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. In an attempt to match the data we consider two model features: (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 show that for these retirees reverse mortgages can be beneficial, but the insurance provided by the government agency can induce excessive moral hazard from borrowers and lenders. We use our model to evaluate different mechanisms for limiting moral hazard, and at the same time designing the loans in a way that they can be beneficial to retirees.

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, there recently have been increasing concerns about the sustainability of these (mainly unfunded) social security systems and the adequacy of households' retirement savings (Scholz, Seshadri, and Khitatrakun, 2006).[1] Our paper studies the role of housing wealth for the financing of retirement consumption, with a special focus on the design of the financial products that allow 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 risks

[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).

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, 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 the house. For example, retirees may not value a new kitchen in the same way as potential buyers of the property.[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 poperty. But they have different cash-flow and wealth dynamics implications.

Reverse mortgages allow retired homeowmers 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 monthly loans increased considerably over this period to a maximum of 12,000 just before the onset of the recent financial crisis. In spite of the large increase, the number of loans is relatively small when compared to the number of potential borrowers. Our model resuts show that for retirees who derive

[2] Davidoff (2005) provides evidence that retirees reduce housing maintenance. This could also be due to retiees not having the resources needed to maintain the property and a reduction in maintenance is valued equally by retirees and potential buyers of the property. We also consider this possibility in the model.

benefits from remaining in the same house reverse mortgages can be beneficial, but for the empirically obseved distributions of housing and financial wealth, and the financial terms of reverse mortgages, including both up-front and on-going costs, the model generates limited demand for these products.

In the second part of the paper our focus is more normative. We study the extent to which, going forward, it is optimal for retirees to release their home equity, and which mechanisms and products are better suited for this purpose. In the current context of declining public pensions and private savings, the increase in the value of housing relative to pensions may create an extra incentive for homeowners to withdraw on home equity to finance retirement consumption (see Banks, Blundell, and Tanner, 2000, for an analysis of the retirement savings puzzle). The attitudes of future generations of retirees towards debt may also change, as an increased number of them reach retirement age with outstanding loans.

We use our model to investigate the reverse mortgage characteristics that different retirees value the most. 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 the comparison to the U.K. reverse mortgages available, which do not receive government guarantees is useful. 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, Post, 2014).[3]

The calculation of the present discounted value of the cash-flows received by lenders and by the insurance agency show that there is a risk that the insurance provided by the government induces moral hazard from both borrowers and lenders. We use our model to investigate ways to limit moral hazard, and find that a higher insurance price is a fairly ineffective tool for limiting moral hazard, and may in fact exarcebate the problem. A more effective way to do so is through a reduction in loan limits.

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

[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).

mortgages. Early important contributions include Mayer and Simons (1994) and Caplin (2002). More recent papers are Davidoff (2014) and Hanewald, Post and Sherris (2014). One dimension along which our paper differs from these is in its quantitative focus, of trying to match the patterns observed in the HRS data. In this respect our paper is closer to that of Telyukova and Nakajima (2014). However, we also model explicitly several of the institutional features of reverse mortgage products, the different types of reverse mortgages available, the financial position of lenders and the insurance agency, and use them 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 design 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 Home Equity Conversion Mortgage (HECM) program insured by the Federal Housing Administration (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 up-front 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.

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

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

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. 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 2.5% of house value for initial loan disbursements higher than this threshold.[5] Table II 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. For comparison this table also reports the difference in interest rates between reverse mortgages and standard principal repayment mortgages.[6] 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).[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 Table II (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 II. The limit increases with the borrower's age and it is higher for the lump-sum than for the line of credit product, since the expected loan rate is lower for the former. 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

[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 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. These differences should be interpreted with caution since the products are different in nature.

[7]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.

[8]The mandatory obligations include initial loan costs (and HECM counseling), delinquent Federal debt,

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 and II 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.

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 and 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

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, that is 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 II. In the U.K. there are small variations across lenders in maximum LTV.

[11]The mortgagee letters describing the changes are available at
$http://portal.hud.gov/hudportal/HUD?src=/program_offices/housing/sfh/hecm/hecmml.$

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). This increase was accompanied by a decline in the average age of borrowers from 73.1 in 2008 to 71.9 in 2010.[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 PLFs for fixed-rate lifetime mortgages. This effectively meant that for the lifetime option 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 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 porportion 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 bor-

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).

[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.

rowing 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).

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 modelling 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 β_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 δ, θ is the expenditure share in non-durable consumption, ϵ measures the degree of substitutability between the two goods, and σ is the coefficient of intertemporal substitution.

The remaining preference parameter, ω_t, requires a more detailed explanation. In some 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:

[16] We give details in the parameterization section.

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

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 ℓ of other parameters. Out-of-pocket medical expenditures, $ME(t, Y_t, \ell, h_t)$ are a function of these variables and health status. Medical expenditures are subject to persistent shocks. We follow De Nardi, French and Jones (2010) in choosing their functional forms, and give 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 expected 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 ε_t is a normally distributed white noise shock with mean zero and variance σ_ε^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 rolled over for n periods plus a constant term premium, ξ:

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

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

[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. Koijen, Van Nieuwerburgh, and Yogo (2014) develop risk measures for the universe of health and life insurance products.

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 μ_H is the mean log housing return and η_{t+1} is a shock that is assumed to be i.i.d. and normally distributed with mean zero and variance σ_η^2. We let innovations to house price shocks 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 ψ_{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]

Pension and interest income are taxed at rate τ. 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 τ.

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]

[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. However, the proportion of retired homeowners who hold equities is relatively small.

[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.

To capture the illiquid nature of housing we assume that a house sale is associated with a monetary cost equal to a proportion λ of the current house value. In the baseline model we assume that homeowners must pay annual maintenance and insurance costs and property taxes equal to proportions m_p and τ_p of house value, respectively. But the ability to reduce property maintenance may be important for some retirees. In addition, 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 derive utility from a putting a new kitchen or a new floor in the property. Therefore we will solve alternative versions of our model that differ in the level of housing maintenance. 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 is 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, φ. For a house of size H_t it is given by:

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

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 three parameters (l_j, f_j, ψ_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, ψ_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 ($R_{1t} + \psi_F$). 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, if 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 and if there is positive home equity they benefit/suffer from any increases/decreases in the value of their house. 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 initial fees paid to third-parties l^{TP}_j (property appraisers, initial

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

mortgage insurance premium paid to the government agency):

$$CF^L_{j,t_0} = -D^C_{j,t_0} - l^{TP}_j. \tag{9}$$

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

$$CF^L_{j,t} = -D^C_{j,t} - \psi^{MIP}_j D^S_{j,t}, \tag{10}$$

where ψ^{MIP}_j denotes the mortgage insurance premium payable to the government agency. At loan termination the cash-flows received by lenders are equal to debt outstanding:

$$CF^L_{j,t'} = D^S_{j,t'}. \tag{11}$$

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

$$CF^A_{j,t'} = MIN[0, (1-\lambda)P^H_{t'}\overline{H} - D^S_{t'}]. \tag{12}$$

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 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.[21] 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. They assume that house prices are correlated with aggregate permanent income, that the latter is equal to aggregate consumption, which together with the assumption of power utility preferences for the representative agent allow the derivation of risk-adjusted discount rates. This results in a discount rate that is higher for cash-flows that occur when house prices are higher.

[21] 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.

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_{jt}^C, and the additional state variables are the type of mortgage chosen and the level of outstanding debt D_{jt}^S. In appendix A 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. We also describe the asset deaccumulation profiles that we estimate, to which we will compare the model results. In the appendix B we give more detailed information.

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 Health and Retirement Study (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 III reports mean and median retirement income for each of these groups for all cohorts (Panel A), for a specific cohort (those born between 1930 and 1934, Panel B), and for this same cohort but conditional on homeownership at age 65. 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 III 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 III 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 III. The proportion of individuals who report fair or poor health declines with permanent income and it is smaller among homeowners.[22] 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 also use a logistic function and the same explanatory variables to estimate survival probabilities. We give details in appendix B.

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 B 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 shocks and they are persistent.

Preferences, asset returns, and other parameters

We use several estimates available in the literature to parameterize the baseline preference parameters (reported in Table IV, we give further details in appendix B). But we recognize that retirees are heterogeneous in their preferences and we will consider alternative values. The values for the user cost of housing, property taxes and property maintenance are from Himmelberg, Mayer, Sinai (2005). We set the tax rate τ to 0.20. The consumption floor is

[22] 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).

from De Nardi et al. (2010). The transaction costs of a house sale are equal to 0.06.

In the last panel of Table IV 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. metropolotitan area 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 0.09.

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 ages 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 decline in 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 B 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.[23]

[23] In the appendix we also 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.

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 plot the model results in Figure 4. Panel A shows the results for homeownership rates and panel B for cash-on-hand. In each of these panels, the lines with markers plot the estimated age patterns in the HRS data, against which we compare the simulated data. We solve the model assuming that individuals start as homeowners, but for easier comparison we re-scale the proportion of homeowners at age 65 to the value estimated in the data. The solid line (without markers) plots the results for the model. The model baseline parameters generate high rates of homeownership in the first few years of retirement, but these rates decline very rapidly from age 70 onwards. It is instructive to briefly consider what triggers a house sale in the model. In Table V we compare the values of several variables, for homewoners who decide to sell their house to those who decide to remain homeowners. Those who decide to sell 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. These variables are in part related to age, which also appears as an important determinant of the decision to sell.

Figure 4 clearly shows that the age decline in homeownership rate predicted by the baseline parameterization of the model is 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. To evaluate this possibility, in Figure 4 we report the results for different values of 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 b, that generate a substantial bequest, retirees in the model decide to sell their house much earlier than in the data. A simple way to generate higher homeownership rates in the model would be 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 Figure 4.

We have investigated the effects of other model parameters, including a stronger precautionary savings motive (a lower value for σ), higher or more uncertain medical expenditures, also in combination with a bequest motive. 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 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.

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. 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 derive no 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. Figure 5 shows that the impact on homeownership rates of this maintenance experiment is similar in magnitude to the impact of setting parameter ω equal to 2.

The second is based on the value of parameter ω. 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 Figure 5 we report results for values of ω of two and three. These values go a long way in generating high homeownership rates late in life.

These two alternative 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.

It is also possible to generate high homeownership rates until later in life through changes to a combination of the baseline parameters (Figure 6). In this figure we report results for combinations of a higher value for the bequest motive, a lower value for the coefficient of intertemporal substitution (corresponding to a stronger precautionary savings motive), a higher value for the preference for homeownership parameter, or lower maintenance expenses. Importantly, this figure shows that strong bequest and precautionary savings motives without a larger value for ω still have difficulty in generating high homeownership rates late in life.

5.2 Line of credit reverse mortgages

We now introduce reverse mortgages in the model. We are particularly interested in evaluating the benefits of such mortgages for different individuals. We proceed in two steps. First we assume that mortgage loans are taken out at age 65 and then solve for the retirees' optimal decisions model. In a second step we compare retirees welfare with and without reverse mortgages.

The model generated age profiles are plotted in Figure 7. In this figure we plot the results for the cases of a higher rental premium (equal to 0.03) and for when there is a preference for remaining homeowner ($\omega = 2$), two of the parameterizations for which retirees borrow more using reverse mortgages (in Table VI we report results for other parameterizations). In Panel A we plot the results for homewonership rates. Comparing the results to those for the model without reverse mortgages, we see that homeownership rates start declining only later in life, and that they decline more slowly. This is explained by the fact that now retirees do not need to sell their house to tap into their home equity. Another noticeable difference relative to the model without reverse mortgages is that homeownership rates remain positive until late in life, even though in the parameterizations considered in Figure 7 retirees do not have a bequest motive. The reason is that for some of the retirees who remain alive until a later age the accumulation of outstanding debt combined with house price declines leads them into a situation of negative equity. The optimal response is to remain homeowner and let outstanding debt accumulate further.

Panel B of Figure 7 plots the average age profiles for cash-on-hand and additional amount borrowed. The latter variable is calculated as an average across those individuals for whom the mortgage loan is still outstanding. Loans are terminated when the retiree decides to sell the house or when he/she dies. Figure 7 shows that most borrowing takes place from age 70 onwards, which is precisely the age at which individuals in the model without reverse mortgages start selling their house. Thus borrowing acts as a substitute for an earlier house sale. And as a result, the cash-on-hand age profile for the model with reverse mortgages is flatter and peaks at a lower maximum than the profile for the model without reverse mortgages.

Table VI reports the above model results is a tabular format, also for other model parameterizations, including the baseline parameterization, a bequest motive ($b = 2$), a stronger precautionary savings motive ($\sigma = 0.125$), and combinations of these parameter values. As expected, a stronger bequest motive ($b = 2$) leads retirees to start borrowing only later in life, and to borrow smaller amounts.

The results reported in Table VI are conditional on retirees taking out a loan. But do they want to do so? In other words, are they better off taking out a reverse mortgage? To answer this question we calculate the welfare gains of reverse mortgages using an equivalent wealth measure, equal to the difference in initial cash-on-hand that makes the retiree indifferent between taking out or not the loan. These welfare gains are reported in the last row of Table VI, as a percentage of the retiree's initial wealth.[24] A negative value means that retirees are worse off with a reverse mortgage than without it.

Line of credit reverse mortgages are welfare improving when there is a higher cost of rental accommodation or when retirees have a preference for remaining in the house in which they retired in (higher ω). However, as expected, stronger incentives to save, either a bequest motive or a higher precautionary savings motive, reduce the benefits of reverse mortgages.

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 same initial conditions and parameter values as for the line of credit reverse mortgages, including the same principal limit factor of 0.541. Among all the parameterizations considered, we found positive welfare gains of lump-sum mortgages only for the case of $\omega = 2$ equal to 24.6 percent of initial wealth (relative to the no mortgage scenario). The comparison of the evolution of cash-on-hand and homeownership rates to the case of line of credit mortgages help us to understand why. Figure 8 shows with lump-sum mortgages cash-on-hand initially increases, as the loan is drawn, and that this cash is used throughout the retiree's lifetime.

[24] The welfare results depend on the value of several of the initial model conditions. We report welfare gains for the initial level of cash-on-hand, low interest rates, good health, and low medical expenditures.

Since there is a spread between the savings rate and the loan rate this is costly. However, there is also a benefit, as retirees are likely to remain homeowners until later in life. As debt outstanding is on average higher, retirees incentives to sell the house and move to rental accommodation are reduced.

Even though lump-sum reverse mortgages are welfare enhancing for the case of ω equal to 2, their welfare benefits are lower than those of line of credit mortgages. Thus, the model parameterizations considered so far have difficulty in generating any 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 would be needed to generate such demand.[25] From the retirees' side lower initial cash-on-hand or the need for a significant amount of cash would increase the benefits of drawing down the whole loan amount up front. We should also consider the case of pre-existing principal repayment debt that could be amortized using the proceeds from the lump-sum loan. But there may also be supply factors at work, which we discuss in the next section.

5.4 Cash-flows of lenders and the insurance agency

We use our model to calculate the present discounted value of the cash-flows received by lenders and by the insurance agency. Table VII reports such present values using two different discount rates, bond yields and a risk-adjusted discount rate. In this table we focus on the parameterizations that are welfare enhancing for retirees. 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.

Table VII includes several interesting results. The expected present discounted values of the cash-flows of the insurance agency are negative for all the cases considered, so that the price of the insurance is too low. They 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 ω is equal to 2.

In contrast, the expected present discounted values of the cash-flows of lenders are always positive and large.[26] Lenders gain more from loans with large amounts outstanding, especially for the case of ω equal to 2 and of a lump-sum loan. This may incentivize them

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

[26] These present values should not be interpreted as being equal to the profits of lenders since we have not subtracted the costs of servicing the loans.

to try to sell these products to retirees. The added risk is borne by the insurance agency. To better understand the nature of these risks in Figure 9 we plot the whole distribution of the present discounted value of the cash-flows of the insurance agency and of lenders, for ω 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.

6 Product Design

The model provides a framework to evaluate the features of reverse mortgages that retirees value the most, which can help to improve the design of such products. It is particularly important that the insurance provided by the government agency does not induce excessive moral hazard behavior on the part of borrowers or of loan providers. The calculations in Table VII point towards that possibility since the present value of the cash-flows of lenders is much higher for the case of a lump-sum loan than for the case of a line of credit mortgage, which may incentivize lenders to sell such products. Furthermore, the present value of the cash-flows of the insurance agency are negative for all cases considered, so that the price of the insurance is too low and debt is subsidized.

In order to reduce the moral hazard that may result from debt subsidies, one might naturally consider an increase in the annual insurance premium that must be paid to the government agency. In the first panel of Table VIII we consider the effects of such increase, while maintaining the loan limit at 0.541 of house value. Recall that in the base case the premium is 0.0125 per year, both for the line of credit and the lump-sum mortgage. We focus on the latter since the expected present discounted value of the future cash-flows for the insurance agency are more negative.

Perhaps surprisingly, as we increase the annual insurance premium the expected present risk-adjusted discounted value of the cash-flows of the insurance agency become more negative, and equal to -14.7 when the annual insurance premium is equal to 0.02, and to -17.5 when it is equal to 0.03. On the other hand, the risk-adjusted present discounted value of the cash-flows of lenders increases as we increase the insurance premium. The economic intuition for this result is simple. A higher insurance premium benefits the agency in periods before loan termination. However, it also means that the outstanding loan amount will be higher at each point in time, which benefits lenders since they receive a premium of 0.025 on outstanding loan balances, and it also makes it much more likely that at loan termination outstanding loan balances will be higher than house values. These results mean that increases in loan insurance premia without reductions in loan limits are likely to simply end up benefiting lenders, and make the agency and retirees worse off.

The second panel of Table VIII analyzes the effects of reducing the borrowing limit, while maintaining the annual insurance premium at the base value of 1.25 percent. A reduction in this limit increases the expected payoff to the insurance agency, and reduces the expected payoff for lenders and the welfare benefits for retirees. For a principal limit factor of 0.35 this product is beneficial for all involved. Thus the results in Table VIII show that the loan limit is a more effective tool in preventing moral hazard than the annual insurance premium.

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 that allow households to tap into their home equity without selling their house has been limited. Several possible explanations have been proposed, including a bequest motive and precautionary savings motive arising from uncertain medical expenditures. While these are plausible explanations, their general validity is still not well understood.

This is in part due to the complexity of the decisions that retirees must make, made more difficult by the many risks that face. They include 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 this question, we have proposed a model of retirees' consumption and homeonwership decisions that incorporates the above risks and psychological considerations. Our focus is quantitative so that we use HRS data to parameterize the model. Our analysis takes into account differences in pension income and financial wealth for individuals in different cohorts and permanent income groups. We evaluate our model's ability to explain the homeownership and wealth deaccumulation patterns observed in the data.

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. This is mainly for two reasons. First, financial wealth can also be used to satisfy a bequest or a precautionary savings motive. Second, 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.

The model is more successful at matching the homeownership rates observed in the data if retirees derive utility from remaining in the same house where they have retired or if they value property maintenance less than potential buyers of the property, so that a reduction in maintenance expenses has a larger effect on the property price than on the utility that retirees derive from the house. For such retirees the benefits of reverse mortgages can be substantial. However, the calculation of the present discounted value of the cash-flows received by lenders and by the insurance agency show that there is a risk that the insurance provided by the government induces moral hazard from both borrowers and lenders.

We have used our model to investigate ways to limit the moral hazard, by analyzing different features of reverse mortgages, how they are valued by retirees, including the trade-off between initial fixed costs and ongoing costs, between insurance price and loan limit. This analysis has shown that a higher insurance price, without additional restrictions on loan limits, is a fairly ineffective tool for limiting moral hazard.

In the future, we plan to investigate further how different features of reverse mortgage products might benefit retirees. For instance, line of credit 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. In addition we plan to use our model to obtain estimates of the benefits of reverse mortgages in an environment characterized by lower pensions and financial savings, and higher house prices relative to retirement income.

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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.

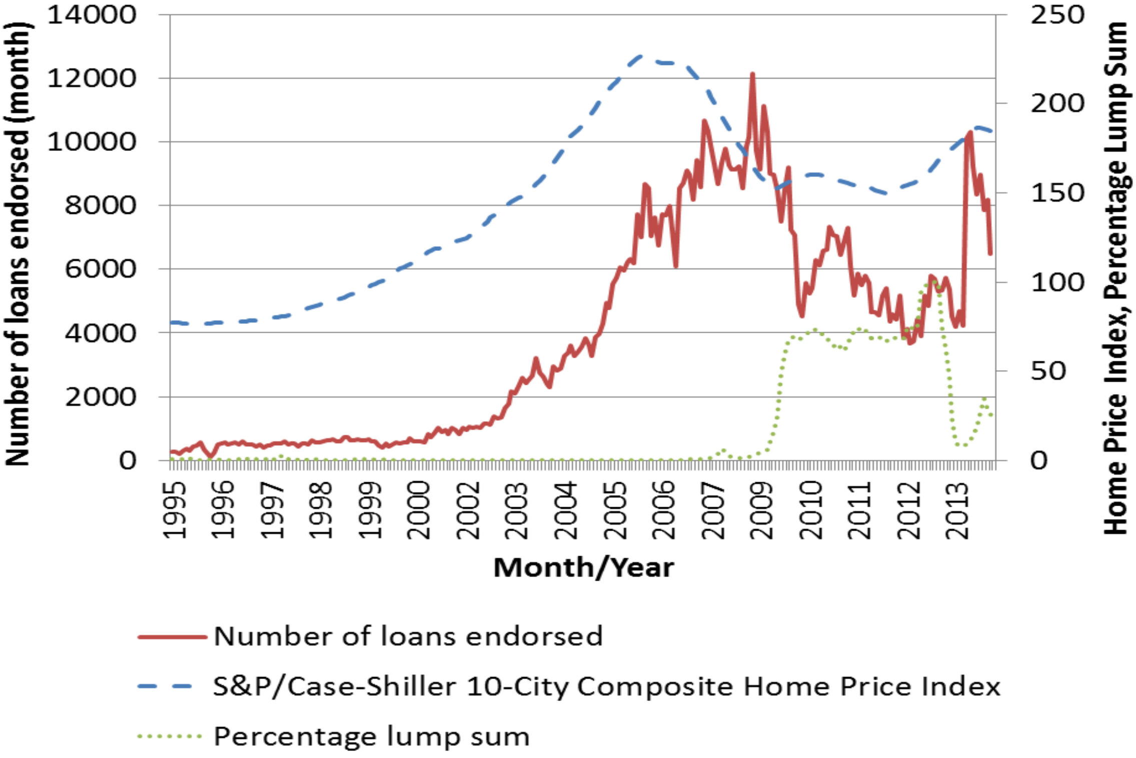

Figure 2. Principal factors or borrowing limits as proportion of assessed house value for different reverse mortgage types as a function of the age of the borrower. The borrowing limits are for the loan interest rates reported in Table II.

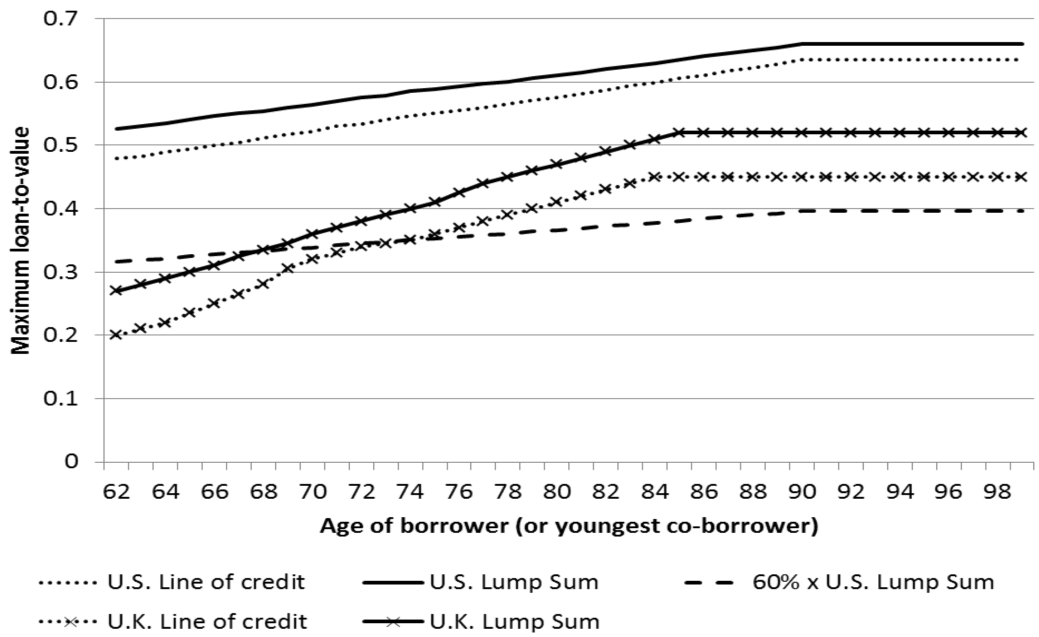

Figure 3. Estimated age profiles. This figure plots the estimated age profiles in the HRS data for homeownership rates, wealth accumulation, both including and excluding housing wealth. The estimation controls for cohort and permanent income fixed effects. The figures plot the average profiles for individuals 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

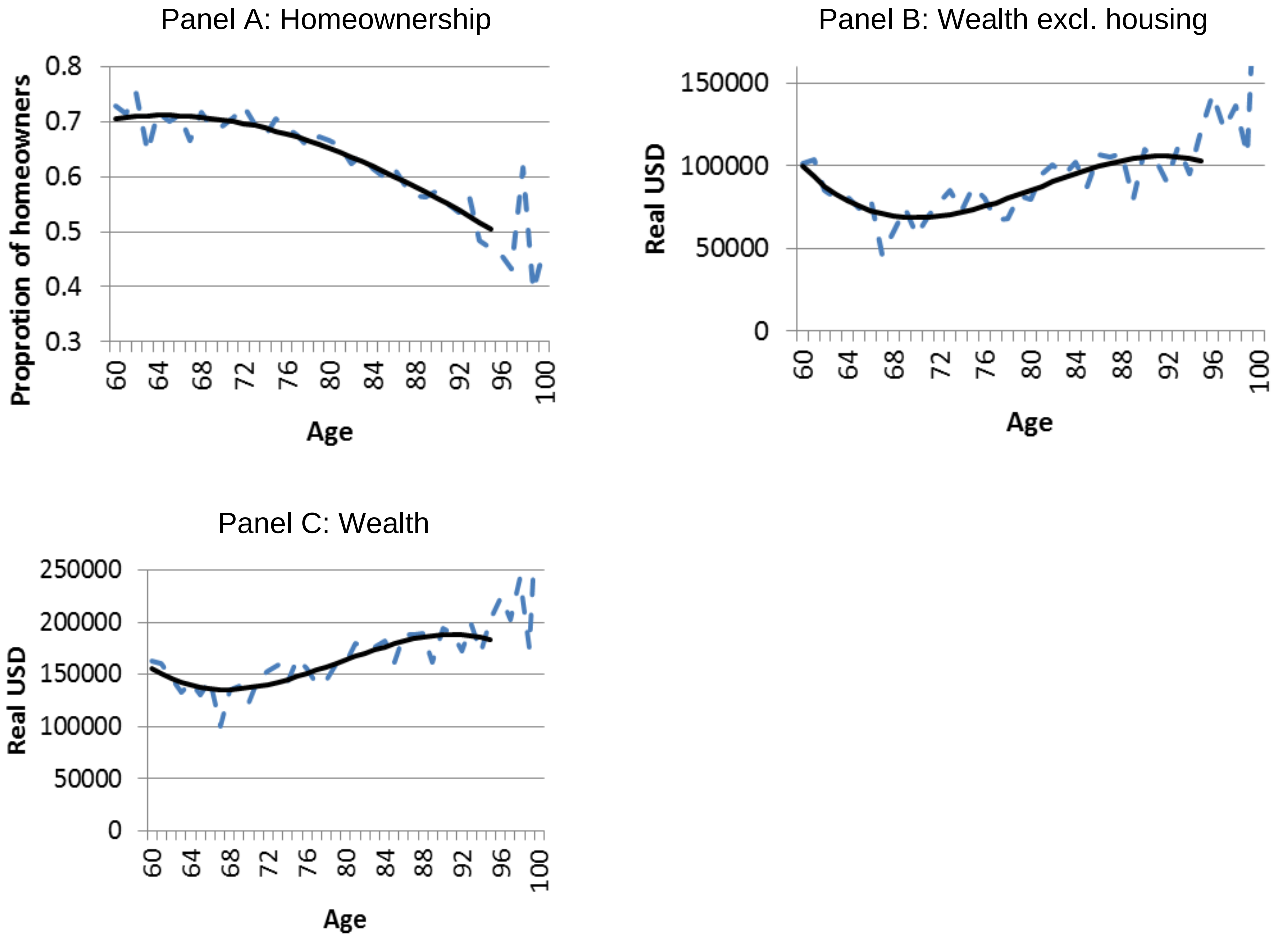

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Figure 4. Model results. This figure plots the age profiles for homeownership rates predicted by the baseline parameterization of the model, when a bequest motive is present (b=1 and b=5) and for a higher rental premium equal to 3%. Panel B plots cash-on-hand. For comparison the figure also plots the estimated age profiles in the HRS data.

Panel A: Homeownership rates

Panel B: Cash-on-hand

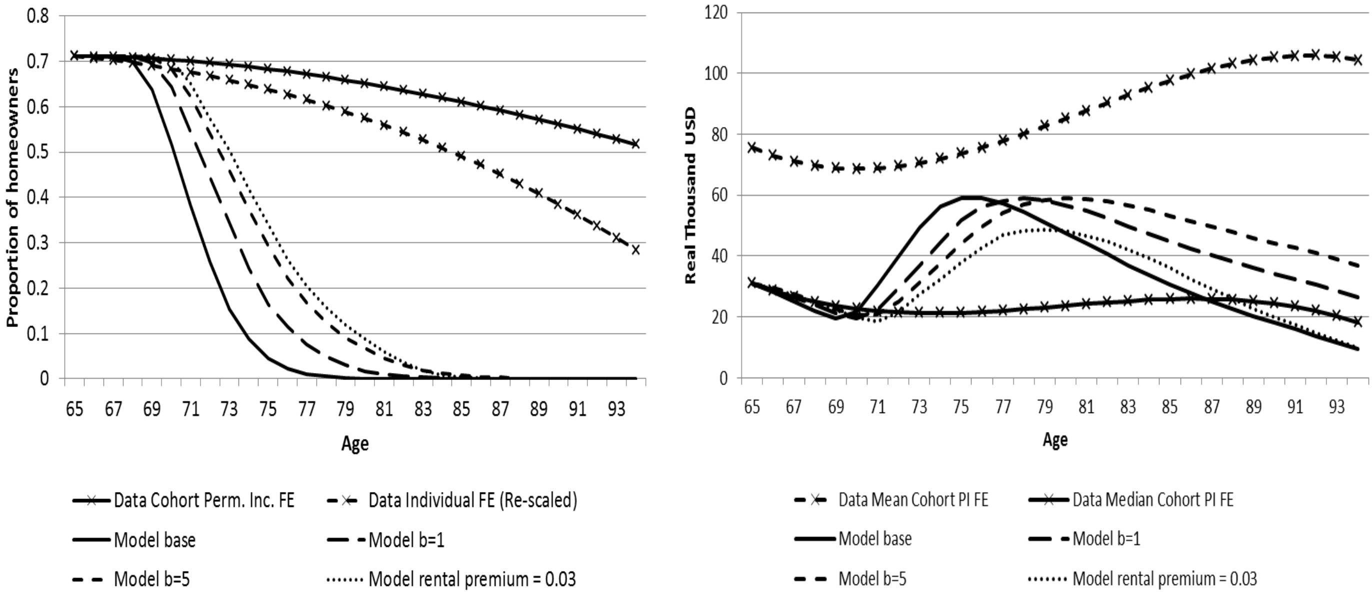


Figure 5. Model results for preference for homeownership and zero maintenance. This figure plots the age profiles for homeownership rates predicted by the baseline parameterization of the model, for when the retiree has a preference for homeownership (for both ω=2 and ω=3) and for zero maintenance. Panel B plots cash-on-hand. For comparison the figure also plots the estimated age profiles in the HRS data.

Panel A: Homeownership rates

Panel B: Cash-on-hand

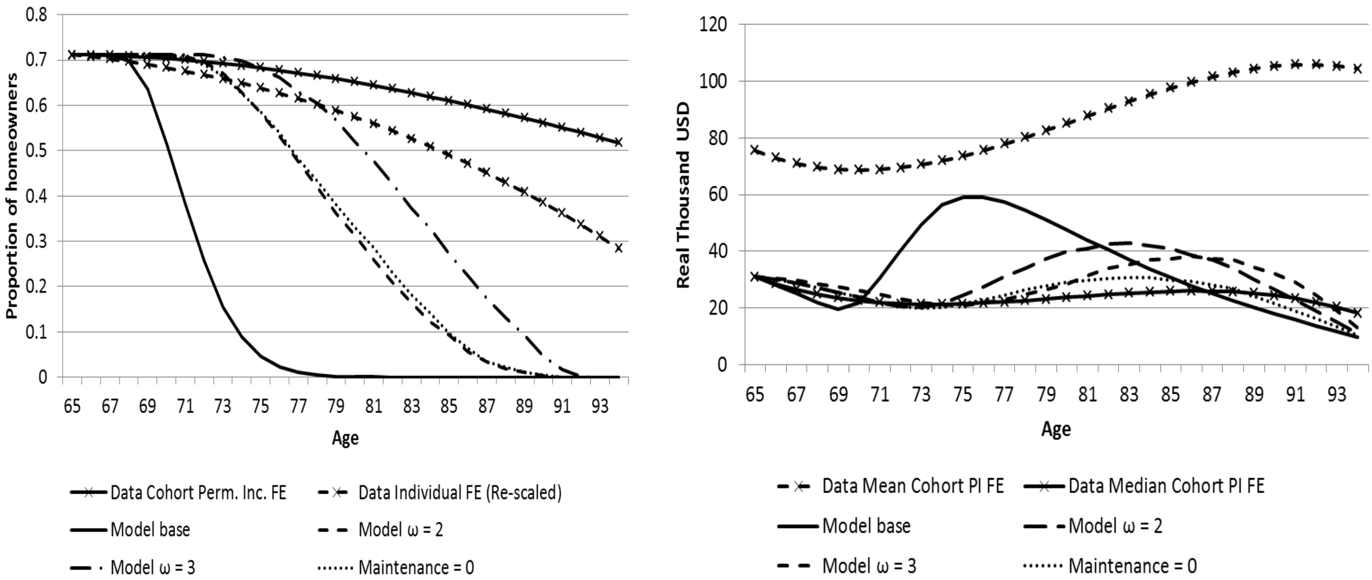
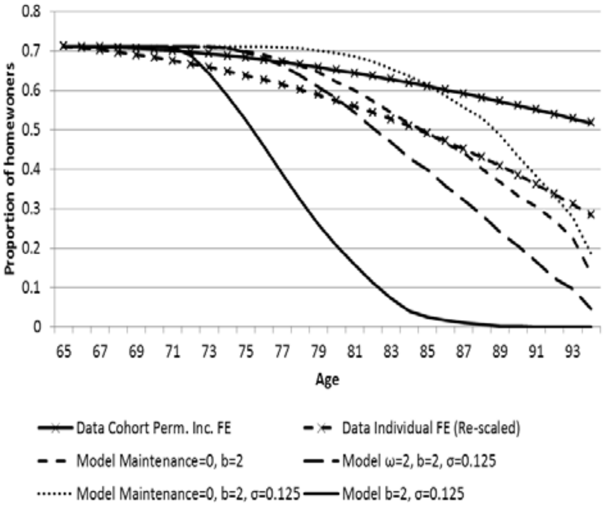


Figure 6. Model results for different parameter combinations. This figure plots the age profiles for homeownership rates predicted by different model parameterizations, when there is a preference for homeownership (ω=2), zero maintenance, a bequest motive (b=2) and a stronger precautionary savings motive (σ=0.125). Panel B plots cash-on-hand. For comparison the figure also plots the estimated age profiles in the HRS data.

Panel A: Homeownership rates



Panel B: Cash-on-hand

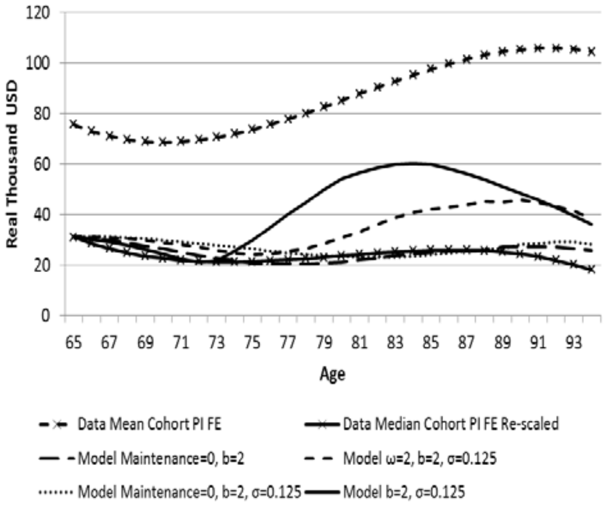
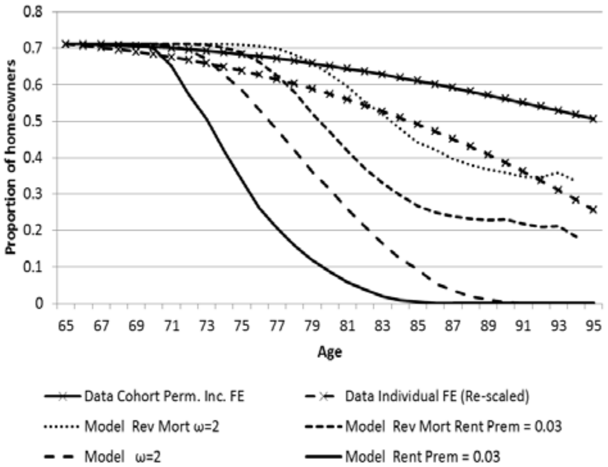


Figure 7. Model results for line of credit reverse mortgages. This figure plots the age profiles for homeownership rates predicted by different model parameterizations for the model with line of credit reverse mortgages, when there is a preference for homeownership (ω=2) and a higher rental premium (rental premium =0.03). For comparison the figure also plots the estimated age profiles in the HRS data. Panel B plots average cash-on-hand and amount borrowed.

Panel A: Homeownership rates



Panel B: Cash-on-hand and debt drawn

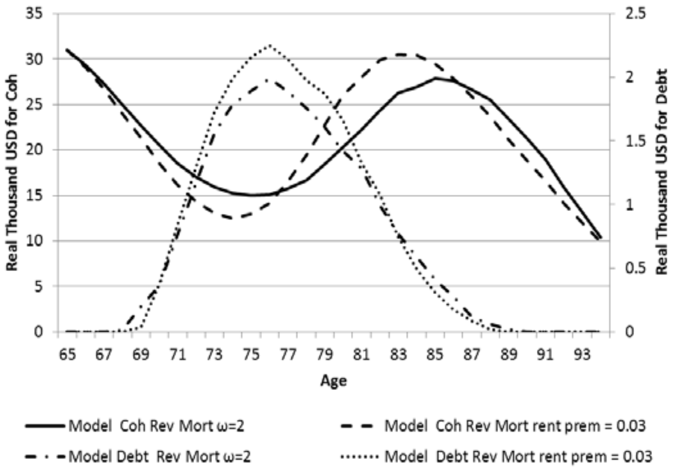


Figure 8. Model results for lump-sum mortgages. This figure plots the age profiles for homeownership rates and cash-on-hand for the model with lump-sum reverse mortgages, when there is a preference for homeownership (ω=2). For comparison the figure also plots the profiles for the model with line of credit mortgages.

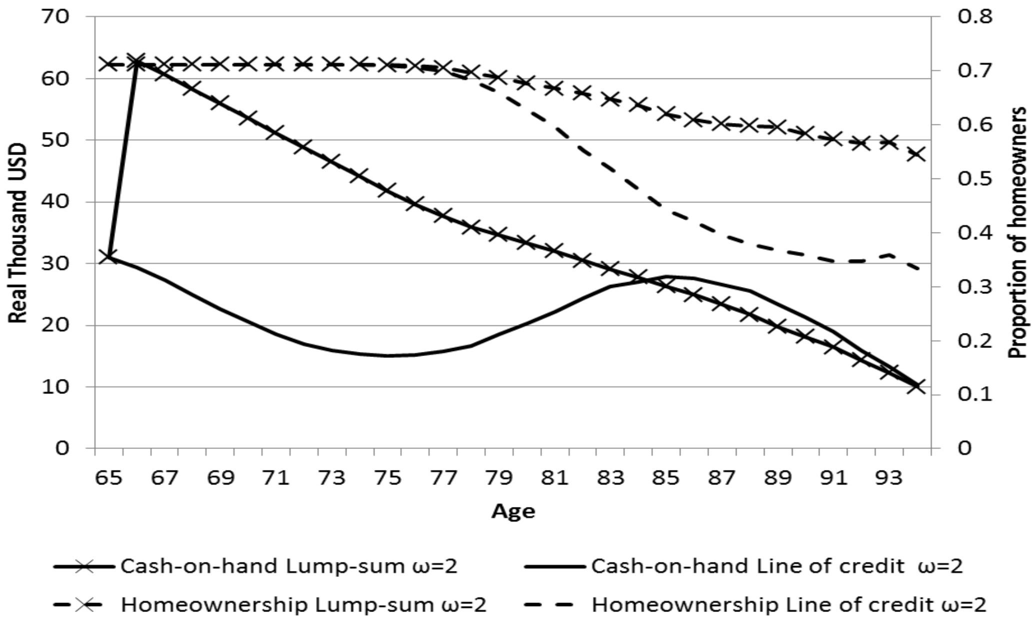


Figure 9. Distribution of present value of risk-adjusted cash-flows for line of credit and lump-sum reverse mortgages, for lenders and the insurance agency. This figure plots the distribution for initial low interest rates and when there is a preference for homeownership (ω=2).

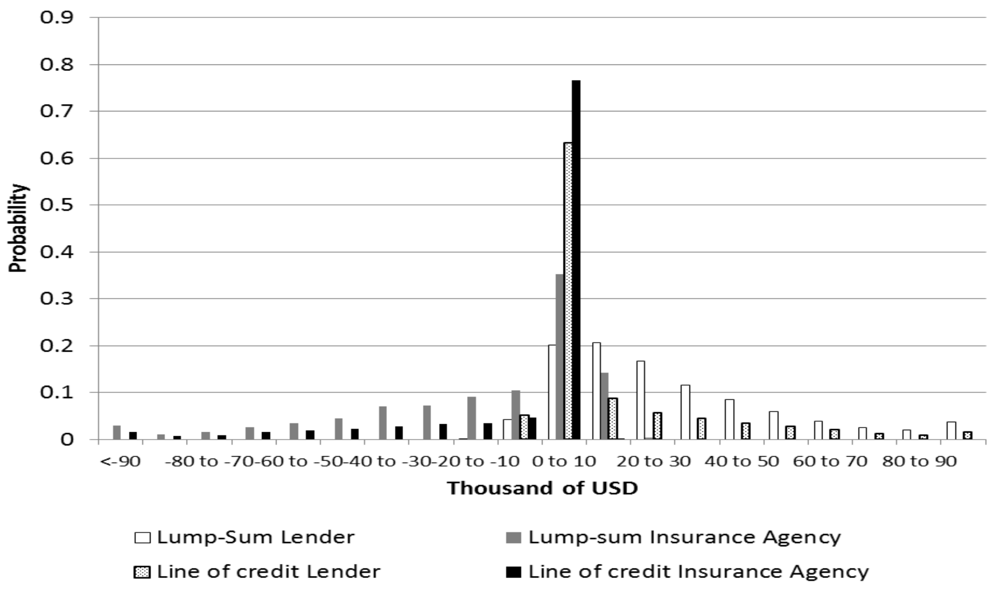


Table I
Initial reverse mortgage costs

This table 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.

	United States		United Kingdom
Description	Initial Amt $\leq$ 60% of Max	Initial Amt $>$ 60% of Max	(in U.S. Dollars)
Loan origination fees	1500	1500	925
Mort ins (House val=70k)	350	1750	
Other closing costs	2000	2000	964
Total	3850	5250	1889

Table II
Interest rates on reverse mortgages

This table reports interest rate on reverse mortgages in the U.S. and the U.K. and its components, for the line of credit and lump-sum alternatives. The table also reports the interest rate difference relative to the standard principal repayment mortgage. For ths U.S. these are the standard 1-year ARM and 10-year FRM, respectively. For the U.K. they are the standard variable rate mortgage and 5-year FRM. The data refers to April 2014.

	United States		United Kingdom	
Description	Line of credit	Lump-sum	Line of credit	Lump-sum
Int rate index: 1-month LIBOR	0.0016			
Lender's margin	0.0250			
Loan rate	0.0266	0.0506	0.0619	0.0739
Mortgage insurance	0.0125	0.0125		
Initial total loan rate	0.0391	0.0631	0.0619	0.0739
Diff to standard mortgage rate	0.0147	0.0198	0.0338	0.0370
HECM expected loan rate	0.0535	0.0506		

Table III
Permanent income and assets in the HRS data.

This table reports permanent income, wealth excluding housing, housing wealth, homeownership rates, and health status for individuals in the HRS data at age 65. The first panel reports data for individuals in all cohorts, the second panel for individuals born between 1930 and 1934, and the third panel for individuals born between 1930 and 1934 conditional on homeownership and the last panel for individuals in all cohorts conditional on homeownership.

Panel A: All cohorts at age 65									
	Permanent income		Wealth excl. house		Housing wealth		Homeownership		Health
Group	Mean	Median	Mean	Median	Mean	Median	Mean	Median	Bad
1	5465	5917	51562	1507	38699	0	0.51	1	0.49
2	8818	8714	54310	5102	45363	7475	0.59	1	0.31
3	11786	11836	82170	17846	73320	43316	0.72	1	0.22
4	15749	15608	122586	23102	79977	60284	0.81	1	0.22
5	27793	25412	142639	55829	103244	74754	0.89	1	0.19
Panel B: 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 C: 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
Panel D: All cohorts at age 65, conditional on homeownership									
	Permanent income		Wealth excl. house		Housing wealth				Health
Group	Mean	Median	Mean	Median	Mean	Median			Bad
1	5315	5775	91329	6738	76547	47968			0.43
2	8736	8561	84478	11025	77309	50113			0.31
3	11869	11914	105375	31000	101381	72193			0.19
4	15827	15619	128094	34193	98694	82532			0.19
5	28010	25575	154497	62656	115963	84810			0.18

Table IV
Baseline Parameters.

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

Description	Parameter	Value
Preference parameters		
Discount factor	β	0.97
Non-durable cons exp. share	θ_C	0.80
Housing expenditure share	θ_H	0.20
Utility from good health	δ	-0.36
Elasticity of substitution	ϵ	1.25
Coefficient of intertemporal subs.	σ	0.27
Preference for homeownership	ω	1.0
Bequest motive	b	0
Tax rates and other parameters		
Income tax rate	τ	0.20
Property tax rate	τ_p	0.015
Property maintenance	m_p	0.025
Rental premium	φ	0.010
Lower bound on consumption	$\underline{C}$	\$2,630
Transaction costs of house sale	λ	0.06
Asset returns		
Mean log real rate	μ_r	0.012
Stdev of the real rate	σ_r	0.018
Log real rate AR(1) coefficient	ϕ_r	0.825
Term premium	ξ	0.005
Mean log real house price growth	μ_H	0.002
Stdev house price return	σ_η	0.10

Table V
Means for several variables by homeownership decision.

This table reports the means for several variables depending on the retiree decides to remain homeowner or to sell the house. The statistics are calculated using simulated data with the baseline model parameterization.

Variable	Sell house	Remain homeowner
Age	71.84	68.18
Consumption	7.87	8.41
Previous period cons.	8.15	8.44
Cash-on-hand	9.42	11.59
Medical expenditures	2.89	1.15
Previous period med. exp.	2.36	0.96
House price	1.05	1.01
Interest rate	0.01	0.01
Dummy for good health	0.62	0.87

Table VI

Mean homeownership rate and line of credit reverse mortgage amount drawn by age group.

This table reports the mean homeownership rate (Panel A) and average annual amount borrowed in thousands of USD (Panel B) for the model with line of credit reverse mortgages. The last row shows the welfare gains at age 65 of taking out a reverse mortgage compared to the case in which such mortgages are not available.

Age group	Base	Bequest $b = 2$	Rent prem = 0.03	$\omega = 2$	$b = 2, \sigma = 0.125$	$\omega = b = 2, \sigma = 0.125$
Panel A: Average homeownership rates						
65 - 69	0.70	0.71	0.71	0.71	0.71	0.71
70 - 74	0.47	0.56	0.71	0.71	0.71	0.71
75 - 79	0.10	0.16	0.62	0.69	0.60	0.71
80 - 84	0.02	0.02	0.38	0.56	0.16	0.68
85 - 89	0.01	0.00	0.24	0.40	0.05	0.53
90 - 94	0.01	0.00	0.21	0.35	0.02	0.32
Panel B: Average annual amount drawn						
65 - 69	0.04	0.00	0.01	0.04	0.00	0.00
70 - 74	1.29	0.49	1.25	1.13	0.18	0.16
75 - 79	1.84	0.68	2.08	1.83	0.63	0.67
80 - 84	0.55	0.67	1.06	1.01	0.66	0.82
85 - 89	0.00	0.00	0.12	0.18	0.17	0.58
90 - 94	0.00	0.00	0.00	0.00	0.00	0.18
Panel C: Welfare gains of reverse mortgages at age 65						
Perc of wealth	-12.57	-15.71	7.64	27.35	-12.37	4.26

Table VII
Mean present discounted value of cash-flows for lenders and for the insurance agency.

This table reports the mean present discounted value of the cash-flows in thousands of US dollars for lenders and for the insurance agency, using bond yields as a discount rate and using a risk-adjusted discount rate. The table reports the results for the case of low initial short-rates, and a principal limit factor of 0.541.

	Line of credit			Lump-sum
Discount rate	Rent prem = 0.03	$\omega = 2$	$\omega = b = 2, \sigma = 0.125$	$\omega = 2$
	Lender			
Bond yield	9.2	13.1	7.2	29.5
Risk-adjusted	10.3	14.3	8.0	29.7
	Insurance agency			
Bond yield	-3.3	-5.3	-1.5	-10.1
Risk-adjusted	-4.8	-7.3	-2.7	-13.3

Table VIII

Mean present discounted value of risk-adjusted cash-flows and welfare gains for the lump-sum mortgage for different insurance premia and principal limit factors.

This table reports the mean risk-adjusted present discounted value of the cash-flows in thousands of US dollars for lenders and for the insurance agency and the age 65 welfare gains of retirees in percentage of initial cash-on-hand for different values of the annual insurance premium and the principal limit factor. The table reports results for the case of low initial short-rates, for $\omega = 2$ and for the lump-sum reverse mortgage.

Paramater value	PV of cash-flows Lenders	PV of cash-flows Agency	Welfare gain of retirees
Ins. prem = 0.0125	29.7	-13.3	24.6
Ins. prem = 0.02	32.6	-14.7	17.7
Ins. prem = 0.03	36.9	-17.5	12.6
Pr. limit fact. = 0.541	29.7	-13.3	24.6
Pr. limit fact. = 0.50	27.2	-9.7	19.3
Pr. limit fact. = 0.40	21.2	-2.2	6.7
Pr. limit fact. = 0.35	18.2	0.6	2.3
Pr. limit fact. = 0.324*	16.7	0.3	4.8

* Lower initial mortgage insurance premium.

Appendix to Reverse Mortgage Design

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This draft: January 2015

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Appendix A: 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:

$$X_{t+1} = [X_t - C_t - ME_t - (m_p + \tau_p(1-\tau))P_t^H \overline{H} + D_{j,t}^C][1 + R_{1t}(1-\tau)] + (1-\tau)Y_{t+1} + Tr_{t+1}. \quad (1)$$

where recall $D_{j,t}^C$ 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:

$$X_{t+1} = (X_t - C_t - ME_t - U_t + MAX[(1-\lambda)P_t^H \overline{H} - D_{j,t}^S, 0])[1 + R_{1t}(1-\tau)] + (1-\tau)Y_{t+1} + Tr_{t+1}. \quad (2)$$

where U_t is the rental cost and $D_{j,t}^S$ 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:

$$W_t = (1-\tau)[X_t + MAX(P_t^H \overline{H} - D_{j,t}^S, 0)]. \quad (3)$$

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 B: 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 datat 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 also allow for persistency in the shocks to medical expenditures. We estimate an AR(1) process regressing the lagged residuals of the random effects regression on the residuals. As an illustration, Figure A.2 plots 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:

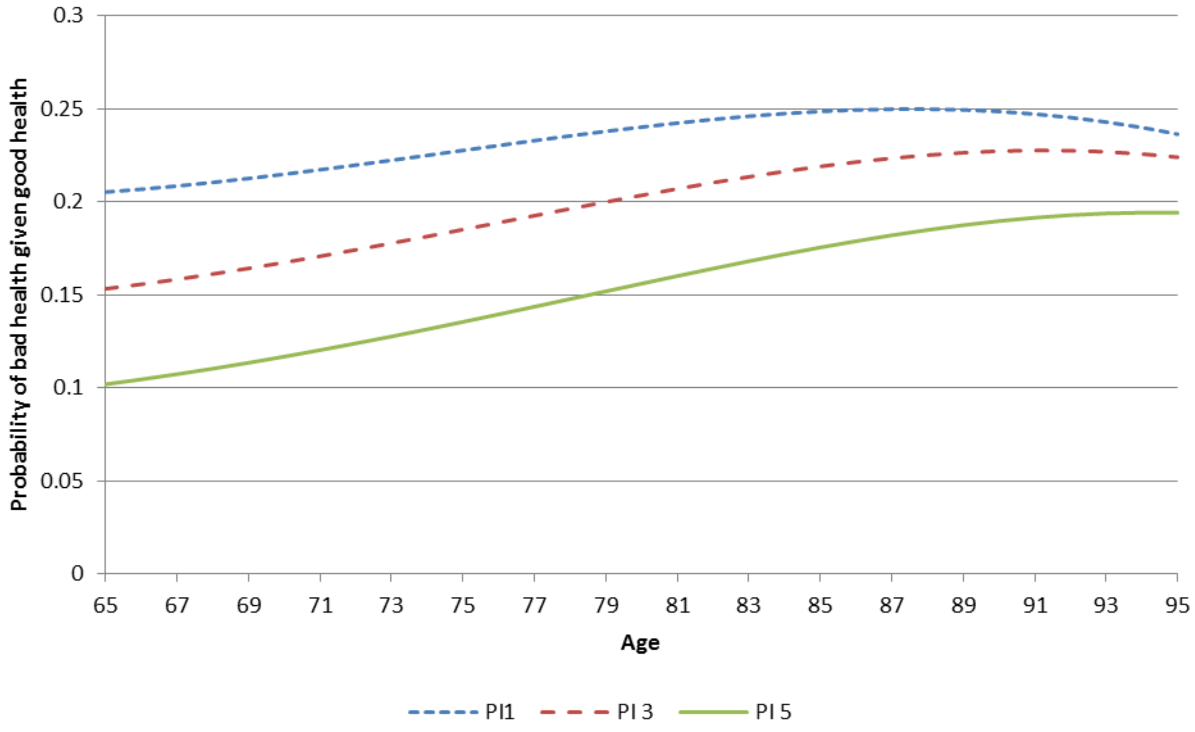
$$Y_{it} = \beta_0 + \sum_{j=60}^{100} \beta_{1j} D_{it}^{Age_j} + \sum_{k=1}^{5} \beta_{2k} D_{it}^{PI_k} + \sum_{l=1}^{10} \beta_{3l} D_{it}^{Cohort_l} + \epsilon it \tag{4}$$

where the unit of observation is retiree i in year t, the independent variables are age dummies, permanent income dummies, cohort dummies, and ϵ_{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.

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

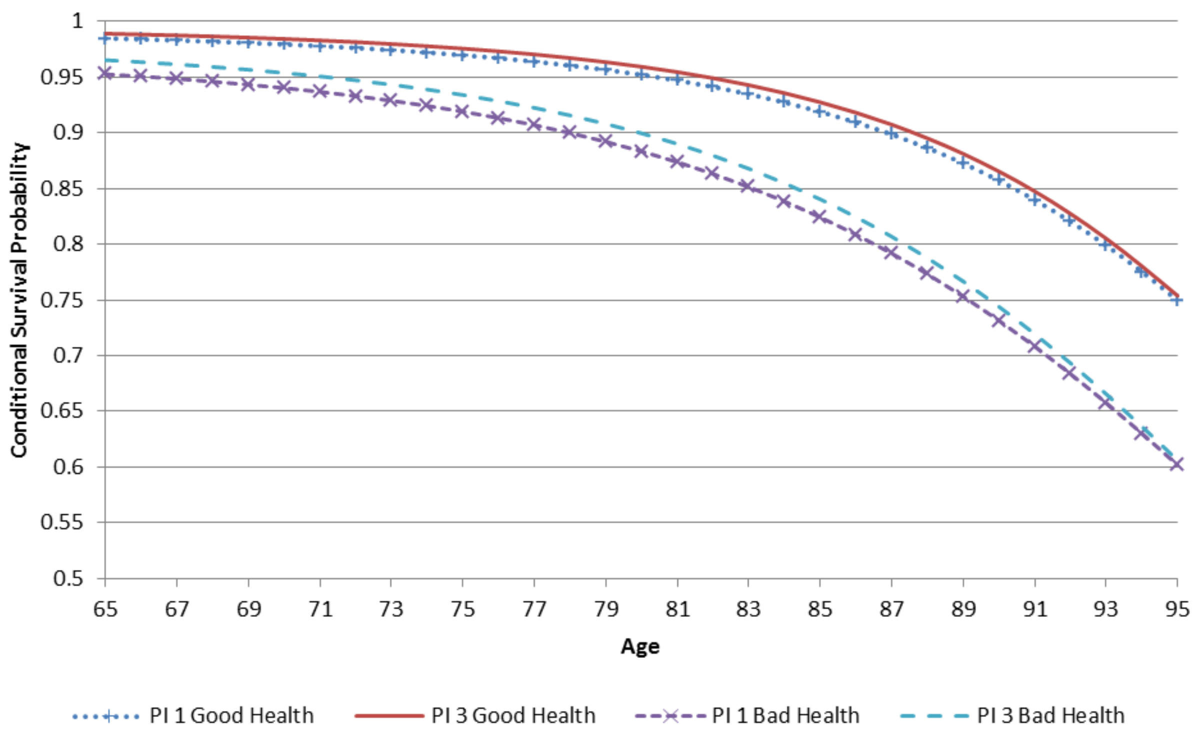


Figure A.2: Estimated average medical expenditures by age. This figure shows the estimated average medical expenditures by health status for individuals in permanent income groups one, three, and five (Cohort seven). The data is from the HRS.

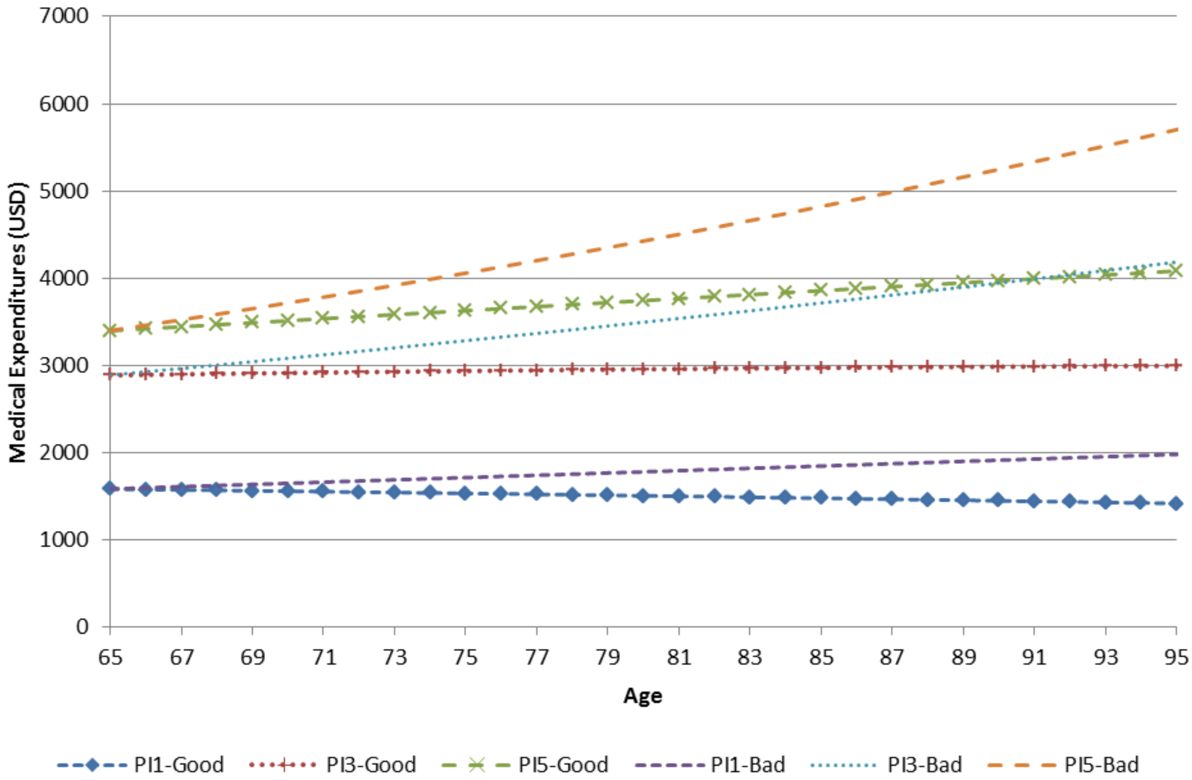
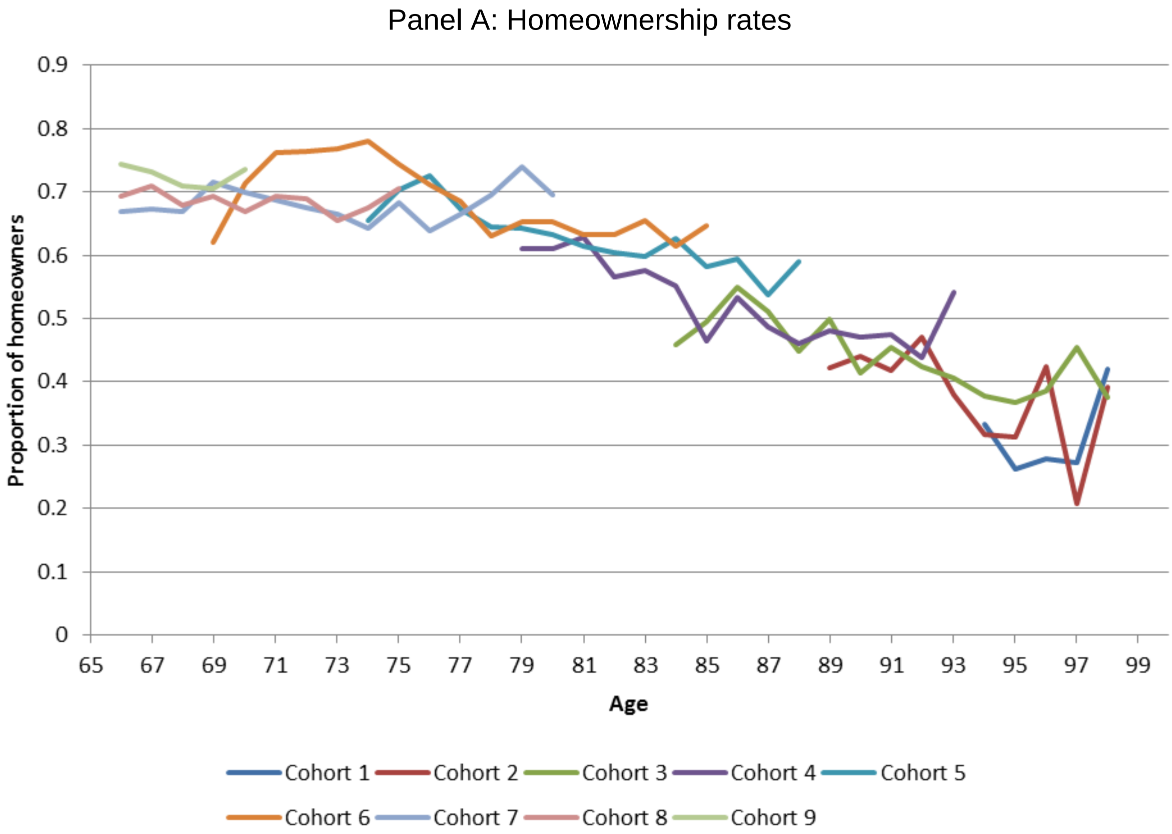
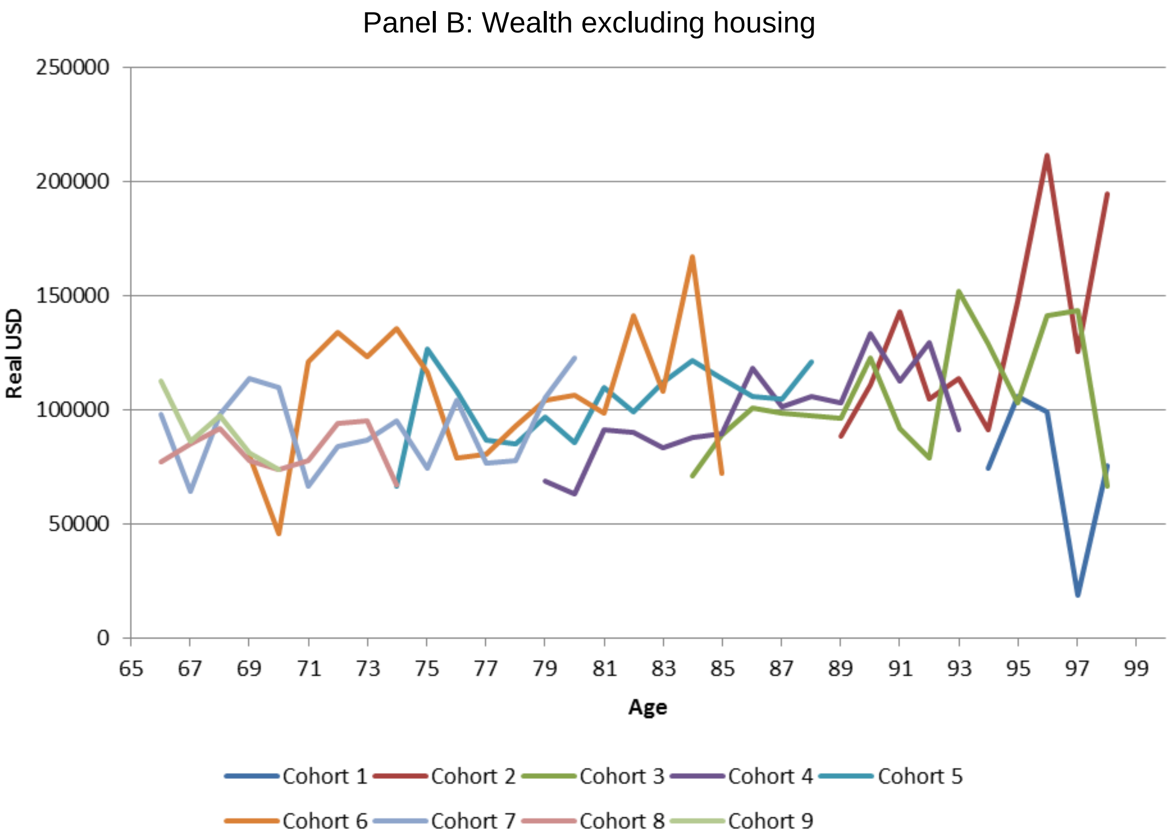


Figure A.3: Estimated age and cohort fixed effects. This figure shows the estimated age and cohort fixed effects for homeownership rates, wealth accumulation, both including and excluding housing wealth. The data is from the HRS.





Panel C: Wealth

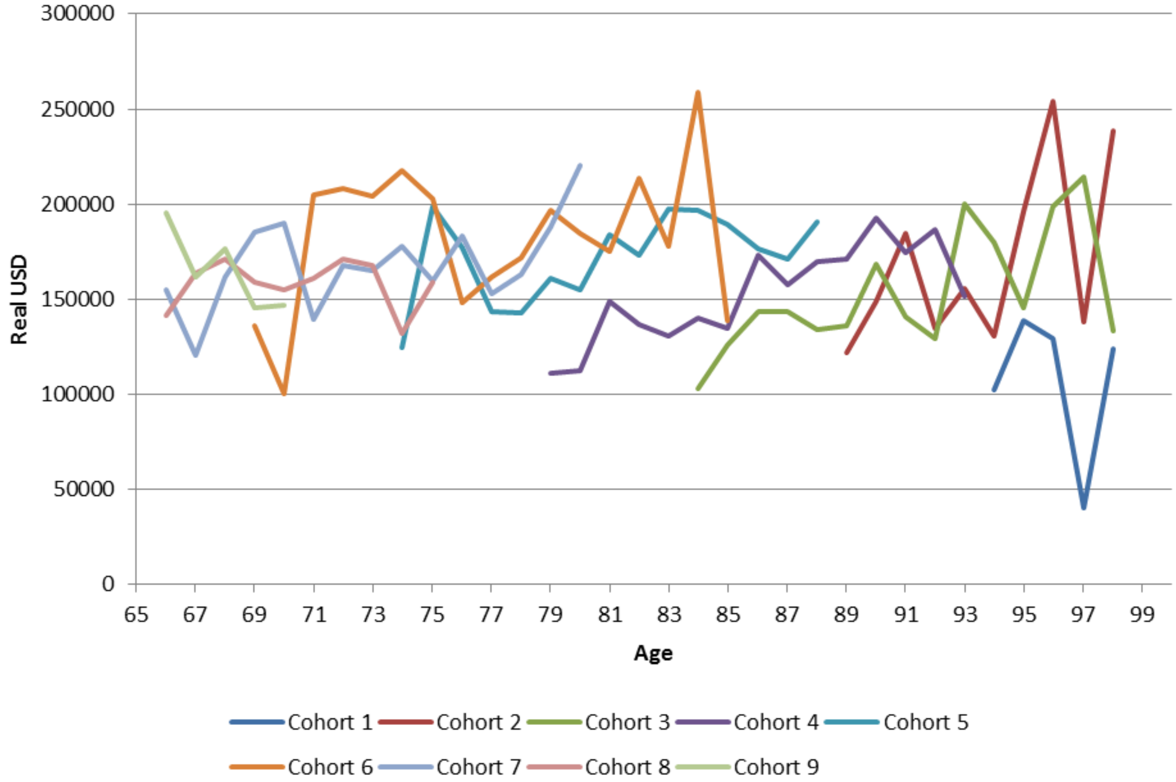


Figure A.4: Estimated cohort and permanent income dummies. This figure shows the estimated cohort and permanent income dummies. The data is from the HRS.

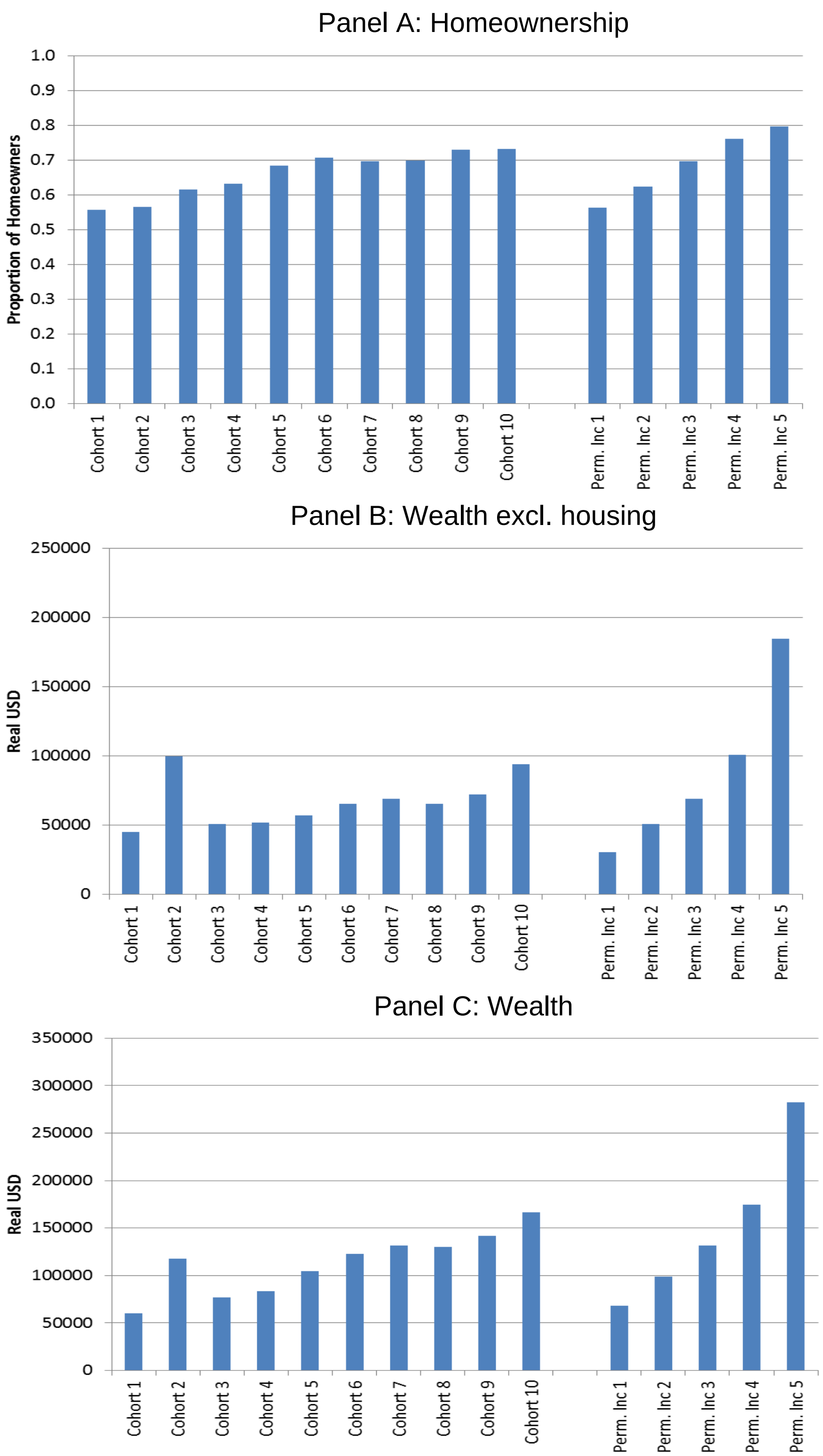
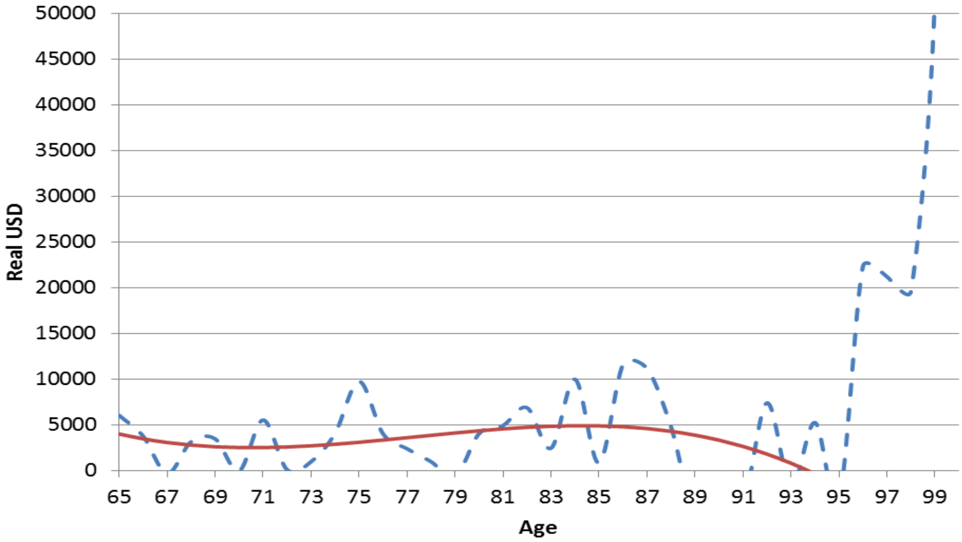


Figure A.5: Estimated median age profiles, cohort and permanent income fixed effects. This figure shows the estimated age profiles for median wealth accumulation, both including and excluding housing wealth. The estimation controls for cohort and permanent income fixed effects. The figures plot the median 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

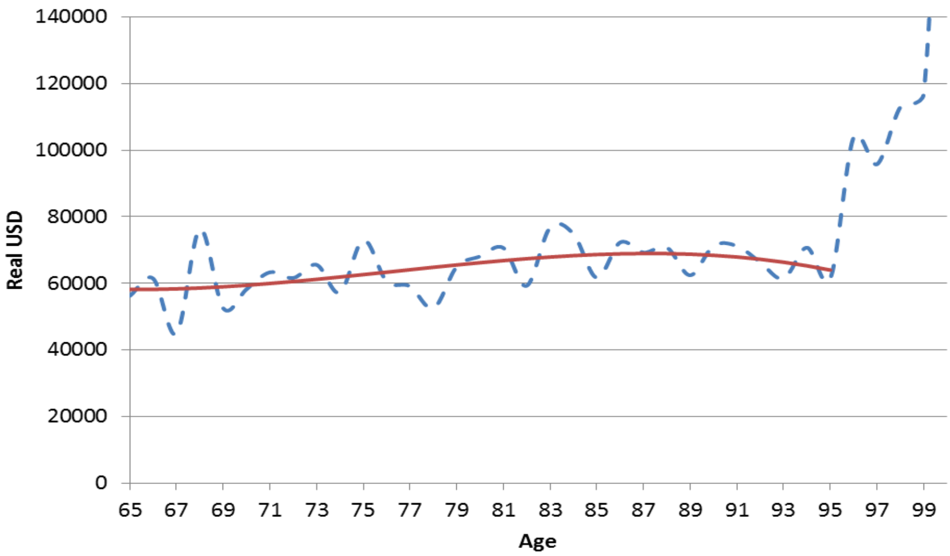
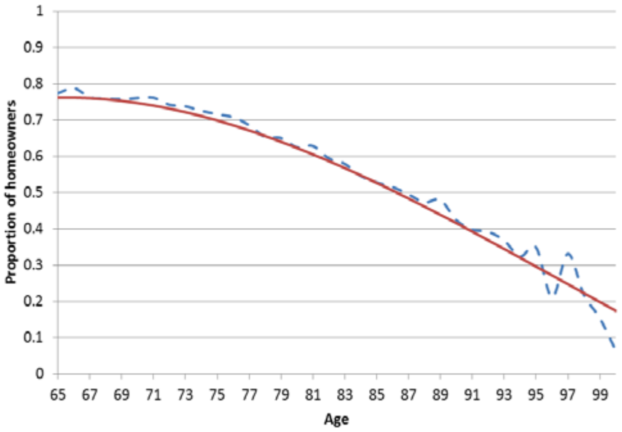
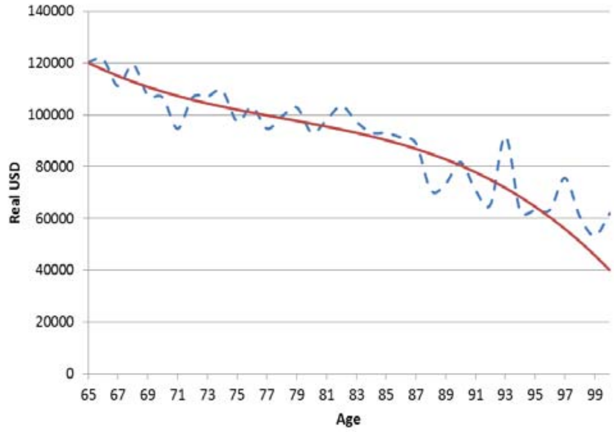


Figure A.6: Estimated age profiles, individual fixed effects. This figure shows the estimated age profiles in the HRS data for homeownership rates, wealth accumulation, both including and excluding housing wealth. The estimation controls for individual fixed effects. The data is from the HRS.

Panel A: Homeownership



Panel B: Wealth excl. housing



Panel C: Wealth

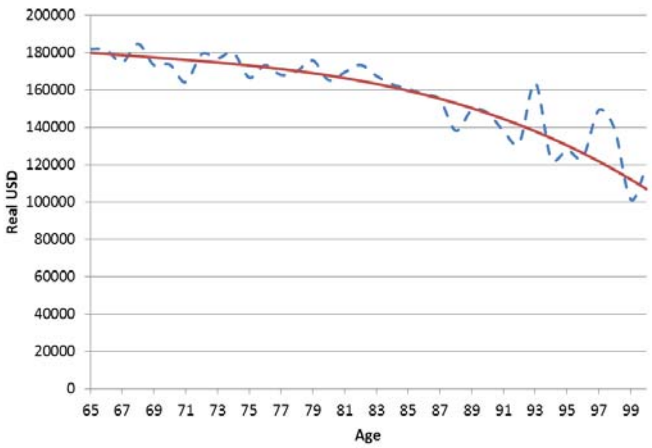


Table A.I
Cohort definition.

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 Cohort and PI	Proportion homeowners	Mean wealth excl. housing	Mean wealth	Median wealth excl. housing	Median 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