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Portfolio Choice in Retirement – What is the Optimal Home Equity Release Product?

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Abstract: We study the optimal product choice of home equity release products from the homeowner's perspective in the presence of longevity, long-term care, house price, and interest rate risk. The individual can choose to buy annuities, long-term care insurance, and release home equity using reverse mortgages or home reversion plans. The individual enjoys utility gains from having access to either one of the two equity release products. Higher utility gains are found for the reverse mortgage as its product features allow for higher lump-sum payouts. When given a timing choice, the individual chooses to unlock home equity early in retirement. These key results emerge consistently across a range of cases with different parameter values. The availability of a government-provided LTCI does not change the use of equity release products significantly, but does change the demand for annuities.

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1 Introduction

We study the optimal product choice of home equity release products from the homeowner's perspective in the presence of longevity, long-term care, house price, and interest rate risk. Home equity release products allow homeowners to convert the equity in their home into liquid wealth without having to move. Markets for equity release products exist in numerous countries including the United States, the UK, Australia, Canada, New Zealand and several countries in the European Union. Home equity release contracts differ substantially in the way house price risks, interest rate risk and longevity risk are shared between the homeowner and the lender. The two main forms of equity release are mortgage schemes ('loan model') and reversion schemes ('sale model') (see, e.g., Hosty et al., 2008; Reifner et al., 2009a). Reverse mortgages are the most common products internationally and also dominate the U.S. market (Consumer Financial Protection Bureau, 2012). Home reversion has existed for a long time in the form of private arrangements, for example in France, Portugal and Poland (Reifner et al., 2009b). Commercial home reversion is available, for example, in Australia, France, Finland, New Zealand and the UK. Reflecting those market conditions, we model a retiree's choice between a reverse mortgage and a home reversion plan.

A recent study compares the cash flows and risk profile of stylized reverse mortgage and home reversion contracts from the perspective of the product provider (Alai et al., 2013). The authors analyze a reverse mortgage with a lump-sum payout, variable interest rates and a guarantee that limits the borrowers' liability to the value of property (no negative equity guarantee). The home reversion contract involves the sale of house equity at a price that is reduced by the present value of future rental payments. The comparison shows that for loan-to-value ratios (LTVs) of less than 50% reverse mortgages are more profitable and less risky for the provider than home reversion plans. The opposite is true for higher LTVs (which are rare outside of the U.S. market). This finding may explain why more reverse mortgages than home reversion providers exist internationally. At the same time it raises the question: Is a home reversion plan more beneficial for homeowners?

In addressing this question, we add to a growing literature examining the role of equity release products in optimal household portfolios. Artle and Varaiya (1978) show that the possibility of borrowing against home equity in retirement and thereby relaxing liquidity constraints and smoothing consumption over the life cycle enhances utility. Fratantoni (1999) models the product choice between two reverse mortgage designs—annuity payout plan and line-of-credit plan—for an homeowner facing non-insurable expenditure shocks. He finds that line-of-credit plans are generally preferred since they are more flexible and can provide large sums of money in case of the expenditure shock. Davidoff (2009, 2010a, 2010b) extends this research by allowing for health and longevity risks. He confirms that the availability of the reverse mortgages itself is utility-enhancing and finds interaction effects with annuities and long-term care insurance. For example, home equity may substitute for long term care insurance. Yogo (2009) and Nakajima and Telyukova (2013) consider stochastic house prices (and stochastic health depreciation), confirming that reverse mortgages are utility enhancing.

We provide the following contributions to the literature. (1) We compare the two main forms of equity release products, reverse mortgages and home reversion plans, in a model that allows for longevity risk, uncertain long-term care costs, house price risk, and interest rate risk. (2) Both equity release products are offered at different points in time and we study the decision of when to optimally release home equity. (3) We analyze the optimal choice in different institutional settings for long term care insurance (LTCI) and examine the resulting interactions. We distinguish between a setting in which costs have to be paid out-of-pocket with private insurance available and a setting in which most long-term care costs are partly born by a government-sponsored system.

We find that the retiree enjoys utility gains from having access to either one of the two equity release products. Higher utility gains are found for the reverse mortgage. The individual chooses to unlock home equity early on in retirement. These key results emerge consistently across a range of cases with different parameter values. The availability of a government-provided LTCI does not change the use of equity release products significantly, but does change the demand for annuities.

2 The Model

2.1 General Structure of the Model and Timing

The decision problem of a single individual is modeled who holds the major fraction of her wealth in her home. The individual faces longevity risk, long-term care risk, house price risk, and interest rate risk and can choose from a range of different insurance and home equity release products.

The decisions of the individual are studied in an augmented life cycle model that extends previous work by Davidoff (2009, 2010b, 2010c) by allowing for interest rate risk, by including home reversion plans in addition to reverse mortgages and by modeling the timing decision of when to release home equity. The model has two periods (three dates) to capture the individual's decisions at retirement and at an advanced age. The model's input parameters are calibrated such that each period reflects a multi-year horizon. Figure 1 illustrates the decision and timing structure of the model.

-- Figure 1 here --

At time $t = 0$, the individual is in good health. The initial endowment consists of the mortgage-free home and liquid wealth. The individual decides on consumption, on saving over the first period of her retirement, on purchasing annuities, long-term care insurance (LTCI) and on taking out an equity release product. Equity release products increase liquid wealth available for consumption, saving, and for purchasing insurance products.

At time $t = 1$, the individual can be dead or in one of three health states, facing different health care expenses (as in Davidoff, 2009). The random house value, as well as the interest rates and mortgage rates for the second period are realized. Annuities and LTCI are not available for purchase at $t = 1$. There are the following main cases at $t = 1$.

1) The individual is alive: She receives payments from insurance contracts and from equity release products bought at $t = 0$. Health state-dependent care expenses not covered by insurance are paid out-of-pocket. The individual decides on consumption and saving over the second period.
    a) The individual is still living at home: She decides whether to take out another equity release product.

b) The individual is in a nursing home: The house is sold and all outstanding loans are repaid from the sale proceeds of the property. Additional sale proceeds are added to her liquid wealth.

2) The individual is dead: Her remaining liquid wealth and housing wealth (net of mortgage repayments) are left as a bequest.

At $t = 2$, the individual is dead with certainty. Her remaining liquid wealth and housing wealth (net of mortgage repayments) are bequeathed.

2.2 Interest Rates, Mortgage Rates, House Price Growth and Savings Growth

We model all economic variables in real (inflation-adjusted) terms. The risk-free interest rate r_0 over the first period is known at $t = 0$. The interest rate r_1 over the second period is a random variable, realized at $t = 1$. Mortgage rates are derived from interest rates by adding a margin π_{RM} to r_0 and r_1 (see Sections 2.6 and 2.8). Savings, S_t, accumulate interest r_t between time t and t+1.

The house value is H_0 at $t = 0$, $H_1 = H_0 \cdot (1 + g_1)$ at $t = 1$ and $H_2 = H_1 \cdot (1 + g_2)$ at $t = 2$, where the growth rates g_1 and g_2 are i.i.d. random variables, uncorrelated with the interest rate.

2.3 Health States and Care Costs

At time $t = 1$, the individual is in one of four states. With probability p_h she is still in good health and does not need long-term care (state h), with probability p_c she needs some care at home at costs LTC_c (state c), with probability p_c she needs to move to a nursing home at costs LTC_n (state n), and with probability $p_d = 1 - p_h + p_c + p_n + p_d$ she is dead (state d).

2.4 Long-Term Care Insurance and Annuity Products

Long-term care insurance (LTCI) covering the care costs LTC_c in state c and LTC_n in state n is available at $t = 0$. The individual chooses the proportion of insurance coverage $\%_{LTCI}$ by choosing the amount of wealth Π_{LTCI} spent on LTCI. The insurance is priced fairly according to the actuarial principle of equivalence. The premium for partial coverage of an individual's care costs is given by:

$$\Pi_{LTCI} = \%_{LTCI} \cdot (p_c \cdot LTC_c + p_n \cdot LTC_n)/(1 + r_0)\ . \tag{2-1}$$

Life annuities are available at $t = 0$. Annuities are also priced based on the actuarial principle of equivalence. The premium for an annuity paying the amount A at $t = 1$ conditional on survival is given by:

$$\Pi_A = A \cdot (1 - p_d)/(1 + r_0)\ . \tag{2-2}$$

The annuity payment A is determined by the amount of wealth Π_{LTCI} the individual decides to invest in the annuity according to Equation (2-2).

2.5 Government-Provided Long-Term Care Insurance

Scenarios are considered in which both public and private long-term care insurance (LTCI) are available. Social insurance arrangements for long-term care services exist in a number of OECD countries, including German, Japan, Korea, the Netherlands and Luxembourg (for an overview, see Productivity Commission, 2012).

In this study, government-provided LTCI is modeled as a compulsory coinsurance arrangement with a stop-loss limit. The insurance scheme covers a percentage $\%_{govt.LTCI}$ of all care costs up to an out-of-pocket spending limit. This arrangement abstracts from the details of different national systems and focuses on the impact of possible structures of sharing care costs. The arrangement is in line with suggestions by the UK Commission on Funding of Care and Support, which suggests introducing a social insurance scheme with coinsurance and a cap. The arrangement also agrees with the suggestions by the Productivity Commission in Australia (Commission on Funding of Care and Support, 2011; Productivity Commission, 2012). The retired individual faces no costs for this insurance: the cost is levied on the working-age population. The individual can decide to buy private LTCI coverage remaining care costs not covered by the public LTCI. Because the remaining care costs are lower, a lower premium for private LTCI results.

2.6 Equity Release Products

We model two types of equity release products: lump-sum reverse mortgages and home reversion plans (also called sale-and-lease-back plan). These two contract designs are the main types of equity release schemes currently available in Australia, Canada, UK, and the US (Oliver Wyman, 2008, Davidoff, 2010c). Reverse mortgages and home reversion plans are offered to the individual at $t = 0$ and $t = 1$. In many markets today, equity release products are only offered to individuals that own a debt-free home. To model this situation, we also consider scenarios in which equity release products are only offered at $t = 0$. The comparison allows us to determine the optimal timing of equity release.

2.6.1 Lump-sum reverse mortgage with variable interest rates and NNEG

We focus on reverse mortgages with a lump-sum payout, variable interest rates and a no-negative equity guarantee (NNEG), which is the most common equity release product internationally. Because the reverse mortgage is available at $t = 0$ and $t = 1$ and private annuities are available for purchase, the line-of-credit and annuity payout plan types of reverse mortgage additionally studied by Fratatoni (1999) are covered (implicitly) in our analysis.

Let $LS_{RM,t}$ denote the loan value of a reverse mortgage taken out at time $t = 1, 2$, which is paid out in full at time t. Let $RM_0\_balance_t$ and $RM_1\_balance_t$ be the time t values of the outstanding loan balances of reverse mortgage loans taken out at time $t = 0$ and $t = 2$. The outstanding loan balances are calculated by compounding $LS_{RM,t}$ at the respective mortgage rate.

The NNEG ensures that the indivudal's loan repayment does not exceed the value of the home. The costs for the NNEG are charged to the individual in the form of a mortgage insurance premium π_{RM} which is added to the interest rate. This assumption is adopted from two recent reverse mortgage pricing studies (Alai et al., 2013; Cho et al., 2013). The value of the NNEG is different for reverse mortgages taken out at $t = 0$ and at $t = 1$, resulting in different insurance premiums. The following mortgage rates apply for a reverse mortgage taken out at $t = 0$: $r_0 + \pi_{RM,,0}$ over the first period and $r_1 + \pi_{RM,0}$ over the second period. For a reverse mortgage taken out at $t = 1$, the mortgage rate $r_1 + \pi_{RM,1}$ applies over the second period. There are no other charges or lending margins.

The loan amounts $LS_{RM,0}$ and $LS_{RM,1}$ are decision variables. The loan amounts are restricted by a maximum loan-to-value ratio, which is defined in terms of the house value H_t. Different (age-specific) maximum loan-to-value ratios $LTV_0^{\max}$ and $LTV_1^{\max}$ apply for reverse mortgages taken out at $t = 0$ and $t = 1$. $LTV_1^{\max}$ is defined as a combined loan-to-value ratio:

$$(RM_0\_balance_1 + RM_1\_balance_1)/H_1 \ \leq LTV_1^{max} \quad . \tag{2-3}$$

A reverse mortgage taken out at $t = 0$ is repaid at $t = 1$ if the individual is in a nursing home or dead (cases 1b) and 2) described in Section 2.1). In case the individual is still living at home, she can decide to take out another reverse mortgage at $t = 1$ and the outstanding loan balances of both contracts are repaid at $t = 2$. In case of repayment, the house is sold and the sale proceeds of are used to pay back the total outstanding loan balance $RM_0\_balance_t + RM_1\_balance_t$. To simplify the pricing, the repayment of $LS_{RM,1}$ has priority over repayment of $LS_{RM,1}$ if at the total loan balance is less than the house value time at $t = 2$.

2.6.2 Home reversion plan

Home reversion is offered at $t = 0, 1$. Under this arrangement, the individual sells a share $\%_{HR,t}$ of the home equity H_t at time t to the product provider and receives a lump sum $LS_{HR,t}$ in return. The lump sum is less than the market value of the equity share, reflecting the value of a lease-for-life agreement and house price risk (Alai et al., 2013). The individual does not have to pay a regular rent on the equity share sold to the bank, but the equivalent present value of rental payments is deducted from the lump-sum payout.

A home-reversion plan taken out at $t = 0$ ends at $t = 1$ if the individual is in a nursing home or dead. If still at home, the individual can decide to take out another home reversion plan at $t = 1$ and both contracts end at $t = 2$. When the contract ends, the house is sold and the sale proceeds are divided according to equity shares. The individual's share is added to the liquid wealth that is bequeathed.

2.7 *The Individual's Maximization Problem*

The individual's lifetime utility function V includes a bequest motive, as, for example, in Inkmann, Lopes, and Michaelides (2011):

$$V(C, W) = \sum_{t=0}^{2} \delta^t [I_t \cdot U(C_t) + (1 - I_t) \cdot \beta \cdot B(W_t)] , \tag{2-4}$$

where δ denotes the subjective discount factor of the individual, β is the utility weight of the bequest motive, I_t is an indicator variable taking the value one if the individual is alive and zero otherwise, and C_t is the consumption in real terms. The wealth bequeathed, W_t, is comprised of liquid wealth and the individual's share of the proceeds from the sale of the house (net of loan repayments). As in Campbell and Cocco (2003), the utility is defined over consumption only and not also over housing. This choice is motivated by the stylized fact that most elderly have strong emotional ties to their house and thus the decision to live there is viewed to be always preferred over selling the home and moving when the individual is still in relatively good health (Whitehead and Yates, 2010; Consumer Financial Protection Bureau, 2012).[1]

The one-period utility functions of the individual, U, is given by:

$$U(C_t) = \frac{{C_t}^{1-\gamma}}{1-\gamma} , \tag{2-5}$$

where γ is the relative risk aversion parameter. The bequest utility function, B, exhibits the same relative risk aversion as U and is given by:

[1] Alternatively, Davidoff (2009) considers an individual whose utility depends on both consumption and the housing stock. He introduces a utility penalty for moving out of the house when in good health and sets this parameter such that moving is never optimal, except when the individual has to go to a nursing home.

$$B(W_t) = \frac{W_t^{1-\gamma}}{1-\gamma} \,. \tag{2-6}$$

The individual's objective is to maximize the expected value of Equation (2-4) subject to a set of constraints. Her optimization problem is given by:

$$\max_{C_t,\, LS_{j,0},\, LS_{j,1},\, \Pi_A,\, \Pi_{LTCI}} \mathrm{E}[V(C,W)], \ j = RM, HR \,, \tag{2-7}$$

where the index *j* refers to cash flows from the equity release schemes (*j* = *RM, HR*), which are alternatively available. The optimization problem is subject to

(i) consumption and bequest constraints:

$$C_0 = W_0 - S_0 - \Pi_A - \Pi_{LTCI} + LS_{j,0} \,, \ j = RM, HR \,, \tag{2-8}$$

$$C_1 = S_0 \cdot (1 + r_0) - S_1 + A - \left(1 - \%_{govt.LTCI} - \%_{LTCI}\right) \cdot LTC + LS_{j,1}, \ j = RM, HR \,,$$

- Bequest constraints with the reverse mortgage:

$$W_1 = S_0 \cdot (1 + r_0) + \max[H_1 - RM_0\_balance_1, 0] \,,$$

$$W_2 = S_1 \cdot (1 + r_1) + \max[H_2 - RM_0\_balance_2 + RM_1\_balance_2, 0] \,,$$

- Bequest constraints with the home reversion plan:

$$W_1 = S_0 \cdot (1 + r_0) + \left(1 - \%_{HR,0}\right) \cdot H_1 \,,$$

$$W_2 = S_1 \cdot (1 + r_1) + \left(1 - \%_{HR,0} - \%_{HR,1}\right) \cdot H_2 \,,$$

(ii) borrowing constraints:

$$0 \leq S_0 \leq W_0 - \Pi_A - \Pi_{LTCI} + LS_{j,0}, j = RM, HR \ , \quad (2\text{-}9)$$

$$0 \leq S_1 \leq S_0 \cdot (1 + r_0) + A - \left(1 - \%_{govt.LTCI} - \%_{LTCI}\right) \cdot LTC + LS_{j,1}, \ j = RM, HR \ ,$$

(iii) no-short sale constraints for equity release and insurance products:

$$0 \leq LS_{j,0}, LS_{j,1}, \Pi_A, \Pi_{LTCI}, j = RM, HR \ , \quad (2\text{-}10)$$

and (iv) further product constraints

- Maximum loan-to-value ratios for the reverse mortgage:

$$\frac{RM_0\_balance_1}{H_0} \leq LTV_0^{max} \ , \quad (2\text{-}11)$$

$$\frac{RM_0\_balance_1 + RM_1\_balance_1}{H_1} \leq LTV_1^{max} \ ,$$

- Maximum home reversion rate:

$$\%_{HR,0} - \%_{HR,1} \leq 1 \ , \quad (2\text{-}12)$$

- LTCI benefits capped by actual care expenses:

$$\%_{LTCI} \leq 1 \ . \quad (2\text{-}13)$$

2.8 Numerical Calibration of Baseline Parameters

This section describes the numerical calibration of the model's baseline parameters. The parameter values are chosen to reflect the U.S. market. Alternative parameter values are introduced in Section 3. Table 1 summarizes the numerical calibration. To focus on product design effects (rather than pricing effects) all products are priced such that the product provider makes a zero expected profit. The pricing of the insurance and equity release products reflects the risks inherent in these products.

-- Table 1 here --

2.8.1 The Individual's Preferences and Endowment

The parameters defining the individual's preferences are set within the range typically used in life cycle models. The relative risk aversion γ is set to 2, the subjective discount factor δ is set to 0.98, and the strength of the bequest motive β is set to 0.5 (see, e.g., Laibson, Repetto, and Tobacman 1998; Cocco, Gomes, and Maenhout 2005; Inkmann, Lopes, and Michaelides 2011).

The HECM equity release program which dominates the U.S. market requires borrowers to be at least 62 years old to access mortgages. Thus, the initial age of the individual is set to 62 at $t = 0$. The maximum age in the model (at $t = 2$) is set to 100, and to have two periods of identical lengths, the age at $t = 1$ is set to 81, making one period 19 years long. The initial endowment consists of liquid wealth of W_0 = \$135,000 and a house worth H_0 = \$250,000, which reflect the median values for financial assets and primary residences for individuals aged 60 to 65 in the 2009 wave of the Survey of Consumer Finances.

2.8.2 Interest Rates and House Price Growth

Interest rates are modeled following Campbell and Cocco (2003), who analyze standard mortgages. That is, future one-year interest rates are modeled as a mean rate plus a transitory i.i.d. shock. Based on one-year U.S. Treasuries, Campbell and Cocco estimate the mean of real interest rates to be 2% with a standard deviation of 2.2%. The interest rate over the first period, $r_{0,}$ is set equal to the mean real rate.

Annual house price growth rates are modeled as normally distributed i.i.d. random variables. The parameters of the distribution are derived from estimates provided by Campbell and Cocco (2003) based on the Panel Study of Income Dynamics (PSID): the mean real growth rate is 1.6% with a standard deviation of 11.7%.[2]

For the numerical solution of the model, the house price process is discretized using a binomial process (as in Yao and Zhang, 2005, or Davidoff, 2010c). The interest rate process is discretized in the same way.

2.8.3 Health States, Care Costs, Long-Term Care Insurance and Annuity Products

The probabilities of the four health states (staying in good health, needing some care at home, needing to move to a nursing home, being death) and the state-dependent care costs (0, moderate, high, 0) are the same values used by Davidoff (2009). That is, the probabilities for entering the different states are based on Robinson (2002) and the annual care expenses are based on Ameriks et al. (2011). Annual care costs in real terms are $10,000 in the second state, $50,000 in the third state and zero otherwise. LTCI for a 62 year old person is priced according to Equation **(2-1)**. Likewise, annuities are priced according to Equation (2-2) using the survival probabilities.

[2] The total value of a house consists of the capital value and the rental yields. The growth rate calibrated here is the capital growth rate. It excludes rental yields.

2.8.4 Pricing of the Reverse Mortgage

The reverse mortgage is priced such that the product provider makes a zero profit on average across all future states. The profit is calculated as the expected present value of the loan repayment (discounted using interest rates) less the initial loan amount. An interest rate margin π_{RM} is calculated such that the product provider is compensated for a possible shortfall arising from the no-negative equity guarantee (NNEG) embedded in the reverse mortgage.

Figure 2 gives the margin $\pi_{RM,0}$ for the variable interest rate reverse mortgage taken out at $t = 0$ for different loan-to-value ratios (LTVs). Given the calibration of interest rate, house price and health states, the value of the house will always be sufficient to repay the loan for small LTVs up to 0.30. For LTVs between 0.35 and 0.85, there are states where the NNEG becomes effective and the provider will charge a positive margin on the interest rate. The margins vary between 0.04% and 1.8% p.a. These values fall into the range reported by Shan (2011), who documents that for U.S. HECM loans the lender's margin is typically between 1-2%. For LTVs higher than 0.85, the expected profit of the lender is always negative in our model, independent of the margin, and this establishes a maximum LTV.

-- *Figure 2 here* --

The pricing of the reverse mortgage offered at $t = 1$ is similar: a margin $\pi_{LS,1}$ is determined to compensate the product provider for the NNEG. The value of the NNEG depends on the loan amount borrowed at $t = 0$, on the house price growth rate over the first period and on interest rates at $t = 1$. Figure 3 gives the margin $\pi_{RM,1}$ for different additional LTVs, each for different

LTV_0 ratios and assuming low house price growth over the first period and low interest rates over the second period.

-- *Figure 3 here* --

2.8.5 Pricing of the Home Reversion Contract

The home reversion contract is priced such that the product provider makes a zero profit on average across all future states. The provider's profit is calculated as the expected present value of the sale proceeds of the released equity share minus the initial lump sum paid out to the individual. The lump sum is the market price of the equity share minus the expected present value of the rent on the released equity share (Alai et al., 2013). The rental yields over the first and the second period are computed by accumulating the annual rental yield $\%_{rent}$ on the home equity released at the beginning of the period.

The present values of the sale proceeds and rental yields are calculated using discount factors that reflect house price risk. The discount factors for the first period are determined by dividing the total value of the released equity share at $t = 1$ by the value of that share at $t = 0$. The total value includes capital growth as described in Section 2.8.2 and rental yields over the first period. The discount factors for the second period are determined in the same way. A rental yield of 2% (equal to the mean interest rate) is used, resulting in 58% of the value of the equity share paid out to the individual.

2.8.6 Government-Provided Long-Term Care Insurance

With the government-provided LTCI, the individual has to cover $(1 - \%_{govt.LTCI}) = 50\%$ of the care costs up to a maximum of $6,276 per year (equal to $100,000 for the 19-year horizon). For care costs higher than $6,276, the individual's out-of-pocket costs are limited to $6,276.

2.8.7 Implementation and Equivalent Wealth Variation

The MATLAB function `fmincon` was used to implement the individual's optimization problem as a constrained nonlinear optimization problem.

Scenarios are compared based on maximized discounted expected utility values. We report measure of equivalent wealth variation that compare, in relative dollar terms, the maximized expected utility values in scenarios where equity release products are available against a benchmark scenario without equity release products. That is, we compute the percentage θ by which initial housing and liquid wealth would have to be increased in the benchmark scenario to make the individual indifferent between the optimized decisions in the benchmark scenario and in a given scenario with equity release products. The benchmark scenario varies across model variants.

3 Results

3.1 Base Case: Comparison of Reverse Mortgages and Home Reversion Offered at Retirement

In the base case, the individual decides on consumption, savings, on buying annuities and private long-term care insurance (LTCI) and on taking out an equity release product. Annuities, LTCI and equity release products are only offered at $t = 0$. Government-provided LTCI is not available. The model parameters are the baseline parameters given in Table 1. We first compare three scenarios: one without equity release products and two scenarios in which either the reverse mortgage or the home reversion plan described in Section 2.6 are offered.

-- *Table 2 here* --

The results given in Table 2 show that the individual demands equity release products at time $t = 0$. When offered the reverse mortgage at $t = 0$, the individual borrows up to the maximum loan-to-value-ratio (LTV) of 85%. When offered the home reversion plan at $t = 0$, the individual converts a substantial proportion $\%_{HR,0}$ of the home (74%). In both cases, the equivalent wealth variation factor θ indicates utility gains. The utility gain is higher with the reverse mortgage than with the home reversion plan.

Table 2 also reports the individual's total liquid wealth after equity release and her demand for annuities and private LTCI. The individual significantly increases her liquid wealth with equity release. Her total liquid wealth is \$135,000 without equity release, \$347,500 with the reverse mortgage and about \$241,500 with the home reversion plan. The reverse mortgage gives a substantially higher payment at $t = 0$ than the home reversion plan, but results in lower payouts at the end of the planning horizon. Both equity release products are fairly priced but imply different ownership rights. The lump-sum payout from the home reversion plan is reduced because of the "sale-and-lease-back" structure of the contract. The differences in the payout pattern explain why the individual's utility gain is higher with the reverse mortgage. The reverse mortgage is better suited to shift financial resources to early periods when the individual is more likely to be alive and utility is not heavily discounted.

The additional liquid wealth from equity release is used to increase consumption, savings and the demand for annuities and private LTCI as in Davidoff (2010b). The individual spends between 22% and 31% of her $t = 0$ liquid wealth on annuities. Private LTCI demand is high in all three scenarios because the individual faces potentially high care costs.

3.2 Base Case: Reverse Mortgages and Home Reversion Offered at Different Points in Time

Table 2 also report the results for two scenarios in which the equity release products are offered at retirement ($t = 0$) and later in retirement ($t = 1$). We find that there are no or very small additional utility gains from having access to equity release at time $t = 1$. When offered the reverse mortgage at $t = 0$ and at $t = 1$, the individual borrows up to the maximum LTV at $t = 0$ and makes very similar financial decisions as in the case when the reverse mortgage is offered at $t = 0$ only.

The timing of equity release is different with the home reversion plan: the individual sells a smaller proportion of home equity at $t = 0$ (58% compared to 74% when the product is only offered at $t = 0$) and releases more equity at $t = 1$. The amount of home equity released depends on the individual's health status and care costs incurred. Averaging across the states at $t = 1$ in which the individual is actually offered the home reversion plan because she is still alive and living at home, we find that she sells another 17% of home equity at $t = 1$. However, the utility gain of this strategy is relatively small compared to the scenario in which home reversion is only available at $t = 0$.

3.3 Government-Provided Long-Term Care Insurance

Next, we consider government-provided LTCI as described in Sections 2.5 and 2.8.6. Again, the individual decides on consumption, saving, annuitization, private LTCI coverage for the remaining out-of-pocket care costs and on equity release. The model parameters are the baseline parameters given in Table 1. Three different scenarios are compared: One scenario without equity release products and two scenarios in which the reverse mortgage or the home reversion plan described in Section 2.6 are offered at $t = 0$ and $t = 1$. The numerical results for these scenarios are given in Table 3. Scenarios with equity release products offered only at $t = 0$ are not compared separately.

-- Table 3 here --

Similar levels of equity release are found to be optimal with the government-provided LTCI. As in the base case without public LTCI, the individual chooses to borrow up the maximum LTV with the reverse mortgage at $t = 0$ and chooses similar levels of home reversion at $t = 0$ and $t = 1$. Compared with the corresponding base case scenarios, similar levels of wealth are invested into the annuity. Also, as suggested by Davidoff (2010b), the individual chooses similar levels of private LTCI coverage for the out-of-pocket care costs not covered by the government-provided LTCI. But because the premium for this is lower, less wealth is spent on private LTCI.

3.4 *Sensitivity Analyses: Higher Risk Aversion, No Bequest Motive, and a Higher House Value*

Table 4 gives the results for three different cases used to test the sensitivity of the base case results. In each case, one model parameter is varied. The first case is when the individual has no bequest motive ($\beta = 0$). In the second case a higher risk aversion is assumed ($\gamma = 5$). In the third case a higher initial house value (H_0 = \$500,000) is considered. For each case, three different scenarios are compared: One scenario without equity release products and two scenarios in which the reverse mortgage or the home reversion plan described in Section 2.6 are offered at $t = 0$ and $t = 1$.

-- *Table 4 here* --

In the case without a bequest motive, the individual decides as in the base case to borrow the maximum LTV allowed with the reverse mortgage at $t = 0$. The utility gains from having access to the reverse mortgage are larger than in the base case and this finding is in line with the results of Nakajima and Telyukova (2013) for reverse mortgages. When offered the home reversion plan at $t = 0$ and at $t = 1$, she chooses to sell her home completely at $t = 0$ ($\%_{HR,0}$ = 100%) in exchange for a lump-sum payment and a lease-for-life agreement. Without a bequest motive, the individual uses the additional liquidity to buy more annuities than in the base case with a bequest motive. The individual does not save (for potential bequests) and increases consumption instead. Private LTCI demand is largely unaffected by the bequest motive.

The middle columns of Table 4 refer to an individual who has a higher risk aversion ($\gamma = 5$ instead of $\gamma = 2$). The level of risk aversion impacts the level and timing of equity release. When offered reverse mortgages, this individual chooses a lower LTV of 80% at $t = 0$ and borrows up to the maximum LTV at $t = 1$ depending on house price growth over the first period. This strategy is more conservative than borrowing the maximum LTV of 85% at $t = 0$ in the base case. With the home reversion plan, the individual decides to release more home equity at $t = 0$ and less at $t = 1$ ($\%_{HR,0} = 76\%$ and $\%_{HR,1} = 13\%$ compared to 58% and 17% in the base case). This strategy reduces her exposure to house price risk. The individual spends slightly less of her liquid wealth on annuities in all three scenarios than in the base case. Her decision to buy high levels of LTCI coverage is unchanged.

The last three columns of Table 4 give the results for the third case, where a higher initial house value of H_0 = \$500,000 is considered. In the base case, the house value was H_0 = \$250,000 and made up 65% of the individual's total wealth at $t = 0$. This ratio is 79% for a house value H_0 = \$500,000. The results show that the individual again chooses to borrow the maximum LTV at $t = 0$ with the reverse mortgage and increases the percentage sold with the home reversion scheme compared to the base case. In either scenario, the total amount of equity released is increased and the utility gain from having access to equity release products is substantially higher compared to the base case. These findings show that individuals who have a higher proportion of their wealth invested in home equity benefit more from having access to equity release products.

Three key findings emerge across the cases with alternative parameter values (no bequest motive, higher risk aversion, and a higher initial house value) and these findings are consistent with the base case: (i) The individual enjoys utility gains from having access to either one of the two equity release products, (ii) reverse mortgages result in higher lump sum payments at present and higher utility gains, and (iii) equity release is preferred early in retirement, in our model at $t = 0$.

4 Summary and Conclusions

We model the decision problem of a retiring individual that holds the major fraction of her wealth as home equity and faces longevity risk, long-term care risk, house price risk, and interest rate risk. The individual can choose to buy annuities, long-term care insurance, and to borrow against the home using different equity release products at different points in time.

Consistent with previous research (Davidoff, 2009; Davidoff, 2010a, b, c; Yogo, 2009), we find that the individual enjoys utility gains from having access to fairly priced equity release products. The individual chooses reverse mortgage loan-to-value (LTV) ratios and home reversion rates of well over 50% in all scenarios according to the results of our stylized model with fairly prices products. The utility gains from having access to reverse mortgages are generally higher because these give higher lump sum payments than home reversion plans. In addition to the supply-side risk and profitability considerations studied in Alai et al. (2013), this finding helps to explain why reverse mortgages dominate most equity release markets.

With respect to the timing of equity release, we find that the individual chooses to unlock home equity early on in retirement in most scenarios studied which agrees with the trends described by a recent on the U.S. market reporting that reverse mortgage borrowers are taking out loans at younger ages than in the past (Consumer Financial Protection Bureau, 2012).

The key results are consistent across a range of cases with different parameter values. The availability of a government-provided LTCI does not change the use of equity release products significantly, but does change the demand for annuities. All financial products are fairly priced in our model and the results give an indication of individuals' willingness to pay for private long-term care insurance, annuities and equity release products.

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Table 1 Model Parameters

Parameter		Baseline Value	Alternative Value
House value at t = 0	H_0	$250,000	$500,000
Liquid wealth at t = 0	W_0	$135,000	
Age in years at t = 0		62	
Relative risk aversion	γ	2	5
Subjective discount factor	δ	0.98	
Strength of bequest motive	β	0.5	0
Long term care expenses per year			
- needing some care at home	LTC_c	$10,000	
- needing care in a nursing home	LTC_n	$50,000	
Mean interest rate per year (= interest rate at t = 0)	r_0	2.0%	
Standard deviation of interest rate per year	$Std(r_0)$	2.2%	
Mean house price growth per year	g	1.6%	
Standard deviation of house price growth per year	$Std(g)$	11.7%	
Rental yield	$\%_{rent}$	2%	
Coinsurance percentage of the govt.-provided LTCI	$\%_{govt.LTCI}$	50%	
Stop loss of the govt.-provided LTCI per year		$6,276	

Notes: This table shows baseline and alternative model parameters. All parameters referring to multiple years (subjective discount factor, interest rate, house price growth, mortgage rate), are scaled by the length of one period in the model, which is 19 years. All monetary values are in real terms.

Table 2 Optimal Equity Release at Different Points in Time

	No Equity Release Products	Reverse Mortgage at $t = 0$	Home Reversion at $t = 0$	Reverse Mortgage at $t = 0, 1$	Home Reversion at $t = 0, 1$
			Financial decisions at $t = 0$		
LTV_0		85%		85%	
$\%_{HR,0}$			74%		58%
Total liquid wealth	135,000	347,500	241,512	347,500	218,349
Consumption	81,123	180,510	144,360	180,510	145,054
Consumption %	*60%*	*52%*	*60%*	*52%*	*66%*
Savings	0	77,835	19,004	77,833	0
Savings %	*0%*	*22%*	*8%*	*22%*	*0%*
Annuity premium	41,852	75,345	64,488	75,345	59,722
Annuity premium %	*31%*	*22%*	*27%*	*22%*	*27%*
LTCI premium	12,025	13,811	13,660	13,812	13,573
LTCI premium %	*9%*	*4%*	*6%*	*4%*	*6%*
LTCI coverage	86%	99%	98%	99%	97%
			Financial decisions at $t = 1$		
Additional LTV_1				0%	
$\%_{HR,1}$					17%
Equivalent wealth variation θ		+86%	+51%	+86%	+53%

Notes: LTV denotes the loan-to-value ratio and $\%_{HR}$ is the optimal percentage of the property sold under the home reversion plan. Consumption %, Saving %, Annuity premium % and LTCI premium % are given as percentages of total liquid wealth at $t = 0$ (after equity release). Additional LTV_1 and $\%HR_1$ are reported as averages over those states $t = 1$ in which equity release products are offered to the individual. θ measures the utility gain in relative dollar terms from having access to home equity release products. That is, θ measures by how much liquid wealth and the house value would have to be increased in the "No Equity Release Products" scenario for the individual to have the same utility as in the given scenario.

Table 3 The Impact of Government-Provided LTCI on Optimal Equity Release

	No Equity Release Products	Reverse Mortgage at $t = 0, 1$	Home Reversion at $t = 0, 1$
	Financial decisions at $t = 0$		
LTV_0		85%	
$\%_{HR,0}$			56%
Total liquid wealth	135,000	347,500	216,208
Consumption	87,312	185,670	150,325
Consumption %	*65%*	*53%*	*70%*
Savings	0	80,290	0
Savings %	*0%*	*23%*	*0%*
Annuity premium	43,798	77,308	61,798
Annuity premium %	*32%*	*22%*	*29%*
LTCI premium	3,890	4,232	4,084
LTCI premium %	*3%*	*1%*	*2%*
LTCI coverage	89%	97%	94%
	Financial decisions at $t = 1$		
Additional LTV_1		0%	
$\%_{HR,1}$			18%
Equivalent wealth variation θ		+79%	+48%

Notes: LTV denotes the loan-to-value ratio and $\%_{HR}$ is the optimal percentage of the property sold under the home reversion plan. Consumption %, Saving %, Annuity premium % and LTCI premium % are given as percentages of total liquid wealth at $t = 0$ (after equity release). Additional LTV_1 and $\%_{HR,1}$ are reported as averages over those states $t = 1$ in which equity release products are offered to the individual. θ measures the utility gain in relative dollar terms from having access to home equity release products. That is, θ measures by how much liquid wealth and the house value would have to be increased in the "No Equity Release Products" scenario for the individual to have the same utility as in the given scenario.

Table 4 Sensitivity Analyses: Higher Risk Aversion, No Bequest Motive, and a Higher House Value

	No bequest motive ($\beta = 0$)			Higher risk aversion ($\gamma = 5$)			Higher house value (H_0 = \$500,000)		
	No Equity Release Products	Reverse Mortgage at $t = 0, 1$	Home Reversion at $t = 0, 1$	No Equity Release Products	Reverse Mortgage at $t = 0, 1$	Home Reversion at $t = 0, 1$	No Equity Release Products	Reverse Mortgage at $t = 0, 1$	Home Reversion at $t = 0, 1$
Financial decisions at $t = 0$									
LTV_0		85%			80%			85%	
$\%_{HR,0}$			100%			76%			68%
Total liquid wealth	135,000	347,500	278,896	135,000	335,000	243,685	135,000	560,000	329,356
Consumption	81,124	222,347	176,542	80,900	175,600	142,810	80,950	296,050	223,847
Consumption %	*60%*	*64%*	*63%*	*60%*	*52%*	*59%*	*60%*	*53%*	*68%*
Savings	0	0	0	0	83,187	30,863	16,672	125,220	0
Savings %	*0%*	*0%*	*0%*	*0%*	*25%*	*13%*	*12%*	*22%*	*0%*
Annuity premium	42,072	111,380	88,363	41,136	62,640	56,480	25,641	125,095	92,163
Annuity premium %	*31%*	*32%*	*32%*	*30%*	*19%*	*23%*	*19%*	*22%*	*28%*
LTCI premium	11,803	13,773	13,991	12,964	13,573	13,532	11,737	13,635	13,345
LTCI premium %	*9%*	*4%*	*5%*	*10%*	*4%*	*6%*	*9%*	*2%*	*4%*
LTCI coverage	84%	97%	100%	93%	97%	97%	84%	97%	95%
Financial decisions at $t = 1$									
Additional LTV_1		0%			5%			0%	
$\%_{HR,1}$			0%			13%			13%
Equivalent wealth variation θ		+173%	+117%		+104%	+66%		+210%	+137%

Notes: LTV denotes the loan-to-value ratio and $\%_{HR}$ is the optimal percentage of the property sold under the home reversion plan. Consumption %, Saving %, Annuity premium % and LTCI premium % are given as percentages of total liquid wealth at $t = 0$ (after equity release). Additional LTV_1 and $\%_{HR,1}$ are reported as averages over those states $t = 1$ in which equity release products are offered to the individual. θ measures the utility gain in relative dollar terms from having access to home equity release products. That is, θ measures by how much liquid wealth and the house value need to be scaled for the individual to have the same utility as in the scenarios without equity release products.

Figure 1 Model Timing

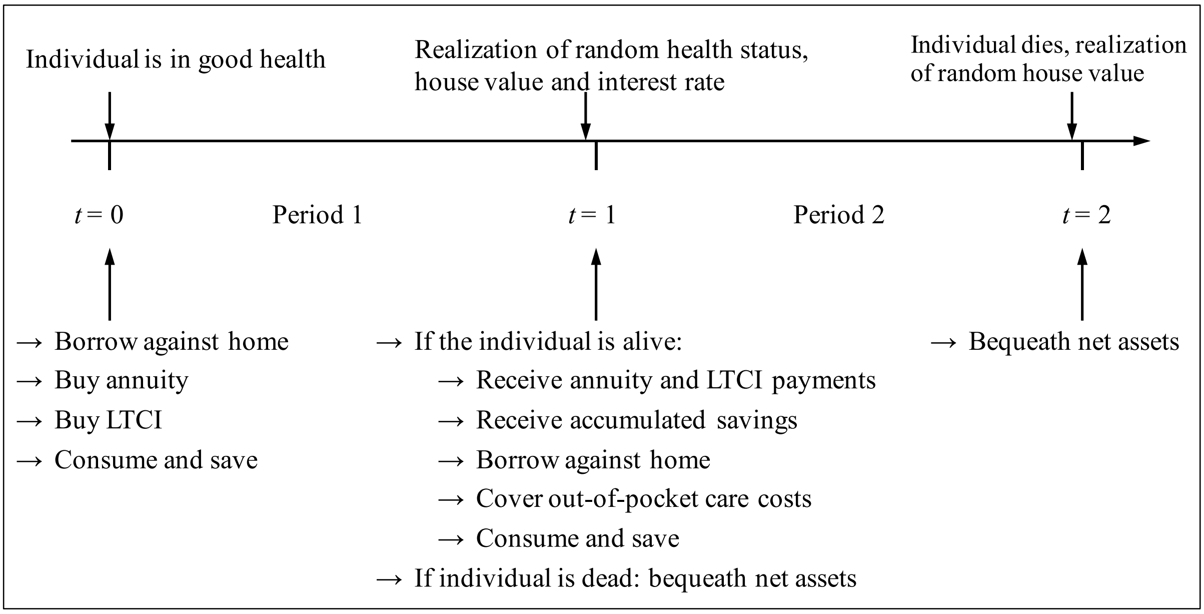
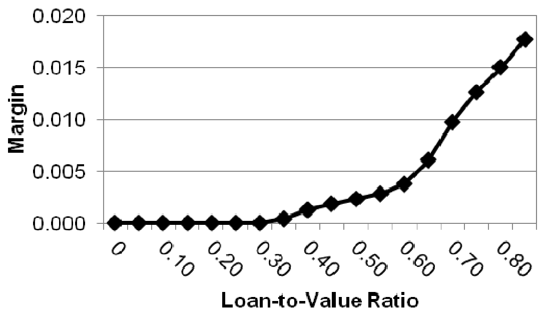
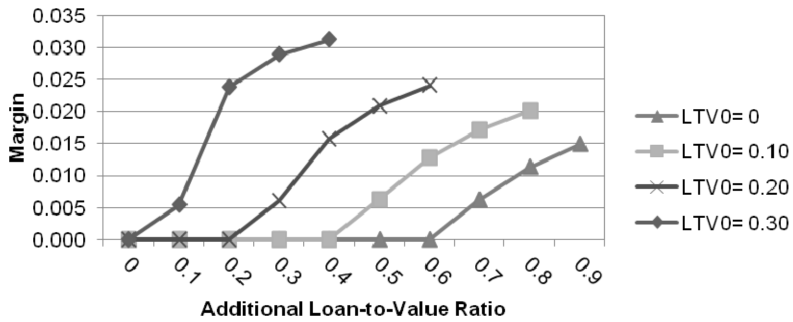


Figure 2 Mortgage insurance premium for a reverse mortgage taken out at $t = 0$.



Notes: This graph shows the mortgage insurance premium $\pi_{RM,0}$ for a variable interest rate reverse mortgage taken out at $t = 0$ for different loan-to-value ratios.

Figure 3 Mortgage insurance premium for a reverse mortgage taken out at t = 1.



Notes: This graph shows the mortgage insurance premium $\pi_{RM,1}$ for a variable interest rate reverse mortgage taken out at t = 1. The premium rate differs according to how much the household borrowed at t = 0. Results are given for different values of initial borrowing (i.e. for different LTV_0 ratios) and refer to cases with low house price growth over the first period and low interest rates over the second period.