Annals of Operations Research
https://doi.org/10.1007/s10479-025-06591-y

ORIGINAL RESEARCH

Exploring reverse mortgage for Italian population: a life-cycle model approach

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Received: 15 July 2024 / Accepted: 28 February 2025

Abstract

Elderly's financial status is affected by stochastic lifespan and states of health. The growth of life expectancy in industrialized countries, the inadequacy of pension systems and the high medical costs shed light on the need to provide adequate solutions for retirees, whose wealth is mostly illiquid and mainly composed by own home. The reverse mortgage (RM) contract allows elder homeowners to borrow money using their home as asset for the loan, maintaining the right to live in the house. The debt is repaid by the heirs when the borrower dies. This contract might constitute a valid support for the spending needs that may arise during retirement. The paper deals with a decision problem of a homeowner who is approaching old age and has to evaluate contracting a reverse mortgage or not. In order to investigate the economic effects of RM on elderly's consumption behavior, we construct a life cycle model tailored to "house rich and cash poor" individuals, whose primary wealth asset is constituted by real estate and who has to deal with the uncertainty about lifespan, future health states and the consequent considerable expenses for medical treatments, as well as house maintenance costs. Elders' lifetime utility functions take into account consumption preferences, lifespan uncertainty and bequest motivations, in order to capture the impact of the attachment to the property on elder's financial planning. We solve the optimization problem to find the optimal savings allocation, with and without RM. We present three exemplary cases related to different occurrences of health status, focusing on Italian retired males. Through our analysis, we found out that, in presence of long-term care expenses and house maintenance costs, individual's liquid wealth significantly increases with reverse mortgage. Moreover, homeowner with a higher bequest motivation experiences lower utility gains from contracting RM plan. Our results provide an alternative tool to explain elderly skepticism in buying this kind of product.

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Published online: 17 April 2025

Keywords Reverse mortgage · Life-cycle model · Backward induction · Ageing · Decision problem

1 Introduction

The demographic framework of an ageing society: challenges for financial and insurance systems

The demographics of ageing, with its multiple economic and social facets, pose one of the most pressing and significant political challenge worldwide. Further demographic dynamics are connected to the debate on this issue, including the processes of reducing birth rates in Western industrialized countries, migration flows, changes in the workforce and families. Increasing life expectancy can lead to poverty and inequality, even in advanced economies. A significant change in the socio-demographic scenario calls for a different social awareness, and therefore, the search for innovative solutions to address the new concerns of elderly services and care. The focus is on the future equilibrium of pension and social protection systems, health care quality, labor market changes, and the dissemination of adequate and informed financial literature [cf. Haan and Prowse (2014), Denuit et al. (2019), Alvarez et al. (2021), Jarner et al. (2024), Atance et al. (2025)]. According to the Eurostat survey (Eurostat, 2024), in the aftermath of the Covid-19 pandemic phase, there was a general rise in the trend of life expectancy at birth throughout the EU, even by 0.2 years when compared to the pre-pandemic period. In Italy (IstatData, 2023), life expectancy at birth increased to 83.1 in 2023, six months more than in 2022, even if there were geographical and gender differences. The average lifespan after 65 years goes up to 10.6 years, compared to 10 years in both 2022 and 2019. However, the disquieting news concern healthy life expectancy in 2023, which will drop to 59.2 years, compared to 60.1 years in 2022. With this reduction, the indicator has nearly reached the level of 2019 (58,6 years).

Finding innovative technical solutions is the primary concern in financial and insurance matters. It is time to reassess the existing architecture of the welfare: as for the insurance market, the focus is on engineered products that follow a life-cycle based structure, while meeting the objective of ensuring health and well-being for all age groups (European, 2024). Complying with the goals established by the United Nations and shared by the European Commission, the guidelines of sustainable development rely heavily on this intent as one of its fundamental indicators. In addition, the goal of protecting health is part of a wider and more systematic plan; this has been confirmed since 2016, when the European Commission published a review of policies to provide adequate responses to broad-spectrum health needs, redefining the European Core Health Indicators (ECHI) system with the aim of establishing a sustainable health monitoring system. To ensure an adequate standard of living for elderly groups without sufficient pension income, financial planning platforms should be implemented. Supporting public actions with synergistic interventions through public and private resources is essential, and this should be done with a fair differentiation based on the average net wealth of the population groups concerned. The insurance industry's focus on protecting individuals can play a significant role in designing innovative strategies for well aging. Reverse Mortgage (RM hereinafter) contracts offer an interesting opportunity within the Silver Economy (Di Lorenzo et al., 2024a), as they cater to the needs of elderly homeowners, where pension levels are not sufficient to ensure adequate living standards. Recent actuarial literature is increasingly focusing on RMs (or Equity Release, in UK); they are characterized as asset-based policies (Hoekstra & Dol, 2021; Di Lorenzo et al., 2024b): to augment retirement income, elderly homeowners can release all or a portion of their home property and obtain a credit line, that is a lump sum or a stream of installments, reserving the option for heirs to eventually redeem the home, differently from the bare ownership product, where all the legal rights on the house are lost after the sale (Morano & Tajani, 2016). To make the target market more comprehensible, we mention for example the case of Italy: 77% of families, at the end of 2022, lived in a home owned and a third of these also owned other properties (Banca d'Italia, 2020). However, the number of elderly homeowners with insufficient pension income, known as the "house rich and cash poor", is alarming on the other hand. The survey carried out by Beltrametti (2017) focused on the families of elderly people with at least sixty-year-old householders, who own the primary residence, based on the monetary income and market value of their home. As many as 13.3 out of 100 senior citizens had a monetary income of less than €10,000 per year. Among these, 190,000 households own a home that is valued at least €200,000, just to mention a few examples. Based on the data provided by the Italian Ministry of Economy and Finance in 2019, when considering all taxpayers, approximately two-thirds claim ownership of at least one or a portion of the property (Pellegrino, 2023). However, the discrepancy between the value of the property and the annual income is striking; just think that 46.8% of taxpayers are owners of at least one property of any kind but receive an annual income of up to 10 thousand euros, and 64.1% have an income between 10 and 26 thousand euros. This evidence, in the context of an ageing society, represents, in perspective, Italy as a country of asset rich but cash poor families (Angelini et al., 2012; Pellegrino, 2023).

In this paper we focus on the decision problem of a homeowner who is approaching old age, in particular we consider elder who is entering retirement or has already retired, and has to evaluate contracting a Reverse Mortgage or not. We build elders' lifetime utility function on the line of Davidoff (2009), Hanewald et al. (2016), considering consumption, bequest motivations and uncertainty about lifespan and future health states. We solve the optimization problem to find the optimal saving streams over the lifetime of the homeowner with and without RM. The decision-making scheme is set within the Italian context, providing numerical examples to address policy guidelines. Italy represents an archetype of wealthy countries where inequalities grow in the aging process, since the number of elderly people is increasing substantially, with a low birth rate and a worrying public debt, and this makes actions to support the poor elderly unlikely at least in the near future. The RM contract could represent a tool to accompany the ageing process, in a context where the private sector complements public interventions. The choice of the application framework is motivated by the need to implement innovative measures in a context where fragility and inequalities just emerge in social classes, that are suddenly deprived of pension levels in line with adequate living standards. The remaining of the paper is structured as follows: Sect. 2 contains some considerations about the relevance of Reverse Mortgages for an ageing society; Sect. 3 describes the mathematical model and deepens the risk drivers impacting on the contract and introduces the scenario hypotheses for the applications; Sect. 4 presents the utility-based model, detailing the probabilistic assumption and the structure of the utility function; Sects. 5 and 6 explain the optimization procedure and provide numerical applications and sensitivity analysis; Sect. 7 concludes the paper.

2 The reverse mortgage

A resource for an ageing society: a varied and challenging market

The RMs contracts are framed in the area of financial insurance products designed to meet the needs of an ageing society. The so-called "decade of healthy aging" (Angelini et al., 2014; WHO, 2021; Apicella et al., 2024) is presently underway: the RMs are tailored to ensure that the elderly have a good quality of life. In a recent Worldmetrics Report (Lindner, 2024), the global Reverse Mortgage market was valued $34.5 billion in 2019 and is expected to grow to $39.2 billion by the end of 2027, with a gradual and steady trend. However, the RM market has developed unevenly in space and time. Their growth has been rapid in Canada and in the US, where they are also known as Home Equity Conversion Mortgage, largely managed by the Federal Housing Administration (Merton & Lai, 2016; D'Amato et al., 2021). Similarly, in the UK, where they are known as Equity Release, they have expanded and well-established. At the end of 2023, the equity release market showed growth with quarterly increases in new customer acquisitions of 10%, as well as an 8% increase in total loans (European, 2024). RMs are growing in Australia (Alai et al., 2014), as well as in Asian economies. A pilot program of RM products in several major Chinese cities has met with very little support. For this reason, a recent study (Hanewald et al., 2020) has explored the results of two online surveys aimed at homeowners aged 45–65 as potential purchasers, and adult children in the 20–49 age group, as children of potential purchasers. After improving the product design and forwarded this in a clear and simple scheme, the results of this study demonstrate that 89% of older Chinese homeowners would be interested in this new reverse mortgage product, and 84% of adult children would recommend such a product to their parents. A survey launched in Germany (Bartsch et al., 2021) found out that consumers' attention is slowly shifting to such contracts. Hitherto, the scarcity of demand was mainly due to lack of awareness and information. Similar reasons are also given in relation to the Spanish market, where the RMs are showing a new attraction, even for foreign residents (Atance et al., 2024). On the whole, potential consumers are hesitant, especially in the countries of Mediterranean Europe, due to the meaning of "hereditary property" connected to the house; so, the house is viewed as an illiquid asset that must be transmitted to the heirs at all costs, instead of being a tool for pension planning (Fornero et al., 2016). In 2012, Angelini et al. (2012) investigated in detail the reasons that explain the lack of demand for RMs in Italy: this appears to be related to pension incomes still quite high in the period under consideration, as well as anti-selection phenomena inherent in products affected by the longevity risk. Indeed, according to Angelini et al. (2012), an important aspect to be taken into account is the information asymmetry due to the discrepancy between the survival probabilities adopted by the lender and the subjective survival probabilities perceived by the borrower. However, the RMs have been proven to be liquidity producers through empirical verifications in this study, also allowing the heirs to make the choice to redeem the property, unlike the sale of the bare ownership.

It is not easy to understand retail market trends. In fact, it's necessary to untangle the connections between the value attributed to consumption and that of inheritance (Wang & Han, 2021); unique behavioral paradigms cannot be identified because these connections vary based on financial education, social class, and health status. Recent studies have cautioned against possible misinterpretations of individual choices caused by bequest preferences; the literature sometimes expresses criticism of the ways to incorporate the preference for bequests into the life-cycle patterns of consumption and wealth (Kraft et al., 2022). Although there are some critical aspects, mostly related to the product's complexity and communication, the

170 financial market experts involved in the survey carried out by the Centre for European Economic Research in Mannheim (ZEW) (Bartsch et al., 2021) predict a growing interest in these products. Moreover, the recent report by Kemmy and Bigley (2023) highlights that new lenders are entering the European RM market and gaining attention from potential recipients of the product. Within this context, the urgency for improving financial and demographic literacy cannot be understated (Apicella et al., 2024).

3 Lender's point of view

3.1 Contract profile, risk drivers and calculation model

This section describes the mathematical model and deepens the risk drivers impacting on the contract and introduces the scenario hypotheses for the applications. The following actuarial valuation is instrumental in performing the analysis, contained in subsequent sections, to evaluate the utility gained by a potential RM subscriber.

Reverse Mortgage contract lines are based on a financial equivalence relationship assessed at $t = 0$, issue time of the contract, between the commitments of the two counterparties, lender/bank or insurer and borrower/homeowner, this last aged x. The borrower can receive at issue time a lump sum, equivalent to the valuation of the contracted house or a percentage of its value, net of the Non-Negative Equity Guarantee (NNEG from here on), which ensures that the debt will not exceed the value of the property. As an alternative to the lump sum, the borrower can receive constant periodic installments throughout the duration of life. This summary, that brings together the various facets of a contract such as the RM, is intended to trace the contractual profile of the RM by highlighting the main components of risk that the lender must control. These risk drivers can be listed and labeled as follows (Di Lorenzo et al., 2022):

- *longevity risk*, related to the uncertainty about the borrower's lifespan. If the borrower lives longer than expected, this exposes the lender to more payments in the case of installment payments and in any case, even in the case of lump sum payments, to an extension of the contract period that will postpone the sale of the property beyond what was budgeted. Importantly, this source of uncertainty also amplifies the exposure of the lender to the other sources of risk, which become less controllable as the vulnerability range increases;
- *house price risk*, due to possible losses caused by the fact that the liquidation value of the house may fall below the borrower's outstanding debt at the time of his/her death;
- *financial risk*, due to the volatility risk of interest rates.

From a strictly financial point of view, the calculation model is based on the definition and description of two different interest rates and mortality rates, related to the three different sources of risk listed above. In details, the *longevity risk* impacts the duration of the contract and it will be controlled by adopting prudential mortality rates, properly projected. There are numerous mathematical models that describe the trend of human survival while also capturing its systematic improvement. The probability that an individual aged x is alive at the age $x+t$ is denoted by the symbol ${}_tp_x$ and the probability of dying between x and $x+t$ is ${}_tq_x$, such that ${}_tp_x = 1 - {}_tq_x$. The *house price risk* will be described by the interest rate r_s^{HV}, the random rate of house value appreciation at the generic time t, with $t \in (0, T)$, where T denotes the maximum duration of the contract. This is the real estate market appreciation rate in the specific market where the contract is signed. The financial risk will be assessed through the rate r_t^{RM} that the lender applies to the loan. This rate is given by the sum of the risk-free interest rate r_t plus the risk premium π. Based on the previous basis for risk analysis, the financial actuarial equivalence relationship established at the issue time of the contract can be assessed, based on the following notation:

- LS_0 is the lump sum payable by the lender at the issue time;
- H_0 is the current market value of the house;
- α denotes a proportion of the current house value H_0 $(0 < \alpha \leq 1)$: from a theoretical point of view, if $\alpha = 1$, then the RM contract is written on the whole value of the house (when the borrower will die, the heirs will pay the accumulated loan or the entire proceeds from the sale of the house); in practice $\alpha < 1$ and the contract is written on a percentage of the initial value of the house (the borrower consequently receives a lower initial lump sum, and when the borrower will die the heirs consequently will have to repay the accumulated debt or a proportion of the proceeds from the sale);
- $A_0 = \alpha H_0$ is the value of the loan on which the interests are accumulated;
- R is the constant amount of money that the lender will pay to the borrower annually from issue time until death;
- $\ddot{\alpha}_x$ is the actuarial present value of a life annuity paid to an individual of age x, of annual unit installment, over lifetime.

The following relation holds:

$$LS_0 = R\ddot{\alpha}_x < A_0 = \alpha H_0. \tag{1}$$

The quantity $(A_0 - LS_0)$ represents the cost of the guarantee to be borne by the borrower. The role of the NNEG is clarified by the following relationship, in which, denoting with A_t and H_t the value of the loan and the value of the property at time t respectively, the amount payable by the heirs at a generic time t, $0 < t < \omega - x$, where ω is the extreme age of the borrower, is the value at maturity of a short position in a put option:

$$V_t = A_t - \max(0, A_t - H_t) = \min(A_t, H_t). \tag{2}$$

Following Wang et al. (2008), considering the stochastic nature of interest rates, random quantities will be denoted by the tilde symbol. We can write:

$$\tilde{A}_t = A_0 \prod_{j=0}^{t-1}(1 + \tilde{r_j}^{RM}) = \alpha H_0 \prod_{j=0}^{t-1}(1 + \tilde{r_j} + \pi), \tag{3}$$

$$\tilde{H}_t = \alpha H_0 \prod_{j=0}^{t-1}(1 + \tilde{r_j}^{HV}). \tag{4}$$

We are now able to establish the financial equilibrium at the time of contracting, based on the relationship between the lump sum (coincident with the actuarial present value of the annual installments payable in the event of the borrower's lifetime) and the sum V_t:

$$\tilde{LS}_0 = \sum_{t=1}^{\omega-x} \tilde{V}_t \left[\prod_{j=1}^{t} (1 + \tilde{r_j})^{-1} \right] {}_{t-1/1}q_x, \tag{5}$$

where ${}_{t-1/1}q_x$ is the probability that the borrower aged x dies between the ages $(x + t - 1)$ and $(x + t)$. Formula (5) expresses the lump sum and consequently the installment payable in the event of the borrower's lifetime as a function of the random variables introduced earlier, namely, the interest rates r_j^{RM}, r_j^{HV}, r_j, and the survival probabilities inferred from an appropriate dynamic model dependent on the borrower's age and time, so as to capture the improvement due to longevity. For this reason, eq. (5) represents the possible values of the lump sum for each possible evolution of the cash flows. In order to derive the lump sum that the householder receives in $t = 0$, following the standard assumption in the actuarial modeling, we assume substantial independence between V_t and the borrower's lifespan and denote by P the model selected to calculate the probabilities of death, so we can write the value of the calculated lump sum as the conditional expected value under a real probability measure:

$$LS_0 = E(E[\tilde{LS_0}]|P). \tag{6}$$

3.2 Scenario assumptions

In this section we describe the assumptions on which we worked in order to provide the descriptive numerical results of the research. From the point of view of the lender, the sources of riskiness were identified as the risk due to longevity (*longevity risk*), the risk related to financial market fluctuations (*financial risk*), and the risk that arises from the dynamics of the real estate market appreciation rate (*house price risk*). Following the guidelines by Di Lorenzo et al. (2022), in what follows we will summarize the scenario assumptions considered to evaluate the value of the lump sum received by the borrower, which is necessary for the following numerical applications.

Mortality Description. As in Di Lorenzo et al. (2022), we apply the Lee Carter model to the Italian mortality data, available on Human Mortality Database from 1874 to 2014. This choice is motivated by the extensive use of the Lee Carter model by academics, actuaries, and social security institutions to forecast mortality rates. Following Lee and Carter (1992), the equation of the logarithm of the observed central mortality rates $m_{x,t}$ at age x and year t, is:

$$\ln m_{x,t} = a_x + b_x k_t + \varepsilon_{x,t}. \tag{7}$$

In Eq. (7), the parameters a_x, b_x and k_t describe, respectively, the shape of the age profile of $\ln m_{x,t}$, during the observation period, the mortality response at each age x for each change in the general level of mortality, and the general level of mortality in year t. The quantity $\varepsilon_{x,t}$ is an error term, i.e. it represents the part of the mortality phenomenon that the model fails to capture as a random variable with expected value 0 and variance σ_ε^2. Having the model no regressors, it cannot be fitted by ordinary regression methods; the authors find a least squares solution of Eq. (7) by minimizing the sum:

$$\sum_{x,t} (\ln m_{x,t} - a_x - b_x k_t)^2. \tag{8}$$

By means of the Singular Value Decomposition method applied to the matrix of the observed mortality rates, it is possible to fit the model to historical rates. The two constraints

$$\sum_x b_x = 1, \qquad \sum_t k_t = 0, \tag{9}$$

together with the assumption of homoschedasticity of the errors, ensure a unique solution.We use Box-Jenkins techniques to estimate and forecast the time-varying parameter k_t as an ARIMA time series model (cfr. (Di Lorenzo et al., 2022)). The probabilities of death in the year needed for (5) can be obtained accordingly.

Financial interest rate description. To describe the short rate dynamics in (3), capturing the high volatility of the interest rate series, we choose the jump diffusion model proposed by Merton (cf. (Chen et al., 2021) and (Di Lorenzo et al., 2022)). It is described by the stochastic differential equation:

$$\mathrm{d}r_t = r(t)(\eta \mathrm{d}t + \theta \mathrm{d}W_t + \mathrm{d}Q(t)), \tag{10}$$

in which η is the annualized expected return on the asset price, θ is the annualized volatility of the asset price, W_t is a Brownian motion and $Q(t)$ is a compound Poisson process. As in Di Lorenzo et al. (2022), we consider a constant volatility and Gaussian jumps. We estimated the parameters of the jump diffusion model on the Italian 10 year government bond daily yield from 2000 to 2018 using the *Deoptim* package of R. The optimization algorithm used to calibrate the models is based on the differential evolution algorithm for global optimization described in Mullen et al. (2011).

House price interest rate description. Refering to Huang et al. (2011), the house prices H_t is modeled considering the geometric Brownian motion:

$$\mathrm{d}H_t = \mu H(t)\mathrm{d}t + \sigma H(t)\mathrm{d}Z(t), \tag{11}$$

in which the parameters μ and σ are respectively the drift and the volatility of the process, while $Z(t)$ is the standard Wiener process. The parameter estimation have been performed on the quarterly variations of the Italian Real Estate Index IPAB diffused by ISTAT between 2010 and 2019 (IstatData, 2020).

4 Borrower's point of view

4.1 General aspects and utility-based models

The decision of whether or not to enter into a RM contract is a complex issue for an elderly person. Following Chiang and Tsai (2016), we can summarize the advantages and disadvantages of undertaking the role of the borrower in a RM contract. The borrower has the advantage of continuing to live at home as well as of being able to rely on a fund or periodic installments with which to meet daily or health expenses. The borrower is not required to pay installments or components of them while living at home; loan repayment is limited to an amount less or equal to the proceeds from the sale of the property and finally, the possibility, should market conditions make it advantageous in terms of the value of the home (i.e. the real estate market appreciates), to proceed to sell the home by reducing interest expenses and anticipating gains. Again, and in any case, thanks to the NNEG, neither the borrower nor relatives will incur financial obligations arising from any unexpected drops in house prices (Merton & Lai, 2016). Despite these objective advantageous aspects, RMs are struggling to take off. Many studies in the field point out that there are basically two critical factors: first, an entrenched culture of inheritance, which sees the house as the main asset to be left behind, from which house bequest motivation originates, to which is added the uncertainty about future consumption needs, the latter aspect related to uncertainty about lifespan, healthy lifespan in particular.

In order to investigate the economic consequences of reverse mortgage on elderly's consumption behavior, we construct a life cycle model for a retired individual aged x with estreme age ω, whose primary wealth asset is constituted by own home and who has to deal with the uncertainty about lifespan, future health states and the consequent considerable expenses for medical treatments, as well as house maintenance costs. For such homeowners, Davidoff (2009) considers a life cycle model to evaluate consumption smoothing benefits offered by annuities, long-term care insurance and reverse mortgages, focusing on the interactions of demand of these different products in the U.S. market. Similar simulations were provided by Mitchell et al. (1999) and Brown and Finkelstein (2007), but only in the setting of annuities and long term care insurance, respectively. Subsequently, Hanewald et al. (2016) analyze the decision problem of the optimal choice between reverse mortgages and home revision plans in an augmented life cycle model. Their paper extends previous work by Davidoff (2009) by allowing for interest rate risk, including home reversion plans in addition to reverse mortgages, and modeling the timing decision of when to release home equity. The model, however, is constructed just on two periods, each of which reflects a multiyear horizon. Shao et al. (2019) jointly consider the role of reverse mortgages and long term care insurance (LTCI) in retirement planning, applying a multi-period life cycle model. They solve the retiree's optimal choice for consumption, reverse mortgage loans, private long term care insurance and risk-free assets, referring to the U.S. market. However, they consider retirees with a relevant amount of starting liquid wealth so to conclude that, when there is no LTCI market, elders do not need to borrow against their house since pension income and base level of wealth result to be sufficient to fund consumption. In the aim to fit the model to the Italian context, our paper focus on the evaluation of RM contracts from the point of view of a homeowner who has low liquidity to bear medical expenses and consumption of other goods. For this reason, we do not consider LTCI or other type of products and shift the focus of the analysis to the optimal savings allocation rather then optimal consumption path. Additionally, we decide to focus on savings allocation to empirically shed light on the fact that RM may help senior citizens to give liquid financial support to children or grandchildren during their lifetime, as already noticed by Fornero et al. (2016). In details, our model considers a general scenario tailored to the "house rich, cash poor" part of elder Italian population, where time moves, period by period, from age x up to age ω (i.e. $t \in [0, \omega - x]$). We suppose that at $t = 0$ the aged-x individual is in good health, owns some liquid wealth W_0 and a mortgage-free home with current market value H_0. At this time, he/she has the opportunity to stipulate a RM plan, structured as explained in Sect. 3. In the following and without any loss in the generality of the model, we assume that the borrower receives an initial lump sum LS_0 rather that a stream of payments, assigned by the lender following the lines in Sect. 3. At each time t, the elder decides on consumption and savings. We assume that he/she is surely dead at age $\omega + 1$. As in the aforementioned works, we measure utility not only on consumption but also on bequest to understand the impact of the attachment to the property on elder's financial planning. Although welfare advantages obtained by contracting a RM contract have been proven, a strong bequest motivation may lower individual's utility gains, confirming it as the most prominent explanation for the absence of demand for this type of products, coherently with Fornero et al. (2016).

Differently from Davidoff (2009) we do not consider any psychological and financial costs as a consequence of leaving the house for non-health reasons, with the intention of focusing on the influence of medical expenses and bequest on elders' economic attitude. However, our construction can be easily generalized to include such type of disutility and conclusions will not be affected at all. As specified in Sect. 3, we incorporate also the possibility of writing RM on a proportion α of the current market value of the house, in which case the borrower will receive a lower initial lump sum $A_0 < LS_0$. At the random time of death, the heirs consequently will have to repay the accumulated debt or a proportion of the proceeds from the sale of the house, according to Eq. (2); individual's remaining liquid wealth and housing wealth, net of RM payments, are bequeathed.

4.2 Health states, transition probabilities and house maintenance costs

During the considered lifespan, we assume that the elderly may be in three different health states[1]: healthy ($s = 1$), severely ill ($s = 2$) or dead ($s = 3$). States $s = 1$ and $s = 2$ are considered as strictly transitory, i.e. it is not possible to go back once passed them, while state $s = 3$ is totally absorbent, in the sense that once reached, one is no longer able to change this state (Di Falco & De Angelis, 2016).

Denote with $p_{s,t}$ the probability of being in health state s at time t and with M_s the amount of medical expenditures in health state s. Such costs are chosen to be zero in case of good health ($s = 1$) or in case of death ($s = 3$); medical expenses for $s = 2$ are estimated by ISTAT dataset about household medical expenses in the period 2014–2021 (IstatData, 2022). We set this value constantly equal to $M_{s,t}$ =€1,000/year, since we just consider the amount charged to the elder, i.e. eroded by the sum covered by government provision. Also, we do not look at any type of long term care insurance, since the target of our model is the "house rich and cash poor" Italian retirees, that usually cannot afford to purchase health or long term care insurances.

Transition probabilities were acquired from demographic technical bases made available by Di Falco and De Angelis (2016) in the form of numerical table collected in ANIA (2019). We refer to male population considering the central scenario, since is that of maximum likelihood among all the others produced by the model. Using these data, we were able to obtain a projected application of our model where the individual enters age 70 in 2013 and turns 100 in 2043 (see Sect. 6).

House maintenance costs, denoted with Z_t and extracted from ISTAT dataset (IstatData, 2022), are designed to represent repairing costs in which the borrowers incur to keep the house as required by RM guidelines; these terms will not look at household expenses, to be fully compensated by the pension income. We set Z_t =€150/year.

4.3 Utility function and constraints

Having in mind the structure of the RM contract described in Sect. 3, we are now looking at the elders decision problem, who has the opportunity to stipulate a RM plan at $t = 0$. Firstly, our model is constructed in order to fit with our target market, the Italian one, which is mostly characterized by "house rich and cash poor" retirees. Secondly, in order to focus on the impact of the reverse mortgage product on elderly consumption and to not further complicate the construction, we do not look for optimal time or age for contracting a reverse mortgage, neither consider the possibility of taking multiple RM loans during retirement, as done in Hanewald et al. (2016), Campbell and Cocco (2003). We describe consumption and bequest preferences considering constant relative risk aversion (CRRA) utilities. However, differently from Davidoff (2009) and Shao et al. (2019), where aggregate CRRA utility functions for housing and non-housing consumption were considered, we follow Campbell and Cocco (2003) and Hanewald et al. (2016) and define utility over consumption only, since housing consumption is related to rent (Piazzesi et al., 2007; Davidoff, 2010): we suppose that elderly always prefer to live in their own house and will leave just in case of death.

[1] The choice of considering just three health states is linked to the availability of data for the Italian market. One can note that Davidoff (2009) and Hanewald et al. (2016) work on four different health states, relying on Ameriks et al. (2011), while Shao et al. (2019) consider five different health states and refer to HRS data (HRS, 2010) to estimate the transition probabilities.

Therefore, consumption and bequest utility functions have the following form:

$$U(C_{s,t}) = \frac{C_{s,t}^{1-\gamma}}{1-\gamma}, \tag{12}$$

$$B(W_{s,t}) = \frac{W_{s,t}^{1-\gamma}}{1-\gamma}, \tag{13}$$

where $\gamma > 1$ denotes the coefficient of relative risk aversion, $C_{s,t}$ is state s-time t consumption, $W_{s,t}$ denotes state s-time t wealth. An x-aged elder maximizes the following lifetime utility function:

$$E_p[C, W] = \sum_{t=0}^{\omega-x} \delta^t \cdot \left[\sum_{s=1}^{2} p_{s,t} \cdot U(C_{s,t}) + \beta \cdot p_{3,t} \cdot B(W_{3,t+1}) \right], \tag{14}$$

where $\delta < 1$ denotes the subjective discount factor, which represents impatience of the individual and β is the parameter indicating the intensity of the bequest motivation.
Denoting with $COH_{s,t}$ the liquid cash-on-hand available at state s-time t and $S_{s,t}$ as the savings carried out to the next period from state s-time t, constraints are constructed, for every $s \in \{1, 2, 3\}$ and $t \in [0, T]$ as follows:

- **Case with RM**:
  (i) $C_{s,t} = \begin{cases} W_0 - S_{s,t} - M_{s,t} - Z_t + LS_0 & \text{if t=0,} \\ COH_{s,t} - S_{s,t} - M_{s,t} - Z_t & \text{if } t > 0; \end{cases}$
  (ii) $W_{s,t+1} = S_{s,t} \cdot (1 + r_t) + \max(0, H_{t+1} - A_{t+1})$;
  (iii) $W_{s,t} \geq 0$;
  (iv) $0 \leq S_{s,0} \leq W_0 - M_{s,t} - Z_t + LS_0$;
  (v) $0 \leq S_{s,t} \leq COH_{s,t} - M_{s,t} - Z_t$;
- **Case without RM**:
  (i') $C_{s,t} = \begin{cases} W_0 - S_{s,t} - M_{s,t} - Z_t & \text{if t=0,} \\ COH_{s,t} - S_{s,t} - M_{s,t} - Z_t & \text{if } t > 0; \end{cases}$
  (ii') $W_{s,t+1} = S_{s,t} \cdot (1 + r_t) + H_{t+1}$;
  (iii') $W_{s,t} \geq 0$;
  (iv') $0 \leq S_{s,0} \leq W_0 - M_{s,t} - Z_t$;
  (v') $0 \leq S_{s,t} \leq COH_{s,t} - M_{s,t} - Z_t$.

Equations $(i) - (i')$ describe the dynamics of consumption flow with and without RM; at $t = 0$, the elder is supposed to be in a healthy state (i.e. $s = 1$) and receives the amount LS_0, established as in (6), in the event of purchasing the RM product. Recall that the cost for the guarantee to be borne by the borrower are not visible in the consumption flow since they are already subtracted from the lump sum, as described in Eq. (1). Equations $(ii) - (ii')$ explain the relationship between bequest and liquid wealth; equation (ii) takes into account the NNEG connected to the RM contract, described in Sect. 3, while equation (ii') considers the house value at $t + 1$ as a liquid amount bequeathed by the heirs. Equations $(iii) - (iii')$ and $(iv) - (iv)'$ avoid negative wealth and negative consumption respectively. Note that, without loss of generality, we do not include pension income in the consumption flow since we suppose that it is totally eroded by household expenses.

5 Optimization procedure

The elder starts the first period in a healthy condition and with liquid wealth W_0; at this time, he has the opportunity to stipulate a RM plan. At each period t, he/she has to decide how much to consume and then consequently how much to save for the next period. Next period cash-on-hand for a certain health state $\hat{s}$ is given by

$$COH_{\hat{s},t+1} = S_{s,t}(1 + r_t), \tag{15}$$

where r_t is the risk-free interest rate. The decision is determined at $t = 0$ by comparing the value of the lifetime expected utility function with and without the RM. Therefore, to understand individual's optimal choice, we need to solve the maximization of Eq. (14), subjected to constraints (i)-(v), $(i') - (v')$.

This problem cannot be solved analytically, hence we exploit the backward induction mechanism. This method is widely used when dealing with consumption and optimal portfolio choices over life cycle models (Campbell & Cocco, 2003; Cocco et al., 2005; Davidoff, 2009; Shao et al., 2019), and in several different settings (Cocco & Lopes, 2011; Andréasson et al., 2017; Daminato & Padula, 2024). The procedure for our case was constructed as follows: knowing that at time $T + 1$ the elder will be surely dead, we could easily establish, for every health state, the value function for the last period, which corresponds to the indirect utility function, solving:

$$V_{s,T}(C, W) = \max_{C_{s,T}} [U(C_{s,T}) + \delta \cdot \beta \cdot B(W_{3,T+1})]. \tag{16}$$

Subsequently, we can use this value to compute the value functions for the previous periods: this value is equal to the current utility plus the discounted expected indirect utility. In general, for each $t \in [0, T)$ and health state $s = 1, 2$, we need to find:

$$V_{s,t}(C, W) = \max_{C_{s,t}} \left[U(C_{s,t}) + \delta \cdot \left(\sum_{s'=1}^{2} p_{s',t} \cdot V_{s',t+1}(C, W) + \beta \cdot p_{3,t} \cdot B(W_{3,t+1}) \right) \right]. \tag{17}$$

In order to implement the optimization procedure, we consider savings as the decision variable, following Davidoff (2009), and use the grid search method to find the optimal savings choice. More precisely, starting from T and going backward for each time period $t \in (0, T]$, we discretize the wealth state variable considering ordered grid with equidistant grid points and solve Eqs. (16)–(17) recursively as indicated above, taking into account constraints (i)-(v), $(i') - (v')$. We set the maximum wealth level in each grid as the maximum attainable wealth, i.e., for each t, $W_{t,\max} = W_0 \cdot (1 + r_t)^t$ represents the wealth that can be accrued by investing the initial wealth until time t at the risk-free interest rate. For each grid point of the wealth state variable, we find and store the optimal savings and consequently the consumption levels elder may bear, as well as the values of the corresponding indirect utility function. Once concluded this iteration, we are ready to get the optimal savings path. Since the starting wealth is equal to W_0 and the elder is in good health at $t = 0$, i.e. $s = 1$, we can extract the optimal savings level (and consequently consumption and next-period starting wealth) which corresponds to our wealth grid point W_0 at $t = 0$. For successive time periods t, once knowing the value of the remaining wealth at $t - 1$, using the relation (15) we are able to repeat the selection procedure until $t = T$, and construct the optimal savings path.

6 Numerical application and results

In this section we show some numerical applications of the model in order to compare optimal savings path when the elder homeowner agrees or not to subscribe the RM. Focusing on the borrower's perspective, we will present three possible scenarios of different illness occurrences: the *median case scenario* in which the elder homeowner becomes seriously ill at 85 and remains in this state until his death, the *worst case scenario*, in which he/she becomes seriously ill at 71 and has to face considerable medical expenses until death, and the *best case scenario* in which he/she reaches extreme age in good health. We will compare optimal savings path with and without RM in all these cases. Secondly, we carry out a sensitivity analysis respect to the parameters that characterize old person's attitude to understand their impact on lifetime utility function: β as the propensity to bequest, γ representing risk aversion, δ describing the impatience of the borrower.

6.1 Parameter settings

We suppose that at $t = 0$ the elder, with starting liquid wealth of $W_0 =$€$20,000$, is $x = 70$ years old and has to decide if to borrow against a proportion $\alpha = 0.7$ of his/her house[2] with initial value $H_0 =$ €$200,000$. We set extreme age at $\omega = 100$. Firstly, we need to quantify the amount of the lump sum LS_0 the pensioner receives in the event of signing the contract. Setting the global interest applied by the lender to the RM loan at $5,56\%$, the evolution of interest rates and house price interest rate are simulated as displayed in Sect. 3; the pricing of the RM was obtained according to the actuarial evaluation formulas developed by Di Lorenzo et al. (2022) and Di Lorenzo et al. (2024a), and returns $LS_0 =$ €$42,126$.

At this point, for the purpose of performing the optimization procedure, we fix[3] as benchmark values $\delta = 0.98$ as the impatience parameter, $\beta = 2$ as the bequest propensity parameter and $\gamma = 2$ as the risk aversion parameter. Transition probabilities, medical expenses and house maintenance costs are chosen as described in Sect. 4. From now on, as a consequence of the demographic technical bases considered, we will refer to male population.

6.2 Results

Given the parameters setting and once the lump sum has been quantified, we implement the optimization procedure searching for the optimal savings path that maximizes the lifetime utility function. During the optimization procedure, we assume that savings accumulate at a constant risk-free interest rate equal to $r = 1,6\%$. The process is repeated in the case the homeowner agrees or not to subscribe the RM. In order to analyze different occurrences elderly may deal with during retirement, we perform the optimization for the three different scenarios, showing the level of liquid wealth which coincides with the optimal choice of savings for each age in Figs. 1, 2, 3. In all the three exemplary cases, it is noticeable that the liquid wealth available in the case of RM may help release the tension on elderly savings behavior, so that the elderly would be able to financially help heirs while still alive.

[2] In this work, we do not consider the proportion α as a decision variable for the elderly since, in the Italian context, it is generally preset by the issuer in relation to the age and health status of the borrower.

[3] It is worth noting that the setting of the parameters is not homogeneous in the existing literature, since the choice is linked to the specific framework one decides to analyze. Moreover, we were not interested in performing any type of estimation for these values in the present work. Therefore, one should interpret our choice as illustrative to understand how the model works.

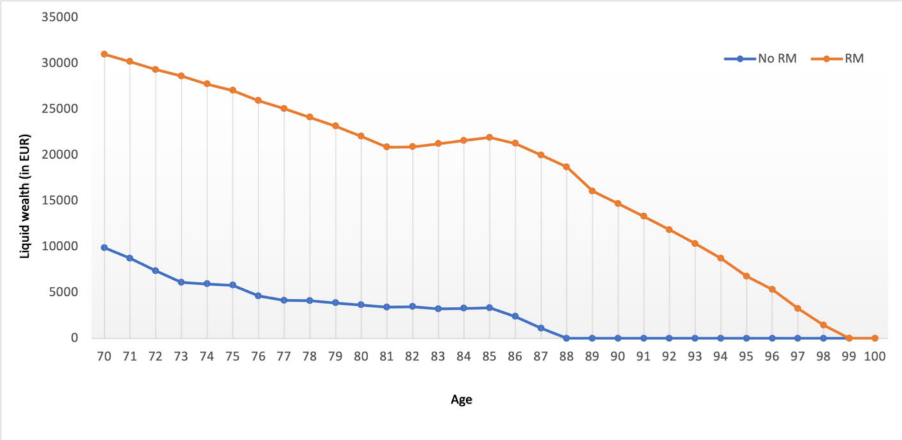


Fig. 1 Optimal savings paths in the median case scenario

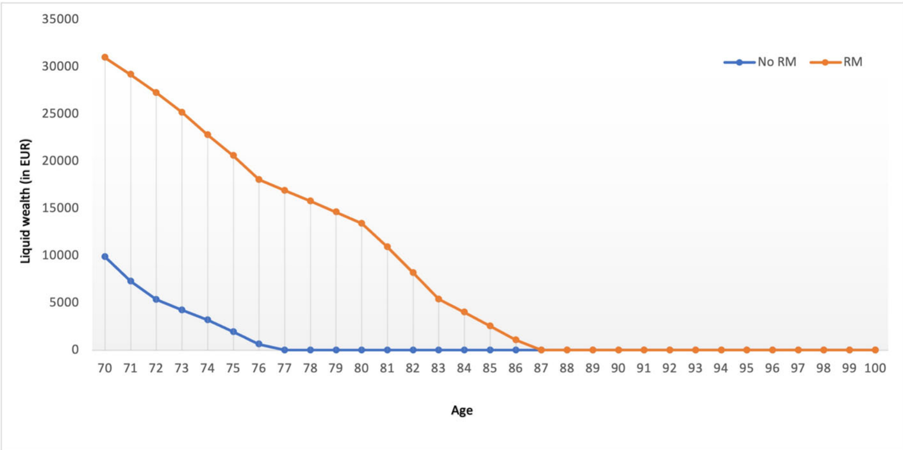


Fig. 2 Optimal savings paths in the worst case scenario

Median case scenario

In this case, according to the parameters setting mentioned earlier, the homeowner becomes seriously ill at 85 and remains in this state until his death. As Fig. 1 shows, without RM, the incidence of medical expenses leads to consuming all the liquidity from savings within 15 years and the individual, at 88 years old, must financially burden the heirs to face his remaining old age. Otherwise, if he stipulates the RM, the lump sum investment guarantees the possibility of covering expenses until the extreme age.

Worst case scenario

As per the aforementioned selection of parameters, in this case the elder becomes seriously ill at 71. The situation becomes more serious respect to the previous one since, if he has not subscribed to RM, the liquidity from savings at his disposal will collapse at the age of 77, while in the case of subscription of the contract, he manages to be financially independent for a further 10 years.

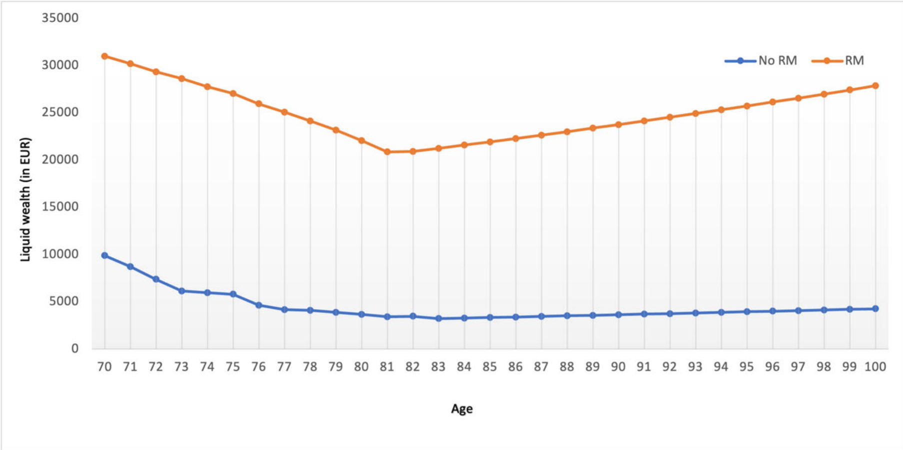


Fig. 3 Optimal savings paths in the best case scenario

Best case scenario

In the best case, given the parameters as stated above, the homeowner will reach extreme age in good health. Although the absence of medical expenses, the advantage deriving from signing the RM can also be notice: the proceeds of the lump sum investment guarantee him superior liquid wealth from savings which allows him to lead a more comfortable lifestyle during his old age and provides him with a sort of supplementary pension, as one can see by the increasing trend of liquid wealth at disposal.

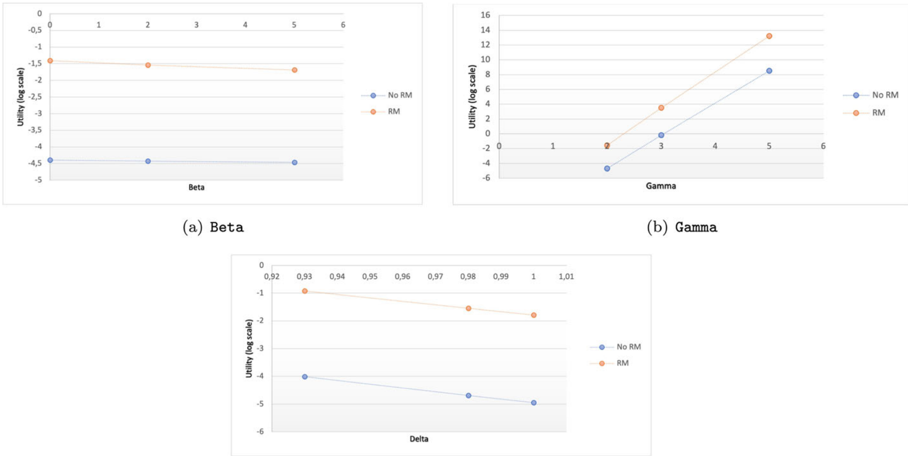
All the examples above clearly illustrate the welfare gains senior citizens may obtain contracting a RM contract. However, this product is struggling to develop on the Italian market. We strongly believe that, despite the bequest motivation may be a predominant element of rejection, poor financial literacy among elderly population is highly preventing this product to be purchased. As already pointed out in Fornero et al. (2016), RM is perceived as a last resort in case of poverty. However, as the best scenario case pointed out, the RM lump sum may be used as an instrument to accomplish consumption smoothing as well as being invested, allowing to create a liquid share of inheritance to be left to heirs. Consequently, from a policy point of view, it results to be fundamental to furnish financial guidance to elderly in order to enable them to understand the possibilities this product is able to provide for their retirement and the future of their relatives.

6.3 Sensitivity analysis

In this last section, we conduct a sensitivity analysis by changing the values of the parameters β, γ and δ in order to emphasize that the issuer has to take into account the different characteristics of the buyer, since they may concretely affect the product personal evaluation. Figure 4a–c show, coherently with the existing literature (Hanewald et al., 2016; Shao et al., 2019), the trend of elder's utility function as the parameters β, γ and δ vary. We choose the following settings:

Considering that the utility obtained after contracting the RM is always dominant, one can notice a decreasing evolution of the lifetime utility function respect to the parameters β and δ: the stronger the bequest motivation and the impatience of the borrower, the less

Parameter	Value 1	Value 2	Value 3
β	0	2	5
γ	2	3	5
δ	0.93	0.98	1



(a) Beta (b) Gamma (c) Delta

Fig. 4 Sensitivity analysis

the utility. This may be explained considering that a stronger bequest motivation prevents elders from giving up the ownership of the house to receive an amount of money. On the other hand, looking at the parameter δ, moving consumption benefits to preceding years makes the product less attractive for more forward-looking individuals. In contrast, when the risk aversion increases, the utility gains when contracting RM increase. This can be explained considering all sources of house-related risk as a financial asset: more risk-averse homeowners prefer to receive an immediate amount of money rather than face house price risk.

Given the clear emotional aspects that come into play in purchasing the RM product, this type of analysis can be useful to policy makers to create a more flexible offer, which is able to take into account the different personal features of buyers.

7 Conclusions

Reverse mortgage contracts are framed in the area of financial insurance products designed to meet the needs of an ageing society. In this paper, we focus our attention on the point of view of “house rich and cash poor” elder Italian homeowners, whose financial status is alarming, due to insufficient pension income, increasing life expectancy and consequent expensive medical costs to be met. Much work has be done in scientific literature in order to investigate the reasons why RM is struggling to develop on Italian market. However, the novelty of our research is to provide an empirical analysis of the impact of RM on Italian elder’s financial planning. Our choice of the stochastic processes in the numerical applications was made for illustrative purposes and is functional to the construction of the life-cycle model, which constitutes the central and innovative part of the paper. However, the generality of our mathematical construction enables to easily employ different stochastic processes and to cover various financial scenarios, including other key variables as inflation. We adapt the widely used life-cycle model (Davidoff, 2010; Hanewald et al., 2016; Shao et al., 2019) to our target market and center the analysis on comparing optimal savings path with and without RM. To pursue the optimization procedure, we exploit the backward induction mechanism and discuss three exemplary cases considering different occurrences elderly may deal with during retirement, related to health state. A sensitivity analysis on the parameters characterizing borrower's attitude was also provided. What emerges is a larger utility gain in the case RM is chosen, which may provide a relevant welfare support to release pressure on elders' consumption and savings allocation. These results shed light on the need for a better communication and presentation of the product; despite the fact that strong bequest motive may be one of the most impacting factors for the lack of demand of RM, we strongly believe that financial education has an important role in this framework. Moreover, given the clear emotional aspects that is involved in this type of product, due to the attachment to the property elders may feel, our analysis can provide important policy indication to make the product more attractive in the market: the evidence obtained by exploring the context of elderly house rich and cash poor Italians are unmistakable, so the saving gains are clear. The problem of information ambiguity, due to the product's complexity, as well as the poor financial literacy, constitutes the main point to be addressed.

Funding Open access funding provided by Università degli Studi di Napoli Federico II within the CRUI-CARE Agreement. Emilia Di Lorenzo,Gabriella Piscopo and Alba Roviello were partially supported by the Grant Agreement "Progetto Partenariati Estesi - PNRR Project "Age-It - Ageing Well in an ageing society "– Codice MUR: PE0000015- CUP E63C22002050006".

Declarations

Conflict of interest The authors have no Conflict of interest to declare that are relevant to the content of this article.

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