Reverse Mortgages, Housing, and Consumption: An Equilibrium Approach*

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Abstract

Reverse Mortgages (RMs) enable eligible homeowners 65 years and older access to the liquidity of their home without them moving out or repaying before loan termination when the borrowers die or move to long-term care facilities. We incorporate RMs into a quantitative equilibrium life-cycle model to assess their impacts on household decisions, the mortgage, and the housing market. We show that the volatility of consumption growth decreases for RM borrowers. Additionally, introducing RMs enhances the house's perceived value to households, making homeownership a more financially attractive option and stimulating housing demand. These effects increase overall household welfare in our model, highlighting the positive impact of RMs.

JEL Classification: G21, E21, J14

Key Words: Reverse Mortgage, Mortgage, Housing, Retirement, Welfare

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1 Introduction

Financial instability in later life has become a global challenge over the past decades due to rising life expectancy, growing socioeconomic inequality, and limited public resources for social security and the pension system, which puts pressure on private savings for retirement.[1] At the same time, most household wealth accumulates in the form of illiquid housing assets.[2] Moreover, some households make suboptimal decisions regarding their pension choices, such as early withdrawals. All of these lead to the phenomenon of "equity-rich and cash-poor" households (see Caplin (2000)).

How shall we tackle this challenge? Reverse Mortgages (RMs hereafter) could be a potential solution. RMs have emerged as a popular financial tool for older households worldwide to finance their retirement living expenses.[3][4] They allow homeowners to extract the value of their homes to supplement their retirement income without having to move out or downsize. Moreover, borrowers are not required to make any payments on the loan until its termination. If, upon termination, the remaining loan balance exceeds the house's value, neither the retirees nor their heirs is liable for the shortfall. The government bears the losses if house value declines. In fact, our paper is motivated by empirical observations of the upward trend in RM adoption globally, across both developed and emerging economies. However, the structural complexity of RMs makes it challenging to analyze their impacts on household decisions, balance sheet dynamics, mortgage and housing markets, as well as social welfare.

In this paper, we estimate RM's economic implications through various channels, using CoreLogic and Black Knight's US loan-level data. We set up a general equilibrium model with heterogeneous households, subject to multiple risks, competitive lenders, endogenous house prices, conventional mortgages, and RMs to account for macroeconomic booms, recessions, and crises with cyclical interest rates. Mortgage and RM spreads are set to break even by lenders. Household decisions influence equilibrium property prices and mortgage and RM spreads, which then feed back to them. Based on their expectations about equilibrium house values, mortgage, and RM rates, households choose consumption, saving, homeownership, default, conventional mortgage (re)financing, property maintenance, and RM borrowing.

[1] The Geneva Association (2024) reports that the total world's pension gap amounts to $41 trillion. There exists about $10–15 trillion projected shortfall in the US pension system.

[2] According to Chen et al. (2020), on the US household balance sheet, housing estates are 10 times the size of liquid assets, such as cash and equivalents (financial securities such as equities and bonds). Similarly, Nakajima and Telyukova (2020) states that excluding housing wealth, retirees' net worth would be 28%-44% lower, depending on age group. Iacoviello (2011) also estimates that housing wealth accounts for about one-half of total household net worth in the U.S. data.

[3] In the US, RMs are commonly Federal Housing Administration (FHA) – insured Home Equity Conversion Mortgages (HECM), available to individuals aged 65 and older and are primarily used to finance retirement consumption.

[4] See Nakajima and Telvukova (2017, 2020), and Chen et al. (2020).

According to our calibrated model, integrating RMs in the credit market aligns the loan-to-value (LTV) ratio with the Survey of Consumer Finances (SCF) and matches the homeownership rate. RMs can be used to repay conventional mortgages within LTV limits, this feature makes them an attractive alternative to refinancing because RMs relieve borrowers from regular repayments, thereby reducing liquidity concerns, which can be observed from CoreLogic and Black Knight datasets. Thus, calibrating our model with such datasets helps us realistically capture RMs' impacts.[5] Most papers modelling RM employed public survey-based datasets like the Panel Study of Income Dynamics (PSID) and Health and Retirement Study (HRS), which require estimate and weighting. RM take-up is low compared to the general eligible population, hence loan-level granular datasets improve our study.

Our model matches empirical evidence for the Payment-to-Income (PTI) ratio with RMs in the model. Without RMs, Guren et al. (2021) shows an exponentially growing PTI ratio during retirement, contradicting empirical findings. Furthermore, in our scenario, conventional mortgage refinancing rates remain stable and moderate during retirement. These findings contrast with Guren et al. (2021), which found a low refinancing rate during employment and a sudden spike following retirement. In our model, households can use RMs as a refinancing substitute with no monthly repayments and aand an embedded put option of housing price, resulting in this moderate refinancing rate during retirement.

Using insurance premium and other cost information from the HECM guidelines, our model generates a relatively low RM take-up rate of 4.2% among eligible homeowners, with a hump-shaped pattern over the life cycle, consistent with empirical observations. We find that lowering initial RM setup and product expenses can boost take-up rates by up to 10% among eligible householders aged 62-65, significantly higher than empirical evidence. Research indicates that high set-up and product costs result in poor take-up rates, supporting findings from literature such as Cocco and Lopes (2020) and Nakajima and Telyukova (2017).

Our major findings show that RMs smooth household consumption over the life cycle. RMs help households 65+ access home equity and address the problem of lowered retirement income. The consumption growth volatility of households with RMs decreases by 17.04% (working) and 8.36% (retiring). In addition, senior households obtain liquidity from RMs, and save less in the early years of their mortgages. This enhanced flexibility smooths consumption during their working and retirement periods.

To assess the impacts of RMs on the housing market and the welfare of households, we evaluate an

[5]CoreLogic and Black Knight access credit data and American Community Survey (ACS) data on household demographics, socioeconomic characteristics, consumption, investment, housing condition, house prices, first liens (conventional mortgages and RMs), and second or junior liens.

alternative economy without RMs in the credit market, with all other parameters held constant as in the economy with RMs. Fixing housing supply, house prices increase significantly (from 0.66% to 1.90%) in the economy with RMs. Homeowners attain substantial welfare gains, with consumption certainty equivalent variation ranging from 1.29%(age <65) to 4.77% (ages 65-75) and 7.47% (age >75). On the other hand, renters' welfare improves marginally. In addition, households in economy with RM had less consumption growth volatility. Therefore, these findings suggest introducing RMs as a financial product for trading liquidations improve housing market efficiency and benefit households.

Our paper is related to existing RM literature. Case and Schnare (1994) investigate RM's growth in mid-2000s, including loan and property characteristics; borrowers' socioeconomic and demographic aspects. They point out regulatory and legal issues may hamper growth. Rasmussen et al. (1995) and Merrill et al. (1994) define RM's potential beneficiaries by age, income, and home equity and identify geographical locations with a high concentration of such target groups for market development. Davidoff (2015) examines the situations in which reverse mortgages might be beneficial for homeowners. Recently, Nakajima and Telyukova (2017) suggest that bequest motives, uncertainty about health and expenses, and loan costs account for low demand. Cocco and Lopes (2020) propose *aging-in-place*, and suggest maintenance cost reduces the benefits of the RMs for borrowers.[6] Both Nakajima and Telyukova (2017) and Cocco and Lopes (2020) predict RMs' low demand, aligned with empirical data, assuming exogenous home prices and RM rates.[7] These papers employ a partial equilibrium life-cycle model that considers only the household balance sheet, not interactions between the credit market and the housing market.

In contrast to them, we endogenize house prices, mortgage rate, and RM rate, which improves the assessment of RMs' impacts on household balance sheets, decisions, and welfare for both retired and working households. To the best of our knowledge, our model is one of the first to clear the housing and credit markets simultaneously, including conventional mortgages and RMs. Meanwhile, our model allows RM borrowers endogenously choose a lump sum or drawdown, in contrast to the common assumption in existing literature that they would only take a lump sum or drawdown. This endogenous choice adds a realistic dimension to our analysis, reflecting the actual decision-making process faced by homeowners considering RMs.

Our paper also contributes to the integrated mortgage-housing market literature. Earlier attempts

[6] *Aging-in-place* was originally raised in environmental psychology, referring to the emotional attachment that binds a person to a particular place.

[7] Campbell and Cocco (2003) estimate only 2%–3% senior homeowners among eligible older homeowners borrow RM, as the US Census Bureau reports. On the other hand, Nakajima and Telyukova (2017) estimate this ratio to be 1.9% in 2013, down from 2.1% in 2011.

to integrate the mortgage-housing market into the same framework treat either the mortgage or housing market as exogenous. For example, Ortalo-Magne and Rady (2006), Favilukis et al. (2017), and Tim et al. (2014) study equilibrium housing markets, treating mortgages as exogenous or stylized; Campbell and Cocco (2015) and Corbae and Quintin (2015) consider equilibrium mortgage market, taking housing market and house prices as given. On the other hand, the real estate's unique characteristics, such as illiquidity, borrowing constraints for low-wealth households, and households' heterogeneous preferences, hinder immediate demand-supply equilibrium; fluctuations in the housing market affect housing prices, which feed back on all types of mortgages, including RMs (see Case and Shiller (1988), Mankiw et al. (1989), DiPasquale and Wheaton (1994), Riddel (2004) and Hwang and Quigley (2006)). Closer to our model, Kung (2014) and Guren et al. (2021) create a general equilibrium housing and mortgage model with endogenous house prices and mortgage rates. Building on this foundation, our study offers a deeper insight into credit market dynamics and complexities by incorporating the interplay between mortgages and reverse mortgages.

Within the mortgage-housing literature, refinancing and default activities are discussed in detail. Empirical studies, such as Campbell (1983) and Deng et al. (2000), suggest that borrowers delay default until it is irreversible and their option to default is deep in the money. More recent studies find that with the presence of precautionary savings, there exist inconsistent correlations between mortgage default and unemployment, and these correlations vary depending on the research period and location. (see Elul et al. (2010)); Quercia et al. (2012); Ghent and Kudlyak (2011); Archer and Smith (2013); Tian et al. (2015)). Chen et al. (2020) follow Campbell and Cocco (2003) and integrate mortgage refinancing and home equity-based borrowing (HELOC) using a partial equilibrium approach. They show that during the recession, liquidity-constraint households refinance even with heightened borrowing costs due to adverse income shocks, contradicting the conventional belief that low interest rates drive refinancing. Our paper strengthens their observations by demonstrating that even when the RM rate is higher than the mortgage rate, households widely use RMs as an alternative to refinancing. Furthermore, we allow homeowners to strategically default to maximize utility, as well as facing forced default. Overall, our model generates a stable refinancing rate and aligns default rates with empirical data across households of all ages.

The remainder of the paper is organized as follows. Section 2 highlights the importance of RMs based on empirical evidence. Section 3 introduces our main model setup. Section 4 demonstrates our calibration methodologies, and Section 5 presents the quantitative analysis. Section 6 evaluates an alternative economy without RMs in the credit market, with all other parameters held constant as in the

original economy with RMs. Section 7 concludes.

2 Empirical Motivation

Using proprietary data from CoreLogic and Black Knight, we compile a complete and granular dataset on household mortgage open liens up to 2021. The advantage of our dataset is that it covers the actual mortgage and RM borrowers' property information, such as their historical and market value, housing type, and condition. All mortgages and RMs (initial balance, interest rate, terms, etc.) were secured on the properties in the entire country during our research period, which covers almost all of the properties secured on such mortgages. Other datasets used in previous literature, such as PSID and HRS, cover only a subset of the population through surveys that can sometimes bias the model results because RM is a relatively small market compared to conventional mortgages and other more developed financial products.

As depicted in graph A of Figure 1, we first notice that the RM take-up rate in the US has increased more than tenfold, from approximately 0.3% in 1997 to 4.3% in 2021.[8] We also find that younger retirees (those aged 65-70) and unmarried retirees are more likely to take up RMs from Figure 2. Younger retirees, who have more years of retirement ahead of them, have opted for RMs to secure additional funds for their extended retirement period and their growing consumption needs. On the other hand, unmarried retirees, who lack a spouse to share financial risks and typically have lower average wealth and retirement income than their married counterparts, may seek RMs to supplement their available funds and enhance their consumption capacity.

Moreover, graph A of Figure 1 shows a noticeable drop (from 1.4% to 1%) from 2008 to 2011. Since the Global Financial Crisis (GFC) in 2008, some lenders have left the market. This results in RM plan issuance in the US being reduced following the GFC (see Cocco and Lopes (2020)). Moreover, the RM market suffered a more severe blow due to the correction in the housing market following the artificial housing boom from the 1990s to 2006. This was intensified by the fact that lending criteria heavily relies on LTV, which is intricately connected to housing market performance. The market gradually recovered in 2011 and has significantly increased over the past decade. Additionally, the 2015 RM reform allowing RMs to be used as a down payment for a property of an eligible senior homeowners' offspring has further contributed to the growth of this market.

[8]The consistent growth pattern has also been observed in several developed economies, such as the UK, Australia, and Hong Kong, which is captured in Figure 10 in Appendix A.

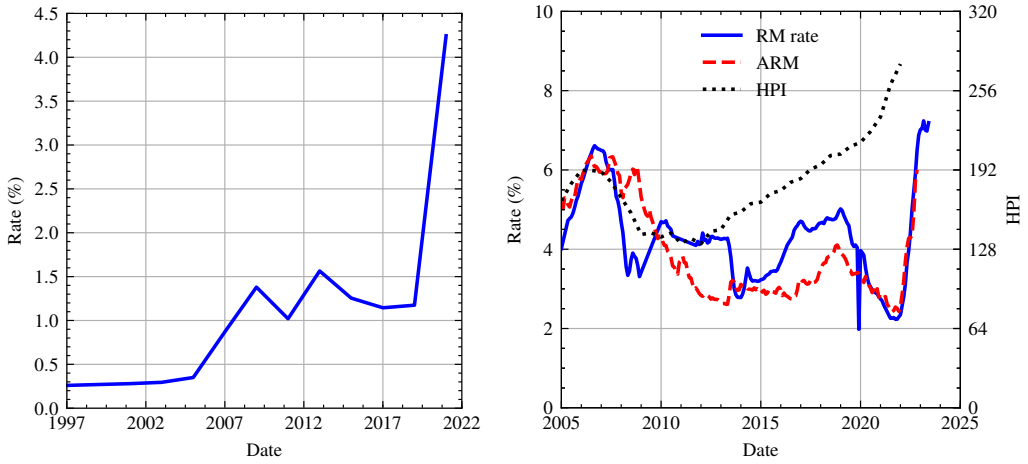


Figure 1: RM Market in the US

This figure shows the current RM market in the US. Graph A plots the RM take-up rate in the US, and graph B plots mortgage, RM rates, and HPI in the US.

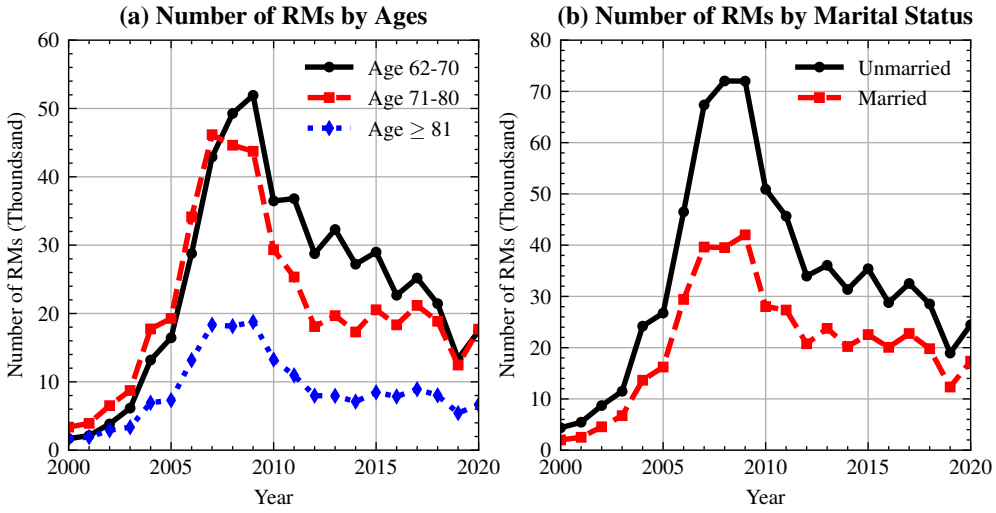


Figure 2: Number of RMs by Borrower Age and Marital Status in the US

This figure shows the RM borrowers' age groups and marital status in the US. Graph A plots three age groups: (1) just retired aged 65-70, (2) mid-retirement (aged 71-80), and (3) old age retirees (aged >81) of RM borrowers in the US. Graph B plots two curves representing unmarried and married RM borrowers' numbers, respectively.

Graph A of Figure 1 also witnesses uninterrupted growth in the RM market following the COVID-19 crisis, in contrast to the market contraction following the GFC. The post-COVID-19 period saw high interest rates as the central banks increased the base rate multiple times in a short period of time in order to cool inflation caused by the prolonged ultra-low interest rate environment. At first glance, the rapid growth in the RM market following the COVID-19 crisis seems to contradict some predictions that suggest higher interest rates usually cool down the housing market and mortgage market. However, this surge in RMs in the post-COVID-19 crisis supports the conclusion by Hurst and Stafford (2004) that enabling households to convert home equity into liquid assets re-adjusts households' decision to refinance, even at the costs of higher borrowing costs. This is one of the reasons that RMs have become increasingly important in the household finance and credit literature, such that RMs provide a direct way to borrow against home value as an alternative to mortgage refinancing.

In summary, the two crisis periods have caused opposite RM market movements because of complex compounding effects of central bank base rates, housing market performances, and labor income instability. These dynamics on the household balance sheet and choices integrate LTV, LTI constraints, and economic states, which are essential and highlight our contribution to this end.

Finally, graph B of Figure 1 shows the growing trends of the conventional mortgage rates, RM rates, and the housing price index (HPI) in the US from 2005 to 2023. HPI is taken from CoreLogic HPI. Recently, a remarkable increase in the HPI has been accompanied by significant mortgage and RM rates increase. It reveals that, as anticipated, RM rates generally exceed conventional mortgage rates to compensate for the riskiness of such instruments. Although fluctuating, declines have been notable during the past two decades, mainly because of increased lenders' appetite to lend, improved regulation and consumer knowledge of the product. In some periods, RM rates fall below conventional mortgage rates during housing and credit market frictions, for example, the period following the GFC in 2008, during which HPI dropped significantly, coupled with extra low interest rates. The inherent reason for the lowered RM rate is driven by the low central bank base rate and the lack of appetite by consumers for borrowing and lenders for lending. RM rates recovered as the HPI rose in 2010 and stayed above conventional mortgage rates. Another period when RM rates experienced a sharp drop below conventional mortgage rates was the immediate aftermath of the COVID-19 crisis in late 2019, but it has quickly picked up and followed the pattern of mortgage rates since then. This is a short-term negative shock on the RM rates, possibly because of the unstable market activities due to the COVID-19 crisis.

These observations emphasize the dynamic nature of these variables and call for an integrated frame-

work when considering RMs. Such a framework encourages us to consider the interplay between the credit and housing markets, recognizing their simultaneous influence on RM market dynamics, ultimately impacting household balance sheets and decisions.

3 The Model

We consider a general equilibrium model that includes heterogeneous households and competitive mortgage lenders, within which house prices, mortgage rates and RM rates are determined at equilibrium. Households have a finite living span divided into two phases: the working period and the retirement period. During the working period, households earn labor income and pay taxes. During retirement, households receive retirement income. In each period, households decide to rent or buy houses. Renters make decisions on consumption and saving. Renters can buy houses and finance housing through conventional mortgages. On the other hand, homeowners choose how much to consume and save, whether to stay in their houses or sell and become renters. Additionally, they can borrow against their home equity using RMs during retirement. However, homeowners who use RMs cannot simultaneously borrow using conventional mortgages.

Mortgage lenders price conventional mortgages and RMs. They receive the mortgage payments until households decide to default or to refinance. In the case of RMs, lenders recover the collateral when households die or move out of the property to long-term care facilities. Since our model abstracts from inflation dynamics, we consider a real economy in which both mortgages and RMs are inflation-indexed.

3.1 Setup

3.1.1 Economy

Our model is discrete, and each period corresponds to 1 year. In each time period t, the economy (θ_t) can be in crisis, recession, and expansion. We employ an exogenous transition probability matrix (P_θ) to describe the evolution between these macroeconomic conditions.

We assume the financial market has only one asset, a one-period riskless bond with return $r^f(\theta_t)$, in which households can invest. The risk-free real interest rate is exogenous and depends on the economy. In expansions, the risk-free real interest rate is higher, and it hits the lowest point during crises.

3.1.2 Households

Following the convention in life-cycle models, we assume households start working at age 25, retire at 65, and can live up to 100 ($T = 75$). The probability that households are alive at age $(a + 1)$ conditional on being alive at age a is denoted by p_a (p_{75} equal to 0).

Preferences Following Campbell and Cocco (2015), we assume household i derive utility from housing H_{it}, from nondurable consumption C_{it} and from leaving a bequest motive. Since house size remains fixed over time, we can drop housing from the preference specification. On the other hand, household i is penalized for default. The recursive utility function of household i in period t can be written as

$$U_{it} = \frac{C_{it}^{1-\gamma_i}}{1-\gamma_i} + u_o D_{it}^o - u_d D_{it}^d + \beta_i \left[p_{a_{it}} \mathbb{E}_t[U_{it+1}] + (1 - p_{a_{it}}) \psi^{bq} \frac{(Q_{it+1} + \xi)^{1-\gamma_i}}{1-\gamma_i} \right] \tag{1}$$

where γ_i is the coefficient of relative risk aversion, β_i is the discount factor, u_o is the utility benefit from owning a house, u_d is the utility penalty from defaulting on mortgages, D_{it}^o and D_{it}^d are indicator functions for owning a house and default on mortgages, respectively. Q_{it} is the terminal wealth, ξ is a bequest motive shift parameter, and ψ^{bq} is the bequest motive weight.

Labor Income Before retirement, households' labor income is exposed to both aggregate shocks from the economic state and idiosyncratic shocks. Specifically, the labor income at age t (Y_{it}) is given in logs ($y_{it} = log(Y_{it})$) by

$$y_{it} = v_t + \epsilon_{it}, \quad t < R, \tag{2}$$

where v_t is the aggregate labor income determined by the economics state θ_t and the idiosyncratic labor income shock ϵ_{it} follows a Markov process with transition matrix $P_y(\theta_t)$ as a function of the economic state θ_t.

Moreover, we assume a linear taxation rule. Households' labor income during the working period is taxed at the constant tax rate τ. For simplicity, income during retirement is assumed to be exogenous and deterministic. Income is specified as a constant fraction λ of the labor income in the last working year,

$$y_{it} = log(\lambda) + y_{iR} \quad t > R, \tag{3}$$

where $R = 44$, corresponding to the retirement age 65.

Government Transfers Households are guaranteed a lower bound per-period cash-on-hand, which can be viewed as a subsistence level. This assumption is motivated by the existence of social welfare programs such as means-tested income support. When households' wealth and housing value drops below this lower bound per-period cash-on-hand, the government provides a consumption floor, which enables them to consume non-durable goods and to rent a house.

Health Risk and Medical Cost During retirement, households are exposed to health risks. We introduce a health status indicator, D_{it}^{med}, to capture this risk. It takes a value of 1 if households are in good health and a value of 0 if they are sick. Once households become sick, they will remain in that state for the rest of their lives. We assume that the health state D_{it}^{med} of household i in period t follows a Markov process independent of the economic and idiosyncratic states.

A senior household i pays medical expenses of $c_{med}(a_{it}, D_{it}^{med})Y_{it}$, where c_{med} represents the proportion of income and is determined by the health state D_{it}^{med} and the age a_{it}.

3.1.3 Housing Market

Our model assumes there is no housing construction, so the housing supply is fixed. The date t real housing price P_t^h is endogenously determined by the equilibrium of each period and depends on the economic state. In each time period, households can decide to be homeowners (denoted as $D_{it}^o = 1$) or renters (denoted as $D_{it}^o = 0$), and housing size H_{it} is fixed for all homeowners.

Homeowners must pay per-period maintenance cost $C_{ma}(H_{it}, P_t^h)$, proportional to the value of the property, to keep the house from depreciating

$$C_{ma}(H_{it}, P_t^h) = c_{ma} H_{it} P_t^h, \tag{4}$$

where c_{ma} measures the maintenance cost per unit of total property value. Borrowers unable to pay the maintenance cost will be forced to sell their houses and become renters.

We assume that homeowners face moving shocks, which forces the homeowners to move out from their houses, capturing the probability p_m of moving involuntarily with moving cost $C_{ms}(H_{it}, P_t^h)$

$$C_{ms}(H_{it}, P_t^h) = k_{ms} + c_{ms} H_{it} P_t^h, \tag{5}$$

where k_{ms} captures the fixed cost and c_{ms} quantifies the variable moving cost per unit of the total property value.

Existing literature has shown that the rental market and owner-occupied markets are segmented. Rental housing can be produced and destroyed at a variable cost q, so in equilibrium, renters face a renting cost $C_r = q$. We do not differentiate the owner-occupied house price and the rental property price and only consider the equilibrium of the owner-occupied housing stock. This implies that in our model, the price-to-rent ratio varies with the house price.

3.1.4 Mortgage Market

Households can Borrowers mortgages when purchasing houses. Let ζ_t^m denote the downpayment ratio. It is subject to the maximum LTV constraint (ϕ_t^m). The initial mortgage balance M_{it}^m for the household i at the beginning of the period t satisfies

$$M_{it}^m = (1 - \zeta_t^m) P_t H_{it}. \tag{6}$$

A lower downpayment ratio leads to a higher LTV ratio, but it can not exceed ϕ_t^m:

$$\zeta_t^m \geq 1 - \phi_t^m. \tag{7}$$

We assume that ϕ_t^m varies exogenously and depends on the macroeconomic states.

Two main types of mortgage contracts are available on the conventional mortgage market: fixed-rate mortgages (FRM) and adjustable-rate mortgages (ARM). For simplicity, we only model one type of the main residential mortgage: the long-term FRM, which represents more than 90% of mortgages originated in the US. Households with an FRM bear the same mortgage rate $r^m(\theta_t)$ endogenously determined by the economic state θ_t at origination. We assume that FRM rates are the same for all households in the same economic states.

With the timing assumption that households pay their interest between periods t and $t+1$ in advance at time t, the minimum payment on a mortgage for an agent who does not move or refinance at age a_{it}

is given by[9]:

$$M^m_{it-1} - M^m_{it}(1 - r^m(\theta_t)) \geq M^m_{it-1} \frac{r^m(\theta_t)\left(1 + \left(\frac{r^m(\theta_t)}{1 - r^m(\theta_t)}\right)^{T-a_{it}+1}\right)}{\left(\frac{r^m(\theta_t)}{1 - r^m(\theta_t)}\right)^{T-a_{it}+1} - 1}. \tag{8}$$

When mortgage rates drop below the initial mortgage rates, households can choose to refinance. If households decide to refinance, they face LTV constraint (7) and need to pay for refinancing costs

$$C_{re}(M^m_{it+1}) = k_{re} + c_{re} M^m_{it+1}, \tag{9}$$

where k_{re} is the fixed refinancing cost and c_{re} is the variable refinancing cost per unit of the mortgage balance. Households can refinance their mortgage and pay the refinancing cost at the beginning of each period.

If households default, they suffer a utility penalty of u_d and lose their house today. Moreover, defaulting households are temporarily barred from the credit markets. However, their default status may be lifted, enabling them to re-enter the housing market using mortgages.

3.1.5 Reverse Mortgages

RMs allow older homeowners to borrow against their housing wealth without moving out of the house. This option also offers insurance against substantial declines in house prices. However, in order to borrow RMs, homeowners must have paid off a significant part of their conventional mortgages. In our model, we incorporate this feature, following the guidelines established by the HECM program, the most popular RM program in the US.

To borrow against the home value, households must be at least 65 years old and have more than $\phi^{rm}_{own}(\theta_t)$ home equity. $\phi^{rm}_{own}(\theta_t)$ is the minimum home equity requirement for RMs determined by the economic state θ_t. Therefore, they must satisfy the following conditions when initiating RMs:

$$1 - \frac{M^m_{it}}{P^h_t H_{it}} \geq \phi^{rm}_{own}(\theta_t). \tag{10}$$

Households are also constrained by the maximum amount of RMs they can borrow, which is determined by the lower value between a constant maximum claim amount (Q^{rm}) and the principal limit

[9] We assume the mortgage's maturity is at age 70 for all households.

based on the home value. According to HECM, the principal limit factor (PLF) ϕ^{rm} is determined by the age of the borrower a_{it} and the RM rate $r^{rm}(\theta_t)$. Let M_{it}^{rm} denote the amount a household chooses to claim. Therefore, M_{it}^{rm} should satisfy

$$M_{it}^{rm} \leq \min\left\{Q^{rm}, \phi^{rm}(a_{it}, r^{rm}(\theta_t))P_t^h H_{it}\right\}. \tag{11}$$

Although HECM provides several types of repayment options for borrowers to choose from, we only focus on the two most common types of RMs: 1) the lump sum RM, which is a single large payout at the start of the loan, and 2) the drawdown RM, which is a stream of unscheduled payments at the borrower's request until the line of credit is exhausted. In addition, households can choose from fixed-rate RMs (FRRM) or adjustable-rate RMs (ARRM). Only lump sum RM is available for FRRM.

If households decide to take a drawdown, they can determine the proportion of the total amount they wish to receive at the start of the loan, denoted by $\alpha_{it}^{rm} M_{it}^{rm}$ at origination, while the remaining amount will be available in the form of a line of credit. Given that the amount M_{it}^{rm} includes the cost c_0^{rm}, which comprises the initial mortgage insurance premium and origination fee, households will receive $(\alpha_{it}^{rm} - c_0^{rm})M_{it}^{rm}$ at closing of the origination. In each time period, households make decisions about whether to draw down the credit line if the credit line is not exhausted ($\alpha_{it}^{rm} < 1$). They are also allowed to prepay the RM balance. The remaining RM balance and credit line both accumulate with the RM rate $r^{rm}(\theta_t)$ and the annual loan fee rate c_a^{rm}, including annual insurance cost and annual service cost. Specifically, after origination, households face the following constraints:

$$M_{it}^{rm} \leq M_{it-1}^{rm}(1 + r^{rm}(\theta_{t-1}) + c_a^{rm}), \tag{12}$$

$$(1 - \alpha_{it}^{rm})M_{it}^{rm} \leq (1 - \alpha_{it-1}^{rm})M_{it-1}^{rm}(1 + r^{rm}(\theta_{t-1}) + c_a^{rm}). \tag{13}$$

where the first constraint indicates how the RM balance accumulates and the second constraint implies that the remaining line of credit cannot be increased as households prepay the RM balance.

If the household chooses to take a lump sum, α_{it}^{rm} is fixed to be 1, indicating that the entire amount, M_{it}^{rm}, will be received at the beginning. Therefore, these borrowers only face constraint 12.

RMs terminate whenever the borrowers move out to long-term care facilities or decease, and RM lenders get paid for the roll-up RM balance or the home value, whichever is lower. Usually, lenders will sell the house to recover the loan balance, and the remaining residue home value is inherited by the borrowers' heirs or returned to the borrowers. There is a possibility that a housing market slump

could result in a decrease in the property portfolio value of lenders, leading to potential losses on RMs upon termination. However, as borrowers pay insurance premiums annually, HUD insures against these potential losses.

3.2 Households Optimization Problem

Households are price takers who maximize their lifetime utility, given their expectations about future economic state and house prices. We denote the aggregate state as a vector $\Theta_t = \{\theta_t, r^f, P_t^h, r^m, r^{rm}, \Pi_t\}$, where Π_t is the distribution of households.[10] Household i's idiosyncratic state at the start of each period t before making decisions is $S_{it} = (a_{it}, Y_{it}^{id}, W_{it}, D_{it}^o, D_{it}^{mov}, D_{it}^{med}, M_{it}^m, r_{it}^m, D_{it}^d, D_{it}^{rm}, M_{it}^{rm}, D_{it}^{fix}, r_{it}^{rm}, \alpha_{it}^{rm})'$, a vector of age, idiosyncratic labor income, saving, homeownership status, moving shocks, health state, mortgage balance, the mortgage accumulated rate determined by the economic state when the mortgage originated, default status, RM availability, RM claim amount, indicators for FRRM, RM accumulated rate (r_{it}^{rm}),[11] and the share of the RM claim amount retrieved.

In each period t, household i makes decisions $A_{it} = (D_{it}^H, W_{it+1}, M_{it+1}^m, M_{it+1}^{rm}, D_{it+1}^{fix}, \alpha_{it+1}^{rm})'$ of housing (D_{it}^H), saving (W_{it+1}), mortgage and RM (M_{it+1}^m, M_{it+1}^{rm}, $D_{it+1}^{fix}, \alpha_{it+1}^{rm}$), to maximize the lifetime utility. The housing decision, represented as D_{it}^H, is characterized by a range of values from -2 to 4, each representing a distinct decision. Renters have the option to continue renting ($D_{it}^H = 0$), while those without a default flag can choose to purchase a house ($D_{it}^H = 3$). On the other hand, homeowners have the choice to retain ownership ($D_{it}^H = 1$), default on their mortgage ($D_{it}^H = -1$), refinance the mortgage ($D_{it}^H = 4$), or become renters ($D_{it}^H = -2$), or move to a new house ($D_{it}^H = 2$). However, homeowners who face a moving shock have only two options: either to move or to default.

The optimization problem is then

$$V(S_{it}, \Theta_t) = \max_{A_{it}} U_{it}(S_{it}, A_{it}, \Theta_t), \tag{14}$$

subject to

$$\begin{aligned} Q_{it}(S_{it}, \Theta_t) =& W_{it} - M_{it}^m + D_{it}^o \max(H_{it} P_t^h - \alpha_{it}^{rm} M_{it}^{rm}, 0), \\ C_{it}(S_{it}, A_{it}, \Theta_t) =& \left[Y_{it} - \tau(Y_{it}) - \phi_c(S_{it}, A_{it}, \Theta_t) - \left(M_{it}^m - (1 - r_{it}^m) M_{it+1}^m\right)\right] \end{aligned} \tag{15}$$

[10] The distribution of households affects the equilibrium and, thus, should be included in the aggregate state. The distribution is over the idiosyncratic states of households.

[11] For FRRM, r_{it}^{rm} depends on the economic state when the RM originated and remains the same until the mortgage is paid off or refinanced; For ARRM, r_{it}^{rm} varies across the mortgage term and only depends on the current rate.

$$+\left[\frac{W_{it}-W_{it+1}}{1+r^f(\theta_t)}\right]+(D^o_{it+1}-D^o_{it})P^h_t$$
$$+\left[\alpha^{rm}_{it+1}M^{rm}_{it+1}-\alpha^{rm}_{it}(1+r^{rm}_t)M^{rm}_{it}\right], \tag{16}$$

$$\phi_c(S_{it},A_{it},\Theta_t) = D^o_{it+1}C_{ma}+(1-D^o_{it+1})q+D^m_{it}C_{ms}+\mathbb{1}(D^H_{it}=4)C_{re}, \tag{17}$$

$$C_{it}(S_{it},A_{it},\Theta_t) \geq C_m, \tag{18}$$

$$D^o_{it+1} = \begin{cases} 1, & \text{if} \quad D^H_{it}>0 \\ 0, & \text{if} \quad D^H_{it}\leq 0 \end{cases}, \tag{19}$$

$$D^d_{it+1} = \begin{cases} 1, & \text{if} \quad D^H_{it}=-1 \\ 0, & \text{if} \quad D^H_{it}\neq -1, D^d_{it}=0 \\ 0 \quad \text{with probability } p_{md}, & \text{if} \quad D^H_{it}\neq -1, D^d_{it}=1 \end{cases}, \tag{20}$$

$$M^m_{it+1} = 0, \quad \text{if} \quad D^H_{it}\leq 0, \tag{21}$$

$$\text{LTV constraint} \quad (7), \quad \text{if} \quad D^H_{it}=2,3,4, \tag{22}$$

$$\text{Minimum payment} \quad (8), \quad \text{if} \quad D^H_{it}=1, \tag{23}$$

$$M^{rm}_{it+1} = 0, \quad \text{if} \quad D^H_{it}\neq 1, \tag{24}$$

$$\text{RM maximum claim} \quad (11), \quad \text{if} \quad D^H_{it}=1, a_{it}\geq R, M^{rm}_{it}=0 \text{ and } (10) \tag{25}$$

$$\alpha^{rm}_{t+1}=1, \quad \text{if} \quad D^{fix}_{it}=1 \text{ or } D^{fix}_{it+1}=1 \tag{26}$$

$$\text{RM balance accumulation} \quad (12), \quad \text{if} \quad D^H_{it}=1, M^{rm}_{it}>0 \tag{27}$$

$$\text{RM credit accumulation} \quad (13), \quad \text{if} \quad D^H_{it}=1, M^{rm}_{it}>0, \tag{28}$$

where $\phi_c(S_{it},A_{it},\Theta_t)$ is the total cost of housing (maintenance), moving and financial services (refinance), and we impose the budget constraint and a minimum level of consumption C_m.

3.3 Mortgage Lenders

Lenders operate in perfectly competitive markets and discount loan payoffs using a projected pricing kernel. Following Rosenberg and Engle (2002), we assume this projected pricing kernel depends on both the current macroeconomic state and the next period's state, and satisfies

$$E_t\left[\Lambda(\theta_t,\theta_{t+1})\right] = \frac{1}{1+r^f(\theta_t)+\kappa(\theta_t)}, \tag{29}$$

where $\kappa(\theta_t)$ represents the risk premium lenders require to bear mortgage lending risk in economic state θ_t. We calibrate $\kappa(\theta_t)$ to match observed real spreads in Section 4.[12]

Lenders receive payments from borrowers in each period t, which depend on borrowers' endogenous decisions (A_{it}) and the aggregate state (Θ_t). Given the multi-period nature of mortgage contracts, lenders must recursively compute the net present value of expected cash flows. For a conventional mortgage originated to household i, this net present value is given by

$$\begin{aligned}\Pi^m(S_{it}, A_{it}, \Theta_t) =& \mathbb{1}(D^H_{it} \in \{-2, 2, 4\}) M^m_{it} + \mathbb{1}(D^H_{it} = -1) \Upsilon H_{it} P^h_t \\ &+ \mathbb{1}(D^H_{it} = 1) \Big[M^m_{it} - M^m_{it+1}(1 - r^m_{it+1}) \\ &\quad + E_t \big[\Lambda^m_{t,t+1} p_{a_{it}} \Pi^m(S_{it+1}, A_{it+1}, \Theta_{t+1}) \\ &\quad + \Lambda^m_{t,t+1}(1 - p_{a_{it}}) \min(M^m_{it+1}, W_{it+1} + H_{it+1} P^h_{t+1}) \big] \Big], \end{aligned} \tag{30}$$

where Υ denotes the foreclosure recovery rate—the fraction of property value recovered by lenders following default. Equation (30) decomposes the lender's expected payoff into three components corresponding to distinct household choices. The first term captures immediate loan repayment when households sell their property, move, or refinance ($D^H_{it} \in \{-2, 2, 4\}$). The second term represents recovery through foreclosure when households default ($D^H_{it} = -1$), with lenders receiving Υ times the current property value. The third term applies when households retain ownership ($D^H_{it} = 1$), comprising the current period's mortgage payment plus the continuation value. This continuation value accounts for both survival (with probability $p_{a_{it}}$, yielding the recursively determined value Π^m) and death (with probability $1 - p_{a_{it}}$, where lenders recover the minimum of the outstanding balance and the borrower's total wealth including housing equity).

Unlike conventional mortgages, HECMs are insured by the Federal Housing Administration (FHA), which guarantees lenders against losses when loan balances exceed home values at termination. This insurance fundamentally alters the pricing mechanism: rather than endogenizing RM rates through a zero-profit condition, we calibrate RM rates directly using observed spreads from HECM data together with the NBER-defined recessions.

[12] Rosenberg and Engle (2002) demonstrate that a projected pricing kernel can be uniquely derived from an underlying pricing kernel, conditional on the payoff structure of specific asset classes.

3.4 Equilibrium

The economy is characterized by the law of motion for the aggregate state $\Theta_t = \{\theta_t, r^f(\theta_t), P_t^h, r^m(\theta_t), r^{rm}(\theta_t), \Pi_t\}$. Households choose their consumption and housing decisions (A_{it}) to maximize their expected lifetime utility, given their expectations on future housing prices.

Solving the equilibrium requires households to forecast the law of motion for Θ_t, which includes an infinite-dimensional object Π_t. Except for housing price, the law of motion for the other components of Θ_t depends on θ_t, which follows a Markov process with exogenous transition probabilities. For the law of motion for house prices, we follow Krusell and Smith (1998) and consider a forecasting model where households use a simple AR(1) forecast rule based on the current and next-period economic states:

$$\ln P_{t+1}^h = f_{(\theta_t,\theta_{t+1})}(\ln P_t^h). \tag{31}$$

We parameterize f as a linear spline:

$$f_{(\theta_t,\theta_{t+1})}(x) = b_h + \sum_{i=1}^{n_h} k_{ih}(x - x_i), \tag{32}$$

where b_h, k_{ih} depends on (θ_t, θ_{t+1}), and x_i are the knots of the spline.

Meanwhile, mortgage lenders reach a break-even point with the mortgage and RM rates:

$$E_{\theta_t=\theta_i}\left[E_{S_{jt}\sim\Pi_{m,t}^{orig}}\left[\Lambda_{t,t+1}^m \Pi^m(S_{jt+1}, A_{jt+1}, \Theta_{t+1}) - (1 - r^m(\theta_t))M_{jt+1}^m\right]\right] = 0, \forall\theta_i, \tag{33}$$

where $\Pi_{m,t}^{orig}$ is the distribution of newly originated mortgages and RMs in period t.

Given the optimal decisions, the housing market clears at P_t^h. Since the supply of houses is fixed, the equilibrium is achieved when the supply from movers, defaulters, and investors who bought last period equals the demand from renters, homeowners who are moving, and investors:

$$\int D_{it}^o d\Pi_t = \int D_{it+1}^o d\Pi_{t+1}. \tag{34}$$

Household expectations for housing prices can be verified in equilibrium.

We solve the equilibrium numerically. Let the endogenous parameters of the equilibrium be denoted as $\Xi = (b_h, k_{ih}, r^m, r^{rm})^T$. We follow the following steps:

i) Initialize Ξ as Ξ_0.

ii) Solve the household's optimization problem under Ξ_{n-1}.

iii) Simulate an economy with a population size of 100,000 for 19,000 periods with the home price decided by (34) each period.[13]

iv) Estimate Ξ as Ξ_n, for $n = 1, 2, \cdots$, by (33) and (32) based on the simulation results.

v) Terminate if:

$$||\Xi_n - \Xi_{n-1}||_\infty < \epsilon. \tag{35}$$

4 Calibration

We use several data sources to calibrate our baseline model. First, we calibrate the stand-alone parameters that can be clearly identified without explicitly referring to our model setting. For example, mortality and survival probabilities are exogenous variables that do not depend on our model. Therefore, we can adopt statistics published by the National Center for Health Statistics to parameterize the conditional survival probabilities. Second, we calibrate a number of parameters to standard values from existing household finance literature, such as the labor income process. Lastly, we estimate the remaining parameters to align with specific moments of the empirical data, ensuring an overall goodness-of-fit between the model and empirical observations. Table 1 summarizes the calibrated parameter values.

Aggregate State Variables We first choose aggregate and idiosyncratic shocks that mimic the dynamics of modern business cycles in the US. Then we exogenously calibrate a set of parameters to widely accepted values in the macroeconomic and housing literature.

Following Guren et al. (2021), we calibrate the Markov transition matrix between macroeconomic states such as crisis, recession, and expansion based on the frequency and duration of such events defined by NBER.[14] If the NBER peak of the previous expansion takes place in the first half of a given year, that year is classified as the first year of the new recession, whereas if the peak happens during the second half of a year, the recession follows in the subsequent year. The ending date of a recession is defined as the year following the start year of the expansion announced by the NBER because the unemployment rate is a lagging variable and does not immediately fall after NBER troughs. Moreover, we assume crises happen every 75 years, and all other NBER recessions are regular, cyclical recessions.

[13] If a household dies, a new household aged 20 with no assets will enter the economy.

[14] Please see Appendix B for the full transition matrix.

Table 1: Baseline Calibration Parameters

Description	Parameter value
Panel A. Preference parameters	
Years in life (T)	75
Risk Aversion (γ)	3.0
Discount factor (β)	0.98
Utility from homeownership (u_o)	6
Bequest motive shifter (ξ)	0.5
Bequest motive multiplier (ψ^{bq})	250
Default penalty (u_d)	10
Panel B. Mortgages	
Max LTV, tight credit (ϕ^m)	0.8
Max LTV, loose credit (ϕ^m)	0.9
Variable refinance cost rate (c_{re})	1.0%
Fixed refinance cost (k_{re})	0.04
Prob. of default flag removed (p_{md})	0.1
Foreclosure sale recovery (Υ)	0.654
Risk premium (κ) in expansion	95bps
Risk premium (κ) in recession/crisis	385bps
Panel C. Reverse mortgages	
Min Equity Req. in crisis/recession, RM (ϕ^{rm}_{own})	0.60
Min Equity Req. in expansion, RM (ϕ^{rm}_{own})	0.50
Initial fee of RM (c^{rm}_0)	0.02
Annual fee of RM (c^{rm}_a)	0.01
Awareness rate of RM	19%
Panel D. Labor income	
Retirement age (R)	65
Social Security ratio (λ)	0.65
Tax rate (τ)	0.1
Aggregate income ($Y^{(agg)}$)	$[0.0976, 0.1426, 0.1776]$
Panel E. Other parameters	
Homeownership rate (H_r)	0.65
Risk-free rate (r^f)	$[0.26\%, 1.32\%, 3.26\%]$
Medical cost rate (c_{med}) (Age $[65, 75)$)	0.05 (good), 0.10 (bad)
Medical cost rate (c_{med}) (Age $[75, 100)$)	0.10 (good), 0.15 (bad)
Rent cost (q)	0.20
Maintenance cost rate (c_{ma})	0.04
Variable moving cost rate (c_{ms})	3.0%
Fixed moving cost (k_{ms})	0.1
Prob. of moving, working (p_{ms})	0.1
Prob. of moving, retiring (p_{ms})	0.02
Lower bound per-period cash-on-hand	0.1

The table shows calibrated parameters for the baseline model. Panel A shows the preference parameters. Panel B shows the mortgage-related parameters, and panel C shows the parameters associated with reverse mortgages. Panel D shows the parameters of labor income process. Panel E presents the remaining parameters.

To determine the risk-free rate, we follow Guren et al. (2021) which uses the historical real interest rate observed between 1985 and 2022. Specifically, during recessions, the risk-free rate is set at 1.32%, reflecting the lower economic activity and market conditions. During expansions, when the economy is performing well, the risk-free rate is set at 3.26%. In the case of a crisis, we assume a significantly lower risk-free rate of 0.26% to account for the heightened uncertainty and economic instability.

Labor Income Process We set the replacement ratio during retirement to be 0.65, and for income shocks in the working period, we rely on the estimates in Guvenen et al. (2014) and Shen (2023), which calibrate a quantitative labor income model using a large and confidential US dataset. The parameters with respect to the mixture of normal distributions during expansions and recessions can be calibrated. We then follow Guren et al. (2021) to discretize the distributions. The tax rate is assumed to be 20%, which is around the average of the current tax scheme.

Health Status and Medical Cost We calibrate the health status and medical costs using the HRS. More specifically, we estimate transition probabilities of household health status, conditional on age and current health. We find that health status is generally persistent, especially for households that are sick. Therefore, we assume once households are sick, they will stay sick for the rest of their lives. Moreover, the probability of transitioning from a good to a bad state is assumed to be 0.2 in each period. Then, we estimate parameters of the distribution of medical costs, conditional on age and health status. Not surprisingly, medical costs tend to be higher for older and less healthy households.

Maintenance and Moving We take the annual maintenance cost from Guren et al. (2021) and assume it is the same for both workers and retirees for simplicity, although we acknowledge that retirees usually face relatively lower maintenance costs.[15] We study the moving decisions of workers using the PSID and of retirees using the HRS data. We estimate probabilities of moving, and we find that workers are often more likely to relocate compared to retirees, which might be due to career opportunities, more flexibility, and less preference for "aging in place". Following Guren et al. (2021), we set the fixed cost of moving to be equivalent to 10% of the average household annual income, approximately amounting to $5,000. Additionally, proportional costs, incurred by both buyers and sellers, are set at 3% of the house value to account for expenses such as closing costs and realtor fees.

[15] Nakajima and Telyukova (2017) calibrated the annual maintenance cost for retirees to be 1.7%, based on the depreciation rate of residential capital. Cocco and Lopes (2020) propose maintenance expenses among retirees for the different permanent income groups and for different ages.

RMs Except for the RM rates[16], we calibrate all other RM-related parameters and age-dependent collateral constraints based on the existing RM contracts from Corelogic and HECM. We find 0.5% for the insurance premium and 1% for the annual fee. We also find that the minimum equity requirement during crisis and recession is 60%, which is higher than that during the expansion of 50%. Table 2 shows the PLF for various RM rates taken from HECM.[17] For example, for the age 65 and RM rate of 3%, homeowners can borrow a maximum of 52.4% of their home equity. Unlike conventional mortgages, the loan amounts granted in RMs depend on the borrowers' ages, increasing as they age. The rationale behind this is that as borrowers grow older, the projected interest expenses decrease, and the anticipated future house price appreciation diminishes, reducing the risk for the lenders. Generally, the collateral constraint related to conventional mortgages becomes more stringent as the borrower ages. However, RMs provide a more relaxed collateral constraint that eases with age, resulting in a more favorable borrowing environment across all life stages.

Table 2: Principal Limit Factor for RMs

	Age						
RM rate	65	70	75	80	85	90	95
3%	52.4%	57.6%	60.9%	64.2%	68.5%	73.0%	75.0%
4%	47.0%	52.2%	54.7%	58.5%	63.6%	69.1%	75.0%
6%	35.7%	41.5%	44.3%	48.8%	54.9%	61.8%	70.1%

This table states the RM rates and principal limit factor (PLF, which is essentially the loan to home equity ratio) that lenders are willing to lend to RM borrowers by various age groups and at three different RM rates levels: 3%, 4%, 6%.

Projected Pricing Kernel and Risk Premia We calibrate the lender's projected pricing kernel to match observed mortgage spreads. The risk premium $\kappa(\theta)$ varies with the macroeconomic state, taking different values during expansions versus recessions/crises. Following empirical patterns in mortgage markets, we target the historical spread between 30-year fixed-rate mortgage rates and 10-year Treasury yields, which averages 169 basis points during expansions and 225 basis points during crises and recessions.

Our calibration yields risk premia of 95 basis points in expansions and 385 basis points in recessions/crises. These values reflect the heightened default risk, reduced liquidity, and increased macroeconomic uncertainty that lenders face during downturns. The calibrated premia, combined with state-

[16]Unlike conventional mortgages, RM rates are not endogenously determined through a zero-profit condition due to FHA insurance. Instead, we calibrate RM rates directly using observed HECM spreads, See table 3 for details.

[17]Please refer to HECM guidelines for the complete table, and we assume the expected interest rate used in HECM is the same as RM rate, for simplicity.

dependent risk-free rates, generate mortgage rates that closely track the cyclical patterns observed in the data.

Preferences We estimate the preference parameters related to households' consumption, financial and housing decisions using the method of simulated moments (MSM). In particular, we use the data from the American Housing Survey (AHS) and the SCF, and we search for the set of parameters that produce simulated life-cycle decision profiles closely aligning with those observed in the empirical data. The mechanics of our MSM approach are fairly standard. We compute life-cycle histories for a large number of artificial households. Each of these households is endowed with a specific value for the state vector, and a series of idiosyncratic shocks are assigned to them in a manner consistent with the stochastic processes explicated in Section 3.

To facilitate the computational process, we discretize the state space and employ value function iteration to solve the model numerically. This iterative procedure enables us to derive a set of decision rules that govern the choices made by the households. By combining these decision rules with the simulated endowments and shocks, we are able to simulate various aspects of household behavior, including wealth accumulation, housing decisions, refinancing, and the decision to take up RMs. Subsequently, we compute age profiles based on the artificial household histories, employing the same methodology used to analyze the actual data. We adjust until the difference between the data and simulated profiles is minimized as follows

$$(\hat{m} - m)' W (\hat{m} - m), \tag{36}$$

where $\hat{m}$ refers to the simulated moments, m refers to the targets, and W is the inverse of the covariance matrix of the empirical moments, which is estimated by bootstrapping the true data.

Our target moments are the age profiles of homeownership rates and default rate. We find that the estimated discount factor β is 0.98 and the coefficient of relative risk aversion is 3, which both fall within the reasonable range in the literature.[18] Moreover, to match the ratio of total net worth at age 60 to net worth at age 45 in the SCF, we calibrate the bequest motive shifter to 0.5 and the bequest motive multiplier to 250.

[18] Yogo (2016) uses Epstein-Zin preferences to study the portfolio choice in retirement with health risk and derives the risk aversion coefficient to be 5. Nakajima and Telyukova (2020) only focus on retirees aged 65 and above and calibrate the risk aversion to be 2 to fit the age profiles in the HRS.

Equilibrium Interest Rates Table **??** presents the equilibrium mortgage and RM rates across different economic states. These rates are endogenously determined by our model through the lenders' zero-profit conditions (equations 33), given the projected pricing kernels calibrated to match observed spreads.

Several patterns emerge from the equilibrium rates. First, both mortgage and RM rates vary systematically with economic conditions, reaching their lowest levels during crises (4.25% and 5.10%, respectively) when the risk-free rate is at its minimum. As the economy transitions from crisis to recession and then to expansion, both rates generally increase, reflecting higher risk-free rates and changing credit conditions.

Second, RM rates consistently exceed conventional mortgage rates across all states, with spreads ranging from 3.10% in crises to 4.76% in expansions with tight credit. This premium compensates lenders for the unique risks associated with RMs: longer loan durations, accumulating interest without periodic payments, and the non-recourse feature that limits recovery to the home's value. The RM spread is largest during expansions with tight credit (4.76%), reflecting heightened concerns about house price volatility and the potential for negative equity positions.

Third, credit regime affects rates differently depending on the economic state. During recessions, the difference between tight and loose credit conditions is minimal for both mortgages (4.69% vs 4.64%) and RMs (both 6.20%). This suggests that during economic downturns, other factors such as default risk and liquidity concerns dominate the effect of credit availability. In contrast, during expansions, rates are lower under loose credit than tight credit for mortgages (4.28% vs 4.35%), though this difference is small.

Importantly, RM rates show less sensitivity to credit regimes than conventional mortgages. RM rates remain unchanged between recession with tight credit and recession with loose credit (both 6.20%), and similarly between expansion states (both 7.40%). This stability reflects the fact that RMs do not involve stringent credit checks or income qualifications—eligibility depends primarily on age, home equity, and property value. The non-recourse nature and FHA insurance further insulate RM rates from variations in credit conditions.

These equilibrium rates provide the foundation for analyzing household decisions in subsequent sections. The systematic variation in rates across economic states generates heterogeneity in household borrowing costs, influencing take-up decisions, refinancing behavior, and welfare outcomes documented in Section 5.

Other Parameters Household refinancing processes are associated with fixed and variable costs. Specifically, following Guren et al. (2021), refinancing entails a fixed cost equal to 4% of the average

Table 3: Mortgage and RM Rates

	Mortgage		FRRM	
	Rate	Spread	Rate	Spread
Crisis	4.25%	2.24%	5.10%	3.10%
Recession and tight	4.69%	2.19%	6.20%	3.69%
Expansion and tight	4.35%	1.70%	7.40%	4.76%
Recession and loose	4.64%	2.13%	6.20%	3.69%
Expansion and loose	4.28%	1.64%	7.40%	4.76%

This table presents the equilibrium model results of mortgage and RM rates at 5 economic states (crisis, recession and loose credit, expansion and loose credit, recessions and tight credit, expansion and tight credit). The left column presents the mortgage rates and spreads above the risk-free rates, reflecting varying risk levels. The right column shows the RM rates and spreads, following similar patterns to the mortgage column.

annual income, roughly equating to $2,000, along with a variable cost equivalent to 1% of the remaining mortgage balance. This variable cost aligns with the average refinancing costs reported by the Federal Reserve. For renters, a monthly rent payment is set at 20% of their income to maintain a rent-to-income ratio of 20%. To be consistent with the average homeownership of 65% in the AHS, we assign a utility benefit of 10 to owning a home.

Following a foreclosure event, we assume that the bank recovers 65.4% of the property's market value. Additionally, we consider maximum LTV is 90% under loose credit and 80% under tight credit. We assume that the probability of default flag being removed is 0.1.

5 Quantitative Results

This section presents our main quantitative findings. We first validate that our model matches key life-cycle patterns observed in the data (Section 5.1). We then examine the economic effects of RMs by comparing two economies—one with RMs and one without—analyzing impacts on households, housing markets, and mortgage markets (Section 5.2). Section 5.3 provides a decomposition of direct versus general equilibrium effects.

5.1 Life-cycle Profiles

We simulate the decisions of saving, consumption, housing, and RMs of 100,000 households over the life cycle and present the average profiles in Figure 3. For comparison, we also report the average profiles in the SCF from 2007 to 2019. The model matches the life-cycle patterns in the SCF data well.

In graph A of Figure 3, we present the homeownership rate patterns over the life cycle. The model's

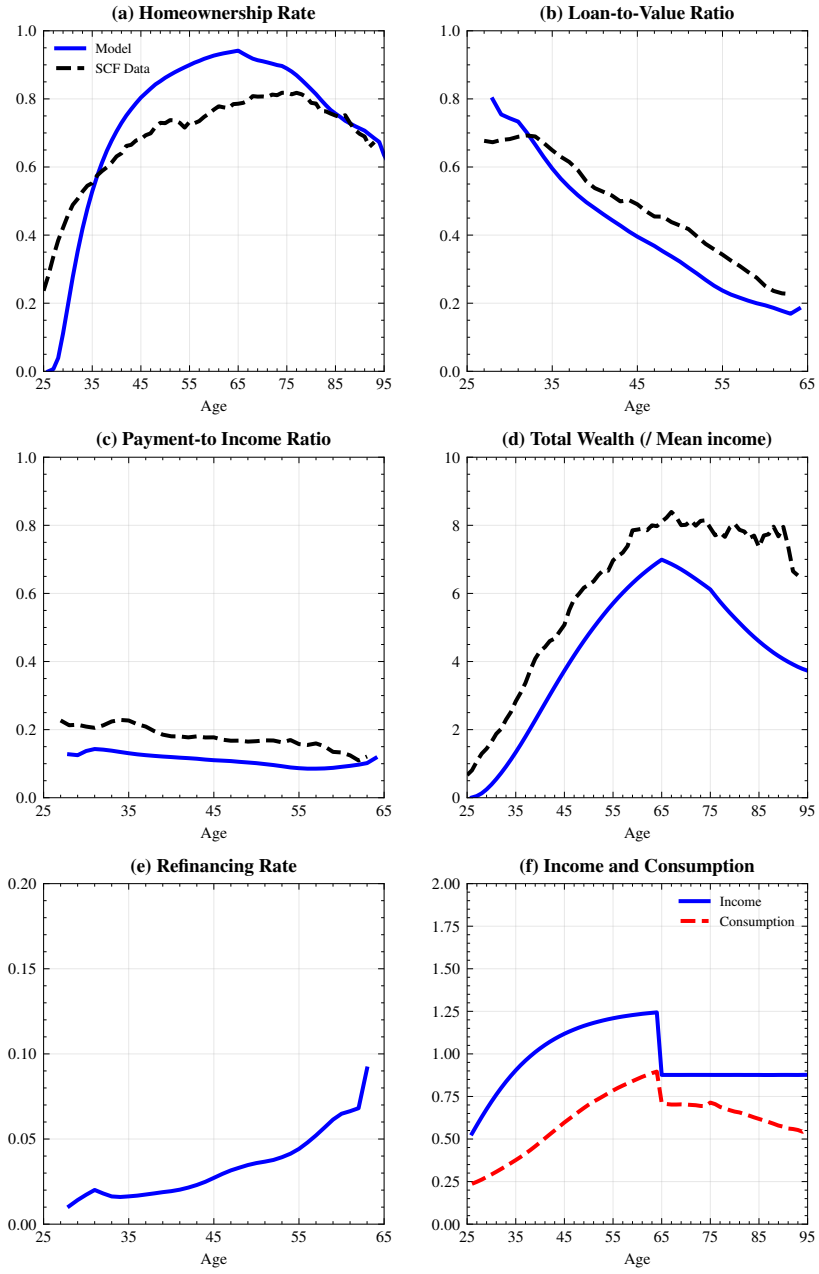


Figure 3: Life-cycle Profiles

This figure plots key variables of model results (blue line) in comparison to empirical evidence (black dashed line) over the household life cycle. Graph (a) plots homeownership rate results; Graph (b) plots the results of Loan to Value (LTV) for homeowners; Graph (c) plots Payment to Income ratios (PTI) for homeowners; Graph (d) plots net wealth for households results; Graph (e) plots household consumption (blue line) and labor income (red line); Graph F plots the homeowner refinancing rates over the life cycle.

simulations yield an average homeownership rate of 65%, which aligns with the data. However, we observe that the model tends to underestimate the homeownership rate for very young households and overestimate it for middle-aged households. This is possibly due to the existence of RM in the model: very young households are penalized financially, such that they cannot get on the property ladder, whereas among the rest of the life cycle, homeowners tend to hold on to property homeownership due to the benefit of RMs.

Graphs B and C of Figure 3 show the LTV and PTI ratio by age. Our model under-predicts LTV for younger households (below 30s) and over-predicts for middle-aged households (above 30s). With RM's presence in the model, the dynamics are asymmetric between younger and older homeowners: Younger homeowners don't have access to RM because they haven't fully repaid their mortgages; middle-aged homeowners have an incentive to repay mortgages early to access RM and hence lower the LTV.[19] Moreover, we observe a close alignment between the PTI ratios and the data for households, with an overall under-prediction for all ages. This is due to the presence of RM, which boosts income.

Figure 3, graph D, shows the wealth accumulation over the life cycle. We find that households are liquidity-constrained during the first 15 years of their working lives. However, as time passes, households begin to accumulate wealth at an accelerated pace. This wealth accumulation serves as a crucial form of insurance, providing a cushion against adverse labor income shocks and uncertainties in the macroeconomic environment. During retirement, we observe rapid wealth decumulation. This decumulation reflects the utilization of accumulated assets to support living expenses and maintain the desired standard of living during the retirement phase. Overall, the dynamic patterns of wealth accumulation and decumulation throughout the life cycle emphasize the significance of building a robust financial foundation and managing resources effectively to address income fluctuations and retirement needs.

Figure 3, graph E, shows the fraction of owners refinancing. Refinancing is relatively low across all ages. Compared with Guren et al. (2021), our model does not generate jumps at retirement, as homeowners have additional options to smooth their consumption and manage their financial obligations. The availability of RMs serves as a supplementary avenue for homeowners to access their home equity and alleviate liquidity constraints, reducing the need for traditional refinancing. By considering the impact of RMs on homeowners' financial strategies, our model provides insights into a more nuanced understanding of refinancing behaviour, highlighting the role of alternative mechanisms in managing liquidity.

Figure 3, graph F, shows the profiles of consumption and income. Consumption closely tracks income

[19] Incorporating downsizing would further reduce the LTV ratios during retirement, and it would complicate the numerical computation. Therefore, we have not included downsizing in our baseline model.

over the life cycle. During the working years, households permanent income increases as households age, leading to a corresponding rise in consumption. As households approach retirement, the income profile becomes less steep and the consumption profile reaching a point where further increases cease. This pattern suggests that as households advance in age, they become less constrained by liquidity concerns. During retirement, we observe a downward slope in the consumption path, as households mainly rely on their accumulated wealth and retirement income to sustain their desired lifestyle. The reduced income during retirement necessitates a more prudent approach to consumption.

5.2 Determinants of Reverse Mortgage Take-up

Understanding the determinants of RM take-up decisions is crucial for assessing the role of RMs in household financial planning and for designing effective policies to expand access to home equity liquidity. We examine RM adoption patterns across three key dimensions: life-cycle factors, macroeconomic and housing market conditions, and household financial resources. Our analysis reveals significant heterogeneity in RM take-up, highlighting how different circumstances influence households' decisions to access home equity through RMs.

5.2.1 Life-Cycle Patterns in RM Adoption

We begin by examining the life-cycle evolution of reverse mortgage (RM) take-up rates. Figure 5 presents model-generated take-up rates from ages 65 to 99, while Figure 4 displays the empirical age distribution of RM borrowers at origination reported in Shan (2011). Both the model and empirical evidence exhibit two key features: a sharp initial spike in take-up rates immediately upon eligibility at age 65 (5.05% in our model), followed by a hump-shaped pattern throughout retirement. Take-up rates peak around age 70, reaching 7.34%, before declining monotonically among older cohorts and falling below 1% by age 85. The initial spike at age 65 captures households facing immediate liquidity needs upon retirement—often due to declining income, accumulated debt, or anticipated medical expenses. These households choose to access home equity as soon as they become eligible, despite receiving lower principal limit factors (PLFs) compared to what they would receive if they waited. This suggests that for a subset of households, the sudden availability of home equity through RMs provides essential liquidity that outweighs the benefits of waiting for higher PLFs.

The subsequent rise in take-up rates from age 65 to the peak around age 70 reflects households' optimal timing decision, balancing the benefits of waiting against the costs of delay. On one hand, delaying RM

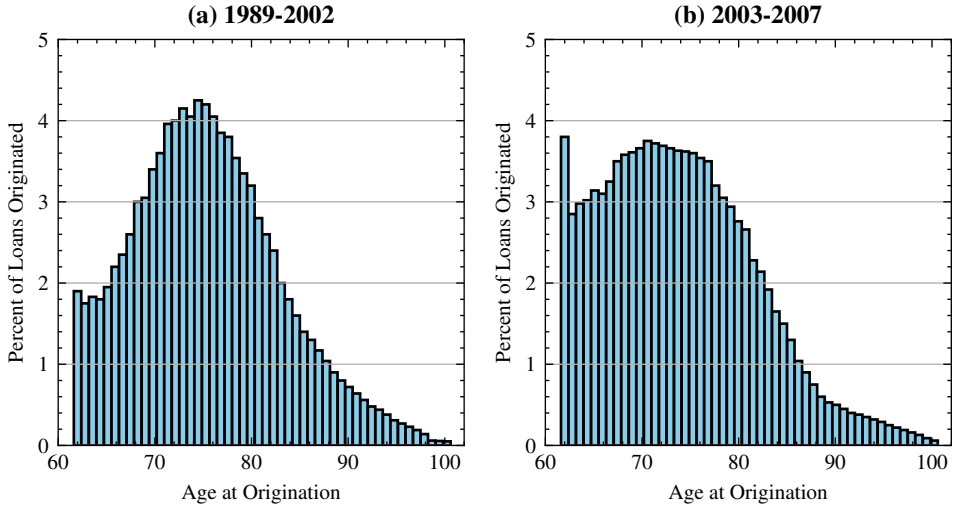


Figure 4: Empirical Age Distribution of Borrowers at RM Origination

This figure shows the distribution of borrowers' age at the inception of HECM programs from Shan (2011). Panel (a) shows the patterns of 1989-2002, and panel (b) shows the pattern of 2003-2007.

origination offers two advantages: (1) higher PLFs as households age (see Table 2), a 70-year-old can borrow 57.6% of home value at a 3% RM rate compared to 52.4% at age 65, representing a 10% increase in borrowing capacity; (2) better resolution of health uncertainty, allowing households to observe whether they genuinely need liquidity or can manage with alternative resources.

On the other hand, delay imposes costs through two channels. First, as remaining lifetimes shorten with age, the consumption-smoothing benefits of RMs diminish while bequest motives intensify. Our model captures this mechanism through the bequest utility term $\psi^{bq}(Q_{it+1} + \xi)^{1-\gamma_i}/(1-\gamma_i)$, which becomes increasingly binding as the expected bequest horizon approaches. Households with strong preferences for leaving inheritances find RMs prohibitively costly once they enter their late 70s and 80s, as each additional year of debt accumulation substantially erodes the estate they can bequeath to heirs.

Second, the non-recourse feature of RMs embeds a valuable put option on house prices: borrowers can never owe more than their home's value regardless of how much debt accumulates. This insurance against house price declines holds greater value for younger retirees facing long, uncertain retirement periods during which severe price drops could occur. As households age beyond 75, their remaining lifetimes, and thus their exposure to house price risk, shrink substantially. With shorter horizons, the probability of experiencing a large enough house price decline to trigger the non-recourse protection diminishes, reducing the option value and making RMs less attractive relative to their costs.

Together, this trade-off between the benefits of waiting (higher PLFs, resolved uncertainty) and the costs of delay (shortened consumption horizons, intensifying bequest motives, declining option value)

renders middle-retirement ages optimal for RM origination, generating the observed hump-shaped pattern.

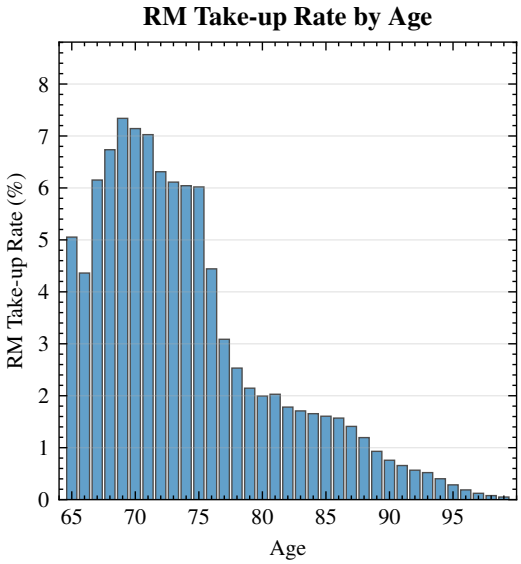


Figure 5: RM Take-up Rate by Age

This figure presents RM take-up rates across different age groups during retirement. The x-axis shows five-year age bins from 65-69 to 90-94, and the y-axis represents the take-up rate as a percentage. Take-up rates are calculated as the ratio of RM borrowers to all eligible homeowners within each age group. The hump-shaped pattern reflects the trade-off between increasing liquidity needs and rising principal limit factors as households age, offset by declining take-up among the oldest cohorts.

5.2.2 Macroeconomic Conditions and Housing Prices

Figure 6 examines how RM take-up varies with macroeconomic conditions and local housing market conditions. Panel (a) shows substantial variation across economic states, with the highest take-up rates observed during recessions, both with loose credit (33.89%) and tight credit (31.44%). Take-up rates during crises and expansions with loose credit are moderately lower (19.08% and 13.69%, respectively), while the lowest rates occur during expansions with tight credit (18.55%).

This pattern reveals important insights about the role of RMs as a consumption-smoothing and insurance device. The elevated take-up during recessions, regardless of credit regime, suggests that households turn to RMs when they face adverse income shocks and heightened employment uncertainty. During recessions, the combination of declining labor income, increased medical expenses, and limited access to other forms of credit makes RMs an attractive option for maintaining consumption levels. Interestingly, take-up rates remain high even during recessions with tight credit, indicating that the insurance value of RMs dominates the effect of tightened borrowing constraints during economic downturns.

The lowest take-up rate during expansions with tight credit can be explained by two reinforcing factors. First, during expansions, households experience more stable income and lower unemployment risk, reducing the immediate need for additional liquidity. Second, tight credit constraints limit households' ability to originate RMs even if they desire to do so, as lenders impose stricter equity requirements (see equation 10). The moderate take-up during expansions with loose credit reflects households who choose to access home equity for consumption smoothing or portfolio rebalancing purposes, even in the absence of pressing financial needs.

Panel (b) shows how RM take-up varies with house prices, measured in terciles of the house price distribution. We observe a hump-shaped pattern: medium house prices (17.62%) exhibit the highest take-up, followed by high house prices (20.81%), with low house prices (20.59%) showing the lowest take-up. This pattern reflects the binding nature of RM borrowing constraints specified in equation 11: households with higher-valued homes can access larger credit lines, making RMs more financially attractive relative to their upfront and ongoing costs.

However, the slightly lower take-up among the highest house price tercile compared to the medium tercile suggests wealth effects: households with very high-value homes typically possess greater financial resources overall (including liquid savings), reducing their reliance on home equity extraction for consumption needs. In contrast, households in the low house price tercile face a double constraint: not only do they have less home equity to access, but the fixed costs of RM origination (initial mortgage insurance premium and origination fees) represent a larger proportional cost relative to the available credit line, making RMs less cost-effective.

5.2.3 Household Financial Resources

Figure 7 examines how household financial resources affect RM take-up decisions. Panel (a) reveals a strong negative relationship between income and RM take-up rates. Households in the lowest income quintile (Q1) exhibit take-up rates of 29.56%, more than 19 times higher than the 1.55% observed among the highest income quintile (Q5). The gradient across quintiles is monotonic, with Q2, Q3, and Q4 showing intermediate and declining rates of 27.6%, 21.2%, and 16.33%, respectively.

This pronounced income gradient is consistent with RMs serving primarily as a liquidity provision tool for income-constrained retirees. Lower-income households face binding cash flow constraints despite possessing substantial housing wealth, a classic manifestation of the "house-rich, cash-poor" phenomenon. For these households, RMs provide a mechanism to convert illiquid housing wealth into liquid resources

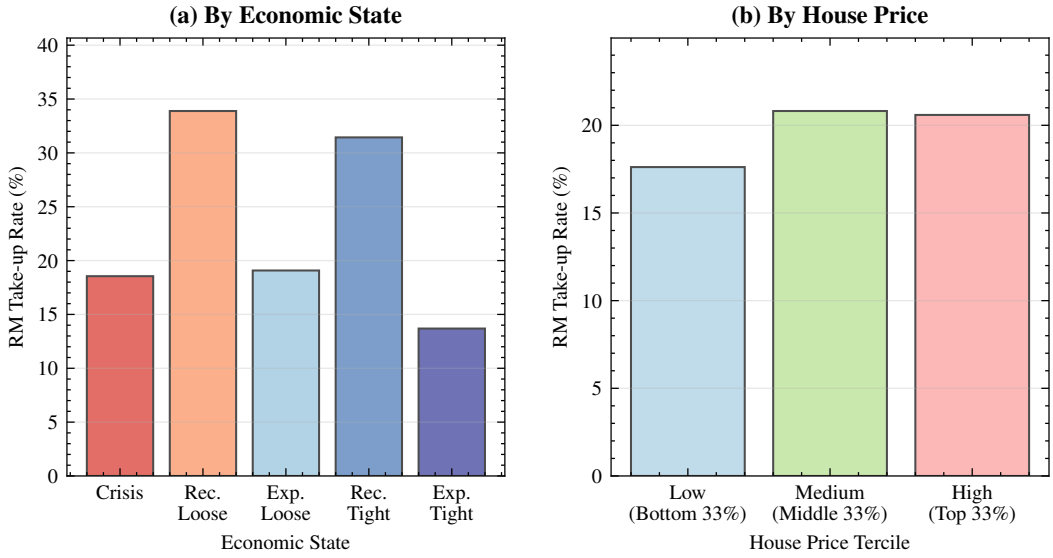


Figure 6: RM Take-up Rates Under Different Macroeconomic Environments

This figure presents RM take-up rates across different environmental conditions. Panel (a) shows take-up rates by economic state, including crisis, recession with loose credit, expansion with loose credit, recession with tight credit, and expansion with tight credit. Panel (b) displays take-up rates by house price terciles (low, medium, and high). Take-up rates are calculated as the ratio of RM borrowers to all eligible homeowners (aged 65 and above) within each category. The bars represent the conditional probability of taking up an RM given the household's environmental circumstances.

that can be used to maintain consumption, pay medical expenses, or meet other financial obligations. In contrast, higher-income households possess sufficient cash flow from Social Security, pensions, and retirement accounts, reducing their need to tap into home equity.

Panel (b) shows a more nuanced pattern for savings. Households in the lowest savings quintile (Q1) exhibit the highest take-up rates (63.88%), as expected given their limited liquid resources. However, households in the highest savings quintiles (Q4 and Q5) show moderately elevated take-up rates (35.34% and 36.62%, respectively) compared to the middle quintiles (Q2 and Q3, with 10.79% and 2.74%). This U-shaped pattern suggests two distinct motivations for RM adoption based on financial resources.

For low-savings households (Q1), RMs serve as a necessity, a last-resort mechanism to access liquidity when other resources have been depleted. For high-savings households (Q4 and Q5), RMs may serve as a strategic financial planning tool. These wealthier households may use RMs for portfolio rebalancing, tax optimization, or to preserve liquid assets for precautionary purposes while still accessing home equity. The middle-savings households (Q2 and Q3) possess enough resources to avoid immediate liquidity needs but insufficient wealth to engage in sophisticated financial planning, resulting in lower take-up rates.

This heterogeneity in take-up patterns across income and savings distributions has important policy implications. The concentration of RM adoption among lower-income and lower-savings households

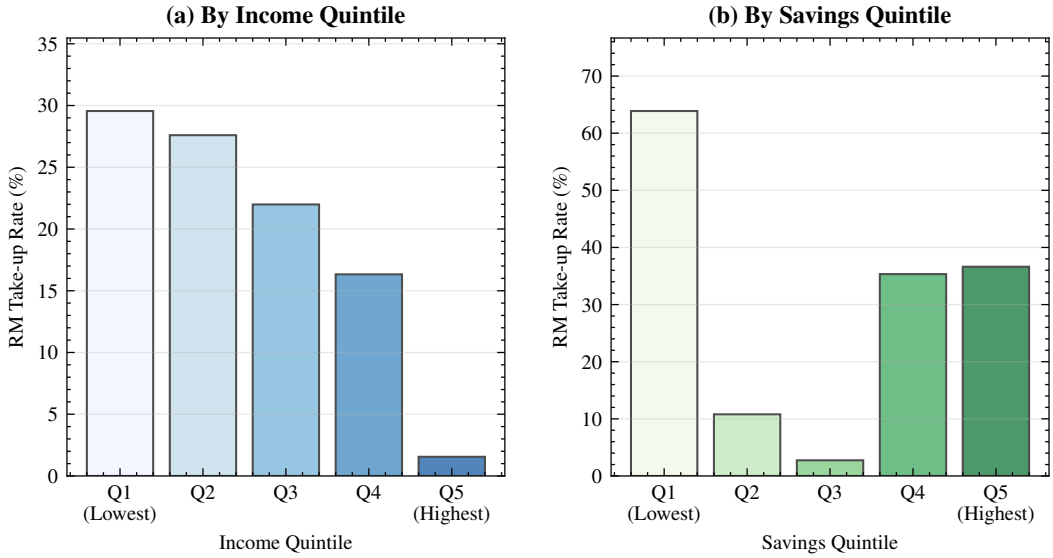


Figure 7: Variation in RM Take-up Rates Across Income and Savings Groups

This figure presents RM take-up rates across different levels of household financial resources. Panel (a) shows take-up rates by income quintiles, from Q1 (lowest) to Q5 (highest). Panel (b) displays take-up rates by savings quintiles, also from Q1 (lowest) to Q5 (highest). Take-up rates are calculated as the ratio of RM borrowers to all eligible homeowners within each quintile. Both panels demonstrate that RM take-up is concentrated among households with lower financial resources, highlighting the role of RMs in providing liquidity to resource-constrained retirees.

suggests that policies aimed at reducing RM costs (such as lower origination fees or insurance premiums) could have progressive distributional effects, disproportionately benefiting vulnerable retiree populations who face binding liquidity constraints.

5.2.4 Choice Between Fixed-Rate and Adjustable-Rate RMs

Figure 8 displays the proportion of RM borrowers opting for fixed-rate reverse mortgages (FRRMs) versus adjustable-rate reverse mortgages (ARRMs) across different ages. We observe a striking age pattern: at age 65, approximately 65% of borrowers choose FRRMs, but this proportion declines steadily to only 8% by age 95. This life-cycle pattern in mortgage contract choice reveals important insights about household preferences and financial sophistication.

The high preference for FRRMs among younger retirees (ages 65-70) can be attributed to several factors. First, FRRMs offer the certainty of locking in current interest rates, which may be particularly attractive when households expect future rate increases or when current rates are historically low. Second, households in early retirement face longer planning horizons and may value the predictability of fixed rates for long-term financial planning. Third, FRRMs typically require lump-sum disbursements, which may align better with the immediate liquidity needs of newly retired households who wish to pay off

existing mortgages, consolidate debt, or finance major expenses.

The declining preference for FRRMs as households age reflects changing financial needs and preferences. Older households increasingly favor ARRMs with line-of-credit features for several reasons. First, ARRMs offer greater flexibility. Borrowers can draw funds as needed rather than receiving a large lump sum upfront, which provides better alignment with periodic expenses such as medical costs or home maintenance. Second, in a rising rate environment, the interest rate risk of ARRMs becomes less concerning as households' planning horizons shorten with age. Third, line-of-credit features available only with ARRMs allow households to preserve remaining credit capacity that grows over time, providing valuable insurance against future financial shocks.

Our model generates an average split of 20% choosing lump-sum (FRRM-only) options and 80% selecting line-of-credit options. This compares to empirical data showing 6.82% lump-sum and 89.44% line-of-credit in 2021. The model's higher lump-sum prediction can be attributed to our exclusion of two additional payment options available in practice: tenure payments (fixed monthly payments for life) and term payments (fixed payments for a specified period). Some households in our model who select lump-sum options would likely choose tenure or term payments if these options were available, particularly households seeking steady income streams rather than large one-time payouts.

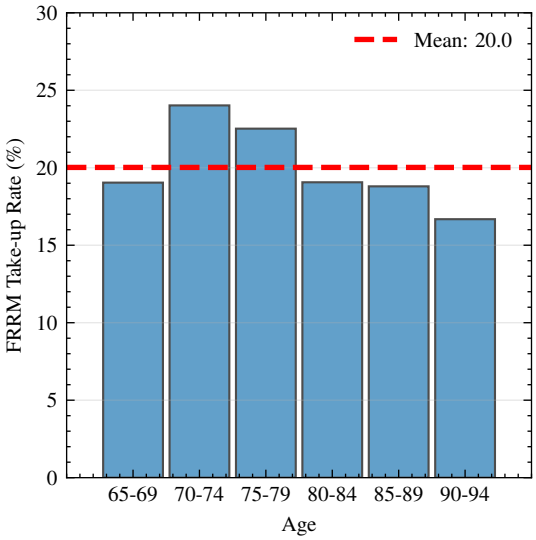


Figure 8: FRRM Take-up Rates Among RM Holders

This figure shows the fractions of households that take FRRM gradually falls as household age.

6 Economic Effects of Reverse Mortgages

To assess the impact of RMs on households and markets, we compare two economies: one with RMs available in the credit market (Economy 1) and one without (Economy 0), while keeping all other structural parameters constant. This counterfactual analysis allows us to isolate the effects of RM availability on household welfare, consumption smoothing, housing prices, and mortgage market dynamics.

6.1 Household-Level Effects

This subsection examines how RM availability affects household consumption smoothing and welfare, and how these effects vary across different household types.

6.1.1 Consumption Smoothing

Table 4 reports the cross-sectional standard deviations of consumption growth for workers and retirees under both economies. In the economy where RMs are accessible, homeowners, regardless of whether they choose to take up RMs, experience lower volatility in consumption growth compared to the economy where RMs are unavailable. This suggests that the presence of RMs has a general stabilizing effect on consumption patterns for homeowners, operating through both direct usage and indirect general equilibrium effects.

Panel A of Table 4 shows that households who have access to RMs exhibit lower volatility in consumption growth throughout their life cycle. Notably, for working-age households, which have often been overlooked in previous literature on RMs, the availability of RMs as a future option for accessing home equity leads to a reduction in the volatility of consumption growth. The presence of RMs narrows the disparity in consumption growth volatility between working households and retirees, underscoring the significance of RMs in improving consumption smoothing across the entire life cycle.

Panel B decomposes these effects by homeownership status. We observe that the consumption smoothing benefits are concentrated among homeowners, particularly retired homeowners who see volatility reductions of up to 34.27%. Working-age homeowners also benefit, though more modestly. For renters, the consumption smoothing effect is subtle due to their non-participation in homeownership. However, the decrease in volatility for both working and retired renters, while small, suggests a positive spillover effect. This may reflect their potential to become homeowners in the future and incorporate RMs into their long-term financial planning.

Panel C further distinguishes between households who take up RMs during their lifetime and those

who do not. RM takers experience substantially larger reductions in consumption volatility (23.32% for retirees), confirming the direct consumption-smoothing benefits of accessing home equity. Interestingly, even non-takers benefit from the availability of RMs in the economy, experiencing modest reductions in volatility. This suggests that the option value of RMs and general equilibrium effects (such as changes in house prices and mortgage rates) create positive externalities for all households in the economy.

Table 4: Consumption Smoothing Effects of Reverse Mortgages

	RM Availability Rate				
Group	19%	40%	60%	80%	100%
Panel A: By Age Group					
All Ages	−0.79	−1.58	−2.37	−3.17	−4.06
Working (<65)	0.00	0.04	0.09	0.06	0.13
Retired (≥65)	−2.15	−4.39	−6.66	−8.90	−11.14
Panel B: By Homeownership					
All Households					
Owners	−1.46	−3.09	−4.64	−6.33	−8.02
Renters	−0.10	−0.08	−0.10	−0.02	−0.04
Working Age					
Owners	0.05	0.04	0.11	0.07	0.04
Renters	−0.06	−0.06	−0.09	−0.11	−0.35
Retired					
Owners	−5.65	−12.10	−18.78	−26.16	−34.27
Renters	0.72	1.51	2.43	3.26	4.19
Panel C: By RM Take-up					
All Households					
Takers	−7.82	−7.80	−7.76	−7.75	−7.86
Non-takers	0.03	0.19	0.32	0.47	0.61
Working Age					
Takers	0.30	0.30	0.29	0.23	0.03
Non-takers	−0.03	−0.03	−0.02	−0.08	−0.32
Retired					
Takers	−23.32	−23.33	−23.28	−23.21	−23.21
Non-takers	0.15	0.61	0.99	1.51	2.34

This table presents the percentage change in consumption growth volatility (measured by cross-sectional standard deviation) relative to the baseline economy without reverse mortgages. Panel A compares all ages, working age (<65), and retired (≥65). Panel B decomposes effects by homeownership status within each age group. Panel C compares households who take up RMs at some point during their lifetime versus those who never take RMs. Negative values indicate reduced consumption volatility (improved consumption smoothing). The columns represent different scenarios with varying RM awareness/availability rates, with 19% corresponding to our calibrated baseline matching observed take-up rates.

6.1.2 Welfare Gains

When examining the presence of RMs, the assessment of welfare gains becomes important for comprehending the potential benefits and implications of these financial instruments. We calculate consumption certainty equivalent variation to quantify household welfare gains. This represents the amount by which households would need to increase their consumption in Economy 0 (without RMs) to achieve the same level of satisfaction as in Economy 1 (with RMs).

Specifically, we denote the value functions under Economy 0 and Economy 1 as V^0 and V^1, respectively. The consumption certainty equivalent variation $\Delta\left(S_{it}, \Sigma_t\right)$ is defined implicitly as:

$$\begin{aligned} V^1\left(S_{it}, \Sigma_t\right) =& E_t\Bigg\{\sum_{n=t}^{t+T-a_{it}} \beta^{n-t} \prod_{m=t+1}^{n} p_m(a_{im}) \left[\frac{\left(C_n^0(1+\Delta(S_n, \Sigma_n))\right)^{1-\gamma_i}}{1-\gamma_i} + \alpha H_n^0 + D_{it}^o u_o - D_{it}^d u_d\right] \\ &+ \beta^{n-t}\left(1 - \prod_{m=t+1}^{n} p_m(a_{im})\right) \psi^{bq} \frac{\left(Q_{in}^0 + \xi\right)^{1-\gamma_i}}{1-\gamma_i}\Bigg\} \\ =& V^0\left(S_{it} \mid \Sigma_t\right) + \left[\left(1+\Delta\left(S_n \mid \Sigma_n\right)\right)^{1-\gamma_i} - 1\right] E_t\left\{\sum_{n=t}^{t+T-a_{it}} \beta^{n-t} \prod_{m=t+1}^{n} p_m(a_{im}) \left[\frac{\left(C_n^0\right)^{1-\gamma_i}}{1-\gamma_i}\right]\right\}, \end{aligned} \tag{37}$$

where C_n^0 and D_{it}^h are the corresponding policies, and Q_{in}^0 is the terminal wealth under Economy 0. Consequently,

$$\Delta\left(S_{it} \mid \Theta_t\right) = \left(1 + \frac{V^1\left(S_{it} \mid \Sigma_t\right) - V^0\left(S_{it} \mid \Sigma_t\right)}{E_t\left\{\sum_{n=t}^{t+T-a_{it}} \beta^{n-t} \prod_{m=t+1}^{n} p_m(a_{im}) \left[\frac{\left(C_n^0\right)^{1-\gamma_i}}{1-\gamma_i}\right]\right\}}\right)^{\frac{1}{1-\gamma}} - 1 \tag{38}$$

Table 5 reports the welfare gains for four groups of households: (1) Young, working homeowners, (2) Young, working renters, (3) Retired homeowners, and (4) Retired renters. We find that retired homeowners experience significant welfare gains, with gains increasing as homeowners age. Specifically, retired homeowners aged 65-75 experience welfare gains of 3.12%, while those over 75 see gains of 2.59%. Young working homeowners also benefit substantially, with welfare gains of 4.82%, reflecting the option value of RMs that they can access in the future.

On the other side, we observe more nuanced effects for renters. While rising house prices may create additional challenges for renters, particularly young households who often aspire to become homeowners, an economy equipped with RMs can provide some advantages for renters, albeit modestly. Young working

renters experience welfare gains of 1.27%, while retired renters experience welfare losses of -2.46% to -2.86%. This positive spillover effect for young renters might come from the fact that they have the potential to become homeowners in the future and use RMs as an additional option for accessing home equity. Understanding the potential benefits of RMs allows renters who intend to become homeowners to incorporate this option into their long-term financial planning and take advantage of the financial stability that RMs offer.

The welfare losses experienced by retired renters reflect the fact that they face higher house prices due to increased housing demand from RMs, without enjoying the direct benefits of accessing home equity through RMs. These distributional effects highlight an important trade-off: while RMs substantially improve welfare for homeowners and future homeowners, they may create modest welfare costs for households who remain renters throughout retirement.

Overall, the economy with RMs offers net positive welfare benefits for most population segments. The overall welfare gain across all households is 3.17%, with homeowners experiencing gains of 4.23% and renters seeing gains of 0.99%. These results suggest that despite some heterogeneity in the distribution of benefits, the introduction of RMs into the credit market generates substantial aggregate welfare improvements.

Table 5: Welfare Gains from Reverse Mortgages

	Age Groups			Overall
	< 65	$[65, 75]$	> 75	
Homeowners	4.82%	3.12%	2.59%	4.23%
Renters	1.27%	−2.46%	−2.86%	0.99%
Overall	3.48%	2.74%	1.88%	3.17%

This table presents welfare gains measured by consumption certainty equivalent variation when introducing RMs into the economy. Welfare gains are reported for homeowners and renters across different age groups: pre-retirement (<65), early retirement (65-75), and late retirement (>75). The rightmost column shows the overall welfare gains for each group, and the bottom row shows the overall welfare gains for each age group. All values represent percentage increases in consumption equivalents. Positive values indicate that households would need that percentage increase in consumption in the economy without RMs to achieve the same utility as in the economy with RMs.

6.1.3 Heterogeneity in Consumption Smoothing and Welfare Effects

The aggregate effects of RMs on consumption smoothing and welfare mask substantial heterogeneity across economic conditions and household income levels. Figure 9 presents the heterogeneity in RM effects across economic states and income quintiles.

Panels (a) and (b) show the consumption smoothing benefits, measured as the percentage reduction in consumption growth volatility compared to the economy without RMs. We observe that consumption smoothing effects are strongest during loose credit conditions and economic crises. Specifically, during crisis periods, consumption volatility decreases by approximately 46.2%, compared to 40.8% during expansions with tight credit. This pattern reflects the insurance role of RMs against adverse macroeconomic shocks, allowing homeowners to maintain stable consumption when other income sources are uncertain. The elevated benefits during loose credit conditions can be attributed to more favorable RM borrowing terms and lower equity requirements, making it easier for households to access home equity when they need it most.

The consumption smoothing benefits also exhibit a clear income gradient. Households in the lowest income quintile (Q1) experience the largest reduction in consumption volatility (58.1%), while those in the highest quintile (Q5) see more modest improvements (40.5%). This pattern is consistent with RMs primarily benefiting liquidity-constrained households who lack other means to smooth consumption over the business cycle. Lower-income households face binding cash flow constraints despite possessing housing wealth, making RMs a particularly valuable tool for maintaining consumption stability. Middle-income households (Q2-Q4) show intermediate levels of consumption smoothing, highlighting how RMs serve as a valuable financial tool across a broad spectrum of the income distribution, not just at the extremes.

Panels (c) and (d) report welfare gains measured by consumption equivalent variation (CEV). The welfare effects mirror the consumption smoothing patterns, with the largest gains accruing to households facing loose credit conditions and those with limited income. During loose credit regimes, households experience welfare gains of approximately 3.4%, substantially higher than the 2.9% gains during tight credit conditions. The more relaxed equity requirements and lower borrowing costs during loose credit periods enable more households to take advantage of RMs, amplifying their welfare benefits. Similarly, the lowest income quintile enjoys welfare improvements of 5.9%, while the highest quintile sees gains of only 1.6%.

These findings underscore that RMs are particularly valuable for vulnerable populations who face both greater income uncertainty and more binding liquidity constraints. The concentration of benefits among lower-income households and during adverse economic conditions highlights the progressive nature of RM programs and their role as a form of implicit social insurance. Unlike traditional social insurance programs funded through taxation, RMs allow households to self-insure by converting illiquid housing wealth into liquid resources, providing financial stability without imposing fiscal costs on the government.

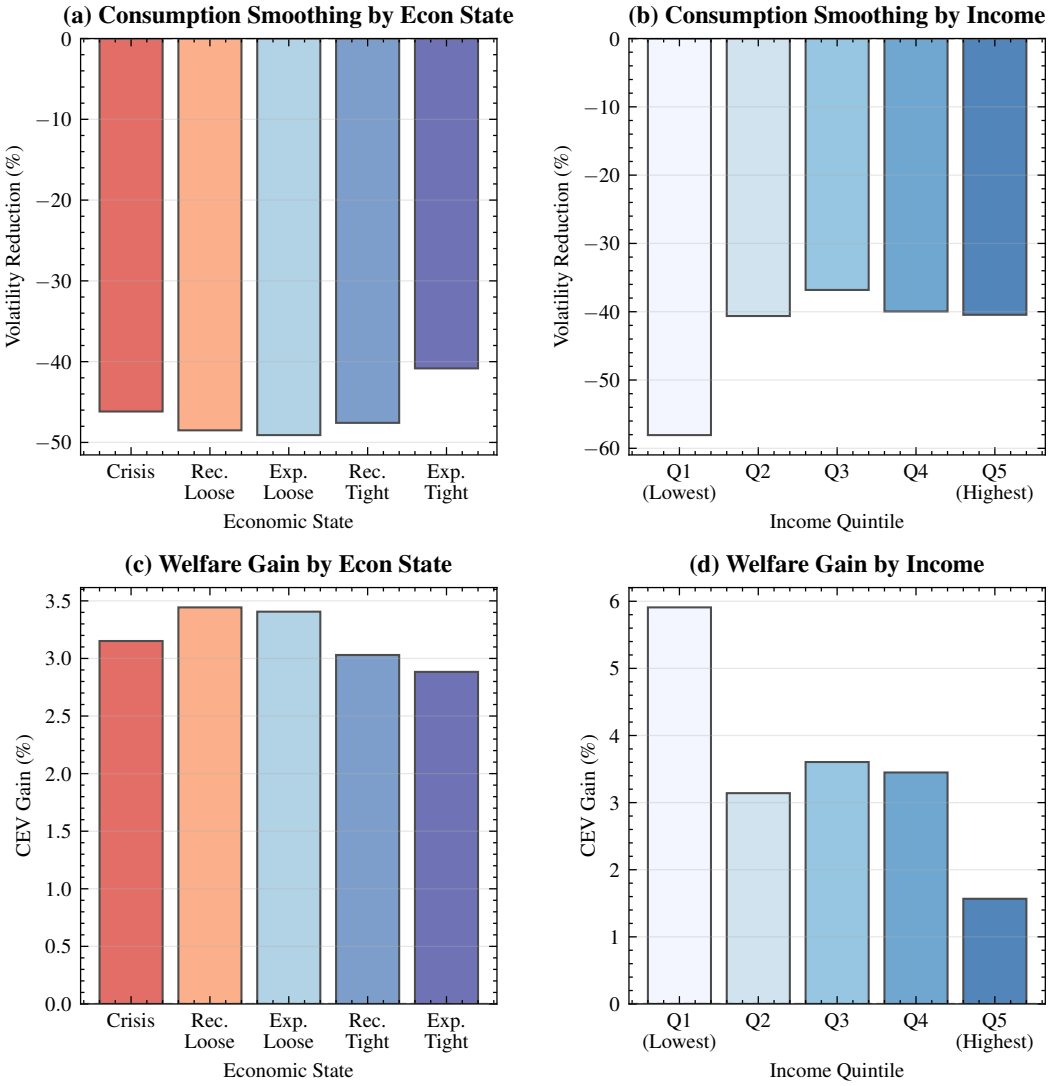


Figure 9: Heterogeneous Effects of Reverse Mortgages

This figure presents the heterogeneous effects of RM availability across different economic states and income levels. Panel (a) shows consumption smoothing benefits (measured as percentage reduction in consumption growth volatility) by economic state: Crisis, Recession with loose credit, Expansion with loose credit, Recession with tight credit, and Expansion with tight credit. Panel (b) displays consumption smoothing benefits by income quintiles from Q1 (lowest) to Q5 (highest). Panel (c) presents welfare gains measured by consumption equivalent variation (CEV) across economic states. Panel (d) shows welfare gains by income quintiles. All effects are computed relative to an economy without RMs. Negative values for consumption smoothing indicate reduced volatility (improved smoothing). Positive values for welfare gains indicate households would require that percentage increase in consumption in the no-RM economy to be indifferent between the two economies.

The heterogeneity in both consumption smoothing and welfare gains has important policy implications. First, it suggests that policies aimed at increasing RM accessibility, such as reducing origination costs or relaxing equity requirements, could have progressive distributional effects, disproportionately benefiting lower-income retirees who face the most severe liquidity constraints. Second, the concentration of benefits during loose credit conditions suggests that countercyclical RM policies (such as relaxing equity requirements during recessions) could enhance the insurance properties of RMs and provide greater consumption stability during economic downturns. Finally, the income gradient in benefits suggests that targeted outreach and education efforts focusing on lower-income homeowners could maximize the social welfare gains from expanding RM markets.

6.2 Housing Market Effects

Exploring the implications of RMs on house prices is crucial, as it sheds light on the broader impact of RM programs on the overall housing market. Table 6 reports the average housing prices and housing price volatility across different economic states, comparing the baseline economy without RMs to scenarios with varying levels of RM availability.

Panel A shows that the inclusion of RMs in the credit market contributes to an overall increase in house prices across all aggregate states, ranging from 0.00% to 2.61% depending on the economic state and RM availability rate. This price appreciation reflects the increased competitiveness and attractiveness of the housing market when RMs are available. The mechanism operates through both supply and demand channels.

On the supply side, RMs allow older homeowners to access home equity without selling their homes. These facts reduce the supply of *available* housing for sale and limit the turnover of houses in the market, both exacerbating the scarcity of available homes and pushing prices higher. Besides, RMs can provide homeowners with additional financial resources, allowing them to maintain their houses against depreciation and avoid being forced to sell due to liquidity constraints. By enabling homeowners to "age in place" without downsizing or selling, RMs effectively reduce housing market turnover, creating upward pressure on prices through reduced supply.

On the demand side, the availability of RMs as an additional funding source enhances the attractiveness of homeownership. Households recognize that owning a home provides not only housing services but also a valuable financial option, the ability to access home equity through RMs during retirement without having to sell or move. This option value increases the willingness to pay for housing among younger

households who anticipate using RMs in the future, thereby increasing housing demand. Consequently, both the supply and demand for houses shift in directions that lead to a rise in house prices.

However, there is notable heterogeneity across economic states. The house price increases are generally larger during tight credit conditions compared to loose credit regimes. For example, during expansions with tight credit, house prices increase by 2.61% when full RM availability is assumed, compared to only 0.35% during expansions with loose credit. This seemingly counterintuitive pattern can be explained by the relative scarcity of credit alternatives during tight credit periods. When conventional mortgage credit is restricted, RMs become a relatively more attractive and important source of housing finance, amplifying their impact on housing demand and prices. In contrast, during loose credit conditions, households have multiple sources of credit available, reducing the marginal impact of RMs on housing market equilibrium.

During crises, house price increases are moderate (1.26%), reflecting the offsetting effects of elevated RM take-up (which reduces supply) and depressed overall housing demand due to economic uncertainty and income shocks. The fact that house prices rise even during crises underscores the stabilizing role of RMs in housing markets, by providing liquidity to constrained homeowners, RMs prevent forced sales that would otherwise depress prices further during downturns.

Panel B presents housing price volatility, measured by the standard deviation of house prices across the simulated economy. A striking finding emerges: while RMs increase average house prices, they substantially reduce housing price volatility. The reduction in volatility ranges from -1.39% to -20.06% depending on the economic state and RM availability rate. This volatility reduction is most pronounced during expansions with loose credit (-20.06% at full RM availability) and least pronounced during expansions with tight credit (-1.78%).

The volatility-reducing effect of RMs operates through two main channels. First, RMs provide liquidity to financially constrained homeowners, reducing the likelihood of forced sales during adverse economic shocks or idiosyncratic hardships. Forced sales, often conducted at fire-sale prices, contribute significantly to housing price volatility, so reducing their frequency stabilizes prices. Second, RMs create a more stable base of long-term homeowners who are less sensitive to short-term price fluctuations and economic shocks. These "sticky" homeowners dampen price swings by reducing the elasticity of housing supply with respect to price changes.

The heterogeneity in volatility reduction across economic states is informative. During loose credit conditions, when households have greater access to RMs and can more easily tap home equity, the

Table 6: Housing Market Effects of Reverse Mortgages

	Panel A: Average Housing Price					
Economic State	Baseline	Main	RM 40%	RM 60%	RM 80%	RM 100%
Crisis	3.55	+0.46%	+0.69%	+0.95%	+1.23%	+1.26%
Rec. (loose)	4.31	+0.00%	+0.48%	+1.04%	+1.34%	+1.29%
Exp. (loose)	4.41	+0.09%	+0.28%	+0.44%	+0.50%	+0.35%
Rec. (tight)	3.60	+0.51%	+0.68%	+0.97%	+1.87%	+2.17%
Exp. (tight)	3.73	+0.32%	+0.78%	+1.14%	+1.74%	+2.61%
	Panel B: Housing Price Volatility (Standard Deviation)					
Economic State	Baseline	Main	RM 40%	RM 60%	RM 80%	RM 100%
Crisis	0.082	-2.09%	-5.70%	-8.11%	-9.97%	-13.48%
Rec. (loose)	0.078	-3.54%	-5.87%	-7.23%	-10.50%	-14.20%
Exp. (loose)	0.098	-3.48%	-8.22%	-11.65%	-15.64%	-20.06%
Rec. (tight)	0.078	-1.78%	-4.53%	-6.98%	-11.61%	-14.98%
Exp. (tight)	0.083	-1.39%	-1.99%	-3.40%	-3.81%	-1.78%

This table reports the effects of RM availability on housing prices across different economic states and RM take-up rates. Panel A shows average housing prices, with the baseline economy (no RMs) in levels and counterfactual economies showing percentage changes relative to baseline. Panel B shows the percentage change in standard deviations of housing prices (volatility) relative to baseline. Economic states are: Crisis, Recession with loose credit, Expansion with loose credit, Recession with tight credit, and Expansion with tight credit. The "Main" column corresponds to our calibrated model with 19% RM awareness matching the observed take-up rate in the data. Higher RM availability increases average prices but substantially reduces volatility, with stronger stabilization effects during loose credit conditions. Baseline house prices are normalized such that the average across all states equals 4.0.

stabilizing effect is strongest. In tight credit conditions, the reduced accessibility of RMs limits their ability to buffer households against shocks, resulting in smaller reductions in price volatility. This suggests that policies aimed at maintaining RM accessibility during economic downturns could enhance housing market stability during precisely the periods when stability is most valuable.

From a policy perspective, these findings have important implications. The price appreciation induced by RMs creates both winners and losers: existing homeowners benefit from higher home values and improved access to liquidity, while prospective homebuyers—particularly young renters—face higher entry costs into homeownership. However, the substantial reduction in housing price volatility represents an unambiguous benefit, as it reduces aggregate risk in the economy and enhances macroeconomic stability. Policymakers should weigh these distributional and efficiency considerations when designing RM programs and related housing policies.

Moreover, the price effects of RMs feedback into household decisions, creating general equilibrium effects that amplify the direct benefits of RM availability. Higher house prices increase home equity for all homeowners, enabling them to borrow larger amounts through RMs when needed. This positive feedback loop between RMs and house prices represents an important channel through which RMs enhance

household welfare beyond the direct liquidity provision. Section 5.4 provides a formal decomposition of these direct versus general equilibrium effects.

6.3 Effects on Mortgage Refinancing Behavior

Beyond their direct effects on households and housing markets, RMs also influence mortgage market dynamics, particularly household refinancing decisions. While we do not present detailed refinancing rate tables in this section (results available upon request), our model generates important insights into how RM availability affects conventional mortgage refinancing behavior.

A key finding is that RMs serve as a substitute for conventional mortgage refinancing, particularly during retirement. In the absence of RMs, retirees facing income declines or increased expenses would typically need to refinance their conventional mortgages to access home equity or reduce monthly payments. However, when RMs are available, many homeowners opt to take RMs instead of refinancing their conventional mortgages. This substitution occurs because RMs offer several advantages over refinancing for retirees: (1) no monthly repayment obligations, which is particularly valuable for households with limited and declining retirement income; (2) no income qualification requirements, making RMs accessible to households who might not qualify for conventional refinancing; and (3) the embedded put option on house prices, which protects borrowers from owing more than their home's value.

Our calibrated model shows that refinancing rates remain stable and moderate throughout the life cycle, including during retirement, when RMs are available. This contrasts sharply with results from models without RMs, such as Guren et al. (2021), which predict a sharp spike in refinancing activity immediately following retirement. In their model without RMs, retirees face a sudden need to access home equity or reduce mortgage payments as their income drops, leading to a surge in refinancing. Our model, which includes RMs, eliminates this spike by providing an alternative mechanism for retirees to manage their housing debt and access liquidity.

This refinancing substitution effect has important implications for mortgage lenders and the broader mortgage market. First, it suggests that the introduction or expansion of RM programs may reduce demand for conventional mortgage refinancing among older homeowners, potentially affecting lenders' refinancing revenues. Second, it highlights that RMs and conventional mortgages are not independent products but rather interconnected components of the housing finance system. Policies affecting RMs (such as changes to lending standards or insurance premiums) will have spillover effects on conventional mortgage markets through changes in refinancing behavior.

Third, the substitution of RMs for refinancing may have welfare implications beyond the direct benefits of RM availability. Refinancing conventional mortgages involves transaction costs, closing costs, and often requires extensive documentation and credit checks. If RMs allow households to achieve similar liquidity goals with lower transaction costs or greater accessibility, the substitution represents an efficiency gain for the financial system. However, this substitution also means that households accumulate debt on their homes without the periodic "reset" that refinancing provides, potentially increasing long-term indebtedness and reducing bequests.

Future research could explore these mortgage market dynamics in greater detail, examining how different RM program designs (such as varying origination costs, insurance premiums, or equity requirements) affect the substitution patterns between RMs and conventional refinancing. Additionally, understanding how RM availability affects mortgage default rates through reduced liquidity constraints and improved consumption smoothing would provide a more complete picture of RMs' effects on mortgage market stability.

7 Conclusion

In this paper, we investigate the effects of RMs using a quantitative model in which households make decisions about saving, consumption, homeownership, and RMs over the life cycle. By incorporating the credit and housing markets into our model, we aim to provide a thorough understanding of how the presence of RMs influences both sectors.

Our model matches the lifecycle profiles observed in the data well, especially for the PTI ratio, the fraction of owners refinancing and the take-up rate. Meanwhile, RM rates consistently remain higher than mortgage rates and the difference between RM rates and mortgage rates tends to be larger under tight credit. We also show that the volatility of consumption growth decreases for older households who opt for RMs compared to those who do not participate in RM programs. Additionally, our model demonstrates that the inclusion of RMs has a significant impact on house prices. As a result, the housing market becomes more competitive, making homeownership more appealing. While these dynamics present challenges for young renters, as they contend with rising house prices, it is important to acknowledge their potential for future homeownership. In an economy with RMs, young renters have the opportunity to aspire to become homeowners and use RMs as an additional means to access home equity. Therefore, despite facing obstacles, young renters still enjoy marginal benefits in an economy that incorporates RMs. On the other hand, as expected, older homeowners experience significant welfare gains. In summary, an

economy that includes RMs demonstrates overall superior total welfare benefits.

From a policy perspective, policymakers play a crucial role in promoting the understanding of RMs among households and minimizing the barriers that hinder access to them, all while maintaining an effective risk control framework. Encouraging older households to consider RMs carries multiple advantages, benefiting not only the households themselves but also the broader society. Additionally, such encouragement helps alleviate the strain on public pension schemes, reducing the related pressures and challenges.

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Appendix A RM Markets in Global Context

Throughout RMs' development in the US, RMs have experienced several major milestones: The first FHA-insured Home Equity Conversion Mortgage (HECM) was issued in 1989, followed by the first major news that HECM would become a permanent product as established by the Housing and Urban Department (HUD) Appropriations Act in 1994. During the 2000s' housing market boom, demand for RM surged, such that homeowners took advantage of the housing value insurance embedded in the RM contract. At the same time, more lenders joined the RM game as HUD increased origination fees and engaged with the American Association of Retired Persons (AARP) to improve counselling services to boost the RM market. More rules were relaxed such that refinancing through existing HECM became possible. Therefore, RMs have become increasingly important for older adults in boosting their retirement incomes.

RM market is growing not only in the US, but also in several developed economies, such as the UK, Australia, and Hong Kong, as shown in Figure 10. Graphs A and C of Figure 10 show the number of new RM plans (including lump sums, draw downs, withdrawals, and home reversion plans) in the UK and Hong Kong, respectively. In comparison, graph B shows the active number of RM plans in any given year in Australia for the same period, allowing expired plans to drop out from the database. In addition, according to Review of Reverse Mortgage Lending Report in Australia, from 2013 to 2017, lenders issued more than 17,000 RM plans. Hence, the market has the potential to reach up to 58,000 active plans in 2017, as represented by the dashed line from 2013 to 2017.

All these economies share similar socio-economic, demographic shifting trend, pension system, as well as financial market advancement and consumer financial literacy level. Among these economies, UK has the most sophisticated and penetrated RM market in the world, defined by the product ranges and optional features such as repayment and withdrawal, number of lenders and consumers, as well as consumer awareness and product reputation and regulation. Since its inception in 1991, the RM market in the UK shows very healthy and significant growth trend, with several turning points. For example, Figure 10 shows that the first downturn of the UK RM market is caused by the GFC rooted by the subprime mortgage crisis in late 2007 in the US, causing a global housing market slump. The RM market gradually recovered since 2008 low point, and has remained healthy growth, with a threefold size in 2016, due to major new product introduction. Another major turning point for the UK RM market is the COVID-19 crisis, which induced the prevailing extra-low interest rate regime during and after the crisis, boosting the housing market, causing a temporary contraction of the new lump sum plans in 2019, and

growth of further advance contracts,which can be observed in Figure 11.[20] Lump sum plans pick up the growth trend in 2020 during the living-cost crisis and stays as stable since then.

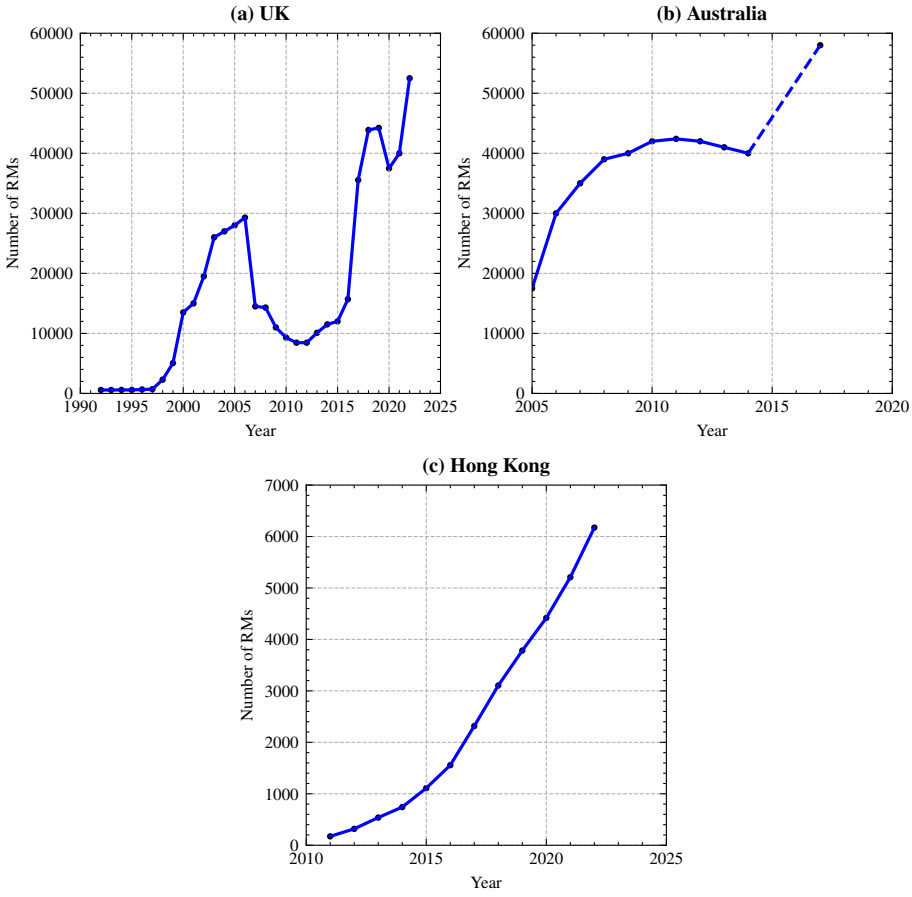


Figure 10: Number of RMs in Different Markets

Graph A plots the total number of RM plans in the UK from the early 1990s until now. Graph B plots the number of RM plans from 2005 to 2015 (continuous line) and shows a 5-year projection from 2015 onwards (dashed line). Graph C plots the total number of RM plans in Hong Kong from 2010s (the inception of the RM program in Hong Kong) until now.

Our estimate using the Equity Release Council (ERC) market report and Census data reveals that around 12% of eligible senior households have taken up RM in the UK, which is a relatively high and healthy number for this market and shows strong appetite by consumers and providers, thus a huge potential for this product to succeed in other countries in similar economic and social conditions.[21]

[20]Before 2005, UK did not report any other detailed information, except the total number of RMs.

[21]The recent UK RM take-up rate is estimated by the cumulative number of RM plans issued since its inception (1991-2022), e.g. according to ERC report, there are 592,000 RM plans issued during this period, divided by the number of eligible senior households who own their main house outright. To make this ratio comparable to the case of US and other countries, we use the number of households headed by someone 65+ by the report of Later Life in UK (2019), 6,500,000, with the homeowner ratios of 78%, and the fraction of those still paying mortgages 6%, this makes the RM eligible households to be

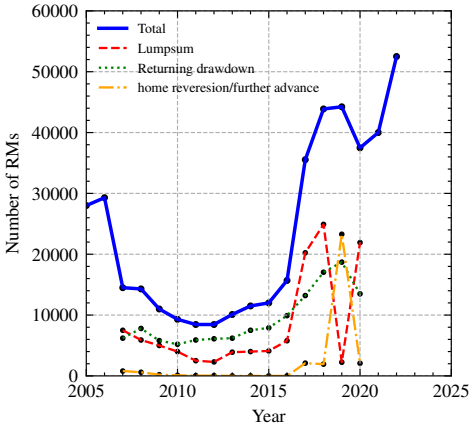


Figure 11: Number of RMs of Different Types in UK Market

This figure plots the number of RMs of different types such as (1) Lump sums (red dash line), (2) Returning drawdowns (green dash line), (3) Home reversion plans (yellow dash line). The total number of RM of all types (blue line).

The case of Hong Kong is described in the Hong Kong Monetary Authority market reports. Although still small, the RM market has gained significant interest and growth since its inception in 2011. There are multiple factors contributing to this slow but upward growth trend: Firstly, the lack of social security (public pension plans) in Hong Kong forces senior households to consider alternative methods to increase retirement income. Secondly, the housing market boom in Hong Kong makes housing assets a significant part of a family's wealth. However, the homeownership rate in Hong Kong is low compared to other developed countries such as US and UK, due to the un-affordability of housing for local citizens, stated by housing price to income ratio of 23.3.[22]

Australian RM regulatory body SEQUAL uses a different estimation method from the US and UK. They calculate the RM participation rate using the population of suitable senior individuals instead of number of eligible households. This makes the estimated RM take-up rate lower and not comparable to those reported by the US and UK regulators or market participants. Deloitte (2021) estimate about half of collective wealth in Australia is tied up in housing, and it is skewed towards the senior population, that

4,765,800. Hence the RM participation ratio is estimated to be 12% in 2022. However, if instead the denominator is the population of 65+, the number becomes significantly large, estimated to be 15,500,000 (ERC report 2022), then the RM take-up rate becomes 3.8%.

[22]According to Research Office (2021) from Hong Kong, in 2019, homeownership ratio in Hong Kong fell to the lowest point in the past two decades, as 49.8%, following a nearly four-fold growth in flat prices during that period. Although homeownership rate modestly grows to 51.2% during 2020, it is still far below the prevailing 60% level in developed economies. Ernst and Young (2022) states that the median house price to median income ratio of Hong Kong in a 2021 survey is 23.3. Moreover, Cox (2023)) compares house to income ratios over 92 major metropolitan areas and shows that Hong Kong was the highest for consecutive 12 years.

is, around AUD$1 trillion. Out of this housing wealth, AUD$300 billion is being accessed by RMs, which amounts to only about 1%-1.5% in 2021, although the market has grown by more than 5 times since its inception. Product ranges, consumer knowledge and brand reputation are not as strong as in the UK and US. The challenges of Australian RM market development is due to major lenders' unwillingness to offer such products, and hence only proprietary and niche lenders are willing to take the risk and offer such products. On the consumer side, the lack of consumer awareness, financial literacy, and product education also contributes to the existing challenges.

Appendix B Numerical Solution

The model does not offer an analytical solution but is amenable to numerical resolution through a method known as backward induction. Both policy functions and value functions are contingent on the state variables. In the last period, the policy functions are determined by the bequest motive, and the value function corresponds to the bequest function. We use a grid search to optimise the value function. We compute the value associated with different control variables. Then we choose the level of control variables achieving the maximum value, which are saved as the policy rules for the previous period. For every time t prior to T, and for each point in the state space, this procedure is iterated backward.

To approximate the distributions of innovations to the permanent labor income shocks, we use numerical integration techniques. Specifically, our density function for permanent income shocks is reformulated as a combination of Hermite polynomials and the Gaussian kernel. This formulation allows us to leverage Gaussian quadrature points along with adjusted weights to approximate the numerical integrations effectively. In cases where points do not align with the state space grid, we utilize cubic spline interpolation to evaluate the value function. This interpolation method enables us to estimate the value function accurately at points that fall outside the grid. We consistently apply cubic spline interpolation for value function evaluation on the selected grids to ensure a smooth and precise estimation of values across the state space. As for the transition matrix among different economic states, we follow Guren et al. (2021) to set the parameters of economics transition. The transition matrix of the three economic states is given by

$$\mathbb{P}^e = \begin{array}{c} \\ \text{Crisis} \\ \text{Recess (l)} \\ \text{Expans (l)} \\ \text{Recess (t)} \\ \text{Expans (t)} \end{array} \left\| \begin{array}{ccccc} \text{Crisis} & \text{Recess (l)} & \text{Expans(l)} & \text{Recess (t)} & \text{Expans(t)} \\ 0.6364 & 0.0000 & 0.0000 & 0.0000 & 0.3636 \\ 0.0000 & 0.1011 & 0.8989 & 0.0000 & 0.0000 \\ 0.0133 & 0.1832 & 0.8035 & 0.0000 & 0.0000 \\ 0.0000 & 0.0000 & 0.0000 & 0.1011 & 0.8989 \\ 0.0133 & 0.0000 & 0.0200 & 0.1832 & 0.7835 \end{array} \right\| \tag{39}$$

After the optimal policy rules are derived, we start simulating the life-cycle profile for each household. Once households die at age 100, they are dropped from the simulation. New 20-year-old households enter the labor market every year.