The Value of Heterogeneous Mortgage Contracts

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Abstract

This paper shows how households choose between different types of mortgage contracts: a fixed-rate fixed-payment mortgage contract, a fixed-payment variable-rate mortgage contract and a variable-payment variable-rate mortgage contract. We show that these three contracts can coexist in equilibrium and that households welfare is substantially improved when all three contracts are available. Our model matches well mortgage dynamics in Canada where these three types of contracts are available. Both aggregate state variables, such as the level of interest rates, and individual state variables, such as income and wealth, drive heterogeneity in mortgage type choice.

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1 Introduction

Mortgages are the largest component of U.S. households balance sheets - 64% of total U.S. household liabilities as of Q4 2024. 92% of U.S. households have fixed-rate mortgages (FRMs) and 8% have adjustable-rate mortgages.[1] Households seem to enjoy the certainty of fixed-rate callable debt, or floating rate debt with caps. We show that the predominance of fixed-rate mortgages in the U.S. economy is sub-optimal and has significant welfare costs. Black (1998) argued for floating-rate debt, with fixed payments, where an interest rate change leaves payment unchanged but affects the allocation between interest and principal. In this paper, we show that there is scope for three types of contracts to coexist in equilibrium: a fixed-rate fixed-payment contract (FF), a variable-rate fixed-payment contract (VF) and a variable-rate variable-payment contract (VV). We also show that there are benefits of not tying the length of the mortgage contract (term) to the length of the amortization period or mortgage maturity (which is predominant in the U.S.).

The Canadian mortgage market, in fact, offers exactly these three types of contracts. Unlike the U.S., where most mortgages are 15 to 30-year fixed-rate mortgages with non-trivial refinancing, prepayment and home-equity extraction decisions, in Canada mortgage contracts have 2 to 5-year terms (with 5-year term being the most common). Thus, there is no inertia in refinancing since all borrowers have to renew their mortgages at the end of the term. Further, penalties for refinancing or prepaying a mortgage outside of the renewal periods are very steep and therefore it is not common for households to either refinance, prepay their mortgage or extract equity from their homes.

Canadian borrowers choose between three types of contract: a FF mortgage (similar to U.S. FRM), a VV mortgage (similar to U.S. ARM), and VF mortgage. We therefore leverage data from Canada to calibrate a quantitative life-cycle model with housing in the spirit of Campbell and Cocco (2003). Our model features forward-looking rational agents, who face a stochastic stream of labour income, stochastic and persistent short-term interest rates and a stochastic term premium. Households can decide to buy or rent a house. Households endogenously choose a type of mortgage contract, either FF, VF or VV, when buying a house, and later in life, when they renew their mortgage and make that choice again.

Our first result is that all three types of contract can coexist in equilibrium. The optimal choice of contract depends on both aggregate state variables (the level of interest rates

[1] https://www.stlouisfed.org/on-the-economy/2024/feb/which-households-prefer-arms-fixed-rat

and term premium) as well as individual agent state variables (wealth, leverage and income). FF contracts are optimal when term premium is low, agents have low wealth and high leverage. When term premium is low, a FF contract allows agents to make lowest payments compared to the VV and VF contract, and provide quicker deleveraging. This is also the contract chosen when agents have low income and high leverage. This is because of risk aversion. More constrained households enjoy the certainty of payments over the contract life. VF and VV contracts are chosen when term premium is high, and agents are less constrained (they have higher income and net wealth). When interest rates are low poorer agents choose a VF contract and richer households a VV contract. The VF contract when interest rates are low delivers fixed payments for the households at the expense of a slower deleveraging. Poorer agents choosing a VF contract are liquidity constrained and thus willing to deleverage slower in order to keep their payments low. When interest rates are high, poorer agents choose a VV contract. This contract due to the expected decline in interest rates yields smaller payments for agents over the life of the contract at the expense of slower deleveraging relative to the variable rate contract with payments fixed at the level implied by higher interest rates. Thus in equilibrium, agents optimally choose the three available contracts and no contract dominates.

We show that our model captures very well the mortgage origination dynamics in Canada between 2014 and 2022. We use Canadian data on short-term and long-term interest rates to estimate stochastic processes for the risk-free rate and term premia and use a large grid search to calibrate preference parameters. Our model is able to match the share of FF, VF and VV mortgages originated during this period, including the decline in the FF mortgages originated in 2018 and after 2020, along with the increase in originations of VF and VV mortgages.

Our second main result, is that restricting the menu of contracts available for households to choose from leads to welfare losses, measured using standard consumption equivalent variations, between 1% and 4% . Using our model we run several counterfactual equilibria where only one type of mortgage contract is available to households. In fact, economies with only fixed rate type contracts have the largest welfare loss (compared to economies with only variable rate type contracts available). Losses are higher when term premium is high and only FF contracts are available or when term premium is low and only VF or VV contracts are available. Indeed, allowing households to endogenously choose any type of contract delivers better consumption smoothing (i.e. higher consumption and lower consumption growth over an agents' life). Agents also have less precautionary savings when they have a larger menu of contracts available and are able to deleverage faster. Economies with only FF type contracts deliver obviously lower volatility of consumption and mortgage payments, but this reduced volatility is not enough to counteract the effects of higher ex-ante consumption when all contracts are available.

Finally, our model also has very stark implications for monetary policy pass-through. Using our model we can easily understand the pass-through of both interest rate changes and forward guidance, conditional on the type of mortgages in the economy. We find strong impacts of changes in the risk-free rate in economies dominated by VV mortgages, moderate pass-through in economies dominated by VF mortgages and limited pass-through in economies dominated by FF mortgages. In stark contrast, forward guidance, has strong impact on economies dominated by FF mortgages, and has limited impact on economies dominated by VF or VV mortgages.

Our paper relates to the literature on mortgage type choice. Andersen et al. (2023), in a concurrent paper, write "The academic literature on the choice between ARMs and FRMs is surprisingly small." This is particularly true for theory models of mortgage choice. To the best of our knowledge, our model is the first model of mortgage choice where agents can swap contract types throughout their life-cycle. Andersen et al. (2023), Campbell and Cocco (2015) develop life-cycle models where agents can choose ARM or FRM contracts when they enter the economy. In their models, income risk, interest rate risk and borrowing constraints drive the mortgage choice. Similarly, Campbell et al. (2021) and Guren et al. (2021) show how ARMs can be beneficial to households in recessions. In particular, they show that there are significant welfare gains of allowing a one-off conversion of a FRM into an ARM in bad times, when there are refinancing frictions. Our results are very consistent with Koijen et al. (2009) who show that a key driver of mortgage type choice is bond risk premium. When risk premium is high FF mortgage payments are high, which makes VV and VF mortgages more attractive. We show that this result holds in a long-horizon quantitative model of mortgage type choice where agents have rational expectations.

Our paper is organized as follows. Section 2 describes the institutional features of the Canadian mortgage market. Section 3 presents our model. Section 4 describes the model calibration. Section 5 is the core of the paper. It describes the economics underlying mortgage type choice, the welfare benefits of having a menu of different mortgage type contracts available, as well as the implications of different contracts for monetary policy transmission.

Section 6 concludes.

2 Institutional Background

The Canadian mortgage market is relatively concentrated in the traditional banking sector, with the dominant Big 6 banks responsible for the largest share of mortgage originations and balances outstanding.[2] Unlike the U.S. mortgage market, where long-term fixed rate mortgages (FRMs) are dominant, the Canadian mortgage market is characterized by contracts with short terms (2-5 years, with the 5-year term being the most prevalent) and long amortization period (25-30 years). Term is the length of time over which a financial institution commits to extending a loan to a borrower under certain conditions. The amortization period is the length of time it takes to pay off a mortgage. Thus, with a mortgage term that is shorter than the amortization period the contract is amortized only partially.

At the end of the term, a borrower is faced with a number of options. The most common option is for the borrower to renew mortgage with their current lender, by rolling over at most their balance outstanding and having their mortgage rate reset to the current level of market interest rates. Typically, by the end of the amortization period, a mortgage contract would have been renewed several times. Alternatively, if the mortgage is not renewed with the current lender, the balance outstanding needs to be repaid in full, either with the proceeds of a home sale or with another lender taking over the mortgage at renewal.[3] Thus unlike in the United States where refinancing inertia is very costly for households, in Canada given that mortgages are renewed every 5 years inertia is not very costly. Further unlike the U.S. there are severe prepayment penalties when mortgages are renewed before the end of contract term, as described in more detail below.

Households in Canada can choose between 3 types of contract: (i) a fixed rate fixed payment mortgage (fixed-fixed mortgage), akin to an FRM mortgage in the United States, (ii)

[2]The share of balances outstanding in the traditional banking sector is about 70% over the 199X-20XX period, with the remainder held by credit unions, loan and trust companies, mortgage finance companies, and mortgage investment companies.

[3]About 70% of borrowers renew with their original lender. These are borrowers who either prefer the convenience of renewing with their lender and don't shop for a more competitive rate at renewal, or those that do shop around, but stay with their original lender as it price matches an outside offer. These outside offers do need to be generated through a qualification process, while only the history of past payments matters for renewal with the original lender.

a variable rate variable payment mortgage (variable-variable mortgage), akin to an ARM mortgage in the United States and a (iii) variable rate fixed payment mortgage. Fixed rate mortgages (fixed-fixed) have both their rate and payment fixed over the length of the term. Variable rate mortgages have their interest payments determined by the current level of short-term rates. However, the total payment varies depending on whether a mortgage is a variable payment mortgage (variable-variable) or a fixed payment mortgage (variable-fixed). In the case of the former, the total payment changes as often as the interest rate used to calculate interest payments. In the case of the latter, the level of total mortgage payments does not change with the current interest rate and the most popular rate used to set the level of payments is the short-term interest rate at origination.[4] With two different interest rates used for setting a level of interest and a level of payments, whenever the two differ from each other, the principal portion of the total payment would absorb the differences. In particular, if interest rates increase over the length of the term relative to the initial interest rates, the interest portion of the payment would increase, and the principal portion decrease, resulting in a slower repayment of principal.[5] The opposite is true when interest rates fall below the level of initial interest rate.[6]

Prepayment of mortgages in full and refinancing (outside of renewal periods) is rare in Canada. Partial prepayments through lump-sum payments, are limited to between 10 and 20% of the initial balance of the mortgage per year. However, unlike in the U.S., where full prepayment is often penalty-free, in Canada full prepayment of a mortgage within a term involves a penalty, whose size depends on the type of the mortgage and the direction of the change in interest rates. For variable rate mortgages of both types, the penalty is three months of interest payments on the balance outstanding at the time of prepayment. The same penalty applies to fixed rate mortgages when interest rates at the time of prepayment

[4]Other interest rates, such as a 5-year mortgage rate are also possible. However, since March 2018 all lenders offering this type of contract in Canada use the short-term rate at origination. It is possible for borrowers to request their payments to be set at a level exceeding that implied by the current interest rate, but this is not very common. In particular, until May 2018 one Big 6 bank offered its variable rate borrowers a choice between variable payments and fixed payments with the level of the former set using the 5-year fixed mortgage rate. The variable rate mortgages with fixed payments, however, had almost no take-up at this lender.

[5]Borrowers can always compensate the shortfall of principal payments relative to the initial principal repayment schedule by either increasing the level of regular installments or making lump-sum payments.

[6]Unlike in the case of rate increases, it is not possible to adjust mortgage payments when rates decline by reborrowing additional mortgage principal paid down. Only prepayments in excess of the regular installments can be reborrowed under certain conditions.

exceed the contract rate in effect, but the incentives to prepay in the rising rate environment may be limited. On the contrary, when interest rates decrease relative to the contractual rate, the penalty is calculated using the interest rate differential between the contractual and current rates and is applied over the remainder of the term.[7] From the borrower's perspective this eliminates any gains from ending the term early to take advantage of lower interest rates.[8] Thus, early renewal is not at all common in Canada in either periods of low or high interest rates.

The existence of prepayment penalties also reduces the incentive of Canadian consumers to extract their home equity through cash-out refinancing that involves paying off the current balance and originating a new loan secured by the same property with a higher balance.[9] Cash-out refinancing is most likely to happen when a consumer approaches her scheduled renewal date and when prepayment penalties do not apply. However, taking out equity through home equity lines of credit (HELOCs) does avoid prepayment penalties and is more flexible in the amount that consumers can borrow. Hence it is more prevalent in Canada compared to cash-out mortgage refinancing (Ho et al. (2019)), which is much more widely used in the U.S.

Thus, the Canadian mortgage system is the right laboratory to study the drivers of different mortgage types, since other kinds of confounding effects such as inertia in refinancing, prepayment or home equity extraction are virtually non-existent.

3 Model

We model the decision of borrowers, at the beginning of their working lifes, who take a mortgage to finance the purchase of a house. In each period, in addition to plans for consuming and saving, each household i makes a decision regarding its mortgage payment and when

[7] More precisely, for all of the Big 6 banks the penalty is calculated using the posted interest rate at the time of origination and the current posted rate on the term closest to the remaining term to renewal. Contractual interest rates for most borrowers feature a discount relative to posted rates. Some smaller lenders keep the penalty at 3 months of interest regardless of the direction of changes in interest rates.

[8] There may still be a benefit of terminating a contract early and renewing a mortgage with a lower interest rate outside of the traditional banking system.

[9] While borrowers may be able to avoid prepayment penalty when increasing the size of the mortgage with their current lender, there is still a cost associated with doing so. While the existing portion of the loan may conserve the current interest rate, the amount of the increase is assessed a rate of interest equal to the current posted rate that is about 200 basis points higher than the average contractual interest rate.

allowed whether change the type of mortgage contract. Households live for $T = T_W + T_R$ periods. In the first T_W working life periods, the household receives stochastic labor income, and during the T_R retirement periods, it receives pension income. Our model abstracts from inflation dynamics. We consider a real economy in which either all mortgages are inflation-indexed or the price level is constant. This allows us to focus on the determinants of mortgage type choice conditional on aggregate interest rate, term-premium and income dynamics. We only model the loan market and otherwise take a partial equilibrium approach.

3.1 Bond Market

Households can save in a one-period bond at rate $R_{1,t}$. Let the log of the one period bond rate be denoted $r_{1,t}$, i.e. $r_{1,t} \equiv \log(1 + R_{1,t})$. The one period log interest rate follows an AR(1) process:

$$r_{1,t+1} = (1 - \rho_r)\bar{r} + \rho_r r_{1,t} + \epsilon_{r,t+1} \tag{1}$$

We assume the expectation hypothesis of interest rates holds. Therefore, the return for an n-period bond, which will be used to price the fixed-rate mortgage, is given by:

$$r_{nt} = (1/n) \sum_{j=0}^{n-1} E_t[r_{1,t+j}] + \omega_{n,t} \tag{2}$$

where $\omega_{n,t}$ is a time-varying term premium that is also persistent:

$$\omega_{n,t} = (1 - \rho_\omega)\bar{\omega} + \rho_\omega \omega_{n,t} + \epsilon_{\omega,t+1} \tag{3}$$

3.2 Mortgage Contracts

A risk-neutral financial institution elastically supplies mortgage debt to households in the economy. The FI offers three types of mortgage contracts: Fixed-Fixed (FF), Variable-Fixed (VF), and Variable-Variable (VV). Each mortgage is designed to amortize after N_A years, and switching between mortgage types does not reset the amortization schedule. The contract is defined by the type, $\chi \in \{FF, VF, VV\}$, and the contractual interest rate, R^M.

3.2.1 Market Interest Rates and Payment Functions

The FI sets the market interest rate on the two variable-rate mortgages, Variable-Fixed and Variable-Variable, as a fixed premium over the one-period risk-free bond:

$$R_{VV,t} = R_{1,t} + \phi_{VV}$$

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On the other hand, the Fixed-Fixed market interest is as a fixed premium over the N_M-period risk-free bond:

$$R_{FF,t} = R_{N_M,t} + \phi_{FF}.$$

When calculating payments for each mortgage, the interest rates will depend on the mortgage type, market rates, and contract rates, as well as the outstanding mortgage balance and periods remaining in the amortization. Therefore, for a given set of interest rates, we define general mortgage payment functions using standard formulae and then tailor them to each type of mortgage in the next section.

Given the types of mortgages that the FI offers, we allow for different interest rates to be used in calculating the total mortgage payment and the interest payment. Letting R_{TP} denote the total payment interest rate, the total mortgage payment is given by:

$$TP(R_T) = \frac{R_T}{1-(1+R_T)^{-T_A}}M,$$

where M is the outstanding balance and T_A is the number of periods remaining in the amortization. Letting R_{IP} denote the interest rate for the interest payment, interest is given by:

$$IP(R_I) = R_I M,$$

and the principal payment is the residual from the total payment after interest has been paid:

$$PP(R_T, R_I) = TP(R_T) - IP(R_I) = \left(\frac{R_{TP}}{1-(1+R_{TP})^{-T_A}} - R_I\right)M.$$

3.2.2 Contract Rates and Payment Structure

In this section, we detail the differences between the three types of mortgages in terms of how the contract rate is set and how the payments depend on market and contract rates. Table 1 summarizes the three types of mortgages.

1. **Fixed-Fixed Mortgages**
   When the household chooses a Fixed-Fixed mortgage in period s, the contract rate is set to the market rate in that period, $R_s^M = R_{FF,s}$. This is incorporated into the mortgage contract rate and remains in effect until the household refinances into a new mortgage. The total and interest payments for the mortgage are both calculated using the mortgage contract rate. In period t for a contract that was signed in period t^*, total and interest payments are $TP(R_{t*}^M)$ and $IP(R_{t*}^M)$.

2. **Variable-Fixed Mortgage**
   As with a Fixed-Fixed mortgage chosen in period s, the contract rate is set to the market rate, $R_s^M = R_{VF,s}$, and remains effective until the household refinances. The key difference is that in each period the household has this mortgage, the contract rate is used to calculate the total payment, but the market rate is used to calculate the interest payment. In period t for a contract signed in period t^*, the total payment is $TP(R_{t*}^M)$, and does not vary with market rates. The interest payment, $IP(R_{VF,t})$, varies with the current market rate for a Variable-Fixed mortgage. As such, while the total payment fluctuates, the share of the total payment going towards principal will change as the market rate changes.

3. **Variable-Variable Mortgage**
   With a Variable-Variable mortgage, there is no contract rate. The market interest rate is used to calculate both the total and interest payments for the mortgage in each period, $TP(R_{VV,t})$ and $IP(R_{VV,t})$.

3.3 Homeowners with Mortgages

Homeowners with mortgages are characterized by their age, Age_{it}, cash-on-hand, W_{it}, persistent income component, Z_{it}, mortgage debt, M_{it}, the mortgage type chosen in the previous period, $\chi_{i,t-1} \in \{FF, VF, VV\}$, and (for Fixed-Fixed and Variable-Fixed mortgages) the corresponding mortgage contract rate, $R_{i,t-1}^M$. The aggregate economy state variables are the interest rate for a one-year bond, R_{1t}, and the term-premium, ω_t. To ease exposition, we define the household's idiosyncratic state variables, $S_{it} \equiv \{Age_{it}, W_{it}, Z_{it}, M_{it}, \chi_{i,t-1}, R_{i,t-1}^M\}$, and the aggregate state variables, $A_t \equiv \{R_{1,t}, \omega_t\}$.

3.3.1 Mortgage Value Function

We can write a general mortgage value function that takes in as arguments the two interest rates used to calculate the total and interest payments.

$$V^{Mortgage}(\{R^{TP}, R^{I}\}, S_{it}, A_t) = \max_{C_{it}} F(C_{it}, V^{Owner,Mortgage}(S_{i,t+1}, A_{t+1})),$$

where F is the Epstein-Zin operator over current consumption and future value, the value function $V^{Owner,Mortgage}$ is defined in the next section, and subject to the budget constraint:

$$W_{i,t+1} = Y_{i,t+1} + (1 + R_{1,t})(W_{it} - C(\cdot) - TP(R^{TP}).$$

The consumption policy function, $C_{it} \equiv C(\{R^{TP}, R^{I}\}, S_{it}, A_t)$, depends on the mortgage interest rates, household state variables, and aggregate state variables. Mortgage debt, M_{it}, is measured at the beginning of the period, and evolves as the existing balance less principal payment, $P(R^{TP}, R^{IP}) = TP(R^{TP}) - I(R^{I})$:

$$M_{i,t+1} = M_{it} - P(R^{T}, R^{I}).$$

3.3.2 Household Optimization

In each period, the household makes a choice $j \in \{Continue, Refinance, Rent\}$. Each of the first four mortgage choices are subject to the costs set by the FI as described above. If the household chooses to rent, it permanently enters the rental market. Otherwise, it faces this same menu of options in each period. The household problem is given by:

$$\begin{aligned} V^{Owner,Mortgage}(S_{it}, A_t) = \max\{&V^{Continue}(S_{it}, A_t), \\ &V^{Refinance}(S_{it}, A_t), \\ &V^{Owner,Rent}(S_{it}, A_t)\}. \end{aligned}$$

Continuing in the Same Mortgage Contract The household can continue in the same mortgage, which uses the contract rate when relevant:

$$V^{Continue}(S_{it}, A_t) = \begin{cases} V^{Mortgage}(\{R^{M}_{i,t-1}, R^{M}_{i,t-1}\}, S_{it}, A_t) - \gamma_t(FF) & \text{if } \chi_{t-1} = FF, \\ V^{Mortgage}(\{R^{M}_{i,t-1}, R_{VF,t}\}, S_{it}, A_t) - \gamma_t(VF) & \text{if } \chi_{t-1} = VF, \\ V^{Mortgage}(\{R_{VV,t}, R_{VV,t}\}, S_{it}, A_t) - \gamma_t(VV) & \text{if } \chi_{t-1} = VV, \end{cases}$$

where $\gamma_t(\chi)$ is the utility cost the household pays to continue in the same contract in period t with mortgage type χ. These expressions highlight the difference between each of the three mortgage types if the household chooses to continue in the existing contract.

With a Fixed-Fixed mortgage, the contract rate, $R^M_{i,t-1}$, which is a state variable for the household, is used to calculate both the total and interest payments. With a Fixed-Variable mortgage, the contract rate is used to calculate the total payment, but the market rate, $R_{VF,t}$, which is calculated as a function of the aggregate state variables, is used to calculate the interest payment. With a Variable-Variable mortgage, the market rates are always used to calculate both types of payments.

If the household chooses to continue, then the mortgage type and mortgage contract rate are the same as in the previous period:

$$\chi_{it} = \chi_{i,t-1}, \;\; R^M_{it} = R^M_{i,t-1}.$$

Refinancing The household can refinance into a new mortgage, subject to the refinancing costs that depend on the new mortgage type and the current mortgage type. We also include a preference shock over each type of refinancing option that represents other factors which influence mortgage choice but are not captured in our model. Specifically, the household solves:

$$\begin{aligned} V^{Refinance}(S_{it}, A_t) = \max\{ & V^{Mortgage}(\{R_{FF,t}, R_{FF,t}\}, S_{it}, A_t) - \kappa_t(FF|\chi_{t-1}) + \sigma\epsilon_{FF,it}, \\ & V^{Mortgage}(\{R_{VF,t}, R_{VF,t}\}, S_{it}, A_t) - \kappa_t(VF|\chi_{t-1}) + \sigma\epsilon_{VF,it}, \\ & V^{Mortgage}(\{R_{VV,t}, R_{VV,t}\}, S_{it}, A_t) - \kappa_t(VV|\chi_{t-1}) + \sigma\epsilon_{VV,it}\}, \end{aligned}$$

where $\kappa_t(\chi|\chi_-)$ is the utility cost that a household with mortgage type χ_- pays to refinance into a new contract with mortgage type χ in period t. These expressions emphasize that with respect to the mortgage calculations, the framework for calculating the value from refinancing is the same as for the value for continuing except for the interest rate used to construct the mortgage payments.[10] Note also that refinancing into the same type of mortgage is essentially a means of resetting the contract rate, while refinancing into a new mortgage type both resets the contract rate and changes the structure of payments. In each of the refinancing options, $\chi \in \{FF, VF, VV\}$, the relevant interest rate is the market rate for each

[10]The choices will also differ based on the continuation and refinancing costs set by the FI. If the continuation cost of a Variable-Variable mortgage and the refinancing cost from Variable-Variable to Variable-Variable are equal, i.e., $\gamma_t(VV) = \kappa_t(VV|VV)$, then the choice between continuing and refinancing is identical.

mortgage type. When the household chooses to refinance, the mortgage type is set to the new choice, and the new contract rate is the market rate for the new mortgage type:

$$\chi_{it} = \chi, \;\; R^M_{it} = R_{\chi,t}.$$

Renting The homeowner also considers becoming a renter. This entails selling the home, which yields (potential) profit $\pi^H_{it} = (1 - \phi_S - \tau_S)(H - M_{it})$, where ϕ_S is the transaction fee charged by a real estate agent, τ_S is the tax rate on real estate transactions, and $(H - M_{it})$ is the net equity in the home. The proceeds from the home sale are added to cash-on-hand and total value is calculated using the renter's value function defined in Section 3.5:

$$V^{Owner,Rent}(S_{it}, A_t) = V^{Renter}(W_{it} + \pi^H_{it}, Z_{it}, R_{1t}, \omega_t).$$

3.4 Homeowners without Mortgages

After their mortgage contract is finished, homeowners live in their homes with no mortgage payments. However, they may still choose to transition to the rental market, which yields the net profit from the home sale but then requires paying rent in each period. Thus for $t \geq N_M$, the value function for a homeowner is given by:

$$V_t(W, z, R) = \max\{V_t^{\text{Owner,NM}}(W, z, R), V_t^{\text{Renter}}(W + \pi_H, z, R), \}$$

with the same home sale profit equation above, except that, by virtue of not having a mortgage, net equity is equal to the value of the house. The value of renting is compared against the value of owning without a mortgage:

$$V_t^{\text{Owner,NM}}(W, z, R) = \max_{c_t^{\text{Owner,NM}}} F(c_t^{\text{Owner,NM}}(W, z, R), V_{t+1}(W', z', R')),$$

with wealth evolving according to $W' = Y' + (1 + R')(W - c_t^{\text{Owner,NM}}(W, z, R))$.

3.5 Renters

In the model, all households are initially homeowners, but may choose to make a permanent transition into the rental market at any point in the lifecycle. The cost of renting is equal to the user cost of housing plus a rental premium.

During the working periods of life, renters occupy the same size house as that available. The date $t \leq J_w$ rental cost, RC, is defined as:

$$RC_t = (R_{1t} + \tau_r^H + \mu_r^H + \phi_r^H)H_t,$$

where τ_r^H and μ_r^H are the property tax rate and maintenance costs of rental housing, respectively, and ϕ_r^H is the rental premium of rental housing.

In retirement, renter households move to an assisted living facility whose quality is proportional to their retirement income. Rental cost during retirement, $t > J_w$, is defined as:

$$RC_t = (R_{1t} + \tau_r^A + \mu_r^A + \phi_r^A)A(Y_t),$$

where $A(Y_t) = \bar{A}Y_t$, τ_r^A and μ_r^A are the property tax rate and maintenance costs of assisted living housing, respectively, and ϕ_r^A is the premium paid for assisted living.

3.5.1 Preferences and Income

As in Campbell (2006) we assume that preferences are separable between housing and non-housing consumption and that house size is fixed throughout each household's lifetime. Under these assumptions, we can drop housing from the preference specification. Our agents have Epstein and Zin (1989) preferences,

$$V_{it} = F(C_{it}, V_{i,t+1}) = \left\{ (1-\beta)C_{it}^{1-1/\psi} + \beta E_t(V_{it+1}^{1-\gamma})^{\frac{1-1/\psi}{1-\gamma}} \right\}^{\frac{1}{1-1/\psi}}, \quad (4)$$

where γ is the coefficient of risk aversion, β is the subjective discount factor, and ψ is the elasticity of intertemporal substitution.

During the work life agent's are endowed with stochastic labor income Y_{it}. Income during the household's working life is modeled following Guvenen et al. (2021). In period t of household i's working life, income is given by:

$$Y_{it} = (1 - \nu_{it}) \exp(g(t) + \alpha_i + z_{it} + \epsilon_{it}), \quad (5)$$

where $g(t)$ captures the age profile of the household's earnings and α_i is a household fixed effect calibrated to match average earnings. The unemployment shock, ν_{it}, generates a large decrease in income when the household is unemployed, while the stochastic processes, z_{it} and ϵ_{it}, capture, respectively, persistent and transitory income shocks for employed households.

The persistent income process, z_{it}, follows an AR(1),

$$z_{it} = \rho z_{i,t-1} + \eta_{it}, \tag{6}$$

with innovations drawn from a mixture of normal distributions. The persistent shock η_{it} is $\mathcal{N}(\mu_{\eta,1}, \sigma_{\eta,1})$ with probability p_z and $\mathcal{N}(\mu_{\eta,2}, \sigma_{\eta,2})$ otherwise.

The transitory shock, ϵ_{it}, is also a mixture of normal distributions drawn from $\mathcal{N}(\mu_{\epsilon,1}, \sigma_{\epsilon,1})$ with probability p_ϵ and $\mathcal{N}(\mu_{\epsilon,2}, \sigma_{\epsilon,2})$, otherwise. In both cases, the expected value of the mixed distribution is zero.

The unemployment shock, $1 - \nu_{it}$, is given by

$$1 - \nu_{it} = \begin{cases} 1 & \text{with prob. } 1 - p_\nu(t, z_t^i), \\ \lambda & \text{with prob. } p_\nu(t, z_t^i), \end{cases} \tag{7}$$

where

$$p_\nu^i(t, z_t) = \frac{\exp(a_\nu + b_\nu t + c_\nu z_t^i + d_\nu z_t^i t)}{1 + \exp(a_\nu + b_\nu t + c_\nu z_t^i + d_\nu z_t^i t)}. \tag{8}$$

This shock depends on the household's age and the persistent component of the income process. When the unemployment shock is realized, the household's income is scaled down by a constant fraction, λ.

Following Cocco et al. (2005), retired households receive a deterministic fraction, ω, of their income in the last period of their working lives. More precisely, for retired household i in period t, income is given by

$$Y_{it} = \omega \cdot \exp(g(T^r) + \alpha^i + z_{i,T^r}) \tag{9}$$

where T^r is the final working period. Income is taxed at a constant rate τ_Y.

3.6 Solution Technique

We solve the household problem in three stages. ...

In renewal periods, the household makes a discrete choice between renting or continuing to own, and for the latter, between the three types of mortgages. We smooth the mortgage choice problem using EVT I shocks with standard deviation σ:

$$\begin{aligned} V_t^{\text{Renewal,Owner}}(M, W, z, R, \omega) = E_t \max\{ & V_t^{\text{Owner,FF}}(M, W, R_{FF}, z, R, \omega) + \sigma\epsilon_{FF,t}), \\ & V_t^{\text{Owner,VF}}(M, W, R_{VF}, z, R, \omega) + \sigma\epsilon^(VF), \\ & V_t^{\text{Owner,VV}}(M, W, z, R, \omega) + \sigma\epsilon^(VV)\}, \end{aligned}$$

where the expectation is taken with respect to the EVT shock. This can then be rewritten as:

$$V_t^{\text{Renewal,Owner}} = \sigma \log \left[\exp\left(\frac{V_t^{\text{Owner,FF}}}{\sigma}\right) + \exp\left(\frac{V_t^{\text{Owner,VF}}}{\sigma}\right) + \exp\left(\frac{V_t^{\text{Owner,VV}}}{\sigma}\right) \right].$$

4 Model Calibration

4.1 Financial Markets

We calibrate the stochastic interest rate and term-premia processes in the following manner. We use Canadian 1-year government bond yields (GOC-1) between 1980 and 2023 to estimate equation (1). We estimate the average 1 year risk-free rate to be 2.977%, the persistence parameter of interest rates to be 0.896 and the standard deviation to be 1.21%. Given our estimates of the AR(1) process for interest rates, we can estimate equation (3). We use data on 5-year Canadian government bond yields, the estimated parameters for equation (1) and the expectation hypothesis of interest rates to get a time-series for the term-premium. We then estimate the average term-premium to be 0.4%, its persistence to be 0.74 and volatility 0.52%. We report all of these parameters in Table 2.

We calibrate the mortgage premia, i.e. the spread over the government bond, to the average mortgage premia in the data during our sample. For VV and VF contracts we take the average difference between the mortgage rate and the one-year bond yield. For FF contracts we take the average difference between the mortgage rate and the five-year bond yield. In all three cases, the spread has been 1.50% on average over the sample period, with very little variance. As such, we set $\phi_{FF} = \phi_{VF} = \phi_{VV} = 0.0150$. The mortgage is used to finance the purchase of a house worth $255,000 CAD, which matches the average house purchase for first time home buyers under 40 years old in the Canadian Survey of Consumer Finances. We set ϕ_S, the transaction cost of selling a house to 5% and τ_S, the tax rate on capital gains to 1%.

4.2 Mortgage Contracts

We set the structure of origination, refinancing, and continuing costs to match the Canadian mortgage market. In the baseline calibration, the household has access to all three mortgage contracts, so the origination cost for each type is zero: $\kappa(FF) = \kappa(VF) = \kappa(VV) = 0$.

As discussed above, the majority of mortgages amortize for $N_A = 25$ years and mortgage contracts are in effect for five years. Households with mortgages must renew their contracts every five years, and we denote these renewal periods as the set $\tau_R = \{6, 11, 16, 21\}$. In all other periods, denoted by the set $\tau_N = \{1, 2, \ldots, 25\} \setminus \tau_R$, households must stay in the same contract.

To model this, we set continuing and refinancing costs in the following way. For each mortgage type χ, the continuing cost is zero in non-renewal periods and infinity in the renewal periods, and, conversely, the refinancing cost is infinity in non-renewal periods and zero in renewal periods:

$$\gamma_t(\chi) = \begin{cases} 0 & \text{if } t \in \tau_R \\ \infty & \text{if } t \in \tau_N \end{cases}, \quad \kappa_t(\chi|\chi_-) = \begin{cases} \infty & \text{if } t \in \tau_R \\ 0 & \text{if } t \in \tau_N \end{cases},$$

where the second equation is for each χ_-, which implies that the new mortgage choice is independent of the previous mortgage choice.

4.3 Income and Preferences

The income process is calibrated in two steps. The stochastic component is specified following Guvenen et al. (2021) and uses the estimated parameters from that paper. The deterministic lifecycle component of the income process is estimated using Canadian data from the Survey of Financial Securities for mortgage holders. The full set of parameters for the income process are reported in Table 3.

Finally we are left with calibrating preference parameters: discount factor β, coefficient of risk aversion is γ, the elasticity of intertemporal substitution is γ and the volatility of the EVT shocks σ which smooth the policy functions and account for taste-based preferences of households (i.e. preferring a bank or a product to another).

We calibrate these four parameters using a very large grid search in order to minimize the distance to a set of target moments. In particular we are interested in matching mortgage share originations over time, i.e., given the path of interest rates and term-premia between 2014 and 2021 (the range of our mortgage origination data), we do a grid search for β, ψ, γ and σ to minimize the distance between mortgage originations in the model and in the data. We use the 2016 Canadian Survey of Consumer Finances to calibrate initial initial mortgage balances, debt-to-income ratios, financial savings to income, and then feed our model with the observed interest rate path and term-premia during the 2014 and 2021 period. We simulate the model in a OLG fashion. Figure 1 plots the average share of FF mortgages originated (top panel), VF mortgages originated (middle panel) and VV mortgages originated (bottom panel) between 2014 and 2022.

The model matches mortgage originations over time fairly well. For most of our sample period, most mortgages originated in Canada were fixed rate mortgages. There is a significant dip in the proportion of fixed rate mortgages originated in 2018 and after 2020. These were periods where term-premia in Canada was increasing. [11]. Table XXX shows targeted moments and untargeted moments from our calibration.

5 Model economics, simulation and counterfactuals

In this section we use our calibrated model to illustrate the economics of mortgage type choice and to run some counterfactual analysis. Subsection 5.1 describes the policy functions for mortgage choice. These illustrate the key economic forces underlying choices by households. In subsections 5.2 and 5.3, respectively, we simulate our model for economies where only one type of mortgage contract is available (a counterfactual world) and where all types of mortgage contracts are available. This will allow us to assess which contracts are more valuable for households conditional on the state of the world and to quantify the impacts of the contract space on household average consumption and volatility of consumption. Section 5.4 illustrates how mortgage contract type choices are impacted by different preference parameters. Section 5.5 shows the passthrough effects of conventional monetary policy and forward-guidance on consumption depending on prevailing type of mortgage outstanding in the economy.

5.1 Drivers of mortgage type choice

Figure 2 shows the policy functions of mortgage type choice as a function of wealth (x-axis), leverage (y-axis), levels of interest rate and term premium. These are the four state variables in the model that are key to understanding agent's decisions. We will focus on extreme cases of levels of interest rate (high and low) and term premium (high and low), since these help

[11] Similar evidence for USA: https://www.pimco.com/us/en/insights/will-the-true-treasury-term-premium-please-stand-up

convey the intuition for household behavior.

In Figure 2 for a given combination of state variables, if the line is blue, the agent is choosing a fixed-fixed mortgage, if the line is red the agent is choosing a variable-fixed mortgage, if the line is yellow the agent is choosing a variable-variable mortgage and, finally, if it is green the agent is moving to the rental market.

Panels A and B of Figure 2 show the choices when the term-premium is very low. For very low levels of cash-on-hand the agent moves to the rental market. These are the agents who do not have enough liquidity to make their mortgage payments. For any other level of cash-on-hand, when the term premium is very low the agent always prefers a fixed-rate mortgage (for both high and low levels of interest rate).

Figure 3 helps understand mortgage choices for different levels of interest rate and term premium, using an example of the mortgage originated in the amount of $200 thousand dollars. The left panels of this figure show the average paths of payments (interest and principal) agents can expect over the next 5 years. The right panels show the speed of debt repayment or deleveraging.

Let's focus on Panel A.1 of the figure. When the term premium is low and interest rate is low, the fixed-rate mortgage allows agents to make much smaller payments compared to variable-fixed and variable-variable mortgages. Because interest rates increase (in expectation), the variable-variable contract payments increase over time. The variable fixed payments are constant, but due to increasing interest rates, deleveraging is much slower under this contract compared to the fixed-fixed contract (Panel A.2). Thus, agents trivially opt for the fixed-fixed contract, which is the one with lowest payments in expectation over the next 5 years and provides the fastest deleveraging. This contract is the best in terms of liquidity and wealth effects (lower payments and fastest deleveraging).

Panel B.1 shows a similar result. When interest rates are high, but term premium is low, a fixed-fixed contract has lower payments over 5 years (in expectation) and provides fast deleveraging for households (variable-fixed provides faster deleveraging, but this effect is not strong enough for this contract to be chosen).

Panels C and D of Figure 2 show the choices of the agent when the term premium is high. This is the most interesting case. When the term premium is high agents never choose the fixed-fixed contract. This is intuitive, since mortgage payments, when the slope of the term structure is high, are very large for a fixed contract. This can be clearly seen in Figure 3: the fixed-fixed contract has the largest payments (Panels C1 and D1) and provides the slowest deleveraging (Panels C2 and D2). The choice between a variable-variable contract and a variable-fixed contract is more subtle. As panels C and D of Figure 2 show, when the interest rate is low, poorer agents choose a variable-fixed contract and richer agents a variable-variable contract. The opposite happens when the interest rate is high, poorer agents choose a variable-variable contract and richer agents a variable-fixed contract.

Panels C and D of Figure 3 help understand why this is the case. When interest rates are low (Panel C), the variable-variable contract has increasing expected payments (because interest rates are expected to increase), but it also has increasing principal payments and thus provides fast deleveraging. On the other hand, as the fixed-variable contract has fixed total payments, expected increasing interest payments mechanically result in decreasing principal payments. Therefore the fixed-variable contract provides much lower total payments over the 5-year horizon, but much slower deleveraging as well. As poorer agents value liquidity more, they would pick the variable-fixed contract, while richer agents would prefer the variable-variable contract.

When the level of interest rates is high (Panel D), in expectation interest payments decrease. Thus payments for the variable-variable contract decrease over time. Total payments for the variable-fixed contract are fixed (and higher than the payments for the variable-variable contract), but interest payments decrease over time, which mechanically implies that this contract provides faster deleveraging. As a result, liquidity constrained poorer agents pick the variable-variable contract, while richer agents would prefer the variable-fixed contract.

The policy functions show some of the economic drivers of mortgage choice for extreme levels of term premia and interest rates. In the next section, we highlight some more nuanced drivers of the mortgage choice by simulating our model.

5.2 Economies with only one type of mortgage contract available

We simulate 250 economies, each with 9,000 agents, using an overlapping generations approach. To better understand the main effects, we start by examining four different scenarios: (i) the baseline model, in which agents can endogenously choose any of the three contracts (FF, VF, and VV) in reset periods, (ii) a model with fixed-fixed contracts only, (iii) a model with variable-fixed contracts only, and (iv) a model with variable-variable contracts only. Thus, the first scenario is the one where agents have larger contract space available.

Table 4 shows the welfare losses in consumption equivalent units of economies with only one mortgage contract available compared to economies with all three contracts available. The first column shows the unconditional welfare losses. The remaining columns show the welfare losses conditional on the state of the economy.

The first thing to notice is that welfare losses are between 1% to 4% of annual consumption, and thus economically are very large. If agents had to pick only one contract to be available, they would pick the variable-fixed contract. Unconditionally, as shown in the first column, the economy with this contract suffers a welfare loss of 1.39% compared to an economy where all contracts are available. This contrasts with the higher welfare losses in economies with only fixed-fixed contracts available (2.48% loss) and economies with only variable-variable contracts available (1.46% loss).

The remaining columns of Table 4 and those in Table 5, help to understand why this is the case. Columns 2-3 of Table 4 show the welfare losses when interest rates are high (and term premium is either high or low) and columns 4-5 show the same when interest rates are low. We define interest rates to be high (low) if they are above (below) the average level of interest rates. We do the same for term premia.

Fixed-fixed mortgage contracts have the lowest welfare losses when term premium is low. On the other hand, variable-variable and variable-fixed contracts have the lowest welfare losses when term premium is high (conditional on term premium being high, variable-variable contracts are better than variable-fixed when interest rates are low). These rankings are consistent with the intuition from section 5.1, where mortgage holders choose fixed-fixed mortgages when term premium is low, since in this state of the world this contract has the lowest total payments and provides fast deleveraging (actually the fastest deleveraging if interest rates are also low). When term premium is high, households prefer contracts with variable interest rates. The choice between fixed or variable total payments on these variable rate contracts depends mainly on households' wealth at that time.

Overall, agents trivially prefer a world where all three contracts are available. If they had to choose just one contract unconditionally, they would prefer a VF contract to a VV or FF one.

Table 5 shows income, consumption, savings and leverage over the life-cycle for each of the four scenarios under consideration (an economy with all mortgage contracts available, and economies with only one mortgage contract available). The first column of the table shows income over the life-cycle. Income in our model is exogenous and independent of the type of mortgage contracts available, and thus identical for all four scenarios.

Columns 2 to 5 show consumption over the life-cycle for each scenario. Consumption is lower than income and inherits the same hump-shape pattern. This is standard in life-cycle models as agents save for retirement.[12] More importantly, over the entire life-cycle the level of consumption is higher when all contracts are in the feasible contract space. This happens because agents do less precautionary saving when they have more flexibility in the mortgage contract they can choose, and they are able to optimally choose contracts that minimize their overall debt burden (more on this below).

Interestingly, VF contracts allow agents to have higher consumption early in their life-cycle and lower later in life compared to FF and VV, implying a better consumption smoothing (and therefore higher ex-ante welfare). Despite the varying interest payments under this contract, agents know that payments are fixed and are able to consume more early in life. This contrasts with the FF contract, which despite the fixed payments and rate, yields the lowest consumption for agents early in life. This is because the average term premium is positive in our economy and therefore a fixed rate contract is more expensive, on average.

Columns 6 to 9 show average financial savings of agents over the life-cycle. Liquid savings, on average, increase over the life-cycle as agents save for retirement, this is true for all scenarios under consideration. They are on average lower when all contracts are available (since agents do less precautionary saving) and higher in economies where only VV contracts are available. In these economies agents are very exposed to interest rate risk and thus save more for precautionary reasons.

The last four columns of the table show average leverage over the life-cycle. Average leverage in the economy is the lowest when all contracts are available. This is because agents are able to endogenously choose the contract that helps them minimize interest payments and deleverage the quickest.

Table 6 helps illustrate why agents do more precautionary saving when they have a limited contract space available. It shows averages and standard deviations of consumption growth, as well as levels of interest payments and total mortgage payments, conditional on agents having a mortgage outstanding. Average consumption growth is the lowest (4.6%) when all contracts are in the choice set of agents, and the highest (4.9%) when only the VV contract is in the choice set. This is consistent with the previous results: having all the contracts available helps agents smooth consumption over the life-cycle (and thus lowers consumption growth), whereas the VV contract is the riskiest of all, forcing agents to save

[12] Further, income in the first column is gross of any income taxes.

more early on in the life-cycle. Interestingly, on average total payments are highest under a FF contract (16.5 thousand dollars) and lowest when all the contracts are available (15.6 thousand dollars). Therefore, a FF contract is in dollar terms much more expensive than a VF contract or a VV contract. The benefit of a FF contract is the certainty of total payments and thus, this is the contract with the lowest standard deviation of total payments (note that the standard deviation of total payments is not zero under a FF contract because agents renew the contract every 5 years and therefore the interest rate resets and so does the total payment).

In the next subsection we describe in more detail a world in which agents can endogenously choose any of the mortgage contracts.

5.3 Economies with all contracts available

What are the drivers of mortgage choice when several contracts with different characteristics are available and agents choose endogenously which type of mortgage contract to take. Recall that in our economy agents can freely change their contract type in reset periods.

Table 7 shows average income, consumption, savings and proportions of mortgage types outstanding as a function of the aggregate state of the economy (the two aggregate state variables in our model are the level of interest rates and the term premium). All the statistics are conditional on agents having a mortgage outstanding, in other words, we focus on the first twenty-five years of agents life. The first two rows of the table show income and income growth. The numbers are virtually unchanged across different states of the economy. This is because income is exogenous and uncorrelated with the aggregate state variables of the model. While in practice, the levels of interest rates and term premia can be correlated with income, we do not want the correlation of income and the aggregate state of the economy to drive mortgage choice, or to confound the effects, thus all the heterogeneity in mortgage choice in our model has little to do with income correlation with aggregate states of the world.

The third and fourth lines of the table show average consumption growth and standard deviation of consumption growth. Consumption growth is higher when interest rates are high and lower when interest rates are low. This result comes straight from the Euler equation for consumption. When interest rates are high, agents save more today, and consume more tomorrow.

More importantly, the last three rows of the table show the proportions of agents in each type of contract. The first thing to notice is that there is a mass of agents in each type of contract for all aggregate states of the world. This is mainly due to the overlapping generation feature of the model, which implies that households are able to change their mortgage type in different periods (and thus different aggregate states) and then have to stick with the contract until the next reset period. So unlike Black (1998) who argued that a variable-fixed contract would dominate any other type of contract, we show that endogenously there is scope for the three types of contract to co-exist. The second thing to notice, is that FF contracts are predominant in periods of low term premia, whereas VF and VV contracts are predominant in periods of high term premia. The intuition is straightforward. When term premium is low the FF contract is the one delivering lower payments over the horizon of the contract and faster deleveraging. Third, VF contracts are more likely to be picked when interest rates are high, whereas VV contracts are more likely to be picked when interest rates are low (for any level of term premium, high or low).

So far we have been focusing on how aggregate states of the economy impact contract choice, since the levels of term premia and interest rates have the first order effects on optimal contract choice. However, individual characteristics, such as level of savings, leverage and income growth, also impact contract choice. Table 8 shows individual agent characteristics as a function of the type of mortgage contract outstanding. Agents that pick fixed rate mortgages (first column) tend to have lower income, lower savings and higher leverage (rows 1-3 of the table). These agents have a lot of leverage compared to their income and savings and therefore value the fixed payments that a FF contract delivers. Rows 5-6 show the standard deviation of the ratio of total mortgage payments to debt outstanding and interest payments to debt outstanding, respectively. Trivially, the FF contract delivers the lower standard deviation of mortgage payments. The choice between the two variable rate contracts is more subtle. Households prefer variable rate fixed payment contracts when interest rates are very high. This is because in expectation, interest rates are likely to decrease going forward and therefore the fixed payment implies principal payments are increasing over time, and thus this contract delivers fast deleveraging. When interest rates are lower, agents opt for variable-variable contracts.

5.4 Preference heterogeneity

Table 9 shows mortgage choice statistics for different preference parameters. Panel A of the table shows the heterogeneity in choices for different calibrations of the subjective discount factor β. The lower β is, the more myopic our agents are, thus they consume more early on in life and have lower consumption growth and lower savings, on average. These agents also prefer fixed-rate fixed-payment mortgages (the fraction of FF mortgages increases monotonically with the subjective discount factor). More myopic agents prefer less of both variable-fixed and variable-variable mortgages.

Panel B of the table shows the same statistics for different calibrations of the risk-aversion parameter. The more risk-averse agents are, the more they want to smooth consumption over different states of the world. Naturally, more risk-averse agents prefer mortgages with payments fixed across different states of the world. However, perhaps surprisingly, in the model more risk-averse prefer mortgages with variable-rate fixed payments and not necessarily mortgages with fixed-payments and fixed-rates. When $\gamma = 5$, the share of VF mortgages outstanding is on average 34.4% (28.8% for FF mortgages outstanding). When $\gamma = 15$ the proportion of VF mortgages outstanding increases to 38.7%, whereas the proportion of FF mortgages decreases to 26.8%. This is mainly driven by the fact that agents dislike states of the world where interest rates and term premia are high. In these states of the world, the fastest deleveraging is achieved with VF mortgages and this is precisely the state of the world when agents want to deleverage.

Panel C of the table shows robustness of the results with respect to the elasticity of intertemporal substitution (EIS) parameter ψ. When agents have a lower EIS, they are less willing to substitute consumption across time. Thus FF mortgages dominate for lower values of EIS. When EIS is low (ψ = 0.6) the average proportion of FF mortgages outstanding is 29.2%, when EIS is high (ψ = 0.9) this proportion decreases to 28.2%. On the other hand, the proportion of VV mortgages outstanding shows the opposite pattern: 34.9% of VV mortgages outstanding when EIS is low, which contrasts with 37.1% when EIS is high. A higher EIS, means higher willingness of households to substitute consumption over time, and therefore more willingness to take on interest rate risk with a VV mortgage.

5.5 Monetary policy passthrough

The type of mortgage contract that is predominant in the economy has important impact on monetary policy passthrough. Monetary policy shocks in an economy like the U.S., where the main type of mortgage contract is a 30-year fixed rate mortgage, have very different effects than in an economy dominated by variable rate contracts. To understand the impact of monetary policy shocks on the economy depending on the predominant type of contract we run Jordà (2005) type regressions inside our model. We do not need to worry about using an instrument as is standard in the empirical literature. Within our model we know exactly agents' expectations of interest rates next period and therefore computing the surprise component, or shock, of an interest rate change is trivial:

$$s_t^r \equiv MP_t^{surprise} = r_t - E_{t-1}[r_t] \tag{10}$$

A positive (negative) monetary policy surprise is therefore a contractionary (expansionary) shock.

To the extent that forward-guidance by the central bank impacts term premia we can also compute the response to surprise changes in term premium – forward-guidance passthrough – computed as below:

$$s_t^{tp} \equiv TP_t^{surprise} = \omega_t - E_{t-1}[\omega_t] \tag{11}$$

Following Jordà (2023) we run the following regression:

$$y_{t+h} = \alpha_h + \beta_h s_t + v_{t+h}; \quad h = 0, 1, 2, ...H \tag{12}$$

where y is the outcome variable of interest (e.g. consumption), s is either a monetary policy shock or forward-guidance shock and h is the horizon.

Panel A of Figure 4 shows cumulative consumption change due to a 1.p.p. unexpected increase in the risk-free rate (i.e. a contractionary monetary shock). The dashed lines show changes in consumption for economies where only one type of mortgage contract is available. The solid line shows changes in consumption when all three contracts are available. Conventional monetary policy passthrough is strongest if there are only VV contracts in the economy. A 1 p.p. increase in the level of the risk-free rate leads to a 1.1% decline in consumption on impact. Consumption four years out still has not recovered (absent any other shocks). This is due to the persistence of interest rates.

Conventional monetary policy passthrough is weakest in economies dominated by FF contracts. This is intuitive - if all contracts in the economy have fixed rates, then a change in the level of interest rates only impacts the level of payments on new mortgages or mortgages being renewed, thus a 1 p.p. increase in the level of the risk-free rate only leads to a decline of around 0.2% in consumption on impact (the red dashed line in Figure 4).

Economies with VF contracts lie in-between FF and VV. In these economies, an increase in interest rate means that households with mortgages outstanding will see their payments unchanged. However, a higher fraction of their payments will go towards interest (and a lower fraction towards principal), which is still a negative wealth shock. Thus, consumption declines 0.8% on impact (yellow dashed lines). Finally, an economy with the three types of contracts (the solid blue line) behaves pretty much as an average of the three other scenarios.

Panel B of the figure shows the impact of a "forward guidance" shock, i.e. a change in forward guidance by the central bank that impacts term premia. Consumption is unaffected if only contracts with variable rates are available in the economy (yellow and purple dashed lines). This is intuitive - in economies with mainly variable rate type contracts forward guidance has limited to no passthrough. On the other hand, in economies where only fixed rate contracts are available, a 1 p.p. increase in term premia leads to a 0.008% decrease in consumption. The impact is small, since when rates in the economy are fixed, many households in the economy are unable to reset their rates.

Overall our model shows that fixed-rate mortgages deliver limited monetary policy passthrough when compared to variable-rate mortgages. Further, conventional monetary policy has a stronger impact than forward guidance. However, in relative terms, forward guidance has a stronger impact on fixed-rate contracts.

6 Conclusion

We use quantitative dynamic model of borrower behavior in the presence of multiple mortgage type contracts. In our model households face income, interest rate risk, and term premia risk and endogenously choose between three types of mortgage contracts: a fixed-rate fixed-payment contract, a variable-rate fixed-payment contract and a variable-rate variable-payment. We find that endogenously all contract can coexist in equilibrium and their existence improves household welfare. We show that both macroeconomic factors, such as interest rates and term premiums, and individual characteristics, such as wealth, leverage, and income, play crucial roles in driving these mortgage choices.

When all three mortgage options are available, households can optimize their contract selection. Our analysis reveals that economies that restrict households to a single type of mortgage experience notable welfare losses, ranging from 1% to 4%, depending on the prevailing economic conditions. Fixed-rate mortgages, while offering payment certainty, tend to impose higher long-term costs, especially in environments with high term premiums. Conversely, variable-rate mortgages provide better consumption smoothing and allow faster deleveraging, though at the expense of higher payment volatility.

Our results have important implications for monetary policy transmission. Economies dominated by variable-rate mortgages experience stronger and faster pass-through of interest rate changes, while economies with a larger share of fixed-rate mortgages are more sensitive to forward guidance. This highlights the need for policymakers to consider the composition of mortgage contracts when designing monetary policies aimed at influencing household consumption and debt dynamics.

Overall, the availability of diverse mortgage contract options enhances household welfare by allowing more efficient consumption smoothing and debt management. Limiting these options not only leads to higher consumption volatility but also results in slower debt reduction. Our findings underscore the importance of maintaining flexibility in mortgage contract offerings, particularly in the face of changing economic conditions.

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Figure 1: Data vs Model

This figure plots the fraction of households choosing to originate Fixed-Fixed, Variable-Fixed, and Variable-Variable mortgages between 2014 and 2022. In each year, we use the observed mortgage rates and simulate the model for all other variables.

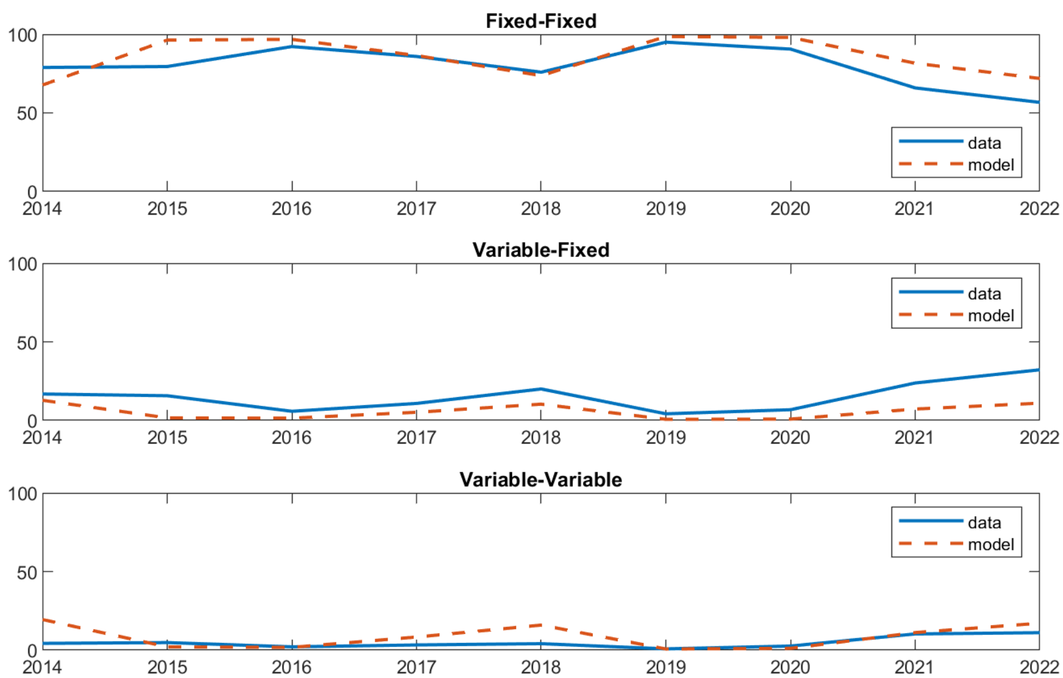

Figure 2: Policy functions for mortgage type choice

This figure shows the policy functions for mortgage type choice as a function of the level of interest rates, term premium, household leverage and cash-on-hand. The top two panels show the policy functions when term premium is low and interest rates are low or high. The bottom two panels show the policy functions when term premium is high and interest rates are low or high. The green color shows when agents leave the housing market and become renters, the blue color shows when households opt for a fixed-rate fixed-payment (FF) mortgage, the red color shows when households opt for a variable-rate fixed-payment (VF) mortgage and the yellow color when households opt for a variable-rate variable-payment (VV) mortgage.

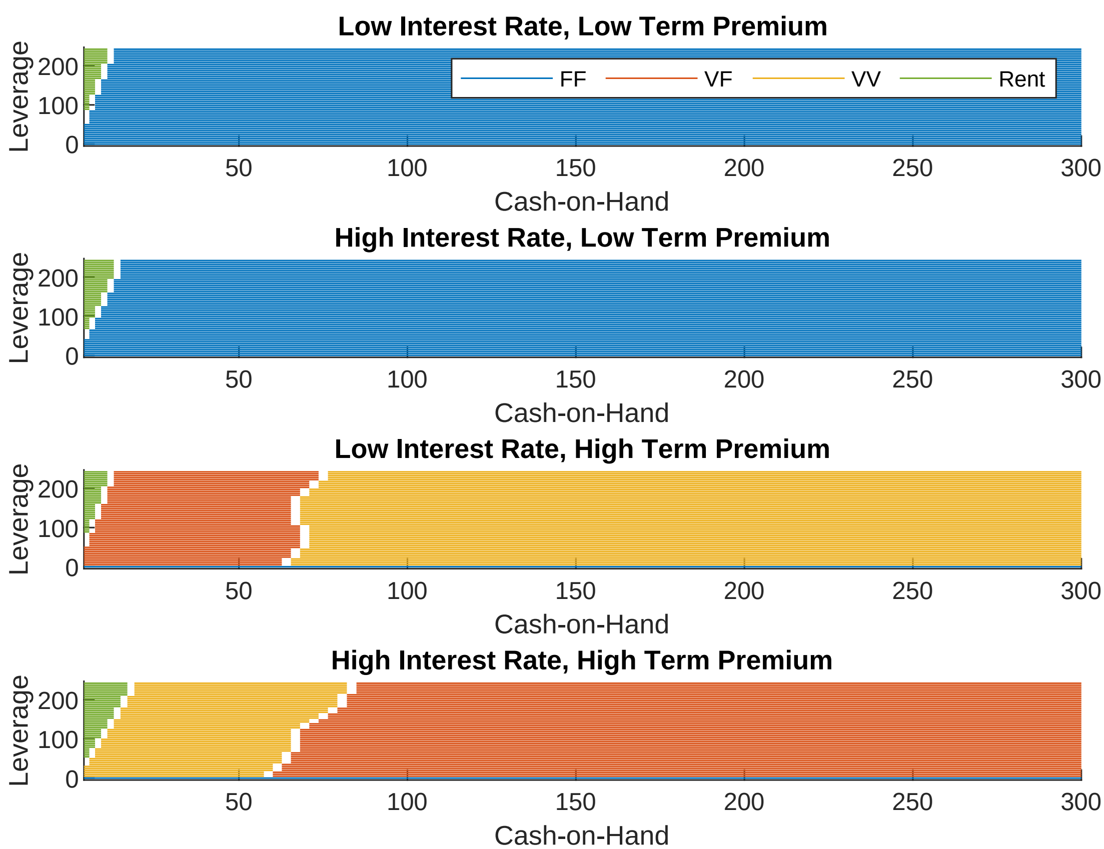

Figure 3: Mortgage payments composition and deleveraging

The left panel of this figure shows for a given level of interest rate and term premium the composition of payments for the three types of mortgage contracts under consideration (FF in blue, VF in red and VV in yellow) for a household that took a mortgage of a given type in period 0 (origination period). Each bar shows the total payments in each year of the 5-year term. The darker areas correspond to principal payments, the lighter ones show interest payments. The right panel shows mortgage balances outstanding at the end of the period for the three types of mortgage. The top two panels show these effects when term premium is low and interest rates are low/high. The bottom two panels show these effects when term premium is high and interest rates are low/high.

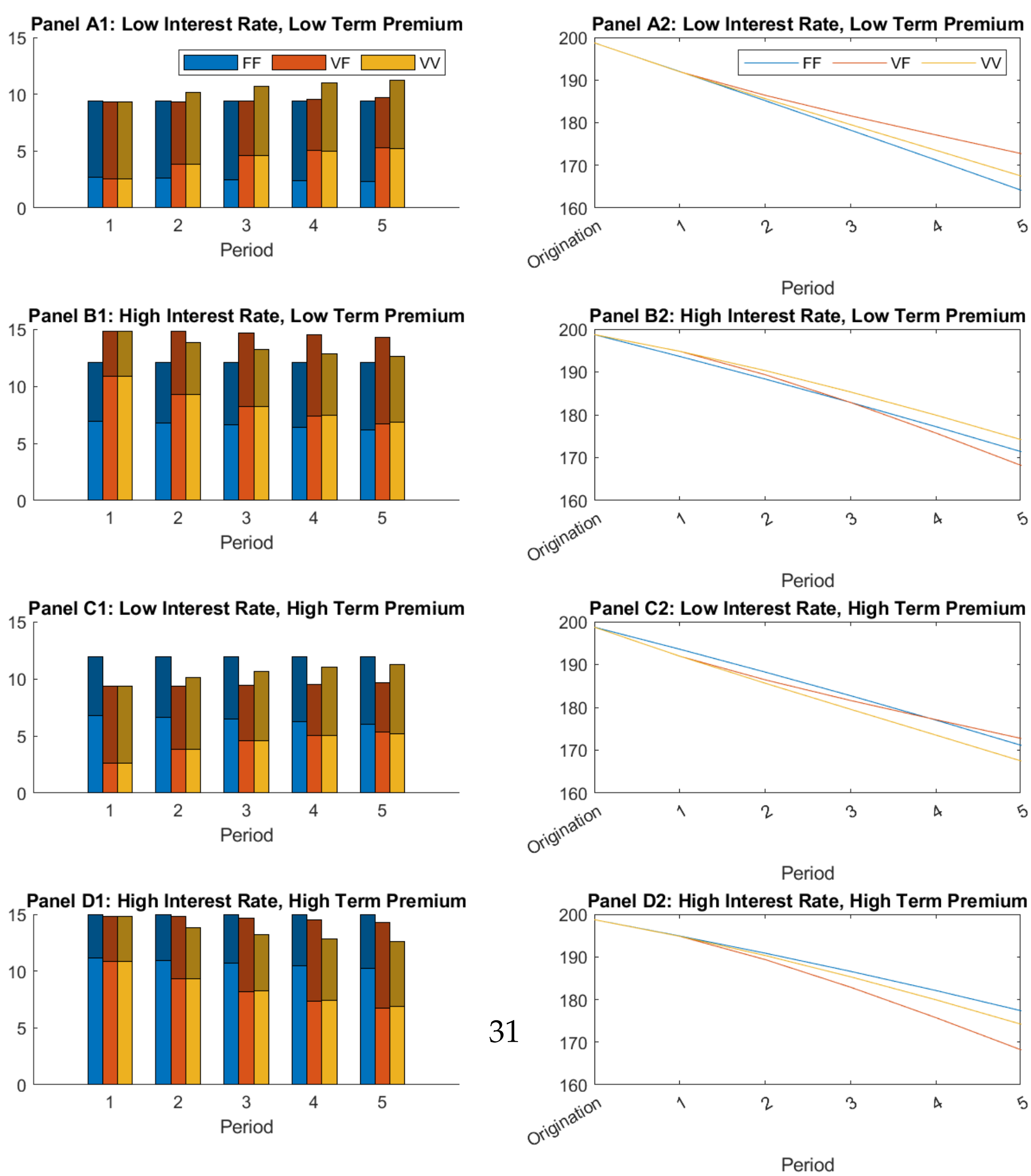

Figure 4: Impulse response functions to monetary policy shocks

This figure shows local projections à la Jordà (2005) within our model. The left panel shows cumulative impulse response functions of consumption for a 1 p.p. increase in the risk-free rate. The right panel shows cumulative impulse response functions to a 1 p.p. increase in term premia. The blue line shows the effects on an economy where all contracts are available. The dashed lines show the effects when only one contract is available.

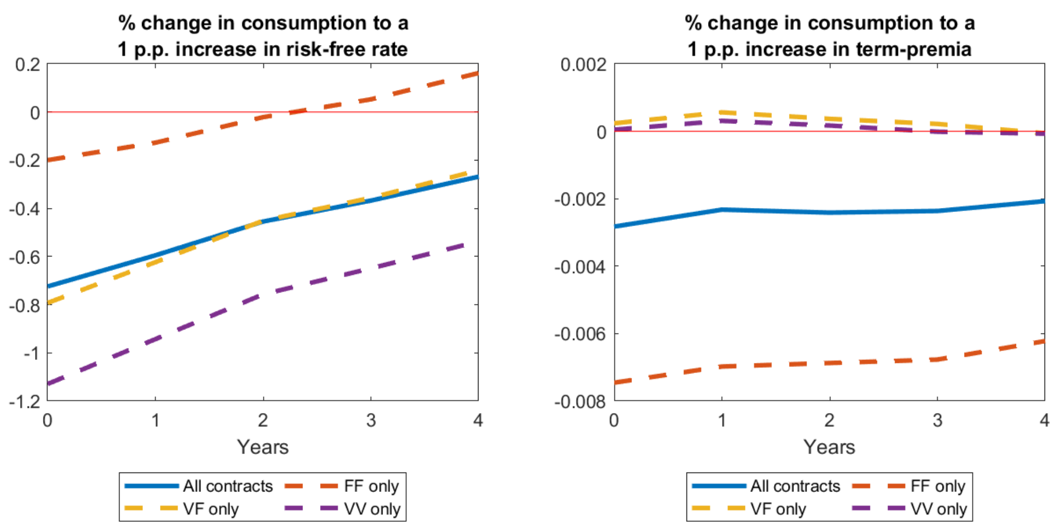

Table 1: Summary of Mortgage Types and Interest Rates

Mortgage	Interest Payment R_I	Total Payment R_{TP}
Fixed-Fixed	Contract Rate	Contract Rate
Variable-Fixed	Market Rate	Contract Rate
Variable-Variable	Market Rate	Market Rate

Table 2: Interest Rates

This table shows parameters governing the interest rates detailed in Sections **??** and **??**. Panel (a) contains parameters for the one period bond. Panel (b) contains parameters for the term premium. Panel (c) contains parameters for mortgage premia.

(a) One-Period Bond

Parameter	Value
$\bar{r}$	0.0298
ρ_r	0.8965
σ_r	0.0121

(b) Term Premium

Parameter	Value
$\bar{\omega}$	0.0042
ρ_ω	0.741
σ_ω	0.0052

(c) Mortgage Terms and Premia

Parameter	Value
N_M	5
ϕ_{FF}	0.015
ϕ_{VF}	0.015
ϕ_{VV}	0.015

Table 3: Income Process Parameters

This table shows parameters governing the income process detailed in Section 3.5.1. Panel (a) contains parameters for the deterministic components of income: the household fixed effect, the lifecycle age profile, and the retirement replacement rate. Panel (b) contains parameters for the unemployment shock, such as the replacement rate. Panels (c) and (d) contain parameters for the persistent and transitory shocks, respectively. The income process and parameters follow closely Guvenen et al. (2021) for the working life and Cocco et al. (2005) during retirement. Over the working life, the variance of the persistent income process is scaled down to match that in Cocco et al. (2005).

(a) Deterministic Type & Lifecycle Components

Parameter	Value
α_i	0.99
a_0	-2.0317
a_1	0.3194
a_2	$-0.0577/10$
a_3	$-0.0033/100$
ω	0.94

(b) Unemployment Shock

Parameter	Value
λ	0.52
a_ν	-2.495
b_ν	-1.037
c_ν	-5.051
d_ν	-1.087

(c) Persistent Process

Parameter	Value
ρ	0.991
p_z	0.176
$\mu_{\eta,1}$	-0.524
$\sigma_{\eta,1}$	0.113
$\sigma_{\eta,2}$	0.046
κ_η	0.470

(d) Transitory Shock

Parameter	Value
p_ϵ	0.044
$\mu_{\epsilon,1}$	0.134
$\sigma_{\epsilon,1}$	0.762
$\sigma_{\epsilon,2}$	0.055

Table 4: Welfare Gains

This table shows the ex-ante welfare gains (losses) in consumption equivalent units for economies with only FF mortgages available (first row), only VF mortgages available (second row) or only VV mortgages available (third row) compared to an economy where all the three types of mortgages are available. The first column shows the gains (losses) unconditionally and the remaining columns shows them conditional on the term-premium and the level of interest rates.

		High Rf		Low Rf	
	Unconditional	High TP	Low TP	High TP	Low TP
FF only	-0.0248	-0.0391	-0.0171	-0.0288	-0.0143
VF only	-0.0139	-0.0076	-0.0219	-0.0078	-0.0181
VV only	-0.0146	-0.0097	-0.0239	-0.0073	-0.0176

Table 5: Income, Consumption, Wealth and Leverage over the Life-Cycle

This table reports average income, consumption, financial wealth, and leverage over the life-cycle, for the four scenarios under consideration. In scenario "All" households can choose any of the 3 mortgage types available (and switch among them), in "FF" households can only choose a fixed-rate fixed-payment mortgage, in "VF" households can only choose a variable-rate fixed-payment mortgage and in "VV" households can only choose a variable-rate variable-payment mortgage.

	Income	Consumption				Financial wealth				Leverage			
Age group		All	FF	VF	VV	All	FF	VF	VV	All	FF	VF	VV
26 - 30	100.907	45.528	44.676	45.039	44.951	185.434	185.430	186.657	187.067	218.659	219.496	218.833	218.845
31 - 35	119.383	72.894	71.919	72.846	72.693	262.290	263.289	263.967	264.556	186.713	189.408	187.554	187.467
36 - 40	134.729	90.621	89.789	90.699	90.632	293.800	295.404	294.599	295.712	147.987	151.786	149.252	149.131
41 - 45	145.353	99.222	98.562	98.997	99.124	305.055	306.216	304.487	306.346	100.506	104.176	101.725	101.601
46 - 50	150.380	105.844	105.272	105.574	105.744	306.096	306.629	305.851	306.420	41.556	43.439	42.147	42.086
51 - 55	148.977	113.963	113.845	113.821	114.035	304.274	304.165	303.971	304.388	0.000	0.000	0.000	0.000
56 - 60	141.754	111.874	111.821	111.852	111.872	309.997	310.133	309.968	309.964	0.000	0.000	0.000	0.000
61 - 65	129.311	101.604	101.571	101.595	101.600	320.396	320.555	320.408	320.367	0.000	0.000	0.000	0.000

Table 6: Mean and volatility of consumption and mortgage payments

This table reports averages and standard deviations of consumption growth, as well as levels of interest and total mortgage payments (in thousands) for the four scenarios under consideration. The statistics reported are conditional on households having a mortgage outstanding.

	All	FF only	VF only	VV only
Av. consumption growth	0.045	0.046	0.047	0.048
Std. consumption growth	0.232	0.225	0.238	0.228
Av. interest payments	6.436	7.251	6.692	6.629
Std. interest payments	5.316	5.259	5.647	5.549
Av. total payments	15.649	16.459	15.909	15.836
Std. total payments	4.157	3.902	4.583	4.220

Table 7: Drivers of mortgage type choice

This table reports income, income growth, consumption, standard deviation of consumption, average financial savings and the proportion of mortgages outstanding by type of mortgage conditional on the aggregate state of the world (levels of interest rates and term premia).

	High interest rates		Low interest rates	
	High TP	Low TP	High TP	Low TP
Income	130.098	130.230	130.238	130.198
Income growth	0.014	0.014	0.014	0.014
Av. consumption growth	0.051	0.051	0.040	0.038
Std. consumption growth	0.255	0.245	0.212	0.210
Savings	179.597	179.215	165.283	163.780
Mtg. type proportion:				
Fixed-fixed	0.136	0.408	0.150	0.422
Variable-fixed	0.467	0.317	0.390	0.264
Variable-variable	0.397	0.275	0.460	0.314

Table 8: Mortgage type choice - additional statistics

This table reports average income, savings, leverage, debt-to-income, standard deviation of mortgage payments and average levels of risk-free rate and term premium conditional on the mortgage type the household has outstanding in an economy where all mortgage types are available to choose from. The first column shows these statistics conditional on the household having a FF mortgage outstanding, the second column shows the statistics conditional on a VF mortgage outstanding, and the last column shows them conditional on a VV mortgage outstanding.

	FF	VF	VV
Av. income	122.570	132.470	133.850
Av. savings	158.340	175.740	179.010
Av. leverage	150.390	134.620	135.100
Debt-to-income	1.750	1.465	1.425
Std. total mortg. pay	0.197	0.209	0.209
Std. total interest pay	0.023	0.028	0.028
Risk-free rate	0.029	0.033	0.028
Term-premia	0.000	0.006	0.006

Table 9: Preference Heterogeneity

This table shows average consumption growth, standard deviation of consumption growth, average savings and proportion of mortgages outstanding by type of contract for different preference parameters. Panel A shows the results for subjective discount factor, panel B for risk aversion and panel C for the elasticity of intertemporal subsitution. The middle column in all the panels is our baseline specification.

Panel A: Different subjective discount factors			
	$\beta = 0.93$	$\beta = 0.95$	$\beta = 0.97$
Av. consumption growth	0.044	0.045	0.048
Std. consumption growth	0.231	0.232	0.238
Savings	163.053	172.087	183.206
Mtg. type proportion:			
Fixed-fixed	0.295	0.278	0.255
Variable-fixed	0.359	0.360	0.365
Variable-variable	0.346	0.361	0.380

Panel B: Different degrees of risk aversion			
	$\gamma = 5$	$\gamma = 10$	$\gamma = 15$
Av. consumption growth	0.033	0.045	0.067
Std. consumption growth	0.243	0.232	0.296
Savings	129.284	172.087	194.079
Mtg. type proportion:			
Fixed-fixed	0.288	0.278	0.268
Variable-fixed	0.344	0.360	0.387
Variable-variable	0.367	0.361	0.345

Panel C: Different degrees of intertemporal substitution			
	$\psi = 0.6$	$\psi = 0.75$	$\psi = 0.9$
Av. consumption growth	0.045	0.045	0.044
Std. consumption growth	0.227	0.232	0.243
Savings	183.530	172.090	164.350
Mtg. type proportion:			
Fixed-fixed	0.292	0.278	0.282
Variable-fixed	0.359	0.360	0.347
Variable-variable	0.349	0.361	0.371

Figure A1: Mortgage premia and mortgage rates

This figure plots average mortgage premia and mortgage rates in Canada between Q1 2014 and Q4 2023. Panel A plots mortgage premia for FF, VF, and VV mortgages. Mortgage premia for FF mortgages is the difference between the FF mortgage rate and the 5-year Canadian government bond yield (GOC5). Mortgage premia for VF and VV mortgages are the difference between the mortgage rate and the 1-year Canadian government bond yield (GOC1). Panel B of this figures plots the average mortgage rates for FF, VF and VV contracts.