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# – What is the Optimal Home Equity Release Product?

**Katja Hanewald[1], Thomas Post[2] and Michael Sherris[3]**

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**Abstract:** We study the decision problem of the optimal choice between home equity release products from a retired homeowner's perspective in the presence of longevity, long-term care, house price, and interest rate risk. The individual can choose to release home equity using reverse mortgages or home reversion plans, to buy annuities, and long-term care insurance. 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 and provide downside protection for house prices. When given a timing choice, the individual chooses to unlock home equity early in retirement. The availability of a government-provided LTCI does not significantly change the optimal choice of equity release products.

**JEL Classification:** D14, D91, G11, R20

**Keywords:** Retirement, home equity release, reverse mortgage, home reversion plan

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# 1 Introduction

We study the decision problem of the optimal choice between different home equity release products from the perspective of a retired homeowner in the presence of longevity, long-term care, house price, and interest rate risk. For elderly homeowners, the home's equity is often the most significant asset. For example, the value of the primary residence for U.S. households aged 65+, comprises on average (median) 49% (52%) of total assets, with 82% of households owning a house (2009 Survey of Consumer Finance). To use the home's equity for consumption purposes generally would require selling the home. However, most homeowners are reluctant to sell the home. They prefer to "age in place" (Davidoff, 2010c). Home equity release products allow elderly homeowners to convert the equity in their home into liquid wealth without having to move. 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 provider of the product. Thus, for a homeowner making the right choice is an important question that we address in this paper.

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. The two main forms of equity release are reverse mortgage schemes ('loan model') and home reversion schemes ('sale model') (see, e.g., Hosty et al., 2008; Reifner et al., 2009a). Reflecting those market conditions, we model a retiree's choice between a reverse mortgage and a home reversion plan.

Reverse mortgages are the most common products internationally and dominate the U.S. market (Consumer Financial Protection Bureau, 2012). When taking out a reverse mortgage, the homeowner receives a lump-sum payment (or annuity or line-of-credit) through borrowing against the home's value. There are no regular interest payments on the mortgage, instead interest is added (rolled-up) to the loan balance over time. The loan is paid back when the homeowner moves out or dies. Even if the loan balance becomes larger than the home's value, the homeowner has the right to continue residing in the home and the loan amount that has to be paid back is typically capped by the home's value (no-negative equity guarantee).

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. With a home reversion plan, the homeowners sells (a part of) his home in exchange for a lump-sum. The homeowner keeps the right to live in the home as long as he lives. When the homeowner moves out or dies there is no payment to the provider of the home reversion plan. However, as compensation for the life-long right to live in the home, the provider of the plan reduces the upfront lump-sum payment by the present value of future rent payments.

Alai et al. (2013) compare the cash flows and risk profile of stylized reverse mortgage and home reversion plans from the perspective of the product provider. 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 a 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 reverse mortgages 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) While previous literature focused on reverse mortgages, 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. That is, the decision problem we address is a retired homeowner's optimal choice of home equity release products. (2) Both equity release products are offered at different points in time and we study the timing 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 currently relevant setting, in which costs have to be paid out-of-pocket with private insurance available, and a setting potentially relevant in the future, in which most long-term care costs are partly born by a government-sponsored system. Suggestions to introduce government-provided LTCI have been made in the UK and Australia (Commission on Funding of Care and Support, 2011; Productivity Commission, 2012). Through introducing government-provided LTCI the choice of reverse mortgages and home reversion plans may be impacted as retirees are relieved from a major risk, the risk of high-out-of-pocket LTC costs.

We find that 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. This product gives larger upfront lump-sum payments and provides downside protection against house price risk. Both features are valuable for risk-averse and impatient individuals. 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 significantly change the use of equity release products.

## 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. The individual can always choose to purchase annuities and long-term care insurance. In addition, there is either a reverse mortgage or a home reversion plan available.

The individual's decisions 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 a 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 the equity release product available (either the reverse mortgage or the home reversion plan). 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 stochastic 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 $t = 1$. At $t = 1$ there are the following main states:

1) The individual is alive: She receives payments from insurance contracts and from equity release products contracted 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 of the product type available (reverse mortgage or home reversion plan).

   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 reverse 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 $\pi_{RM}$ 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 $p_n$ 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 $\Pi_{LTCI}$ spent on LTCI. The insurance is priced 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 $\Pi_{LTCI}$ 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).

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 a lump-sum reverse mortgage and a home reversion plan (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 several 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 $t = 0$ or $t = 1$. The comparison allows us to determine the optimal timing of equity release.

### 2.6.1 The Reverse Mortgage

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. In the U.S. almost 70% of products sold in 2011 are lump-sum products and consumers of alternative products primarily line of credit plans, typically borrow amounts close to the maximum lump-sum available (Consumer Financial Protection Bureau, 2012). We also note that 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 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 $t = 0$, 1, 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 $t = 1$. The outstanding loan balances are calculated by compounding $LS_{RM,t}$ at the respective mortgage rate.

The NNEG ensures that the individual'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 $\pi_{RM}$ which is added to the interest rate (see 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:

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

A reverse mortgage taken out at $t = 0$ is repaid at $t = 1$ if the individual is in a nursing home or dead (states 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 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 The 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 sold, 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):

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

where $\delta$ denotes the subjective discount factor of the individual, $\beta$ 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 the Campbell and Cocco (2003) paper on (conventional) mortgage choice, the utility is defined over consumption only and not also over housing. Similar to those authors, we are interested in the (reverse) mortgage choice, but not in the choice of the housing stock over time (as this topic is covered elsewhere, for example in Yao and Zhang, 2005). The choice of the utility function is further motivated by the stylized fact that most elderly have strong emotional ties to their home and thus the decision to live there is treated 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] In particular, the modeling choice of the individual's utility bases the consumption value of the home on the whole house (and its characteristics) and not just on the home equity share the individual owns. This modeling choice is realistic, given that people with very small home equity shares of 10% or even less perceive themselves as home owners (Whitehead and Yates, 2010). Therefore we propose that the consumption value of the home originates from living in their own home—a place of strong emotional ties—and not from the details of the financial arrangement allowing individuals to reside in the home. In consequence, the consumption value of the home does not change with taking out a reverse mortgage or home reversion plan.

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

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

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:

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

[1] Alternatively, Davidoff (2009) considers an individual who's 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.

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:

$$0 \le S_0 \le W_0 - \Pi_A - \Pi_{LTCI} + LS_{j,0}, j = RM, HR\ , \tag{2-9}$$

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

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

$$0 \le LS_{j,0}, LS_{j,1}, \Pi_A, \Pi_{LTCI}, j = RM, HR\ , \tag{2-10}$$

and (iv) further product constraints:

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

$$\frac{RM_0\_balance_1}{H_0} \leq LTV_0^{max} \;, \tag{2-11}$$

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

- Maximum home reversion rate:

$$\%_{HR,0} - \%_{HR,1} \leq 1 \;, \tag{2-12}$$

- LTCI benefits capped by actual care expenses:

$$\%_{LTCI} \leq 1 \;. \tag{2-13}$$

### *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 $\gamma$ is set to 2, the subjective discount factor $\delta$ is set to

0.98 per year and the strength of the bequest motive $\beta$ 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 reverse mortgage 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 conventional 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.

#### *2.8.4 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 $\pi_{RM}$ 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.

[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.

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 Plan*

The home reversion plan 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` is 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 measures 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 $\theta$ by which initial housing and liquid wealth would have to be increased in the benchmark scenario to make the individual indifferent between the optimal decisions in the benchmark scenario and in a given scenario with equity release products. The benchmark scenario varies across model variants (e.g., with different preference parameters).

# 3 Results

## *3.1 Comparison of Reverse Mortgages and Home Reversion*

The individual decides on consumption, savings, on buying annuities and private long-term care insurance (LTCI) and on taking out one of the two equity release products. First, 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 compare three scenarios: one without equity release products with two scenarios in which either the reverse mortgage or the home reversion plan described in Section 2.6 are offered.

*-- Table 2 here --*

The first three columns of Table 2 give the results. 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 74% ($\%_{HR,0}$) of the home. 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 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. In both scenarios, the equivalent wealth variation factor $\theta$ indicates utility gains.[3] The utility gain is higher with the reverse mortgage than with the home reversion plan.

Table 2 also reports the results for a case in which the equity release products are offered only later in retirement (at $t = 1$) and for a full flexibility case where equity release is offered both at retirement ($t = 0$) and later in retirement ($t = 1$).

We find that in the full flexibility case there are virtually no additional utility gains from having access to reverse mortgages at time $t = 0$ and 1. The individual again 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 utility gain of having access to the reverse mortgage is substantially lower (more than 10 percentage points) when the reverse mortgage is only available at $t = 1$. That is, when faced with an all-or-nothing decision between borrowing in $t = 0$ or $t = 1$ the individual prefers to borrow early.

[3] The absolute values of the utility gains derived from the model are high (more than 100% of wealth for some later simulations). As we base our derivations on an augmented life-cycle model with two periods, these values should not be interpreted in isolation, as their magnitude may be different for different model setups (e.g., with more periods). The values for the utility gains should only be used to identify whether an equity release product increases utility (i.e., when welfare gains are larger than zero) and to perform relative comparisons between the products.

For the home reversion plan, adding full flexibility is of some value for the individual and utility gains increase slightly. The timing of equity release changes: 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 $t = 1$. That is, equity release is delayed. The amount of home equity released at $t = 1$ depends on the realization of house prices and interest rates at $t = 1$. Larger shares are released when house prices and interest rates are high. 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 $t = 1$.[4] When access to the home reversion plan is limited to $t = 1$ only, utility gains are still higher than when in the case where home reversion is only available at $t = 0$ (but lower than under full flexibility). That is, when faced with an all-or-nothing decision between a home reversion plan in $t = 0$ or $t = 1$ the individual would prefer to contract late.

Overall, the results show that the individual generally prefers to release equity via the reverse mortgage rather than with the home reversion plan. With respect to the timing, the individual favors early equity release with the reverse mortgage. For the home reversion plan the timing matters less (in terms of utility gains), and the individual uses timing flexibility to contract a larger fraction of home reversion in the future period.

[4] The general tendencies derived hold when adding closing costs to for the products (e.g. 5% of the payout from the products). The individual prefers early borrowing with the reverse mortgage and a mix between a larger portion of early equity release and smaller portion later for the home reversion plan. In particular, the individual still borrows up to the maximum loan amount for the reverse mortgage, while for the home reversion plan equity release at $t = 1$ decreases by two percentage points. Utility gains, however, are lower when considering contracting costs (six percentage points for the reverse mortgage and three percentage points for the home reversion plan, detailed results available from the authors on request).

Two product features are responsible for the greater attractiveness of the reverse mortgage and the higher preference for early equity release with this product. First, the reverse mortgage has an asymmetric payout profile that allows the homeowner to benefit from house price increases, but protects him from house price decreases through the no-negative equity guarantee. With the home reversion plan, the homeowner is fully exposed to the house price risk for the share of the home retained. Thus, for a risk-averse home owner, this option makes the reverse mortgage more attractive. Second, the reverse mortgage gives a higher payment at $t = 0$ than the home reversion plan but results in lower payouts at the end of the planning horizon (both products are fairly priced). The lump-sum payout from the home reversion plan is reduced because of the "sale-and-lease-back" structure of the contract in which the provider deducts the present value of future rents upfront. 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, which explains its higher utility gains and preference for early usage.

To demonstrate those effects, we vary the individual's preference parameters. Table 3 gives the results for different values of the parameters of the utility function: the risk aversion parameter $\gamma$, the subjective discount factor $\delta$ and the strength of the bequest motive $\beta$.

*-- Table 3 here --*

In Panel A of Table 3 the risk aversion parameter $\gamma$ is varied. Both products' utility gains increase with higher risk aversion. But because of the effects explained above the welfare gains for the reverse mortgage (which comes with downside protection for house price risks) increase more strongly. Likewise, a more risk-averse individual sells larger fraction of the home under the home reversion plan at $t = 0$ to decrease exposure to house price risk.

When increasing the subjective discount factor $\delta$ (Table 3, Panel B), that is, when making the individual more oriented toward future consumption, the utility gains for both products decrease. Shifting consumption to earlier periods with equity release products becomes less valuable for more future oriented individuals. But, as expected, the difference in utility gains between the reverse mortgages and the home reversion plan is largest for individuals with a higher valuation for present utility (low $\delta$). For such individuals, the upfront deduction of expected rents in the home reversion plan is more undesirable. A higher bequest motive (Table 3, Panel C) leads to similar tendencies. Individuals with higher bequest motives value future utility more (they put a higher weight on bequests) and have lower utility gains from equity release products (as shown for reverse mortgages by Nakajima and Telyukova, 2013). Again, the upfront deduction of the expected rent for the home reversion plan results in the largest utility gain difference between the two products for individuals with a greater weight on present utility (i.e., no bequest motive).

As the home reversion plan is thus generally less attractive for the individual, the optimal strategy for using this product is more adapted toward timing its usage. Compared to the equity release with the reverse mortgage, a smaller fraction of the home is sold at $t = 0$ and more equity is released at $t = 1$, with usage based on the realization of house prices and interest rates. For example, in the base case with products available both at $t = 0$ and $t = 1$, the average fraction of the home sold at $t = 1$ over all house price and interest rate scenarios is 17% for the home reversion plan (compare Table 2). This fraction is higher conditional on high house prices realized and high interest rates realized. These are scenarios where the home equity increases and high interest rates make the upfront deduction of expected rents smaller as they are more heavily discounted. Conversely, as the reverse mortgage has a payout profile that favors early usage, additional future flexibility (allowing contracting at $t = 1$ vs. only at $t = 0$) has little value to the individual (compare Table 2).

### *3.2 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 4. Scenarios with equity release products offered only at $t = 0$ are not compared separately.

*-- Table 4 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, slightly higher 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, which is used to increase consumption and savings.

### *3.3 Sensitivity Analyses: The House Value and Pre-existing Debt*

In this section, a lower or a higher initial house value ($H_0$ = $ 200.000 or $500,000) are considered.

*-- Table 5 here --*

The last three columns of Table 5 give the results for a higher initial house value of $H_0$ = $500,000. 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 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. Likewise, individuals with a lower house value relative to liquid assets (first three columns of Table 5) enjoy smaller utility gains from having access to equity release products.

Based on the results above we can also analyze the utility gains of home equity release for individuals with pre-existing debt. In the U.S., the share of individuals entering retirement with pre-existing conventional mortgage debt is increasing which is reflected in a larger share of individuals using reverse mortgages with pre-existing mortgage debt (Consumer Financial Protection Bureau, 2012). Such debt needs to be retired by the proceeds from equity release products and thus decreases the amount of home equity accessible as liquid wealth. As the decisions and utility gains of an individual with CRRA preferences are constant in relative (%) terms when scaling all monetary arguments of the utility function, we can use the results in Table 5 to analyze the effect of pre-existing debt.

In particular, an individual with a (lower) house value of $200,000 and $135,000 liquid wealth (house value to total wealth ratio = 65%) mimics in his decisions an individual who owns a house value of $250.000 as in the base case, liquid wealth of $168,750 and pre-existing debt of $33,750 (the house to total wealth ration is still 65% and the total wealth is again 335,000). The comparison of the utility gains between the first three columns in Table 5 and the base case show that pre-existing debt reduces the gains from having access to home equity release products. All other things equal, individuals with pre-existing debt can access less home equity as part of the equity release proceeds are needed to retire pre-existing debt and thus equity release products are of lower value for them.

## 4 Summary and Conclusions

We model the decision problem of a retired 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 unlock home equity using a reverse mortgage or a home reversion plan at different points in time, to buy annuities, and long-term care insurance.

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 most scenarios according to the results of our stylized model with fairly priced products. The availability of a government-provided LTCI does not change the use of equity release products significantly.

With respect to the timing of equity release, we find that the individual chooses to unlock home equity early in retirement in most scenarios studied, which agrees with the trends described by a recent study 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 utility gains from having access to reverse mortgages are generally higher because these give higher lump-sum payments than home reversion plans and provide downside protection against house price risk. 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. Our model's results match observed preferences between equity release products, but produce take-up rates that are higher than those currently observed in international markets. Psychological characteristics of elderly borrowers and their limited product knowledge help explain this discrepancy (Davidoff et al., 2014), but are beyond the scope of this study.

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**Table 1** Model Parameters

| Parameter | | Baseline Value | Alternative Values |
|---|---|---|---|
| House value at $t = 0$ | $H_0$ | \$250,000 | \$ 200.000; \$500,000 |
| Liquid wealth at $t = 0$ | $W_0$ | \$135,000 | |
| Age in years at $t = 0$ | | 62 | |
| Relative risk aversion | $\gamma$ | 2 | 3; 5 |
| Subjective discount factor | $\delta$ | 0.98 | 0.93; 1.00 |
| Strength of bequest motive | $\beta$ | 0.5 | 0; 2 |
| 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 $t = 1$ | Home Reversion at $t = 1$ | Reverse Mortgage at $t = 0, 1$ | Home Reversion at $t = 0, 1$ |
|---|---|---|---|---|---|---|---|
| | | | Financial decisions at $t = 0$ | | | | |
| $LTV_0$ | | 85% | | 0% | | 85% | |
| $\%_{HR,0}$ | | | 74% | | 0% | | 58% |
| Total liquid wealth | 135,000 | 347,500 | 241,512 | 135,000 | 135,000 | 347,500 | 218,349 |
| Consumption | 81,123 | 180,510 | 144,360 | 121,009 | 121,009 | 180,510 | 145,054 |
| *Consumption %* | *60%* | *52%* | *60%* | *90%* | *90%* | *52%* | *66%* |
| Savings | 0 | 77,835 | 19,004 | 0 | 0 | 77,833 | 0 |
| *Savings %* | *0%* | *22%* | *8%* | *0%* | *0%* | *22%* | *0%* |
| Annuity premium | 41,852 | 75,345 | 64,488 | 0 | 0 | 75,345 | 59,722 |
| *Annuity premium %* | *31%* | *22%* | *27%* | *0%* | *0%* | *22%* | *27%* |
| LTCI premium | 12,025 | 13,811 | 13,660 | 13,991 | 13,991 | 13,812 | 13,573 |
| *LTCI premium %* | *9%* | *4%* | *6%* | *10%* | *10%* | *4%* | *6%* |
| LTCI coverage | 86% | 99% | 98% | 100% | 100% | 99% | 97% |
| | | | Financial decisions at $t = 1$ | | | | |
| Additional $LTV_1$ | | | | 85% | | 0% | |
| $\%_{HR,1}$ | | | | | 100% | | 17% |
| Equivalent wealth variation $\theta$ | | +86% | +51% | +73% | +52% | +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. $\theta$ measures the utility gain in relative dollar terms from having access to home equity release products. That is, $\theta$ 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** Sensitivity Analyses: Preference Parameters

*Panel A: Risk Aversion $\gamma$*

| | Base Case: $\gamma = 2$ | | | $\gamma = 3$ | | | $\gamma = 5$ | | |
|---|---|---|---|---|---|---|---|---|---|
| | 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% | | | 85% | | | 80% | |
| $\%_{HR,0}$ | | | 58% | | | 60% | | | 76% |
| Total liquid wealth | 135,000 | 347,500 | 218,349 | 135,000 | 347,500 | 221,520 | 135,000 | 335,000 | 243,685 |
| Consumption | 81,123 | 180,510 | 145,054 | 81,015 | 176,129 | 141,562 | 80,900 | 175,600 | 142,810 |
| *Consumption %* | *60%* | *52%* | *66%* | *60%* | *51%* | *64%* | *60%* | *52%* | *59%* |
| Savings | 0 | 77,833 | 0 | 0 | 86,532 | 5,751 | 0 | 83,187 | 30,863 |
| *Savings %* | *0%* | *22%* | *0%* | *0%* | *25%* | *3%* | *0%* | *25%* | *13%* |
| Annuity premium | 41,852 | 75,345 | 59,722 | 41,528 | 71,022 | 60,591 | 41,136 | 62,640 | 56,480 |
| *Annuity premium %* | *31%* | *22%* | *27%* | *31%* | *20%* | *27%* | *30%* | *19%* | *23%* |
| LTCI premium | 12,025 | 13,812 | 13,573 | 12,456 | 13,817 | 13,616 | 12,964 | 13,573 | 13,532 |
| *LTCI premium %* | *9%* | *4%* | *6%* | *9%* | *4%* | *6%* | *10%* | *4%* | *6%* |
| LTCI coverage | 86% | 99% | 97% | 89% | 99% | 97% | 93% | 97% | 97% |
| Financial decisions at $t = 1$ | | | | | | | | | |
| Additional $LTV_1$ | | 0% | | | 0% | | | 5% | |
| $\%_{HR,1}$ | | | 17% | | | 22% | | | 13% |
| Equivalent wealth variation $\theta$ | | +86% | +53% | | +94% | +57% | | +104% | +66% |

**Table 3 continued** Sensitivity Analyses: Preference Parameters

*Panel B: Subjective Discount Factor $\delta$*

| | $\delta = 0.93$ | | | Base Case: $\delta = 0.98$ | | | $\delta = 1.00$ | | |
|---|---|---|---|---|---|---|---|---|---|
| | 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% | | | 85% | | | 85% | |
| $\%_{HR,0}$ | | | 68% | | | 58% | | | 54% |
| Total liquid wealth | 135,000 | 347,500 | 233,433 | 135,000 | 347,500 | 218,349 | 135,000 | 347,414 | 212,602 |
| Consumption | 93,139 | 229,010 | 182,864 | 81,123 | 180,510 | 145,054 | 75,822 | 157,792 | 128,651 |
| *Consumption %* | *69%* | *66%* | *78%* | *60%* | *52%* | *66%* | *56%* | *45%* | *61%* |
| Savings | 0 | 58,543 | 0 | 0 | 77,833 | 0 | 0 | 82,849 | 0 |
| *Savings %* | *0%* | *17%* | *0%* | *0%* | *22%* | *0%* | *0%* | *24%* | *0%* |
| Annuity premium | 29,423 | 46,135 | 36,899 | 41,852 | 75,345 | 59,722 | 47,210 | 92,781 | 70,406 |
| *Annuity premium %* | *22%* | *13%* | *16%* | *31%* | *22%* | *27%* | *35%* | *27%* | *33%* |
| LTCI premium | 12,438 | 13,812 | 13,670 | 12,025 | 13,812 | 13,573 | 11,967 | 13,991 | 13,545 |
| *LTCI premium %* | *9%* | *4%* | *6%* | *9%* | *4%* | *6%* | *9%* | *4%* | *6%* |
| LTCI coverage | 89% | 99% | 98% | 86% | 99% | 97% | 86% | 100% | 97% |
| Financial decisions at $t$ = 1 | | | | | | | | | |
| Additional $LTV_1$ | | 0% | | | 0% | | | 0% | |
| $\%_{HR,1}$ | | | 20% | | | 17% | | | 15% |
| Equivalent wealth variation $\theta$ | | +120% | +79% | | +86% | +53% | | +67% | +42% |

**Table 3 continued** Sensitivity Analyses: Preference Parameters

| | $\beta = 0$ | | | Base Case: $\beta = 0.5$ | | | $\beta = 2$ | | |
|---|---|---|---|---|---|---|---|---|---|
| *Panel C: Bequest Motive $\beta$* | | | | | | | | | |
| | 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% | | | 85% | | | 85% | |
| $\%_{HR,0}$ | | | 100% | | | 58% | | | 33% |
| Total liquid wealth | 135,000 | 347,500 | 278,896 | 135,000 | 347,500 | 218,349 | 135,000 | 347,500 | 183,193 |
| Consumption | 81,124 | 222,347 | 176,542 | 81,123 | 180,510 | 145,054 | 80,870 | 150,930 | 122,514 |
| *Consumption %* | *60%* | *64%* | *63%* | *60%* | *52%* | *66%* | *60%* | *43%* | *67%* |
| Savings | 0 | 0 | 0 | 0 | 77,833 | 0 | 0 | 135,477 | 0 |
| *Savings %* | *0%* | *0%* | *0%* | *0%* | *22%* | *0%* | *0%* | *39%* | *0%* |
| Annuity premium | 42,072 | 111,380 | 88,363 | 41,852 | 75,345 | 59,722 | 40,139 | 47,278 | 47,296 |
| *Annuity premium %* | *31%* | *32%* | *32%* | *31%* | *22%* | *27%* | *30%* | *14%* | *26%* |
| LTCI premium | 11,803 | 13,773 | 13,991 | 12,025 | 13,812 | 13,573 | 13,991 | 13,815 | 13,383 |
| *LTCI premium %* | *9%* | *4%* | *5%* | *9%* | *4%* | *6%* | *10%* | *4%* | *7%* |
| LTCI coverage | 84% | 98% | 100% | 86% | 99% | 97% | 100% | 99% | 96% |
| Financial decisions at $t$ = 1 | | | | | | | | | |
| Additional $LTV_1$ | | 0% | | | 0% | | | 0% | |
| $\%_{HR,1}$ | | | 0% | | | 17% | | | 24% |
| Equivalent wealth variation $\theta$ | | +173% | +117% | | +86% | +53% | | +47% | +23% |

*Notes:* Panel A shows the results for different levels of the risk aversion parameter $\gamma$, in Panel B the subjective discount factor $\delta$, is varied and Panel C the strength of the bequest motive $\beta$. The 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. $\theta$ measures the utility gain in relative dollar terms from having access to home equity release products. That is, $\theta$ 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.

**Table 4** 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 $\theta$ | | +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. $\theta$ measures the utility gain in relative dollar terms from having access to home equity release products. That is, $\theta$ 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 5** Sensitivity Analyses: House Value

| | $H_0$ = \$200,000 | | | Base case: House Value $H_0$ = \$250,000 | | | $H_0$ = \$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% | | | 85% | | | 85% | |
| $\%_{HR,0}$ | | | 53% | | | 58% | | | 68% |
| Total liquid wealth | 135,000 | 305,000 | 196,147 | 135,000 | 347,500 | 218,349 | 135,000 | 560,000 | 329,356 |
| Consumption | 81,108 | 157,385 | 129,295 | 81,123 | 180,510 | 145,054 | 80,950 | 296,050 | 223,847 |
| *Consumption %* | *60%* | *52%* | *66%* | *60%* | *52%* | *66%* | *60%* | *53%* | *68%* |
| Savings | 0 | 68,396 | 0 | 0 | 77,833 | 0 | 16,672 | 125,220 | 0 |
| *Savings %* | *0%* | *22%* | *0%* | *0%* | *22%* | *0%* | *12%* | *22%* | *0%* |
| Annuity premium | 41,646 | 65,372 | 53,234 | 41,852 | 75,345 | 59,722 | 25,641 | 125,095 | 92,163 |
| *Annuity premium %* | *31%* | *21%* | *27%* | *31%* | *22%* | *27%* | *19%* | *22%* | *28%* |
| LTCI premium | 12,246 | 13,847 | 13,618 | 12,025 | 13,812 | 13,573 | 11,737 | 13,635 | 13,345 |
| *LTCI premium %* | *9%* | *5%* | *7%* | *9%* | *4%* | *6%* | *9%* | *2%* | *4%* |
| LTCI coverage | 88% | 99% | 97% | 86% | 99% | 97% | 84% | 97% | 95% |
| | | | | Financial decisions at $t$ = 1 | | | | | |
| Additional $LTV_1$ | | 0% | | | 0% | | | 0% | |
| $\%_{HR,1}$ | | | 19% | | | 17% | | | 13% |
| Equivalent wealth variation $\theta$ | | +70% | +41% | | +86% | +53% | | +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. $\theta$ measures the utility gain in relative dollar terms from having access to home equity release products. That is, $\theta$ 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

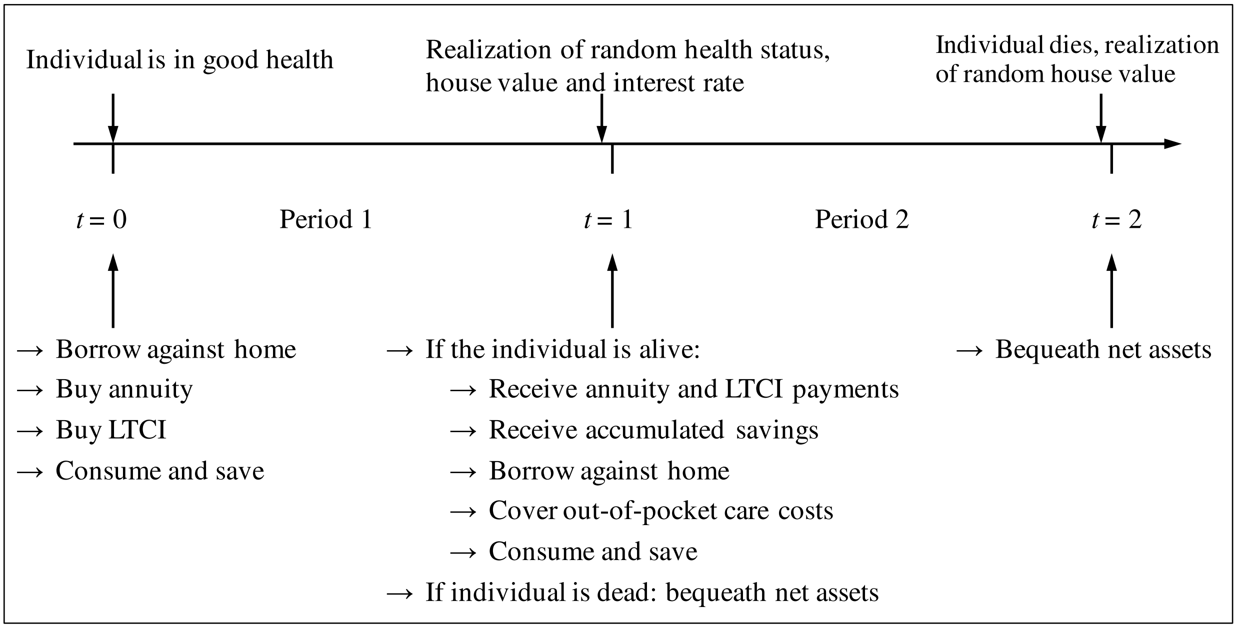
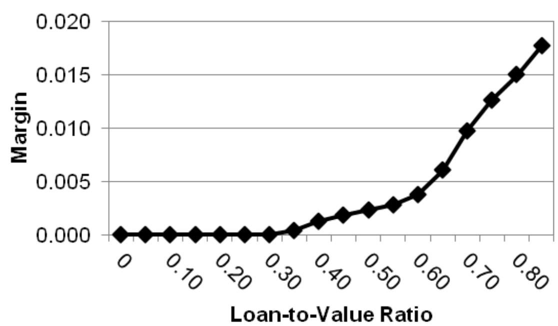
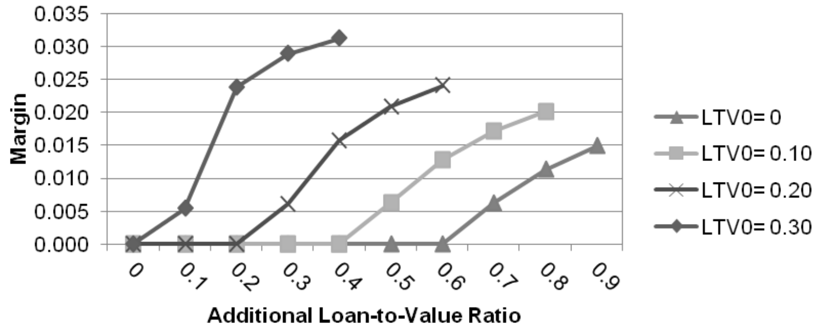



**Figure 2** Mortgage insurance premium for a reverse mortgage taken out at $t = 0$.




*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.