three percent of eligible homeowners take out a reverse mortgage. The annual number of new contracts reached a peak of 115,000 in 2009 but this number declined to 72,000 in 2011, before increasing again in 2014 (Figure 1).

With respect to mortgage type, in 2008 the proportion of contracts of the lump-sum type was only two percent. By 2010 their proportion had increased to 70 percent (Figure 1).[12] From 2010 onwards there was a large increase in the number of borrowers who were unable to meet the taxes and insurance payments on their properties required by the reverse mortgage contract, and who were forced to default. These property charge defaults were much higher for borrowers who had chosen the lump-sum alternative. At the same time several of the larger reverse mortgage providers decided to withdraw from the originations market.[13]

As a response to the higher defaults of lump-sum mortgages the U.S. Department of Housing and Urban Development (HUD) implemented a number of product changes, focused mainly on the insurance premia and borrowing limits. In January 2013 it announced the consolidation of the pricing options and borrowing limits for fixed-rate lifetime mortgages. This effectively meant that only a "saver" product characterized by lower initial mortgage insurance premium (MIP) and lower borrowing limits would be available.[14]

In September of 2013 there was a further consolidation of products offerings, and adjustment of insurance premia and borrowing limits (Mortgagee Letter 2013-27). The initial insurance premium was set at 0.5% of the assessed house value and the ongoing annual insurance premium at 1.25% of the loan outstanding, both for the fixed rate and the adjustable rate mortgages, provided that first-year loan disbursements were lower than 60% of the maximum loan amount. Otherwise the initial insurance premium would increase to 2.5%. The

[11] The mortgagee letters describing the changes are available at
$http://portal.hud.gov/hudportal/HUD?src=/program_offices/housing/sfh/hecm/hecmml.$
We will not attempt to describe all the changes, but we will focus on those that are more relevant for the analysis.

[12] The data reported in this paragraph are from the Fiscal Report to Congress on Reverse Mortgages, Consumer Financial Protection Bureau, June 2012.

[13] The Bank of America withdrew in February 2011 followed by Wells Fargo in June of the same year, and by MetLife in April of 2012. In a statement Wells Fargo said it was leaving the business as a result of "unpredictable home values." There have however been suggestions that the reputational risk arising from foreclosing on retirees in property charge defaults was a more important concern.

[14] For the adjustable-rate mortgages both a saver and a standard product with higher MIP and borrowing limits would be offered (Mortgagee Letter 2013-01).

principal limit factors were revised and a financial assessment of all prospective mortgagors position was introduced, effective January 2014.[15] This led a dramatic decline in the proportion of new loans that are of the lump-sum type (Figure 1). In spite of these revisions, the existing U.S. products are characterized by higher initial costs and higher borrowing limits than their U.K. counterparts. In the U.K. around two-thirds of the reverse mortgages are of the line of credit type and one-third are lump-sum. The total lending in 2013 was 1.07 billion pounds (Equity Release Market Report, Equity Release Council, 2014). With this description of the products available in mind, in the next section we set up a model of reverse mortgages.

# 3 The Model

We model the risks that retirees face, their decisions, and benefits from reverse mortgages, the cash-flows received by lenders and, for our modeling of the U.S. products, by the government agency. The latter allow us to determine the fair value of mortgage insurance premia.

## 3.1 Preferences and health

Retired individuals live for a maximum of $T$ periods, but they face mortality risk. We let $p_{i,t+1}$ denote the probability that retiree $i$ 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, that depend on age, health status ($h_{it}$), permanent income ($Y_{it}$) and other parameters (such as gender).[16] Retirees discount the future exponentially, with discount factor $\beta_i$. They derive utility from the consumption of housing, $H_{it}$, and non-durable goods, $C_{it}$. We model retiree heterogeneity in preferences, pension income and assets, among others, but in the model description that follows, to simplify notation, we drop the subscript $i$. The per-period preferences are given by a constant elasticity of substitution (CES) function:

$$u(C_t, H_t) = (1+\delta h_t)\frac{\{[\theta^{\frac{1}{\epsilon}} C_t^{\frac{\epsilon-1}{\epsilon}} + (1-\theta)^{\frac{1}{\epsilon}}(\omega_t H_t)^{\frac{\epsilon-1}{\epsilon}}]^{\frac{\epsilon}{\epsilon-1}}\}^{1-\frac{1}{\sigma}}}{1-\frac{1}{\sigma}} \tag{1}$$

where $h_t$ is an indicator variable for good health which is assumed to affect utility through $\delta$, $\theta$ is the expenditure share in non-durable consumption, $\epsilon$ measures the degree of substitutability between the two goods, and $\sigma$ is the coefficient of intertemporal substitution.

The remaining preference parameter, $\omega_t$, requires a more detailed explanation. In some

[15] As a result of the financial assessment, the lender may decide to set aside part of the maximum loan amount for property charges, based on the life expectancy of the borrower.

[16] We give details in the parameterization section.

parameterizations we will set $\omega_t > 1$ in case the retiree remains homeowner of the *specific* house that he/she has retired with. This is meant to capture the possibility that retirees derive utility from staying in the same house where they have lived for a number of years. Their house may bring good memories or they may be familiar with their next door neighbors. For some old individuals these psychological reasons for remaining in the same house are likely to be important.

In case of death the retiree derives utility from bequeathed wealth, $W_t$, according to the following preferences:

$$v(W_{t_D}) = b\frac{W_{t_D}^{1-\frac{1}{\sigma}}}{1-\frac{1}{\sigma}} \tag{2}$$

where $t_D$ denotes the time of death and $b$ measures the intensity of the bequest motive. Bequeathed wealth is equal to financial wealth plus housing wealth net of debt outstanding.

Retirees face health and medical expenditures risk. In each period their health status can be good or bad, with $h_t = 1$ ($h_t = 0$) for good (bad) health, and transition probability matrix $\Pi[h_t, h_{t+1}](t, Y_t, \ell)$.[17] These transition probabilities depend on age, permanent income, and a vector $\ell$ of other parameters. As in De Nardi, French and Jones (2010), out-of-pocket medical expenditures, $ME(t, Y_t, \ell, h_t)$, are also are a function of these variables and health status. Medical expenditures are subject to persistent shocks. We give more details in the parameterization section.

## 3.2 The term structure of interest rates and house prices

For some retirees the interest received on their financial savings is an important source of income, and fluctuations in interest rates 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:

$$r_{1t} = \mu_r(1 - \phi_r) + \phi_r r_{1,t-1} + \varepsilon_t, \tag{3}$$

where $\varepsilon_t$ is a normally distributed white noise shock with mean zero and variance $\sigma_\varepsilon^2$.

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

[17] Yogo (2012) develops a life-cyle 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 paramterize them. See also Koijen, Van Nieuwerburgh, and Yogo (2014) who develop risk measures for the universe of health and life insurance products.

rolled over for $n$ periods plus a constant term premium, $\xi$:

$$r_{nt} = (1/n)\sum_{i=0}^{n-1} E_t[r_{1,t+i}] + \xi. \tag{4}$$

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.

House prices fluctuate over time. The date $t$ price per unit of housing is denoted by $P_t^H$, such that a house of size $\overline{H}$ is worth $P_t^H\overline{H}$ at date $t$. The size of the house should be interpreted broadly as reflecting not only the physical size, but also its quality. The price of other goods consumption (the numeraire) is fixed and normalized to one. We normalize the initial house price $P_1^H = 1$. We assume that changes in the log price of housing, $\Delta p_{t+1}^H = log(P_{t+1}^H) - log(P_t^H)$, follow a random walk with drift:

$$\Delta p_{t+1}^H = \mu_H + \eta_{t+1}, \tag{5}$$

where $\mu_H$ is the mean log housing return and $\eta_{t+1}$ is a shock that is assumed to be i.i.d. and normally distributed with mean zero and variance $\sigma_\eta^2$. We allow the innovations to house prices to be correlated with innovations to the log real interest rate and let $\rho_{\varepsilon,\eta}$ denote the coefficient of correlation.

## 3.3 Pension income, assets, and taxation

The retiree receives in each period $t$ that she is alive 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.

We assume that the individual starts retirement as an homeowner of a given house size $H_1 = \overline{H}$ and with (non-annuitized) financial assets or cash-on-hand of $X_1$. She may have initial mortgage debt outstanding, which we denote by $D_1^{PR}$, where the superscript denotes that it is a principal-repayment mortgage. It requires annual mortgage payments of $M^{PR}$ so that it is repaid by date $t^{PR}$. The interest rate on this debt is fixed, and equal to the yield on a long-term bond of the same maturity as the mortgage, plus a premium $\psi_{PR}$. The retiree may decide to prepay the mortgage using her existing financial assets. She will have to do so if she sells the house or takes out a reverse mortgage. In the baseline model we assume that non-consumed financial assets are invested in a one-period bond.[18]

[18] We do so in order to model with more realism the risks that retirees face and the features of reverse mortgages. It is possible to extend our model to consider investment in long-term bonds or equities. Our focus in this paper is on the design of reverse mortgage products, that are likely to be more beneficial for individuals with lower financial investments.

Pension and interest income are taxed at rate $\tau$. For individuals who have low financial assets, government and social security transfers ($Tr_t$) provide a consumption floor equal to $\underline{C}$. Renters who do not have sufficient financial assets also receive transfers that allow them to rent the smallest house size available, $\underline{H}$. Therefore, the taking out of a reverse mortgage or the selling of the house, to the extent that it affects retirees' financial savings, it may also affect their eligibility to receive these government transfers. Bequeathed wealth is taxed at rate $\tau$.

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.[19] To capture the illiquid nature of housing we assume that a house sale is associated with a monetary cost equal to a proportion $\lambda$ of the current house value. In the baseline model we assume that homeowners must pay annual maintenance and insurance costs and property taxes equal to proportions $m_p$ and $\tau_p$ of house value, respectively.

But the ability to reduce property maintenance may be important for some retirees (Davidoff, 2005). It may also be the case that some retirees do not value property maintenance in the same way as potential buyers of the property. For example, retirees may not derive utility from fitting a new kitchen or a new floor in the property. With this in mind, we solve alternative versions of our model. In all of them a reduction in housing maintenance leads to a corresponding reduction in the sale price of the property, but we consider alternative hypothesis with respect to the impact that such reduction has on the utility that the retiree derives from living in the house. Most reverse mortgages impose the requirement that borrowers must maintain their property, although enforcing this requirement may be difficult.

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

$$U_t = [R_{1t} - \mathrm{E}_t[(\exp(\Delta p_{t+1}^H) - 1] + \tau_p + m_p + \varphi] P_t^H H_t. \tag{6}$$

Thus rental accommodation exposes retirees to fluctuations in the cost of housing.

## 3.4 Home equity release products

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. With the discussion in section 2 in mind, we model two different types of reverse mortgages, line of credit ($LC$) and lump-sum ($LS$). Each type is characterized by

[19] Thus we do not allow homeowners to sell and to buy a house of a different size. We do so to simplify the problem. In practice the large transaction costs associated with buying and selling property mean that most retirees who sell their house move into rental accommodation or residential care.

three parameters $(l_j, f_j, \psi_j)$, for $j = LC, LS$, which denote loan limit, loan arrangement and valuation fees, and interest rate premium, respectively. For each type, the borrowing limit depends on the retiree's age, house value and interest rates at the time that the loan is initiated. The loan arrangement and valuation fees are added to the loan balance. The mortgage premium, $\psi_j$, is a spread over interest rates, and it includes the lender's margin and the mortgage insurance premium due to the government agency (denoted $\psi_{j,L}$ and $\psi_{j,A}$, respectively). The initial loan fees include an insurance premium payable to the government $(f_{j,A})$. The taking out of a reverse mortgage requires that retirees prepay any pre-existing mortgage debt.

Line of credit reverse mortgages come with interest rate risk. The period $t$ loan interest rate is equal to the short rate plus the mortgage premium $(R_{1t} + \psi_{LC})$. The loan interest rate determines the rate at which the interest on outstanding debt accrues. For this type of mortgage the $e$xpected loan rate is also relevant, since it is used to determine the borrowing limit. It is equal to the ten-year bond rate at the time that the mortgage begins plus the lender's margin (it does not include the mortgage insurance premium).

In each period, retirees who owe less than the line of credit borrowing limit can access additional funds. We let $D^S_{LC,t}$ denote the beginning of period $t$ outstanding loan amount, and $D^C_{LC,t}$ the additional amount that the homeowner decides to borrow in that period. The equation describing the evolution of outstanding debt:

$$D^S_{LC,t+1} = (D^S_{LC,t} + D^C_{LC,t})(1 + R_{1t} + \psi_{LC}). \tag{7}$$

In a lump-sum reverse mortgage all funds must be borrowed up-front and the interest rate is fixed at mortgage initiation. It is equal to the interest rate on a ten-year bond plus the mortgage premium. The equation describing the evolution of outstanding debt is given by:

$$D^S_{LS,t+1} = D^S_{LS,t}(1 + R_{10,t_0} + \psi_{LS}), \tag{8}$$

where $t_0$ denotes the period in which the mortgage begun.

In case the retiree decides to sell the house at date $t$ the value of $D^S_{j,t}$, for $j = LC, LS$, is deducted from the proceeds of the sale. Similarly, when the retiree dies the outstanding loan value is deducted from the proceeds of the sale, leading to a reduction in the value of bequeathed wealth. In this mortgage product retirees retain homeownership 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 his/her heirs are not liable for any shortfalls, even if there are other financial assets.

The mortgage contracts specify that retirees must maintain their property, pay insurance and property taxes. Provided that borrowers comply with these obligations, lenders cannot force them out of the house, even if they are in a situation of negative home equity.

## 3.5 Private lenders, the insurance agency, and pricing kernel

In our baseline model loan losses are insured by a government agency. This describes the U.S. experience. But we will also model the possibility that private reverse mortgage lenders bear the risk of house price declines as in the U.K.; in such a setting the cash-flows of lenders and the government agency described below are consolidated.[20]

At mortgage initiation, $t_0$, the cash-flows received by private lenders (L) are equal to the initial funds disbursed plus the initial mortgage insurance premium paid to the government agency $(l_j^{MIP})$ :

$$CF_{j,t_0}^L = -D_{j,t_0}^C - l_j^{MIP}. \tag{9}$$

In each subsequent period $t$ prior to loan termination, $t^{'}$, the cash-flows received by lenders are:

$$CF_{j,t}^L = -D_{j,t}^C - \psi_j^{MIP} D_{j,t}^S, \tag{10}$$

where $\psi_j^{MIP}$ denotes the mortgage insurance interest premium payable to the government agency.[21] At loan termination the cash-flows received by lenders are equal to debt outstanding:

$$CF_{j,t'}^L = D_{j,t'}^S. \tag{11}$$

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

$$CF_{j,t'}^A = MIN[0, (1-\lambda) P_{t'}^H \overline{H} - D_{t'}^S]. \tag{12}$$

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.

We use the previously described U.S. and U.K. reverse mortgage data on premia and borrowing limits to parameterize the model. But we are also interested in evaluating the extent to which the mortgage insurance is correctly priced or, in the absence of government

[20] In the U.S. there are also non-government insured reverse mortgages, but the size of this market is very small.

[21] It is important to note that in these cash-flow calculations we are not subtracting the costs of servicing the loans and other costs incurred by lenders. The present value of the cash-flows should be interpreted accordingly.

insurance, whether mortgage margins allow lenders to break-even on loans on a risk-adjusted basis. In order to do so we assume a competitive market for loan providers that price mortgages on a loan by loan basis, by taking into account at the date of mortgage arrangement the parameters that influence retiree survival probabilities.[22]

Furthermore, we need to specify a discount rate to calculate the present value of the cash-flows of loan providers. 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 (2014) in specifying a pricing kernel. To be clear, our model is not a general equilibrium one. But if we assume that house prices in our model are correlated with aggregate permanent income, that the latter is equal to aggregate consumption, this together with preference assumptions for the representative agent allows us to derive risk-adjusted discount rates. These discount rates are lower for cash-flows that occur when house prices are low, so that such cash-flows are more valuable. We give details in Appendix A.

### 3.6 Solution technique

We solve alternative versions and parameterizations of our model. In the simplest we assume that retirees are not allowed to take out a reverse mortgage. In this case the choice variables are non-durable consumption, $C_t$, whether to move to rental accommodation if that has not previously happened, and house size $H_t$. The state variables are age, cash-on-hand, current interest rates, house prices, whether the retiree is currently a homeowner, health status, and medical expenditures. When reverse mortgages are available, the additional choice variables are which reverse mortgage to choose, how much to borrow, $D^C_{jt}$, and the additional state variables are the type of mortgage chosen and the level of outstanding debt $D^S_{jt}$. In Appendix B we describe the equations for the evolution of cash-on-hand and the numerical procedure that we use to solve the model.

## 4 The Data

We use several data sources to parameterize the model. In this section we briefly describe the data sources and the methodology that we use. These are in part similar to De Nardi, French, and Jones (2010), so that in section 4.1 we focus mainly on the additional contribution, namely the housing variables, and include further details in Appendix C. In section 4.2 we describe the asset homeownership and wealth deaccumulation profiles that we estimate to which we will compare the model results.

[22]Namely gender, age, health status and permanent income. The latter two are not directly observable, but we assume that loan providers may obtain the medical history of the borrower, pension payslips, etc. If they cannot be observed, and borrowers are better informed than lenders, there is the potential for adverse selection. It would be interesting to extend the model to allow for such possibility.

## 4.1 Model parameterization

**Pension income, assets, survival probabilities, and health**

To evaluate the extent to which retirees benefit from reverse mortgages we need to parameterize their pension income and house values. For this purpose we use data from the HRS from 1996 to 2010. We restrict the analysis to single retired individuals who are aged 65 or over. We use the Rand version of the data and combine it with information from the exit interviews.

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 to group individuals into quintiles. Table II reports mean and median retirement income for each of these groups for those born in 1930-1934 (we report additional results in the appendix), and for this same cohort but conditional on homeownership at age 65 (Panel B). It also reports, for each permanent income group, mean and median real financial wealth (excluding housing wealth) and housing wealth (house value less mortgage debt outstanding, but debt values tend to be fairly small) at age 65. Table II shows that individuals with higher permanent income also tend to have higher financial wealth and higher housing wealth. We use income values to parameterize $Y$, financial wealth at age 65 to parameterize $X_1$, and housing wealth to parameterize $\overline{H}$. Since as Table II shows the relative values of retirement income, cash-on-hand, and housing wealth differ for retirees in different groups, the benefits of reverse mortgage products may also be different. Our analysis takes these differences into account.

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 retirees aged 65 is reported in the last column of Table II. The proportion of individuals who report fair or poor health declines with permanent income and it is smaller among homeowners.[23] We also 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. We give more details in Appendix C.

[23] These patterns may in part be due to reverse causality: if there is persistence in health status, then individuals who at age 65 have poor health will also be more likely to have had poor health in the years prior to this age and may have accumulated lower retirement benefits (Poterba, Venti, and Wise, 2011b).

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, permanent income rank, permanent income rank squared, and permanent income rank interacted with age. We estimate this function controlling for health and cohort effects. In appendix C we plot some of the estimated profiles and give further details on the estimated parameters. Older retirees and those in higher permanent income groups spend considerably more in out-of-pocket medical expenditures. Individuals with fair or poor health face higher medical expenses than those in good health, particularly so for those in higher permanent income groups. Medical expenditures are subject to persistent shocks.

**Preferences, asset returns, and other parameters**

We use several estimates available in the literature to parameterize the baseline preference parameters (reported in Table III, we give further details in appendix C). But we recognize that for some of these there is not consensus in the literature and that retirees are heterogeneous in their preferences, so that we will consider alternative values. The values for the user cost of housing, property taxes and property maintenance are from Himmelberg, Mayer and Sinai (2005). We set the tax rate $\tau$ to 0.20. The consumption floor is from De Nardi et al. (2010). The transaction costs of a house sale are equal to 0.06.

In the last panel of Table III we report the parameters that we use for the interest rate and house price processes. For interest rates we use data on US 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 major 20 U.S. Metropolitan Statistical Area (MSA) from 1987 to 2012, but the period covered differs across MSA. The mean log real house price return and standard deviation across these MSAs is 0.002 and 0.10. In the baseline case we set the correlation between innovations to house prices and real interest rates to zero. We will also solve the model for alternative parameterizations.

## 4.2 Asset deaccumulation patterns

We are interested in evaluating the extent to which the model is able to generate the age patterns of homeownership and wealth deaccumlation observed in the data. To describe the HRS data we regress these variables on age, cohort, and permanent income group dummies. We plot the estimated age dummies in Figure 3 (for permanent income group three and cohort seven, we report results for the other groups in the appendix). In this figure we also plot the fit of a third-order polynomial to the estimated age dummies (we exclude the last five years when estimating the polynomial due to the much higher volatility in the estimates).

Panel A of Figure 3 shows that there is a decline in homeownership with age, but that it only happens late in life after age 75. Furthermore the decline is not substantial: of those individuals still alive at age 90, roughly fifty percent are still homeowners. Panel B shows that in the first few years of retirement there is a modest decline in average financial (non-housing) wealth, but that it starts to increase again around age 75. Average total wealth has a similar pattern. The increase in wealth late in life is likely to be due to sample selection: wealthier individuals are more likely to be in good health and to live longer.

In Appendix C we report the estimated cohort and permanent income dummies. Average homeownership rates and wealth are higher for more recent cohorts and for higher permanent income groups. We also plot the estimated age profiles for median wealth instead of average wealth. The shape of the profiles is similar, but the wealth levels are substantially lower. When evaluating the potential demand for reverse mortgages it is important to take into account the distribution of wealth.[24]

# 5 Model Results

We first investigate whether the model is able to quantitatively match the homeownership and wealth deaccummulation rates of past and current generations of retirees. Retirees in different cohorts and permanent income groups have different levels of financial and housing wealth, and face different survival probabilities and health risk, which our analysis takes into account. But the ability of the model to explain the empirically observed asset deaccumulation patterns also depends on preference parameters. Therefore, as a first step, we investigate what sort of preference parameters and associated savings motives can potentially explain the observed data patterns. In this first step we assume that retirees do not have access to reverse mortgages. Even though reverse mortgages have been available for many years, the number of loans originated has been very small, particularly during the first part of the HRS data sample. Furthermore, the initial assumption that retirees do not have access to reverse mortgages allows us to investigate the effects of introducing housing in a model of retirement saving, separately from the effects of the mortgages. We will then introduce reverse mortgages, both line of credit and lump-sum, assess their benefits, and the potential reasons behind the historically limited demand.

## 5.1 Matching asset deaccumulation patterns

We solve the model for each set of preference parameters and use the policy functions to generate simulated data. It is this data that we use to calculate the model predicted

[24] In the appendix we also plot estimated homeownership age profiles controlling for individual fixed effects instead of cohort and permanent income fixed effects. The homeownership rates decline more steeply with age. The reason is that age effects for individuals who remain homeowners throughout the sample are picked up by the individual fixed effect. When comparing the model with the data we focus mainly on the estimates from the regressions with cohort and permanent income fixed effects.

homeownership rates (Panel A) and cash-on-hand (Panel B) at different ages reported in Table IV. In each of these panels, the first row reports the estimated values in the HRS data (we use the median initial cash-on-hand to parameterize the model). We solve the model assuming that individuals start as homeowners, but for easier comparison we re-scale the initial proportion of homeowners to the value estimated in the data. The baseline model parameters have difficulty generating the rates of homeownership observed in the data, from very early on in retirement. It is instructive to briefly consider what triggers a house sale in the model. Those who decide to sell earlier have lower cash-on-hand, higher house values, and face higher medical expenditures (both in the period of the sale and in the previous period). All of these constitute an incentive for individuals to tap into their home equity through a house sale.

But the main message from the comparison of the first two rows of Table IV is that the large decline in homeownership rates predicted by the baseline parameterization of the model is strongly at odds with the data. 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 (Bernheim (1992) in an important reference in this literature).[25] To evaluate this possibility, and in addition to a stronger precautionary savings motive ($\sigma = 0.125$), in Table IV we report the results for a higher value for parameter $b$, that measures the intensity of the bequest motive. A stronger bequest motive delays the decision to sell the house, but the success of this parameter is limited. Even for fairly high values for $\sigma$ and $b$, that generate substantial savings, retirees in the model decide to sell their house much earlier than in the data. Another way to generate higher homeownership rates in the model is to increase the monetary premium paid on rental accommodation. However, even a rental premium as high as three percent has limited success, as shown in Table IV. Furthermore, as retirees sell their house too early, the model predicted levels of cash-on-hand are higher than in the data (Panel B).

We have investigated the effects of other model parameters, including an even stronger precautionary savings motive, higher or more uncertain medical expenditures, also in combination with a bequest motive (we report these results in Appendix D). For all of these parameterizations, retirees still decide to sell their house too early. The fundamental economic reason is simple. Even though they provide retirees with stronger incentives to save, 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, the likelihood that at all points in time the value of the retirees' house matches the amount that they wish to consume of housing and to save

[25] More recently, Ameriks, Caplin, Laufer, and Van Nieuwerburgh (2011) have used strategic surveys to separate bequest and precautionary motives.

is fairly small. As a result, and in the model, many of them decide to sell their house too early compared to the data.[26]

This does not mean that in reality precautionary savings and/or bequest motives are not important determinants of the observed rates of asset deaccumulation during retirement. In fact our preferred specification relies on these savings motives to be able to match the data. However, a more complete explanation must address the composition of retirees' savings, tilted heavily towards housing as a result of their decision to remain homeowners for a large number of years. We propose two explanations.

The first explanation is based on housing maintenance. We assume that retirees do not value the maintenance of their house as much as potential buyers of the property, and that they do not derive utility from putting in a new kitchen or a new floor in the house. Therefore in the model we set maintenance expenses to zero. This leads to a proportional reduction in the price of the property, of $(1 - m_p)$ per each year of missed maintenance, but not in the utility that the retiree derives from the house. Panel A of Table IV (line 7) shows that such an assumption has a large impact on homeownership rates. Furthemore, when combined with precautionary savings and bequest motives, the model is able to generate patterns of homeownership that match those observed in the data (line 8).

For comparison, in Table IV we also report results for the case in which a reduction in maintenance has a proportional impact on the value of the house size that enters the utility of the retiree. We consider both the case in which maintenance is set equal to zero and the case in which the retiree decides in each period whether to maintain the property or not. Comparing these two cases, we see that the model predicted homeownership rates are higher when maintenance is treated as a choice variable, but for both of them the decline in homeownership rates late in life (from age 80 onwards) is too large compared with the data.

The second explanation is based on the value of parameter $\omega$. Recall that this parameter denotes the extra utility benefit of remaining in the same house in which the individual has retired, compared to a similar size rental unit. The motivation for these extra utility benefits is simple. The house may bring the retiree good memories, e.g. because his/her children were raised in it. Alternatively, the retiree may have a good relationship with the next door neighbors, whom he/she has known for many years, and this may be something highly valued in old age. These psychological considerations and extra utility benefits cannot be easily measured, but is is conceivable that at least for some retirees they are very important. In Table IV we report results for $\omega$ equal to two. This value of $\omega$, when combined with precautionary savings and bequest motives, helps to generate high homeownership rates late in life (line 15 of Table IV).

[26] A higher expected rate of return on housing also has 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 maintenance equal to zero without utility impact and the $\omega$ based explanations are related, since in both of them retirees derive more utility from the house they own compared to a rented house. However, the two are different in their cash-flow and wealth accumulation implications. When maintenance expenses are equal to zero, retirees have more cash available earlier on, but receive a smaller value for the property at the time of the sale. The lower collateral value of the property has implications for lenders in reverse mortgages.

Figure 4 provides a graphical description of the model predicted homeownership rates for some of the cases reported in Table IV. The patterns that we have estimated in the data are shown with a cross marker. This figure shows that our preferred specifications go a long way in predicting the homeownership patterns observed in the data, but they still predict too low homeownersip after age ninety.

## 5.2 Line of credit reverse mortgages

We now introduce line of credit reverse mortgages in the model. Recall that these mortgages require that borrowers maintain their house, so that in the model we assume that if retirees do take out such mortgage they must make maintenance expenses (in the next section we relax this requirement). We are particularly interested in evaluating the benefits of the mortgages for different individuals, and gauge the demand for them. Therefore, we calculate the percentage of initial (age 65) cash-on-hand that retirees are willing to pay to have access to line of credit reverse mortgages.[27]

For the vast majority of the cases considered retirees do not benefit from reverse mortgages, with the costs and rates reported in Table I. In Table V we report the welfare gains for a subset of the parameterizations considered in the previous table (we have also solved the model for all the other parameterizations previously considered and the welfare gains are zero). Table V shows that for our two preferred specifications (in bold), and for the median level of initial cash-on-hand (Panel A), the welfare gains of line of credit reverse mortgages are zero.

One parameterization for which they are positive is that of preference for homeownershop ($\omega = 2$), together with the absence of a bequest motive ($b = 0$) and the baseline value for the coefficient of intertemporal substitution ($\sigma = 0.27$). For this case the welfare gains are equal to 32 percent of initial wealth and retirees do use them to borrow. This has an impact on the homeownership rates predicted by the model. Whereas they are equal to 44, 16 and 1 percent at ages 80, 85 and 90 for the model without debt (line 13 of Table IV) they are equal to 68, 60, and 51 percent, respectively, for the model with line of credit reverse mortgages.

[27]The welfare gains depend on the value of several of the initial model conditions. We report welfare gains for the median level of initial cash-on-hand (percentile 25 of initial cash-on-hand in Panel B), low interest rates, good health, and low medical expenditures.

Retirees do not have to sell their house to access their home equity, and borrowing acts as a substitute for an earlier house sale.

In Figure 5 we plot the age profiles of debt drawn and debt outstanding. These profiles are calculated as an average across those individuals for whom the mortgage loan is still active. From age 85 onwards there is almost no additional borrowing since those retirees who have not yet terminated the loan have exhausted their debt capacity. The most common motives for loan termination are death and the sale of the house and associated loan termination so that retirees can tap into any additional home equity, beyond the loan limit. However, there is a small proportion of retirees, equal to 0.8 percent of the total, that are forced to default on the loan. These are retirees who have exhausted their debt capacity, are in a situation of negative equity, and who are not able to meet the property tax and maintenance expenses. 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.

Parameter combinations that increase the incentives to save reduce the benefits of reverse mortgages. On the other hand, lower initial cash-on-hand increases their benefits. Panel B of Table V reports the welfare gains when initial cash-on-hand is equal to percentile 25 of the distribution of age 65 cash-on-hand.[28]

We calculate the present discounted value of the cash-flows received by lenders and by the insurance agency. Table V reports such present values using two different discount rates, bond yields and a risk-adjusted discount rate. The present values reported are in U.S. dollars per loan, but calculated as an average across many different realizations for the aggregate and individual specific shocks. The expected present discounted values of the cash-flows of the insurance agency are negative for all the cases in which reverse mortgages benefit retirees, so that the price of the insurance is too low, and the government is subsidizing these products. Davidoff (2014) obtains a similar result, in the context of a different model set in continuous time.

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. They also are more negative for the cases in which retirees benefit more from reverse mortgages and borrow larger amounts, such as when initial cash-on-hand is lower. In contrast, the expected present discounted values of the cash-flows of lenders are positive and large.[29]

[28]For all the other parameter combinations considered in Table IV the welfare gains are zero, even at percentile 25 of the distribution of initial cash-on-hnad.

[29]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 present value of the cash-flows of lenders are slightly higher when we use a risk-adjusted discount rate since borrowers are more likely to drawdown on the loan when house prices increase.

## 5.3 Lump-sum reverse mortgages

In lump-sum reverse mortgages 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 costs and rates reported in Table I. For the median initial cash-on-hand we found positive welfare gains of lump-sum mortgages only for the case of $\omega = 2$ equal to 20 percent of initial wealth (relative to the no mortgage scenario, Panel A of Table VI). But even in this case the welfare benefits are lower than those of line of credit mortgages. Thus, these model parameterizations considered so far have difficulty in generating demand for lump-sum mortgage products. This contrasts with the fact that in 2010 in the U.S. the proportion of reverse mortgages that were of the lump-sum type was as high as 70 percent, and raises the question of what might have motivated such demand. [30]

From the retirees' side lower initial cash-on-hand (or the need for a significant amount of cash up-front) increases the benefits of drawing down the whole loan amount up front (the difference in the welfare benefits of line of credit and lump-sum mortgages is smaller for lower levels of initial cash-on-hand). This would be the case if retirees had pre-existing debt that would be amortized using the proceeds from the lump-sum loan. This points to the importance of understanding what uses retirees give to the cash borrowed using reverse mortgages, particularly for lump-sum loans, an issue for which there is relatively little information.

But there may also be supply factors at work. The comparison of Tables V and VI shows that the present value of the cash-flows of lenders is higher for lump sum than for line of credit reverse mortgages, since the former have higher amounts outstsanding. This may incentivize them to try to sell these products to retirees. The added risk is borne by the insurance agency, which has a more negative present value of cash-flows. To better understand the nature of these cash-flows in Figure 5 we plot the whole distribution of the present discounted values of the cash-flows of the insurance agency and of lenders, for $\omega$ equal to 2, and for the line of credit and the lump-sum loans. For both of them, the most likely state is a payoff between 0 and 10 thousand dollars. However, the insurance agency faces a significant probability of a large negative present value, higher for the lump-sum than for the line of credit loan, in states with house price declines.

Another feature of the lump-sum loans is that the proportion of borrowers who are forced to default because they cannot meet property tax and insurance payments, albeit still small, is subtstantially higher than for line of credit mortgages. For median initial cash-on-hand and $\omega$ equal to 2 it is equal to 1.5 percent (recall that it was equal to 0.8 percent for the line of credit). This is important since the reputation risk arising from foreclosing on old retirees has been suggested as one of the reasons why the larger lenders in the U.S. have decided to

[30] We have solved our model for the case of more myopic retirees, with a $\beta$ equal to 0.8, but they prefer to sell the house earlier instead of taking out a lump-sum mortgage.

withdraw from the reverse mortgage market.

# 6 Product terms and features

The model results in the previous section predicted: (i) very limited demand for reverse mortgages; (ii) negative expected present value of cash-flows for the insurance agency. In this section we analyze the terms and features of reverse mortgages, how to make them more beneficial for a lager number of retirees, and at the same time allow the insurance agency to break-even. We focus on the parameterizations for which we were better able to match the homeownership rates and asset deaccumulation patterns observed in the data, namely $\omega = 2, b = 2, \sigma = 0.125$ and maintenance equal to zero with no utility impact combined with $b = 2$ and $\sigma = 0.125$. In Table VII we report the results for the former.

In an attempt to improve the present value of the cash-flows of the insurance agency in Panel A we consider the effects of increasing the annual insurance premium. Perhaps surprisingly, this has a small effect on the payoffs of the agency. The economic reason is simple, though. A higher insurance 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 are higher than house values which the agency must pay for. An increase in loan insurance premia without reductions in loan limits benefits mostly lenders.

In Panel B we consider instead the effects of a reduction in the borrowing limit, or PLF, while maintaining the baseline value for the mortgage insurance premium of 0.0125. Reductions in the borrowing limit are a much more effective tool for improving the financial position of the agency. Naturally they also lead to a decrease in the benefits for retirees and in the cash-flows of lenders.

Panel C evaluates quantitatively the effects of the initial mortgage costs. In the first row we set the initial mortgage insurance premium equal to zero (but we keep the annual insurance premium at its baseline value). Interestingly, reverse mortgages are now beneficial, albeit marginally, also for individuals with the median level of initial cash-on-hand. Focusing on the effects of initial fees further, Table I showed that they are much higher in the U.S. than in the U.K. In the second row of Panel C we investigate the quantitative effects of reducing them to the U.K. value. And in an attempt to make the present value of the cash-flows of the insurance agency positive, in the next two rows of the same panel we reduce the borrowing limit. When it is equal to 0.4, reverse mortgages are beneficial for a larger number of retirees, that includes those with median initial cash-on-hand, the insurance agency and lenders have positive cash-flows. The per mortgage cash-flows of lenders are lower than for other parameterizations, but it is important to note that there is a much larger potential demand for a product with such features.[31]

In the last panel of Table VII we examine the removal of mortgage insurance and all the associated costs (it does not exist in the U.K.) and setting the lender's margin equal to a slightly lower value (comparable to that in principal repayment mortgages) but maintaining the initial fees equal to the baseline value of 3.5 thousand dollars. Mortgages with these features and costs are generally beneficial for retirees and the present value of the cash-flows of lenders are positive.

We now turn our attention to another feature of reverse mortgages, namely the requirement that borrowers must maintain their property. We consider the effects of removing such requirement for borrowers who do not derive additional utility from property maintenance (but the lack of maintenance has an impact on the property price and retirees recognize this), who have a bequest motive ($b = 2$) and a precautionary savings motive ($\sigma = 0.125$). The results for when the requirement is removed (and retirees do not maintain the property) are shown in Table VIII. The results for the baseline parameterization are shown in the first row.

The removal of the maintenance requirement makes line of credit reverse mortgages beneficial for retirees. But the impact that the lack of maintenance has on the collateral value makes the present value of the expected payoffs for the insurance agency become significantly more negative. As before, the best way to make them less negative is through a reduction in the loan limit. We consider different possibilities in Table VIII, including the removal of insurance (and its costs), for which mortgages are beneficial to retirees and the present value of the cash-flows of lenders are positive.

# 7 Conclusion

The financing of retirement consumption is an issue of great concern to many individuals and to policy makers. The declines in public pension provision and in individual savings, together with the ageing of the population, have raised questions of how the increasing number of retirees will finance their old age consumption. Given that housing is the single most important asset of retired households, it is natural to question the extent to which it can be used for such purpose. The existing empirical evidence is not encouraging, however. Most old households do not discontinue homeownerhsip. The demand for reverse mortgages has been limited.

The reasons for this are not sufficiently well understood. This is in part due to the complexity of the decisions that retirees must make, made more difficult by the many risks

[31] A larger market may allow lenders to benefit from economies of scale in the origination and servicing of the loans.

they face, including an uncertain life span, health risk, medical expenditure shocks, interest rate risk and house price fluctuations. Psychological considerations such as a strong desire to remain in their home may also play a role. In order to shed additional light on these issues, we have proposed a quantitative model of retirees' consumption and homeonwership decisions that incorporates the above risks and psychological considerations.

Our model shows that even though a bequest motive or a precautionary savings motive lead individuals to remain homeowners until a later age, the decline in homeownership rates with age is still too large compared with the data. In other words, these savings motives lead to an increase in savings, but they have difficulty matching the composition of savings late in life. The model is more successful at matching the data, including a limited demand for reverse mortgages, if in addition to bequest and precautionary savings motives, retirees value property maintenance less than potential buyers of the property or if they derive utility benefits from remaining in the same house where they have retired.

We have used our model to quantitatively evaluate the different mortgage terms, costs and features, and how they impact the demand for these products. Our focus has been on how to make these products more beneficial to a larger number of retirees. We have shown that a reduction in their requirement and costs, including a reduction in insurance costs, accompanied by a reduction in borrowing limits may make reverse mortgages more appealling to a wider number of individuals, while at the same time generating positive expected cash-flows for lenders and the insurance agency. Our analysis has also shown that a higher insurance price, without additional restrictions on loan limits, is a fairly ineffective tool for limiting the losses of the insurance agency.

It would be interesting to investigate further how different features of reverse mortgage products might benefit retirees, including loan limits that depend on the evolution of house prices in the area where the property is located, or loan limits that depend on the relative importance of land and structures for property value. The difference being that value of the land is less sensitive to whether property maintenance is incurred or not. This might however add complexity to the products.

The decision of whether to take on a reverse mortgage 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, lower pensions and financial savings, and higher house prices relative to retirement income, are likely to create an extra incentive for homeowners to tap into their home equity to finance retirement consumption.

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**Figure 1. Number of reverse mortgages endorsed in the U.S., house prices, and reverse mortgage type.** The figure plots the number of reverse mortgage loans endorsed by the U.S. Federal Housing Administration (FHA) per month. The house price data is the S&P/Case-Shiller composite home price index. The figure also plots the proportion of reverse mortgage loans that are of the lump-sum type. The reverse mortgage data is from the FHA.

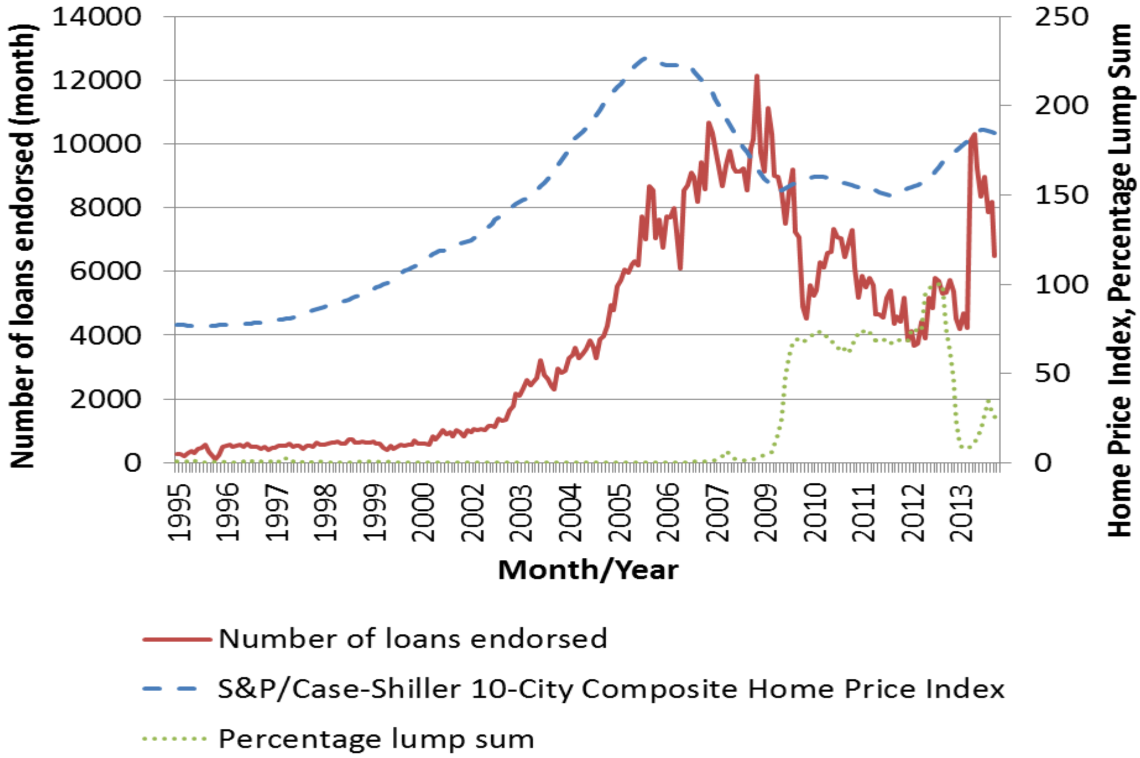


**Figure 2. Principal factors or borrowing limits as proportion of assessed house value for different reverse mortgage types as a function of the age of the borrower.** The borrowing limits are for the loan interest rates reported in Table I.

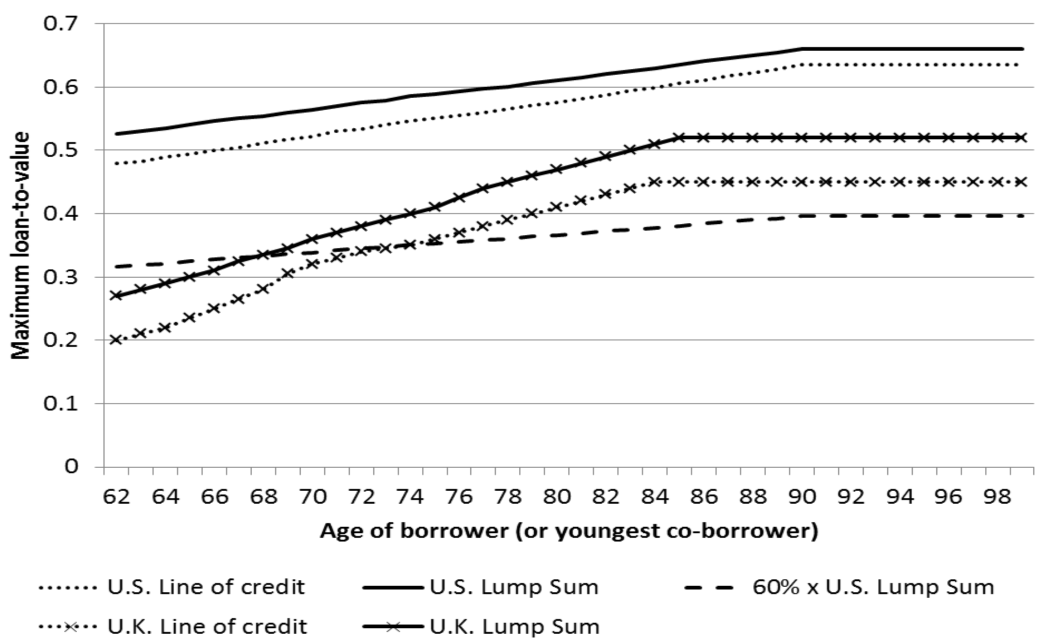

**Figure 3. Estimated age profiles.** This figure plots the estimated age profiles in the HRS data for homeownership rates, wealth accumulation, both including and excluding housing wealth. The estimation controls for cohort and permanent income fixed effects. The figures plot the average profiles for individuals in cohort 7 and permanent income group 3. The estimated dummies for the other groups are included in the appendix. The data is from the HRS

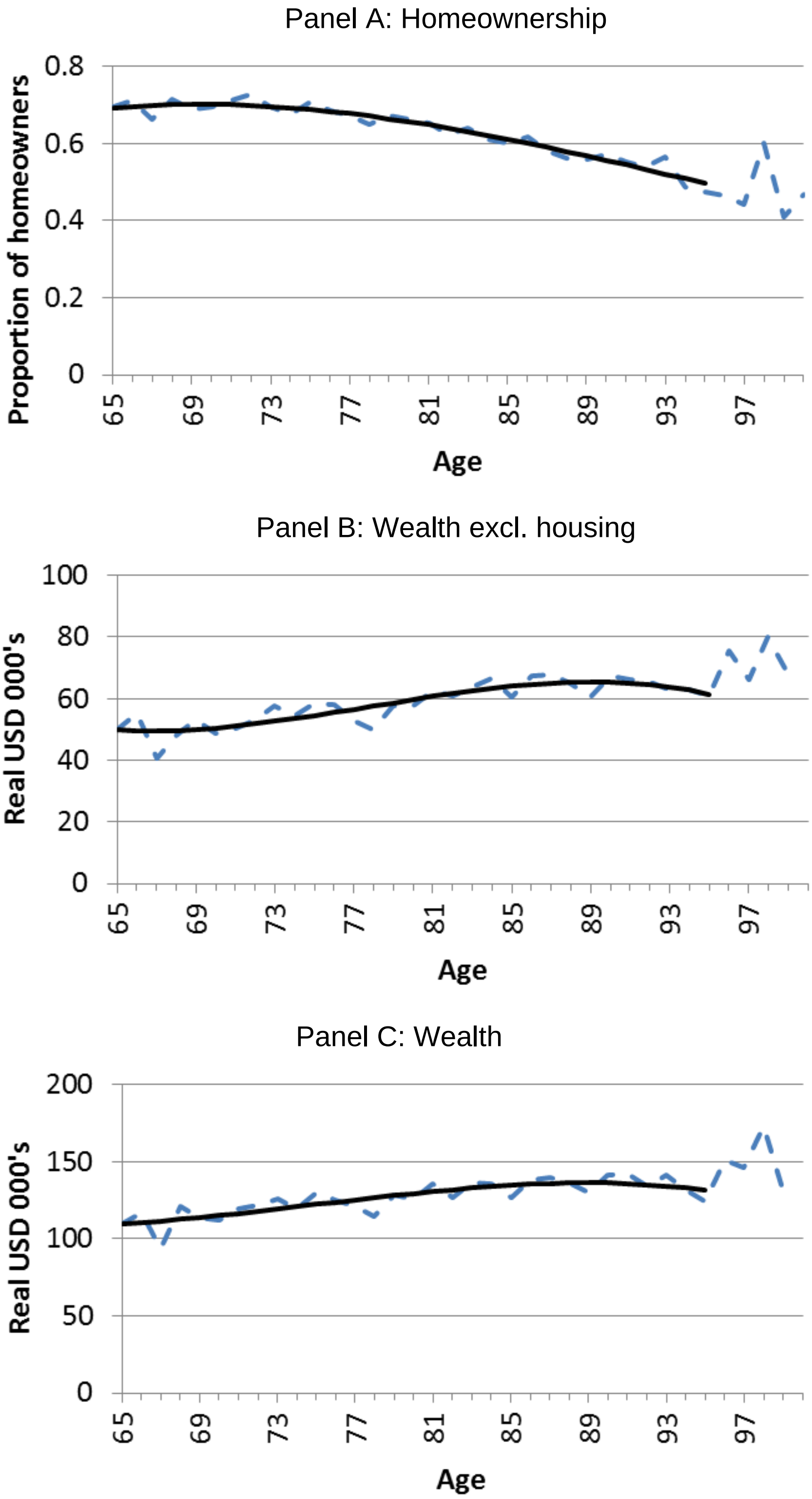

**Figure 4. Model results.** This figure plots the age profiles for homeownership rates predicted by the model. For comparison the figure also plots the estimated age profiles in the HRS data.

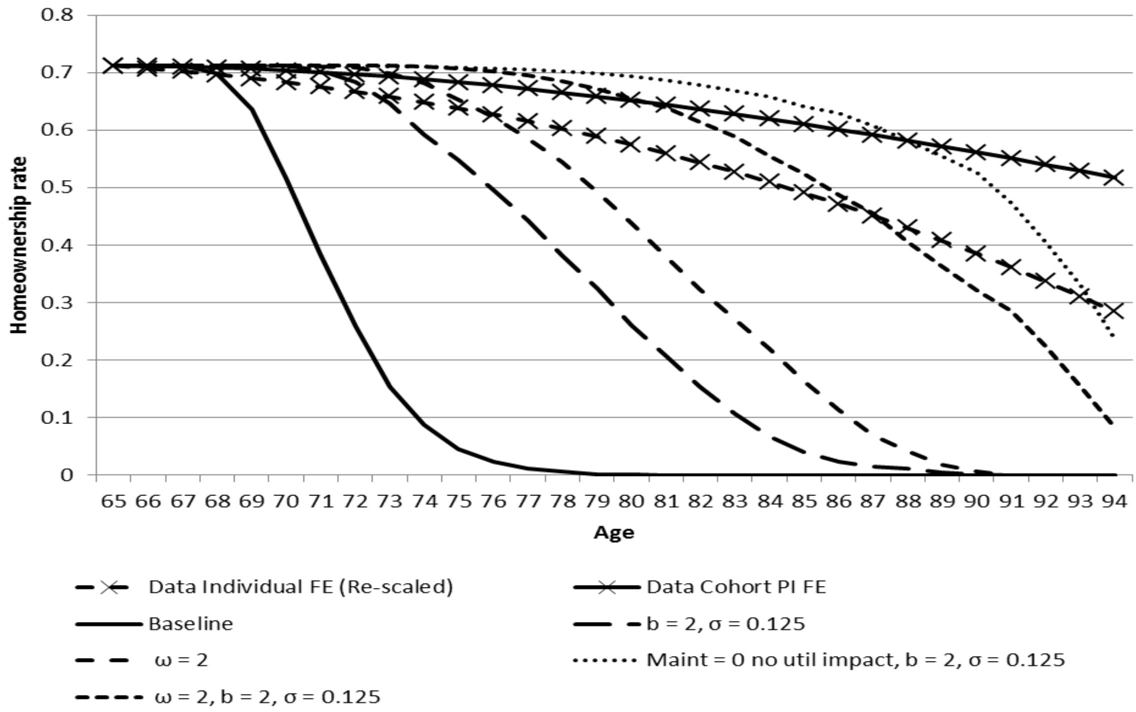


**Figure 5. Model results for line of credit reverse mortgages.** This figure plots the age profiles for debt drawn and debt outstanding predicted by the model with line of credit reverse mortgages, when there is a preference for homeownership (ω=2).

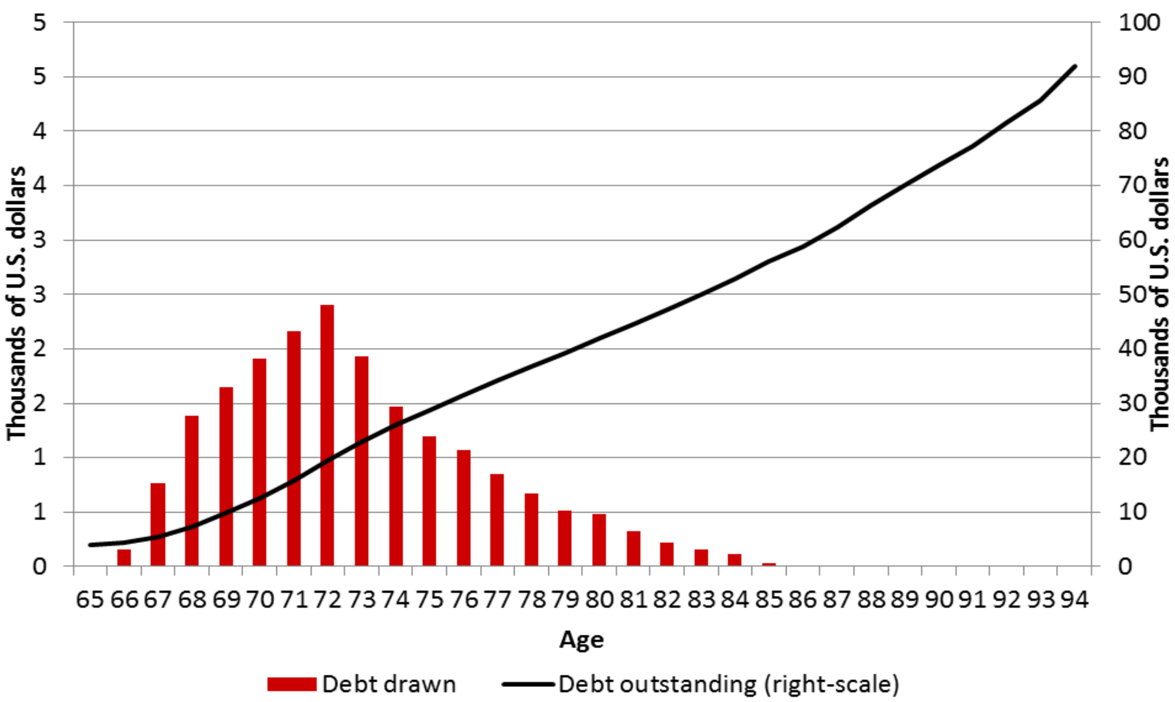

**Figure 6. Distribution of present value of risk-adjusted cash-flows for line of credit and lump-sum reverse mortgages, for lenders and the insurance agency.** This figure plots the distribution for initial low interest rates and when there is a preference for homeownership (ω=2).

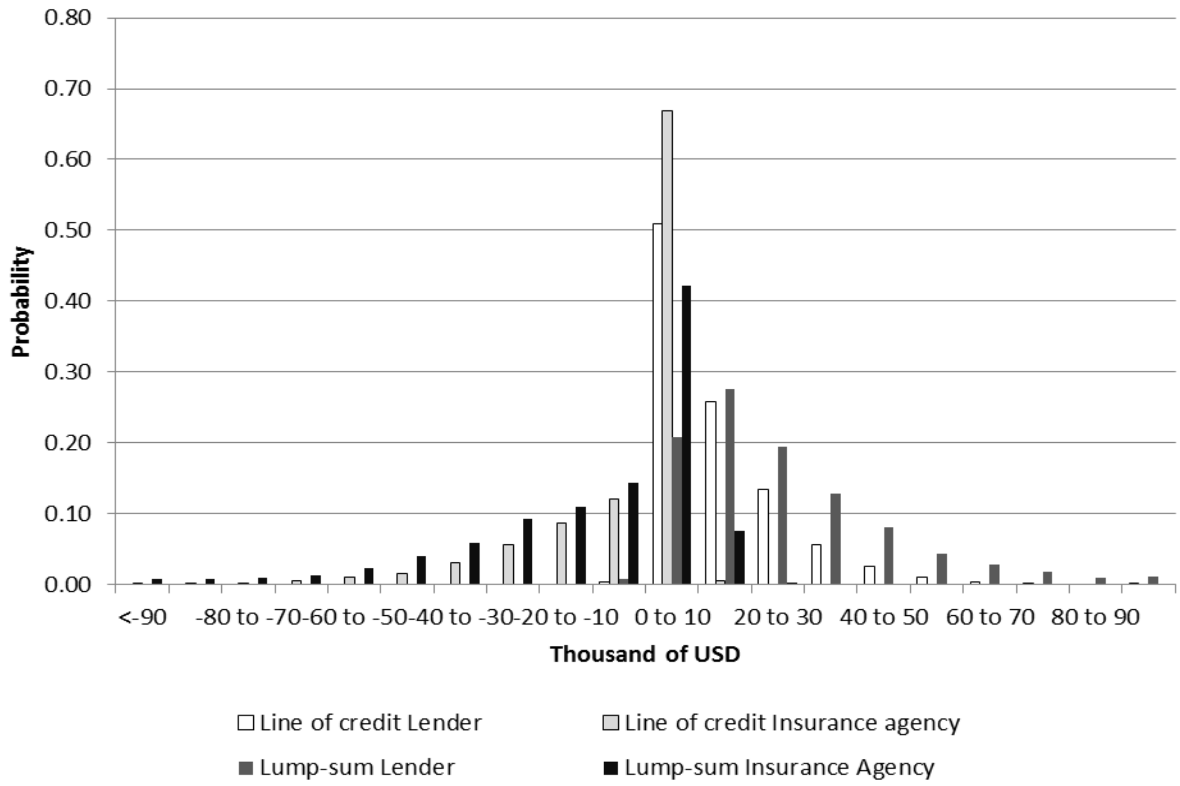

**Table I**
**Initial reverse mortgage costs and interest rates.**

Panel A reports the initial reverse mortgage costs for the U.S. and the U.K. For comparison the values for the U.K. were converted into US dollars. Panel B reports interest rates on reverse mortgages in the U.S. and the U.K. and their components, for the line of credit and lump-sum alternatives. This panel also reports the interest rate difference relative to the standard principal repayment mortgage rate. For the U.S. these are the standard 1-year ARM and 30-year FRM, respectively. For the U.K. they are the standard variable rate mortgage and 5-year FRM. The data refers to April 2014.

| Panel A: Initial Reverse Mortgage Costs | | | | |
|---|---|---|---|---|
| | Initial Amt$\leq$ 60%$\times$Max | | Initial Amt$>$60%$\times$Max | |
| Description | U.S. | U.K. | U.S. | U.K. |
| Loan origination fees | 1500 | 925 | 1500 | 925 |
| Mort insurance (Value = 70,000) | 350 | | 1750 | |
| Other closing costs | 2000 | 964 | 2000 | 964 |
| Total | 3850 | 1889 | 5250 | 1889 |
| **Panel B: Reverse Mortgage Rates** | | | | |
| | Line of Credit | | Lump-sum | |
| Description | U.S. | U.K. | U.S. | U.K. |
| Int rate index: 1-month LIBOR | 0.0016 | | | |
| Lender's margin | 0.0250 | | | |
| Loan rate | 0.0266 | 0.0619 | 0.0506 | 0.0739 |
| Mortgage insurance | 0.0125 | | 0.0125 | |
| Initial total loan rate | 0.0391 | 0.0619 | 0.0631 | 0.0739 |
| Diff to standard mortgage rate | 0.0147 | 0.0338 | 0.0198 | 0.0370 |
| Expected loan rate | 0.0535 | | 0.0506 | |

## Table II
## Permanent income and assets in the HRS data.

Panel A reports mean and median permanent income, wealth excluding housing, housing wealth and homeownership rates for individuals in the HRS data at age 65 born between 1930 and 1934 (cohort 7), by permanent income group. Panel B reports similar results conditional on homeownership. In each panel the last column reports the proportion of cohort 7 age 65 individuals in each permanent income group with bad health.

| Panel A: Cohort born 1930 - 1934, at age 65 | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Permanent income | | | Wealth excl. house | | Housing wealth | | Homeownership | | Health |
| Group | Mean | Median | Mean | Median | Mean | Median | Mean | Median | Bad |
| 1 | 5231 | 5734 | 34725 | 481 | 24575 | 0 | 0.43 | 0 | 0.57 |
| 2 | 8820 | 8663 | 18940 | 6738 | 21323 | 2888 | 0.55 | 1 | 0.27 |
| 3 | 11898 | 11951 | 30976 | 15100 | 37434 | 24000 | 0.69 | 1 | 0.28 |
| 4 | 16045 | 15789 | 99890 | 36401 | 66022 | 60284 | 0.78 | 1 | 0.22 |
| 5 | 28011 | 26346 | 173131 | 81338 | 98441 | 70500 | 0.90 | 1 | 0.26 |
| Panel B: Cohort born 1930 - 1934 at age 65, conditional on homeownership | | | | | | | | | |
| Permanent income | | | Wealth excl. house | | Housing wealth | | | | Health |
| Group | Mean | Median | Mean | Median | Mean | Median | | | Bad |
| 1 | 5140 | 5446 | 75295 | 4533 | 56969 | 38503 | | | 0.45 |
| 2 | 8595 | 8343 | 20089 | 10550 | 39092 | 27500 | | | 0.22 |
| 3 | 12028 | 11936 | 37855 | 27500 | 54280 | 52942 | | | 0.25 |
| 4 | 16073 | 15733 | 115844 | 46687 | 84885 | 83410 | | | 0.21 |
| 5 | 28516 | 26353 | 188267 | 100000 | 109691 | 77006 | | | 0.26 |

**Table III**
**Baseline Parameters.**

This table reports the baseline preference parameters, tax rates and other parameters, and asset returns.

| Description | Parameter | Value |
|---|---|---|
| Preference parameters | | |
| Discount factor | $\beta$ | 0.97 |
| Non-durable cons exp. share | $\theta_C$ | 0.80 |
| Housing expenditure share | $\theta_H$ | 0.20 |
| Utility from good health | $\delta$ | -0.36 |
| Elasticity of substitution | $\epsilon$ | 1.25 |
| Coefficient of intertemporal subs. | $\sigma$ | 0.27 |
| Preference for homeownership | $\omega$ | 1.0 |
| Bequest motive | $b$ | 0 |
| Tax rates and other parameters | | |
| Income tax rate | $\tau$ | 0.20 |
| Property tax rate | $\tau_p$ | 0.015 |
| Property maintenance | $m_p$ | 0.025 |
| Rental premium | $\varphi$ | 0.010 |
| Lower bound on consumption | $\underline{C}$ | \$2,630 |
| Transaction costs of house sale | $\lambda$ | 0.06 |
| Asset returns | | |
| Mean log real rate | $\mu_r$ | 0.012 |
| Stdev of the real rate | $\sigma_r$ | 0.018 |
| Log real rate AR(1) coefficient | $\phi_r$ | 0.825 |
| Term premium | $\xi$ | 0.005 |
| Mean log real house price growth | $\mu_H$ | 0.002 |
| Stdev house price return | $\sigma_\eta$ | 0.10 |

## Table IV
### Model results: matching asset deaccumulation patterns.

Panel A (Panel B) reports the homeownership rates (cash-on-hand) predicted by the model at different ages for alternative model parameterizations. For comparison the first row of each panel reports the results from the HRS data (for cohort 7 and permanent income group 3, the group used to parameterize the model). This table reports the results for the model in which retirees do not have access to reverse mortgages.

| Parameter/Age | 70 | 75 | 80 | 85 | 90 |
|---|---|---|---|---|---|
| Panel A: Homeownership rates | | | | | |
| **1. Data cohort and perm. inc. fixed-eff.** | **0.70** | **0.68** | **0.65** | **0.61** | **0.56** |
| 2. Baseline model parameters | 0.38 | 0.06 | 0.00 | 0.00 | 0.00 |
| 3. Stronger precaut. motive ($\sigma = 0.125$) | 0.71 | 0.55 | 0.26 | 0.04 | 0.00 |
| 4. Bequest motive $b = 2$ | 0.56 | 0.21 | 0.04 | 0.01 | 0.00 |
| 5. Bequest ($b = 2$) and precaut. ($\sigma = 0.125$) | 0.71 | 0.55 | 0.26 | 0.04 | 0.00 |
| 6. Higher rental premium = 0.03 | 0.71 | 0.46 | 0.16 | 0.01 | 0.00 |
| 7. Maint. $m_p = 0$, no utility impact | 0.69 | 0.56 | 0.37 | 0.17 | 0.01 |
| **8. Maint. $\mathbf{m_p = 0}$ no util. imp., $\mathbf{b = 2}$, $\boldsymbol{\sigma} = \mathbf{0.125}$** | **0.71** | **0.71** | **0.69** | **0.64** | **0.53** |
| 9. Maint. $m_p = 0$, utility impact | 0.42 | 0.18 | 0.03 | 0.00 | 0.00 |
| 10. Maintenance choice, utility impact | 0.51 | 0.19 | 0.03 | 0.00 | 0.00 |
| 11. Maint. $m_p = 0$ util. impact, $b = 2$, $\sigma = 0.125$ | 0.70 | 0.58 | 0.40 | 0.14 | 0.01 |
| 12. Maint. choice util. impact, $b = 2$, $\sigma = 0.125$ | 0.71 | 0.67 | 0.49 | 0.17 | 0.03 |
| 13. Pref. for homeownership ($\omega = 2$) | 0.71 | 0.65 | 0.44 | 0.16 | 0.01 |
| 14. Pref. for ownership $\omega = 2, b = 2$ | 0.71 | 0.65 | 0.44 | 0.16 | 0.01 |
| **15. Pref. for ownership $\boldsymbol{\omega} = \mathbf{2, b = 2}, \boldsymbol{\sigma} = \mathbf{0.125}$** | **0.71** | **0.71** | **0.66** | **0.52** | **0.32** |
| Panel B: Cash-on-hand | | | | | |
| **1. Data cohort and perm. inc. fixed-eff.** | **19.2** | **17.9** | **20.2** | **22.4** | **21.0** |
| 2. Baseline model parameters | 31.5 | 45.6 | 38.5 | 26.2 | 16.8 |
| 3. Stronger precaut. motive ($\sigma = 0.125$) | 23.6 | 25.9 | 38.8 | 49.1 | 43.1 |
| 4. Bequest motive $b = 2$ | 24.1 | 39.7 | 47.6 | 41.8 | 35.0 |
| 5. Bequest ($b = 2$) and precaut. ($\sigma = 0.125$) | 23.6 | 25.9 | 38.8 | 49.1 | 43.1 |
| 6. Higher rental premium = 0.03 | 20.1 | 24.8 | 34.8 | 31.3 | 19.4 |
| 7. Maint. $m_p = 0$, no utility impact | 22.3 | 20.6 | 22.5 | 22.8 | 20.0 |
| **8. Maint. $\mathbf{m_p = 0}$ no util. imp., $\mathbf{b = 2}$, $\boldsymbol{\sigma} = \mathbf{0.125}$** | **27.2** | **24.8** | **22.9** | **21.8** | **22.5** |
| 9. Maint. $m_p = 0$, utility impact | 33.7 | 37.8 | 35.8 | 26.4 | 17.0 |
| 10. Maintenance choice, utility impact | 27.0 | 35.6 | 36.0 | 26.7 | 17.1 |
| 11. Maint. $m_p = 0$ util. impact, $b = 2$, $\sigma = 0.125$ | 28.9 | 30.5 | 34.4 | 40.4 | 41.8 |
| 12. Maint. choice util. impact, $b = 2$, $\sigma = 0.125$ | 24.2 | 21.4 | 25.2 | 37.3 | 41.4 |
| 13. Pref. for homeownership ($\omega = 2$) | 22.9 | 18.8 | 25.8 | 31.1 | 24.8 |
| 14. Pref. for ownership $\omega = 2, b = 2$ | 22.9 | 18.8 | 25.8 | 31.1 | 24.8 |
| **15. Pref. for ownership $\boldsymbol{\omega} = \mathbf{2, b = 2}, \boldsymbol{\sigma} = \mathbf{0.125}$** | **27.4** | **24.3** | **24.2** | **28.8** | **37.8** |

**Table V**
**Model results for line of credit reverse mortgages.**

This table reports the welfare gains to retirees from line of credit reverse mortgages calculated as the percentage of the initial cash-on-hand that retirees are willing to pay to have access to the mortgages. In addition the table reports the present discounted value of the cash-flows of lenders and of the insurance agency (in expected thousand U.S. dollars per loan) for alternative model parameterizations, for the reverse mortgage costs and rates reported in Table I. The table reports present values calculated using bond-yields and using risk-adjusted discount rates. The results are for retirees in cohort 7 and permanent income group 3, and for two different levels of initial cash-on-hand that correspond to the median level (27.5 thousand dollars, in Panel A) and to percentile 25 (12.9 thousand dollars, in Panel B). **For all the other parameterizations reported in Table IV the welfare gains are zero.** The table reports welfare gains for initial good health, low medical expenditures, and low interest rates.

| Parameter | Welf. gain of retirees (%) | PV CF Lenders Yield | PV CF Lenders Risk-adj. | PV CF IA Yield | PV CF IA Risk-adj. |
|---|---|---|---|---|---|
| Panel A: Median level of cash-on-hand | | | | | |
| Baseline model parameters | 0.00 | n/a | n/a | n/a | n/a |
| Higher rental premium = 0.03 | 0.08 | 7.5 | 8.0 | -2.0 | -3.1 |
| Pref. for homeownership ($\omega = 2$) | 0.32 | 13.4 | 13.7 | -2.8 | -4.1 |
| **Maint. $\mathbf{m_p = 0}$ no util. imp., $\mathbf{b = 2}$, $\boldsymbol{\sigma} = \mathbf{0.125}$** | **0.00** | **n/a** | **n/a** | **n/a** | **n/a** |
| **Pref. for ownership $\boldsymbol{\omega} = \mathbf{2, b = 2}, \boldsymbol{\sigma} = \mathbf{0.125}$** | **0.00** | **n/a** | **n/a** | **n/a** | **n/a** |
| Panel B: Percentile 25 of cash-on-hand | | | | | |
| Baseline model parameters | 0.00 | n/a | n/a | n/a | n/a |
| Higher rental premium = 0.03 | 0.36 | 12.3 | 12.6 | -2.4 | -3.6 |
| Pref. for homeownership ($\omega = 2$) | 0.82 | 14.6 | 14.9 | -3.2 | -4.7 |
| **Maint. $\mathbf{m_p = 0}$ no util. imp., $\mathbf{b = 2}$, $\boldsymbol{\sigma} = \mathbf{0.125}$** | **0.00** | **n/a** | **n/a** | **n/a** | **n/a** |
| **Pref. for ownership $\boldsymbol{\omega} = \mathbf{2, b = 2}, \boldsymbol{\sigma} = \mathbf{0.125}$** | **0.20** | **10.6** | **10.9** | **-1.4** | **-2.5** |

## Table VI
## Model results for lump sum reverse mortgages.

This table reports the welfare gains to retirees from lump-sum reverse mortgages calculated as the percentage of the initial cash-on-hand that retirees are willing to pay to have access to the mortgages. In addition the table reports the present discounted value of the cash-flows of lenders and of the insurance agency (in expected thousand U.S. dollars per loan) for alternative model parameterizations, for the reverse mortgage costs and rates reported in Table I. The table reports present values calculated using bond-yields and using risk-adjusted discount rates. The results are for retirees in cohort 7 and permanent income group 3, and for two different levels of initial cash-on-hand that correspond to the median level (27.5 thousand dollars, in Panel A) and to percentile 25 (12.9 thousand dollars, in Panel B). **For all the other parameterizations reported in Table IV the welfare gains are zero.** The table reports welfare gains for initial good health, low medical expenditures, and low interest rates.

| Parameter | Welf. gain of retirees (%) | PV CF Lenders Yield | PV CF Lenders Risk-adj. | PV CF IA Yield | PV CF IA Risk-adj. |
|---|---|---|---|---|---|
| Panel A: Median level of age 65 cash-on-hand | | | | | |
| Baseline model parameters | 0.00 | n/a | n/a | n/a | n/a |
| Higher rental premium = 0.03 | 0.00 | n/a | n/a | n/a | n/a |
| Pref. for homeownership ($\omega = 2$) | 0.20 | 25.6 | 25.6 | -7.0 | -9.4 |
| **Maint. $\mathbf{m_p = 0}$ no util. imp., $\mathbf{b = 2}$, $\boldsymbol{\sigma} \mathbf{= 0.125}$** | **0.00** | **n/a** | **n/a** | **n/a** | **n/a** |
| **Pref. for ownership $\boldsymbol{\omega} \mathbf{= 2, b = 2,} \boldsymbol{\sigma} \mathbf{= 0.125}$** | **0.00** | **n/a** | **n/a** | **n/a** | **n/a** |
| Panel B: Percentile 25 of age 65 cash-on-hand | | | | | |
| Baseline model parameters | 0.00 | n/a | n/a | n/a | n/a |
| Higher rental premium = 0.03 | 0.12 | 24.1 | 24.2 | -6.6 | -8.8 |
| Pref. for homeownership ($\omega = 2$) | 0.71 | 25.4 | 25.4 | -6.9 | -9.3 |
| **Maint. $\mathbf{m_p = 0}$ no util. imp., $\mathbf{b = 2}$, $\boldsymbol{\sigma} \mathbf{= 0.125}$** | **0.00** | **n/a** | **n/a** | **n/a** | **n/a** |
| **Pref. for ownership $\boldsymbol{\omega} \mathbf{= 2, b = 2,} \boldsymbol{\sigma} \mathbf{= 0.125}$** | **0.00** | **n/a** | **n/a** | **n/a** | **n/a** |

**Table VII**
**Line of credit reverse mortgage design: $\boldsymbol{\omega = 2, b = 2, \sigma = 0.125}$.**

This table reports the welfare gains to retirees from line of credit reverse mortgages calculated as the percentage of the initial cash-on-hand that retirees are willing to pay to have access to the mortgages. In addition the table reports the present discounted value of the cash-flows of lenders and the insurance agency (in expected thousand U.S. dollars per loan) calculated using risk-adjusted discount rates. The results are for individuals who have a preference for ownership so that $\omega = 2$, a stronger bequest ($b = 2$) and precautionary savings motive ($\sigma = 0.125$), in cohort 7 and permanent income group 3, and for two different levels of initial cash-on-hand that correspond to the median level (27.5 thousand dollars) and to percentile 25 (12.9 thousand dollars). Panel A reports results for higher annual insurance premia, Panel B for lower principal limit factors, Panel C for lower initial costs (fees and initial mortgage insurance premium) and principal limit factors, and Panel D for lower lender margin, zero insurance premia and lower principal limit factors.

| | Median initial cash-on-hand | | | Perc. 25 of initial cash-on-hand | | |
|---|---|---|---|---|---|---|
| Parameterization | Welf. (%) | Lenders | Agency | Welf. (%) | Lenders | Agency |
| $\omega = 2, b = 2, \sigma = 0.125$ | 0.00 | n/a | n/a | 0.20 | 10.9 | -2.5 |
| Panel A: Higher annual mortgage insurance premium | | | | | | |
| Annual ins prem = 0.015 | 0.00 | n/a | n/a | 0.17 | 11.0 | -2.3 |
| Annual ins prem = 0.020 | 0.00 | n/a | n/a | 0.12 | 11.6 | -2.3 |
| Panel B: Lower Principal Limit Factor (PLF) | | | | | | |
| PLF=0.50 | 0.00 | n/a | n/a | 0.15 | 9.7 | -1.0 |
| PLF=0.45 | 0.00 | n/a | n/a | 0.09 | 9.3 | -0.4 |
| PLF=0.43 | 0.00 | n/a | n/a | 0.07 | 8.8 | 0.2 |
| PLF=0.40 | 0.00 | n/a | n/a | 0.05 | 8.4 | 0.6 |
| Panel C: Lower initial costs | | | | | | |
| PLF=0.54, in. ins=0.0, fees=3.5 | 0.01 | 10.1 | -2.7 | 0.25 | 10.5 | -2.8 |
| PLF=0.54, in. ins=0.0, fees=1.889 | 0.11 | 5.9 | -1.8 | 0.41 | 6.4 | -1.8 |
| PLF=0.45, in. ins=0.0, fees=1.889 | 0.08 | 4.8 | -0.3 | 0.33 | 5.2 | -0.4 |
| PLF=0.40, in. ins=0.0, fees=1.889 | 0.06 | 4.2 | 0.4 | 0.30 | 4.5 | 0.4 |
| Panel D: No insurance, lower margin | | | | | | |
| PLF=0.54, ins=0.0, margin=0.0225 | 0.11 | 5.1 | n/a | 0.45 | 5.4 | n/a |
| PLF=0.40, ins=0.0, margin=0.0225 | 0.05 | 5.7 | n/a | 0.29 | 5.9 | n/a |
| PLF=0.30, ins=0.0, margin=0.0225 | 0.02 | 5.9 | n/a | 0.23 | 6.0 | n/a |

## Table VIII

**Line of credit reverse mortgage design: maintenance set equal to zero with no utility impact, $\mathbf{b = 2, \sigma = 0.125}$.**

This table reports the welfare gains to retirees from line of credit reverse mortgages calculated as the percentage of the initial cash-on-hand that retirees are willing to pay to have access to the mortgages. In addition the table reports the present discounted value of the cash-flows of lenders and the insurance agency (in expected thousand U.S. dollars per loan) calculated using risk-adjusted discount rates. The results are for the case in which retirees do not value property maintenance in the same way as potential buyers of the property (and set it equal to zero with no impact on utility), a stronger bequest ($b = 2$) and precautionary savings motive ($\sigma = 0.125$), in cohort 7 and permanent income group 3, and for two different levels of initial cash-on-hand that correspond to the median level (27.5 thousand dollars) and to percentile 25 (12.9 thousand dollars). Panel A reports results for higher annual insurance premia, Panel B for lower principal limit factors, Panel C for lower initial costs (fees and initial mortgage insurance premium) and principal limit factors, and Panel D for lower lender margin, zero insurance premia and lower principal limit factors.

| | Median initial cash-on-hand | | | Perc. 25 of initial cash-on-hand | | |
|---|---|---|---|---|---|---|
| Parameterization | Welf. (%) | Lenders | Agency | Welf. (%) | Lenders | Agency |
| Maint = 0 no util impact, $b = 2, \sigma = 0.125$ | 0.19 | 20.5 | -17.7 | 0.46 | 20.3 | -17.5 |
| Panel A: Higher annual mortgage insurance premium | | | | | | |
| Annual ins prem = 0.015 | 0.18 | 20.8 | -17.9 | 0.45 | 20.6 | -17.6 |
| Annual ins prem = 0.020 | 0.17 | 22.6 | -19.8 | 0.44 | 22.5 | -19.7 |
| Panel B: Lower Principal Limit Factor (PLF) | | | | | | |
| PLF=0.50 | 0.13 | 19.2 | -15.4 | 0.34 | 19.2 | -15.3 |
| PLF=0.45 | 0.05 | 16.5 | -11.5 | 0.18 | 15.4 | -10.6 |
| PLF=0.43 | 0.01 | 15.4 | -9.8 | 0.10 | 14.6 | -9.1 |
| PLF=0.40 | 0.00 | n/a | n/a | 0.01 | 13.5 | -7.2 |
| Panel C: Lower initial costs and lower PLF | | | | | | |
| PLF=0.54, in. ins=0.0, fees=3.5 | 0.22 | 20.7 | -18.6 | 0.52 | 20.5 | -18.4 |
| PLF=0.54, in. ins=0.0, fees=1.889 | 0.26 | 16.4 | -15.7 | 0.62 | 16.3 | -15.5 |
| PLF=0.45, in. ins=0.0, fees=1.889 | 0.14 | 11.1 | -9.0 | 0.36 | 11.4 | -9.3 |
| PLF=0.40, in. ins=0.0, fees=1.889 | 0.05 | 10.2 | -6.8 | 0.19 | 9.8 | -6.2 |
| Panel D: No insurance, lower margin | | | | | | |
| PLF=0.54, ins=0.0, margin=0.0225 | 0.26 | 0.6 | n/a | 0.61 | 0.7 | n/a |
| PLF=0.40, ins=0.0, margin=0.0225 | 0.02 | 4.2 | n/a | 0.14 | 4.2 | n/a |
| PLF=0.30, ins=0.0, margin=0.0225 | 0.00 | n/a | n/a | 0.00 | n/a | n/a |

# Appendix to Reverse Mortgage Design

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## Appendix A: Pricing kernel

In order to calculate the present value of the cash-flows that mortgage providers receive we need to discount them by a rate that takes into account their risk. Our model is partial equilibrium so that we cannot derive a pricing kernel endogenously within the model. But to try to capture the risks faced by lenders and the insurance agency, we follow Campbell and Cocco (2014) in the derivation of a pricing kernel. They assume that the representative household's $i$ permanent income $v_{it}$ follows a random walk, with innovations given by $\eta_{it}$:

$$v_{it} = v_{i,t-1} + \eta_{it}. \tag{A1}$$

The innovations to permanent income can be decomposed into an individual specific component $\eta_t^i$ and an aggregate component $\eta_t^a$:

$$\eta_{it} = \eta_t^i + \eta_t^a \tag{A2}$$

Furthemore, they assume that the shocks to the aggregate component of permanent income are perfectly correlated with innovations to house prices, so that $\eta_t^a = \alpha\delta_t$, and we can re-write:

$$\eta_{it} = \eta_t^i + \alpha\delta_t \tag{A3}$$

And since $\eta_t^i$ and $\delta_t$ are uncorrelated with each other:

$$\sigma_{\eta_i}^2 = \sigma_{\eta^i}^2 + \alpha^2\sigma_\delta^2 \tag{A4}$$

In their parameterization, $\sigma_{\eta_i} = 0.063$, $\sigma_\delta = 0.162$ and $corr(\eta_t, \delta_t) = 0.191$. It follows that $\alpha = 0.0743$, $\sigma_{\eta^j} = 0.062$ and $\sigma_{\eta^a} = 0.012$. The parameter of interest is the variance of aggregate permanent income shocks.

Let $C_t^a$ denote the date $t$ level of aggregate real consumption. For power utility:

$$E_t\beta(\frac{C_{t+1}^a}{C_t^a})^{-\gamma} = \frac{1}{1+R_{1t}} \tag{A5}$$

where $R_{1t}$ is the one period real interest rate. Assuming log normality and letting lower-case letters denote the log of their upper-case counterpart:

$$E_t\Delta c_{t+1}^a = \frac{1}{\gamma}[log(1+R_{1t}) + log(\beta) + \gamma^2\frac{\sigma_{c_a}^2}{2}]. \tag{A6}$$

Campbell and Cocco (2014) assume that aggregate consumption innovations equal the innovations to aggregate permanent income, and that the expected consumption growth rate is related to the real interest rate. In their baseline parameterization, $\gamma = 2$, $\beta = 0.98$ and

$\sigma^2_{y_a} = 0.012^2$.

In our model the log real interest rate can either be low or high, equal to -0.006 or 0.03. We can use equation $(A6)$ to calculate expected consumption growth. It follows that the corresponding values of $E_t\Delta c^a_{t+1}$ are $-0.01296$ and 0.005. For each of these cases innovations to aggregate income can be negative or positive so that the corresponding discount factors are given by:

$$0.98 \times exp(-0.01296 - 0.012)^{-2} = 1.030158 \tag{A7}$$

$$0.98 \times exp(-0.01296 + 0.012)^{-2} = 0.981878 \tag{A8}$$

$$0.98 \times exp(0.005043 - 0.012)^{-2} = 0.993732 \tag{A9}$$

$$0.98 \times exp(-0.005043 + 0.012)^{-2} = 0.947159 \tag{A10}$$

The first and third values correspond to states with low house price growth. Thus cash-flows received at such times are more valuale. We use the above discount factors to calculate the present value of the cash-flows received by lenders and the insurance agency.

## Appendix B: Model solution

The equation describing the evolution of cash-on-hand, $X_t$, for a retiree who took out a reverse mortgage of type $j$ and who chooses to remain homeowner is given by:

$$X_{t+1} = [X_t - C_t - ME_t - (m_p + \tau_p(1-\tau))P^H_t\overline{H} + D^C_{j,t}][1 + R_{1t}(1-\tau)] + (1-\tau)Y_{t+1} + Tr_{t+1}. \tag{A11}$$

where recall $D^C_{j,t}$ is the additional mortgage debt that the retiree has decided to take out in period $t$, $ME$ denotes medical expenditures and $Tr$ government transfers.

And for periods in which he/she decides to become a renter:

$$X_{t+1} = (X_t - C_t - ME_t - U_t + MAX[(1-\lambda)P^H_t\overline{H} - D^S_{j,t}, 0])[1 + R_{1t}(1-\tau)] + (1-\tau)Y_{t+1} + Tr_{t+1}. \tag{A12}$$

where $U_t$ is the rental cost and $D^S_{j,t}$ is the outstanding debt at the beginning of period $t$. If the proceeds from the house sale are lower than the outstanding debt, the retiree is not responsible for the difference.

In case the homeowner dies in period $t$ the bequeathed wealth is net of estate taxes:

$$W_t = (1-\tau)[X_t + MAX(P_t^H \overline{H} - D_{j,t}^S, 0)]. \qquad \text{(A13)}$$

The problem cannot be solved analytically. We use numerical techniques for solving it. Given the finite nature of the problem a solution exists and can be obtained by backward induction. We approximate the state-space and the variables over which the choices are made with equally spaced grids, in the logarithmic scale. The density functions for the random variables is be approximated using Gaussian quadrature methods to perform numerical integration (Tauchen and Hussey, 1991).

In the last period, and for each admissible combination of the state variables, we obtain the utility associated with each level of terminal wealth. Since this is the terminal period the utility function coincides with the value function. In every period prior to the terminal date we can then obtain the utility associated with the different choices. To compute the continuation value for points which do not lie on the grid we will use cubic spline interpolation or linear interpolation for those parts of the grid where the value function has less curvature. We optimize over the different choices using grid search. We then iterate backwards.

## Appendix C: HRS Data

### Model parameterization

We use Health and Retirement Study (HRS) data to parameterize the model. It is a survey of American individuals carried out every two years. The first wave was carried out in 1992, but since assets in the 1994 survey are under-reported, we use data from 1996 to 2010. We restrict the analysis to single retired individuals who are aged 65 or over. We use the Rand version of the data and combine it with information from the exit interviews.

In the data there is strong evidence of cohort effects. Therefore in our analysis we control for cohort effects, defined according to birth year, and described in Table A.1. This table reports, for each cohort, the birth years, the retirees' age in 1996 and in 2010, which are the first and last year covered by the data, and the number of observations available. Our analysis also takes permanent income into consideration. We follow De Nardi, French, and Jones (2010) and calculate for each individual a measure of his/her permanent/retirement income by averaging their annual real non-asset income over the years in which the individual appears in the data. We use this measure of permanent income to group individuals into quintiles.

Individuals covered by the survey 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. In order to model the transition probability matrix for health status we follow De Nardi, French, and Jones (2010). We estimate the probability of bad health as 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. As an example, Panel A of Figure A.1 plots the transition probability into bad health given good health, for female retirees in three of the permanent income groups that we consider, namely one, three and five. The probability of transition from good to bad health is higher for individuals in lower permanent income groups. For all of them the transition probability is significantly smaller than a half, which reflects the fact that there is persistence in health status. Finally, for all permanent income groups the transition probabilities from good to bad health decline with age. This is likely to be due to sample selection: if individuals remain alive until a later age, they are more likely to be in good health at that later age, so that they are less likely to transition from good to bad health.

We also use a logistic function and the same explanatory variables to estimate survival probabilities. As an illustration, Panel B of Figure A.1 plots the estimated conditional survival probabilities for a female individual in permanent income groups one and three, conditional on health status. Conditional survival probabilities are significantly smaller for individuals in bad than in good health, and conditional on health status they are smaller for individuals in lower permanent income groups.

We construct a measure of out-of-pocket medical expenditures by adding the amount the retiree has paid for hospital and nursing home stays, outpatient surgery, doctor visits, prescription drugs, and dental care. We also include costs in in home medical care, other health services such as rehabilitation programs and special health equipment. In the exit files expenses in home modification and hospice are included. Health insurance premiums are added to out-of-pocket medical expenditures. These include payments to Medicare/Medicaid excluding co-pays or deductions from the Social Security, private medical insurance and long term care insurance. We use the information in the exit files to obtain data for these variables in the year prior to death. The Health and Retirement Survey a biennial survey therefore in order tho find annual medical expenditures we divide out-of-pocket medical expenditures by two. For the exit files we calculate annualized expenditures by taking into account the time of death. We restrict our sample to retired single individuals aged between 65 and 100 inclusive. This leaves us with a sample of 10,349 individuals.

We follow De Nardi, French, and Jones (2010) and model the mean of log medical expenses as a function of a quadratic in age, gender, gender interacted with age, health status, health status interacted with age, permanent income rank, permanent income rank squared, permanent income rank interacted with age. We estimate this function using random effects. By doing so we are able to estimate the effect of time-invariant variables such as cohort, gender and permanent income rank which are then used to construct the medical expenditure profiles that are fed into the model. The rationale behind random effects is that the variation across entities is assumed to be random and uncorrelated with the independent variables, since our sample of interviewed individuals is randomly selected from a wider population this is a reasonable assumption. Our volatility measure is the regression's standard error, which is the square root of the sum of the within and between estimated variances. We allow for persistence in the shocks to medical expenditures. We estimate an AR(1) process for the residuals of the random effects regression. The estimated autocorrelation parameter is 0.51 and the standard deviation of the shock is 1.23.

As an illustration, in Figure A.2 we plot the estimated medical expenditures for individuals in three of the income groups that we consider (and in cohort 7). Older retirees and those in higher permanent income groups spend considerably more in out-of-pocket medical expenditures. Individuals with fair or poor health face higher medical expenses than those in good health, particularly those in higher permanent income groups.

**Asset deaccumulation profiles**

We estimate age asset deaccmulation profiles in the HRS data to which we compare the model results. As a first description of the data, in Figure A.3 we plot mean age and cohort values for homeownership rates (Panel A), wealth excluding housing (Panel B), and total wealth (Panel C). Each of the lines represents a different cohort. Panel A illustrates the well known fact that homeownership rates decline very slowly with age, with any significant decline taking place only late in life. In Panel B there seems to be a decline in financial wealth up to around age 75, only to subsequently increase. However, the large volatility in mean weath (both including and excluding housing wealth) makes it hard to draw such conclusion. Furtheremore, as previously explained, there are significant differences in the data across permanent income groups. Therefore, in order to take into account both cohort and permanent income effects, we estimate the following regression:

$$Y_{it} = \beta_0 + \sum_{j=60}^{100} \beta_{1j} D_{it}^{Age_j} + \sum_{k=1}^{5} \beta_{2k} D_{it}^{PI_k} + \sum_{l=1}^{10} \beta_{3l} D_{it}^{Cohort_l} + \epsilon it \tag{A14}$$

where the unit of observation is retiree $i$ in year $t$, the independent variables are age dummies, permanent income dummies, cohort dummies, and $\epsilon_{it}$ is the residual. We estimate this regression for three different dependent variables: homeownership, wealth excluding housing, and total wealth. In Figure 3 we plotted the age dummies for permanent income group three and cohort seven. In table A.II and in Figure A.4 we plot the estimated cohort and permanent income dummies. Average homeownerhip rates and wealth are higher for more recent cohorts and for higher permanent income groups.

In Figure A.5 we plot the estimated age profiles for median wealth instead of average wealth. The shape of the profiles is similar, but the wealth levels are substantially lower. In particular, later in life median non-housing wealth is fairly low with values close to zero. Finally, in Figure A.6 we plot estimated age profiles controlling for individual fixed effects instead of cohort and permanent income fixed effects. The patterns are somewhat different. For instance, the homeownership rates decline more steeply with age. The reason is that age effects for individuals who remain homeowners throughout the sample are picked up by the individual fixed effect. Any age related patterns are driven by those individuals who change homeownership status during the sample. When comparing the model with the data we focus mainly on the estimates from the regressions with cohort and permanent income fixed effects.

## Appendix D: Additional model results

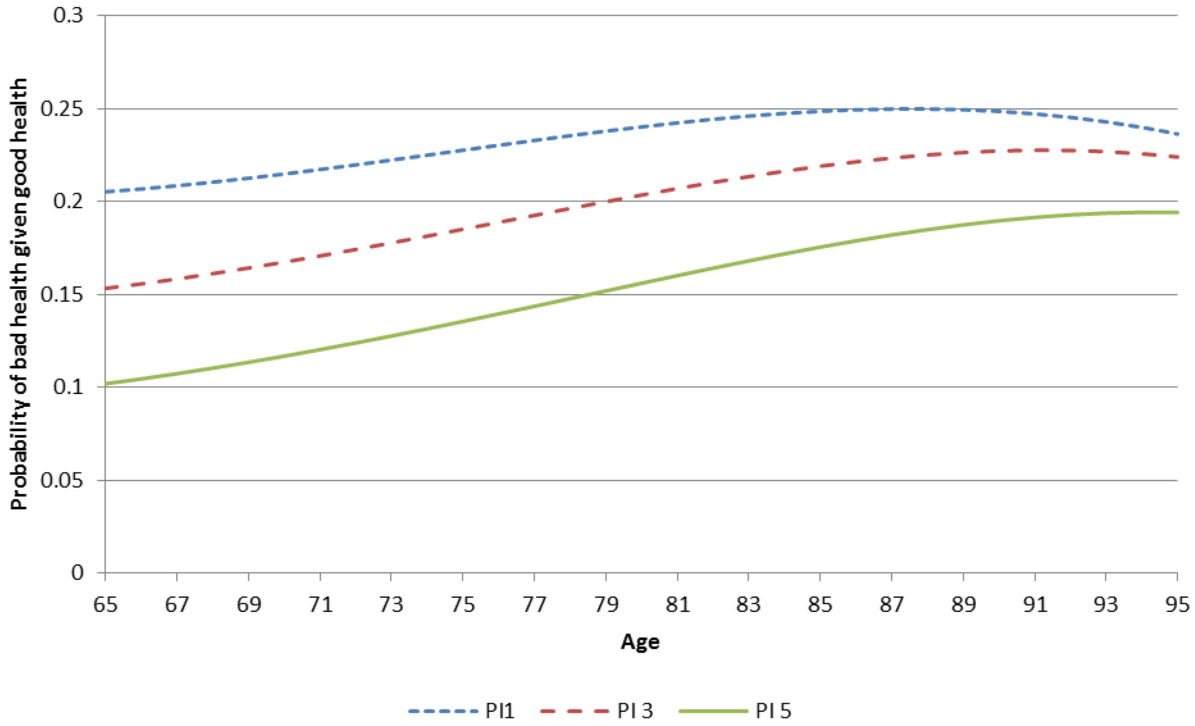
In this appendix we report additional model results, for alternative parameterizations. A much stronger bequest motive ($b$ equal to five) and a lower coefficient of intertemporal substitution ($\sigma$ equal to 0.10) increase retirees' incentives to save. This results in an increase in homeownership rates early on during retirement, but only very modest increases later in life (after age 80). The reason is simple: bequest and precautionary savings motives can be met using financial savings. And late in life financial savings are more adequate for meeting those savings motives.

We have also considered an increase in medical expenditure risk and an increase in the average level of medical expenditures. More precisely we have doubled the standard deviation of innovations to medical expenditures and the average level of medical expenditures. Both lead retirees to remain homeowners for longer, but as before the quantitative effects on homeownership rates late in life are limited. The higher realizations associated with the higher medical expenditure risk and higher average medical expenditures also mean that some retirees need to sell their house to meet them.

The results for an higher expected rate of return on housing are perhaps surprising in that they lead to a decline in homewonership rates. A higher expected rate of return on housing increases the attractiveness of housing as a vehicle for saving. But in equilibrium it also reduces the rental cost of housing which in the absence of a preference for homeownership leads individuals to sell their house sooner.

**Figure A.1: Estimated health status and survival probabilities.** Panel A shows the estimated probabilities of bad health given good health for individuals in permanent income group one, three, and five (Cohort 7). Panel B shows the estimated conditional survival probabilities by health status for individuals in permanent income group one and three (Cohort 7). The data is from the HRS.

Panel A: Estimated health status transition probability




Panel B: Estimated conditional survival probabilities

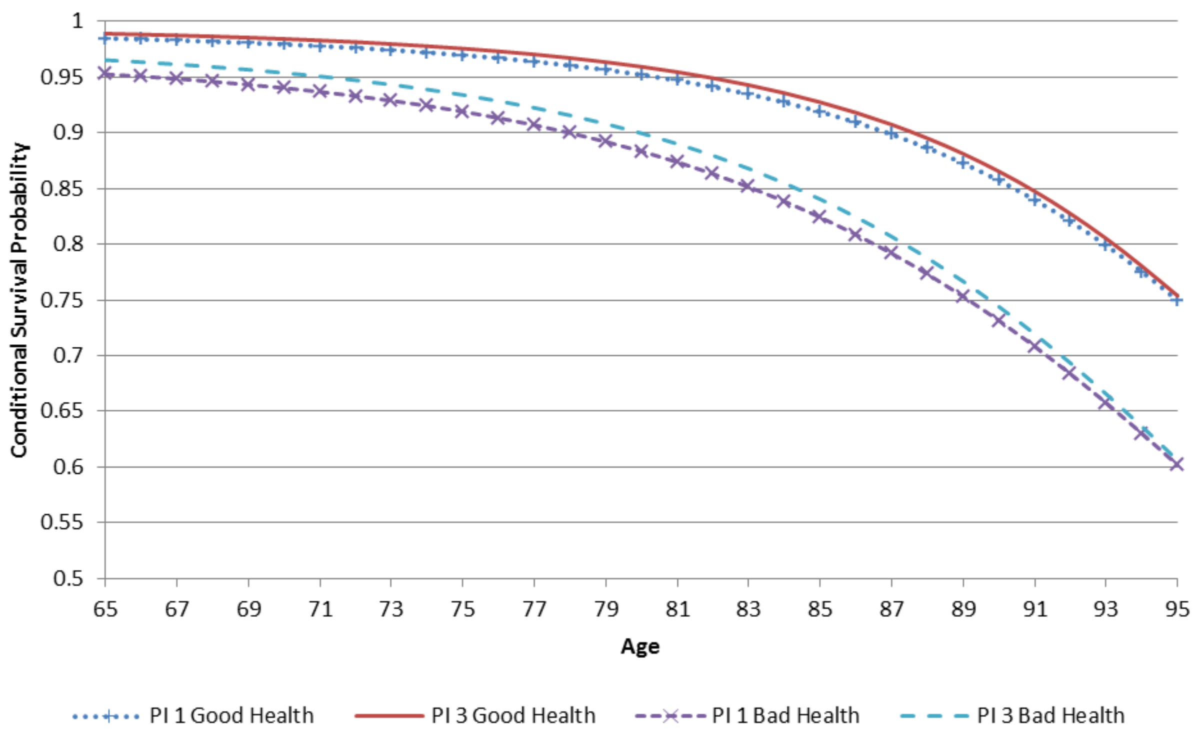


**Figure A.2: Estimated average medical expenditures by age.** This figure shows the estimated average medical expenditures by health status for individuals in permanent income groups one, three, and five (Cohort seven). The data is from the HRS.

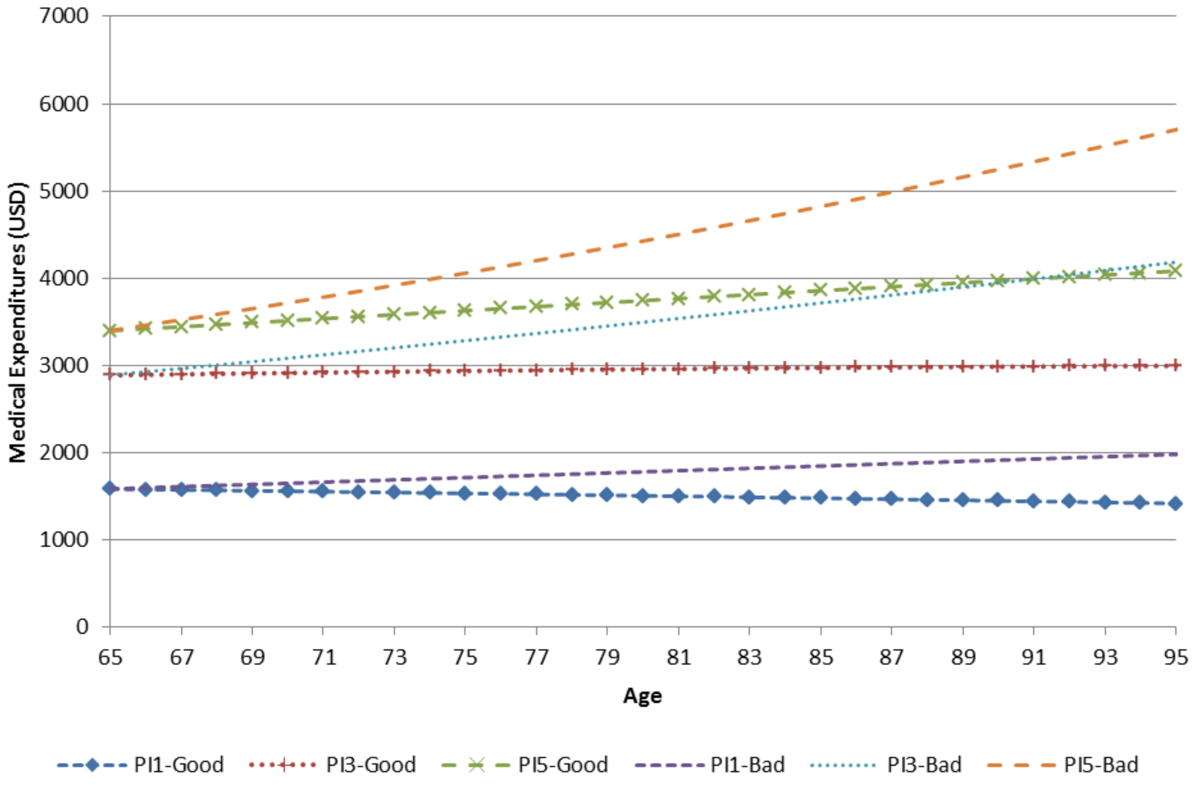
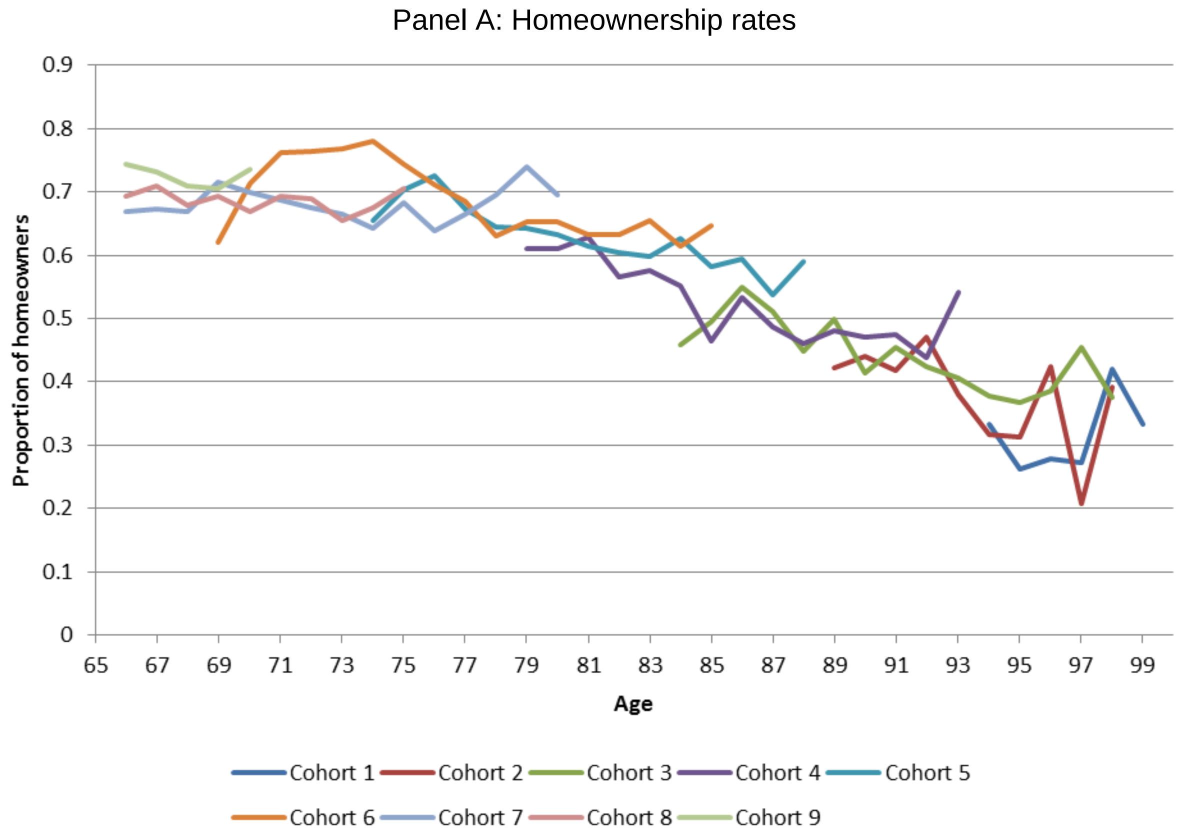
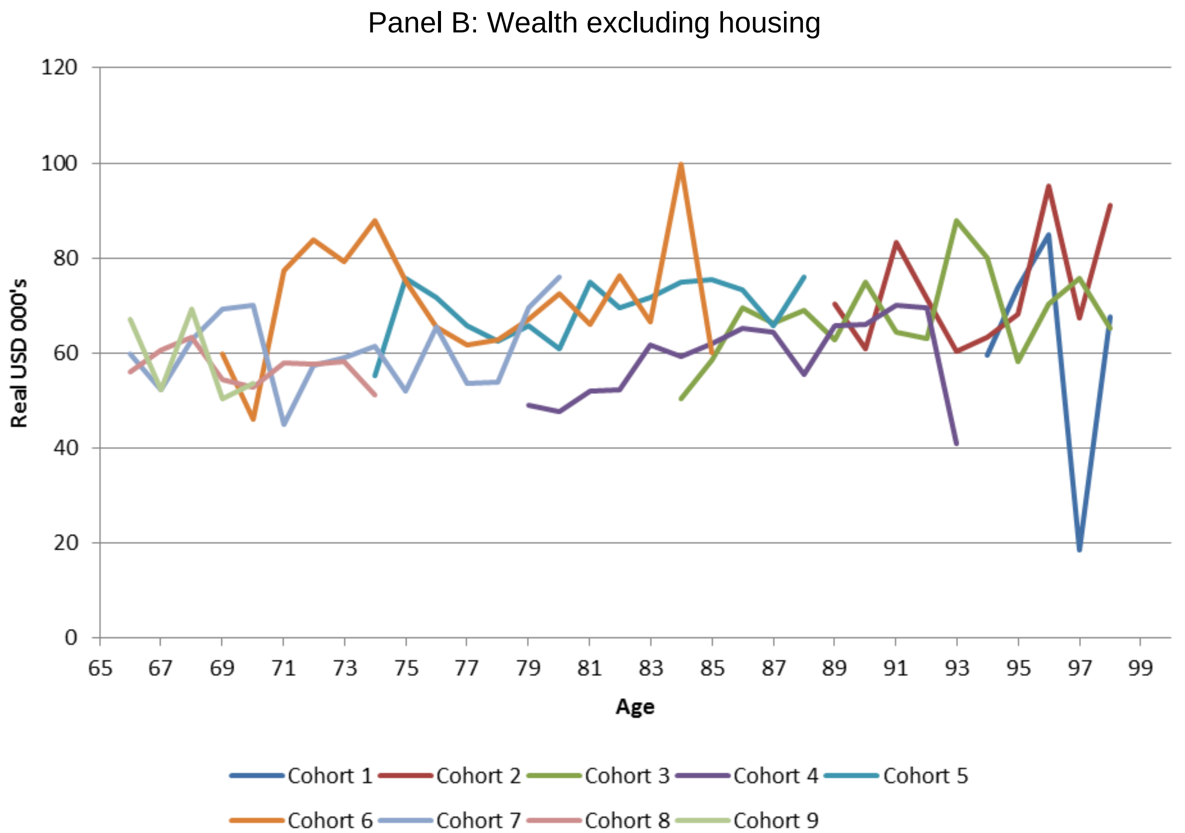


**Figure A.3: Estimated age and cohort fixed effects.** This figure shows the estimated age and cohort fixed effects for homeownership rates, wealth accumulation, both including and excluding housing wealth. The data is from the HRS.



Panel C:  Wealth

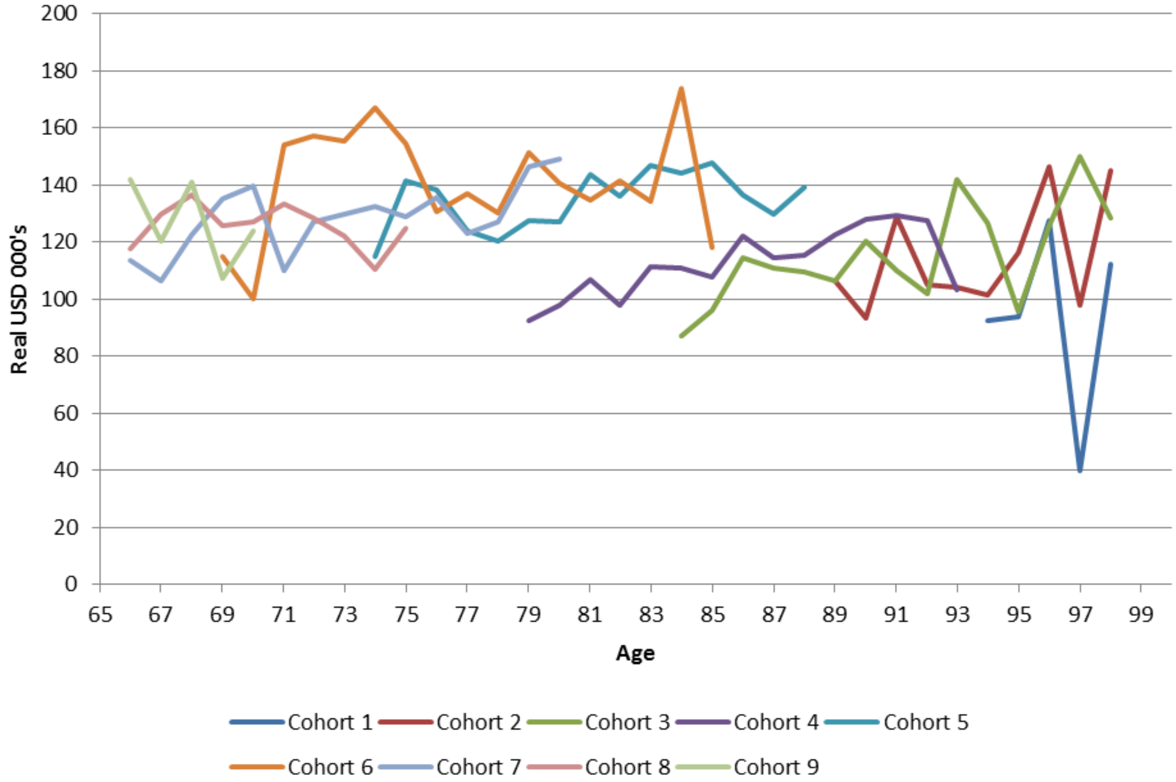


**Figure A.4: Estimated cohort and permanent income dummies.** This figure shows the estimated cohort and permanent income dummies. The data is from the HRS.

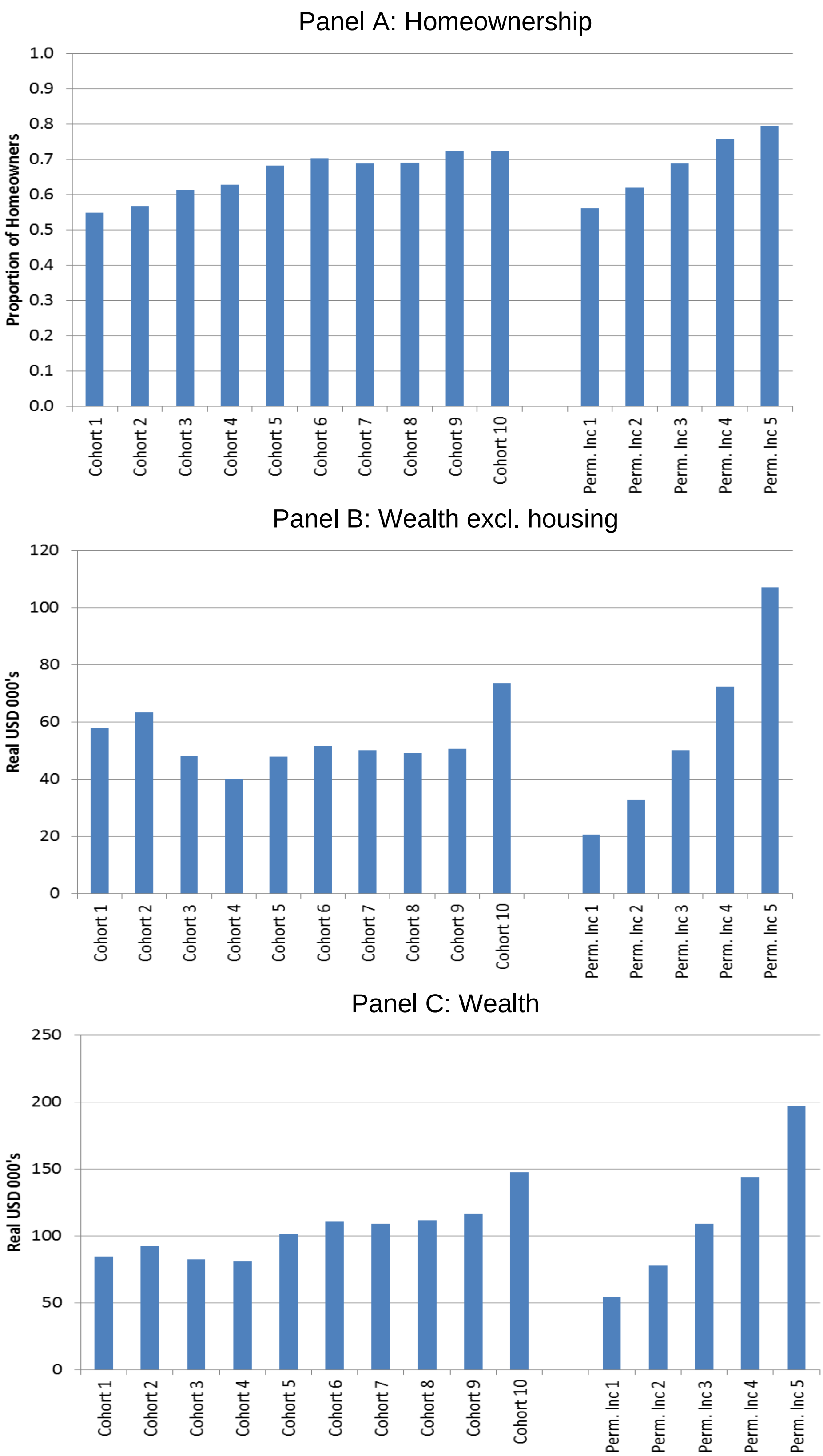
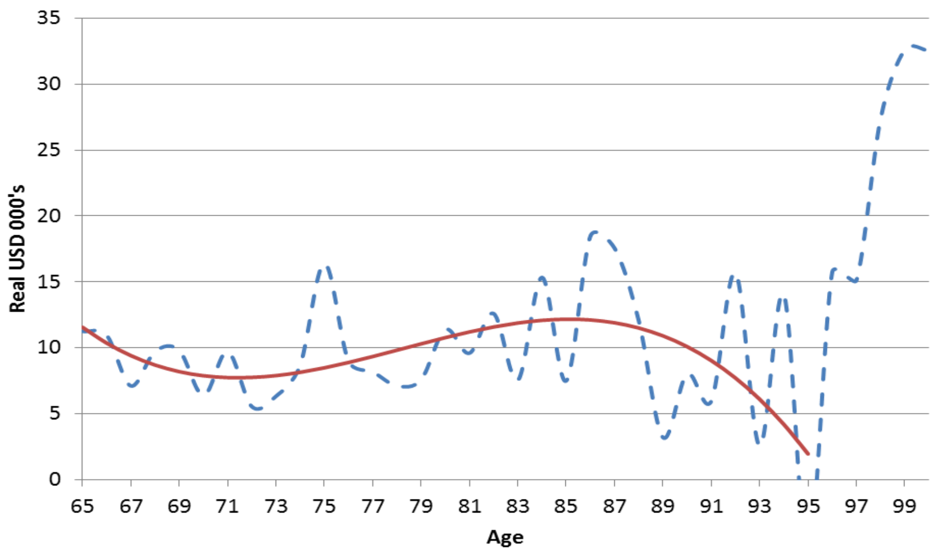


**Figure A.5: Estimated median age profiles, cohort and permanent income fixed effects.** This figure shows the estimated age profiles for median wealth accumulation, both including and excluding housing wealth. The estimation controls for cohort and permanent income fixed effects. The figures plot the median profiles for individuals in cohort 7 and permanent income group 3. The data is from the HRS.

Panel A: Median wealth excluding housing




Panel B: Median wealth

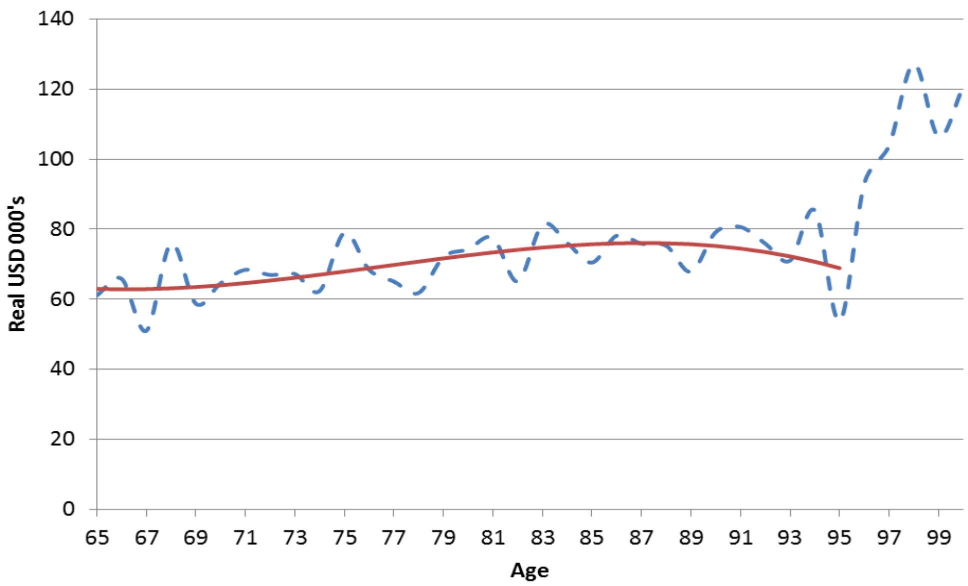


**Figure A.6: Estimated age profiles, individual fixed effects.** This figure shows the estimated age profiles in the HRS data for homeownership rates, wealth accumulation, both including and excluding housing wealth. The estimation controls for individual fixed effects. The data is from the HRS.

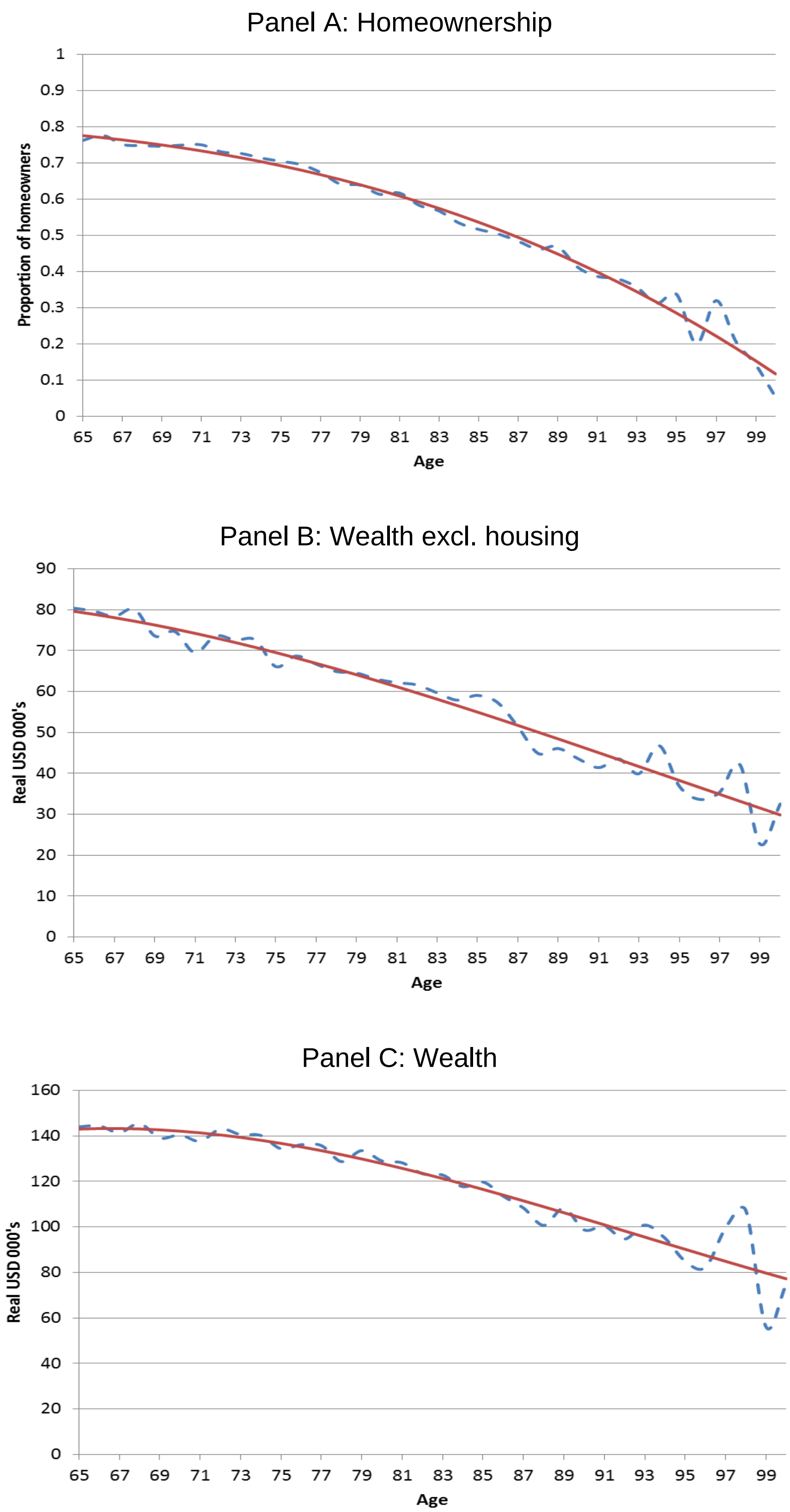


**Table A.I**
**Cohort definition.**

This table reports the birth age for the different cohorts that we consider, their age in 1996 and in 2010, the first and last year in the data, and the number of observations.

| Cohort | Birth years | | Age in 1996 | | Age in 2010 | | N obs |
|---|---|---|---|---|---|---|---|
| 1 | 1900 | 1904 | 96 | 92 | 110 | 106 | 156 |
| 2 | 1905 | 1909 | 91 | 87 | 105 | 101 | 833 |
| 3 | 1910 | 1914 | 86 | 82 | 100 | 96 | 2,215 |
| 4 | 1915 | 1919 | 81 | 77 | 95 | 91 | 3,792 |
| 5 | 1920 | 1924 | 76 | 72 | 90 | 86 | 5,304 |
| 6 | 1925 | 1929 | 71 | 67 | 85 | 81 | 5,009 |
| 7 | 1930 | 1934 | 66 | 62 | 80 | 76 | 5,157 |
| 8 | 1935 | 1939 | 61 | 57 | 75 | 71 | 3,402 |
| 9 | 1940 | 1944 | 56 | 52 | 70 | 66 | 1,246 |
| 10 | 1945 | 1949 | 51 | 47 | 65 | 61 | 53 |

## Table A.II
## Estimated cohort and permanent income dummies.

This table reports the estimated cohort and permanent income dummies for homeownership, mean wealth (including and excluding housing), and median wealth (including and excluding housing). The data is from the HRS.

| Group<br>Cohort and PI | Proportion<br>homeowners | Mean wealth<br>excl. housing | Mean<br>wealth | Median wealth<br>excl. housing | Median<br>wealth |
|---|---|---|---|---|---|
| Cohort 1 | 0.557 | 44864 | 60370 | 54096 | 65501 |
| Cohort 2 | 0.565 | 99628 | 117740 | 59239 | 65887 |
| Cohort 3 | 0.614 | 50512 | 76632 | 15553 | 36204 |
| Cohort 4 | 0.633 | 51600 | 83514 | 9447 | 41623 |
| Cohort 5 | 0.684 | 56734 | 104553 | 11978 | 59232 |
| Cohort 6 | 0.708 | 65410 | 122631 | 13552 | 68349 |
| Cohort 7 | 0.696 | 68738 | 131216 | 6052 | 56245 |
| Cohort 8 | 0.698 | 65132 | 130242 | 4958 | 60390 |
| Cohort 9 | 0.730 | 72166 | 141570 | 4282 | 47292 |
| Cohort 10 | 0.732 | 93941 | 166670 | 19833 | 76684 |
| Perm. Inc 1 | 0.564 | 30517 | 68381 | -7651 | 6762 |
| Perm. Inc 2 | 0.624 | 50896 | 98458 | -6111 | 23934 |
| Perm. Inc 3 | 0.696 | 68738 | 131216 | 6052 | 56245 |
| Perm. Inc 4 | 0.761 | 100490 | 174477 | 33844 | 102747 |
| Perm. Inc 5 | 0.796 | 184780 | 282719 | 94978 | 188428 |

**Table A.III**
**Additional Model Results.**

Panel A (Panel B) reports the homeownership rates (cash-on-hand) predicted by the model at different ages for alternative model parameterizations. For comparison the first row of each panel reports the results from the HRS data (for cohort 7 and permanent income group 3, the group used to parameterize the model). This table reports the results for the model in which retirees do not have access to reverse mortgages.

| Parameter/Age | 70 | 75 | 80 | 85 | 90 |
|---|---|---|---|---|---|
| Panel A: Homeownership rates | | | | | |
| 1. Data cohort and perm. inc. fixed-eff. | 0.70 | 0.68 | 0.65 | 0.61 | 0.56 |
| 2. Baseline model parameters | 0.38 | 0.06 | 0.00 | 0.00 | 0.00 |
| 3. Stronger beq. ($b = 5$) and precaut. ($\sigma = 0.10$) motives | 0.71 | 0.62 | 0.39 | 0.09 | 0.02 |
| 4. Higher expected med. expenditures (x2) | 0.65 | 0.44 | 0.25 | 0.10 | 0.01 |
| 5. Higher risk in med. expenditures (x2) | 0.60 | 0.30 | 0.04 | 0.00 | 0.00 |
| 6. Higher expect. return on housing | 0.29 | 0.04 | 0.00 | 0.00 | 0.00 |
| Panel B: Cash-on-hand | | | | | |
| 1. Data cohort and perm. inc. fixed-eff. | 19.2 | 17.9 | 20.2 | 22.4 | 21.0 |
| 2. Baseline model parameters | 31.5 | 45.6 | 38.5 | 26.2 | 16.8 |
| 3. Stronger beq. ($b = 5$) and precaut. ($\sigma = 0.10$) motives | 25.1 | 24.2 | 34.0 | 47.8 | 47.0 |
| 4. Higher expected med. expenditures (x2) | 25.0 | 31.8 | 35.8 | 35.0 | 28.8 |
| 5. Higher risk in med. expenditures (x2) | 26.0 | 34.5 | 46.6 | 34.0 | 18.0 |
| 6. Higher expect. return on housing | 37.2 | 48.3 | 38.9 | 26.5 | 17.0 |