Mortgages, Monetary Policy, and the Great Inflation of 2021–24?*

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March 2025

Abstract

This paper investigates the role of mortgage market structures in shaping economic responses to the unprecedented interest rate and inflation dynamics of 2021-2024. First we show that economies with a larger share of variable-rate mortgages exhibit stronger peak output and house price responses to monetary policy shocks, suggesting a more potent transmission mechanism. We then develop a structural model featuring incomplete markets, frictional housing markets, long-term nominal mortgages, and endogenous credit constraints to compare outcomes across countries with different prevalent mortgage types. Our analysis reveals that 45-60% of the U.S. house price boom was driven by early pandemic mortgage rate cuts. Cross-country variations in house price dynamics are substantially explained by differences in mortgage structures, with adjustable-rate mortgage (ARM) dominant economies showing greater sensitivity to interest rate changes. Fixed-rate mortgage (FRM) regimes exhibit more pronounced path dependence in house prices due to the lock-in effect. The model demonstrates that welfare costs of monetary tightening are generally larger in ARM regimes, suggesting that optimal tightening strategies may differ across mortgage structures. Our findings also highlight significant distributional consequences, with low-income homeowners benefiting most from the initial low-rate environment, especially in FRM regimes, while renters faced reduced affordability. These results provide important insights into monetary policy transmission through housing markets and the design of optimal policy responses across different mortgage regimes.

JEL Codes: D31, E21, E52
Keywords: Housing, Mortgages, Monetary Policy, Heterogeneous Agents, Foreclosure, Consumption, Inflation

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*The views expressed are those of the authors and not necessarily of the Federal Reserve Bank of St. Louis or the Federal Reserve System.

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1 Introduction

After decades of low and stable inflation, 2021 inaugurated a surge of inflation across developed economies not experienced since the early 1980s. The Great Inflation of 2021-2024 marked an unprecedented period of interest rate and inflation swings, with far-reaching consequences for housing markets and household finances. As central banks responded to rising inflation pressures by rapidly tightening monetary policy---which immediately drove up mortgage rates and curtailed credit supply for housing---the divergent paths of house prices and market activity across countries with different mortgage structures raised important questions about the transmission of monetary policy through housing markets. This paper investigates how differences in mortgage market structures shaped the economic response to pandemic-era interest rate and inflation dynamics, with a particular focus on comparing outcomes between countries dominated by fixed-rate mortgages (FRMs) like the US versus those with primarily adjustable-rate mortgages (ARMs) or shorter-term fixed rates (such as the UK, Sweden, and Canada).

Our analysis is motivated by several key empirical observations that highlight the complex interaction between mortgage market structures and macroeconomic dynamics. First, there is substantial cross-country heterogeneity in mortgage market structures. The US, Germany, and France are dominated by long-term fixed-rate mortgages, typically 30-year terms, while other advanced economies such as the UK, Canada, and Sweden feature higher shares of adjustable-rate or shorter-term fixed-rate products. Second, our analysis of Euro area countries reveals that economies with a larger share of variable-rate mortgages exhibit stronger peak output and house price responses to monetary policy shocks, suggesting a more potent transmission mechanism. This pattern is further epitomized by recent experiences: the US witnessed a dramatic house price boom in 2020-2021 as mortgage rates plummeted to historic lows, followed by a notable moderation—but not an outright decline—in prices as the Federal Reserve aggressively tightened monetary policy starting in 2022. In contrast, countries like Canada, Sweden, and the UK, with their higher prevalence of variable-rate mortgages, experienced more pronounced house price declines in response to rising interest rates. Lastly, data from NY Fed's Survey of Consumer Expectations point to an emerging misallocation in housing markets, where homeowners report declining expectations of long-term residency in their current homes. This trend potentially reflects a "lock-in" effect, whereby homeowners with low fixed-rate mortgages become reluctant to move and refinance at higher prevailing rates.

To analyze these patterns, we develop a structural model of housing and mortgage markets featuring (1) incomplete financial markets with uninsurable idiosyncratic labor income risk; (2) a frictional housing market that endogenizes the price and liquidity of the housing market; (3) long-term nominal mortgages that generate nominal rigidity in household budget constraint, and (4) endogenous credit constraints and default risk. We also incorporate different mortgage regimes to our model, thereby comparing outcomes under fixed-rate, adjustable-rate, and hybrid mortgage structures.

We calibrate the steady state of the model to match pre-pandemic U.S. microeconomic and macroeconomic data over the past twenty years. Given the importance of housing and debt in the mechanisms we emphasize in this paper, the calibration pays particularly close attention to matching the important dimensions of the joint distribution of assets, housing wealth, and mortgage debt as well as key moments related to household price posting and selling behavior in the housing market, households choices related to mortgage debt and default.

The model generates several quantitatively important deviations from standard incomplete markets models where households are able to easily access their entire portfolio of wealth. First, heavily leveraged homeowners experience long selling delays in the housing market because their outstanding debt acts as a binding lower bound on the list price. This inability to quickly sell increases the exposure of such homeowners to idiosyncratic and aggregate risk, thereby making mortgage default more likely. This effect is amplified for borrowers with ARMs which lead to immediate increase in mortgage payments in response to contractionary monetary shocks. The elevated default risk from housing illiquidity causes access to mortgage credit to tighten, thereby further impeding consumption smoothing. Renters, and homeowners with substantial equity are relatively insensitive to income fluctuations, while heavily indebted homeowners stuck with houses they cannot quickly sell are far more responsive to shocks.

We simulate the Great Inflation episode across different economies by exogenously feeding in country-specific paths for inflation, risk-free rates, and mortgage rates. Our analysis yields several important findings. First, we show 45–60% of house price boom in the US is driven by mortgage rate cuts earlier in the pandemic. Furthermore, that differences in mortgage market structure can account for a substantial portion of the cross-country variation in house price dynamics during this period. In our baseline simulation, modeling the correct mortgage arrangement improves the model's fit to observed price declines by 40% on average across countries. Second, we find that economies dominated by adjustable-rate mortgages exhibit greater sensitivity of house prices and market activity to interest rate changes, helping explain the larger busts observed in countries like Sweden and Canada. Third, we demonstrate that fixed-rate mortgage regimes generate more pronounced path dependence in house prices, with the lock-in effect from the low-rate period dampening price declines as rates rise.

These results have important implications for understanding monetary policy transmission and optimal policy design. We show that the welfare costs of monetary tightening are generally larger in ARM regimes, as households face more direct pass-through of higher interest rates. Moreover, our findings suggest that the optimal tightening schedule may differ across mortgage regimes, with fixed-rate dominant economies potentially benefiting from a strategy of tighter but shorter-duration policy tightening.

The distributional consequences of these dynamics are also significant. Our model indicates that low-income homeowners were the largest beneficiaries of the initial low-rate environment, particularly in fixed-rate regimes where these gains persisted even as rates rose. However, renters generally lost out as surging house prices reduced affordability, highlighting the complex equity implications of monetary policy operating through housing markets.

By shedding light on these mechanisms, our paper contributes to several strands of literature. We build on a rich body of work examining the role of housing in monetary policy transmission (e.g., Berger *et al.* (2021), Garriga and Hedlund (2020)) and extend it to a novel setting of extreme interest rate volatility. Our modeling of different mortgage regimes relates to studies of mortgage design and household risk exposure (Campbell and Cocco (2003), Guren *et al.* (2021)), while our focus on recent inflation dynamics connects to emerging work on the causes and consequences of the post-pandemic inflation surge (Bolhuis *et al.* (2022), Bianchi *et al.* (2024)).

The remainder of the paper is structured as follows. Section 2 outlines the empirical facts that motivate our study. In Sections 3 and 4 we introduce our structural model and calibration strategy. Section 5 explain the steady state implications of the model. In Section 6 we present our main quantitative results comparing house price dynamics and monetary policy transmission across different mortgage regimes. Section 7 concludes with a discussion of broader implications for monetary policy and financial stability.

2 Motivating Empirical Evidence

2.1 Cross country descriptive statistics

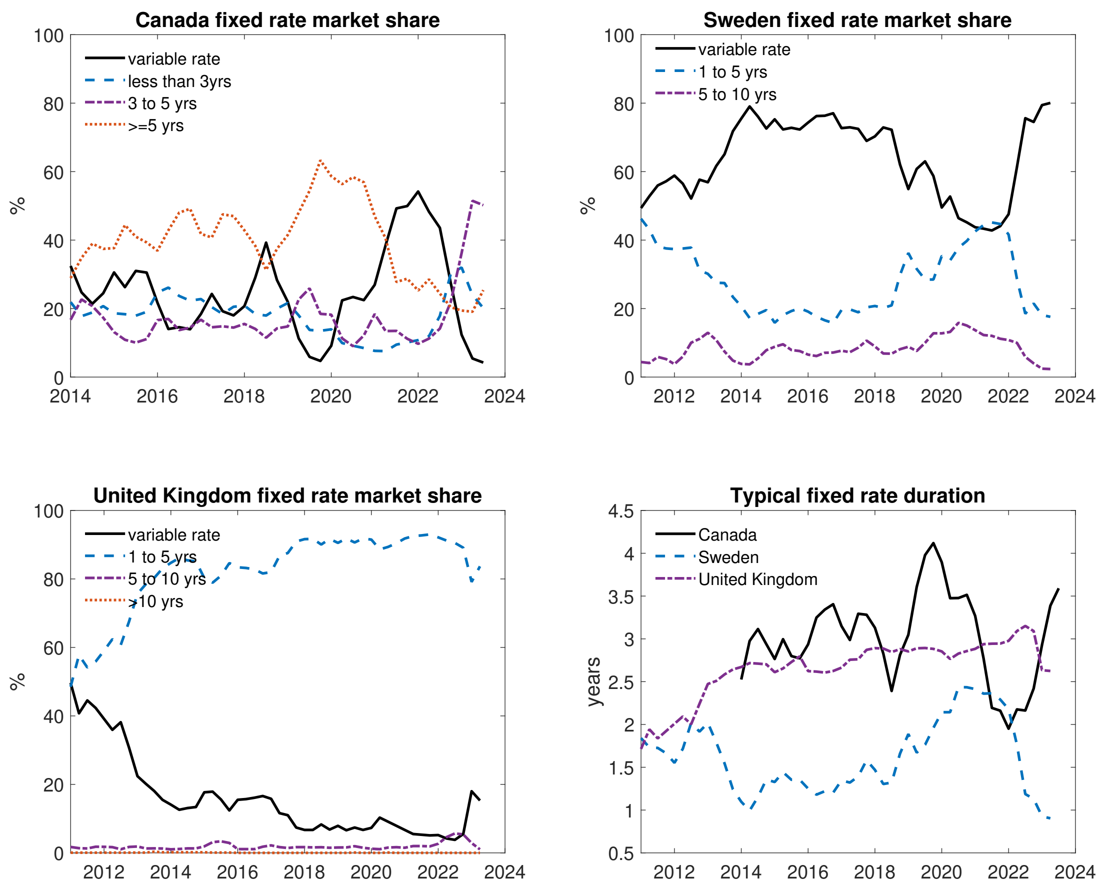
Outside of the US—where more than 90% of the mortgages are fixed rate—, there is significant variation is the structure of mortgage markets. Thirty year fixed rate mortgage are far less common. Figure 1 plots the share of new loans accounted for by mortgages of differing fixed rate horizons for our three main comparison countries: Canada, Sweden and the UK. The data for Canada is from the Bank of Canada, the data for Sweden and the United Kingdom is from the European Mortgage Federation. The overall picture is one of significant heterogeneity. In Canada prior to 2020, the dominant form of mortgage was a fixed rate duration of longer than five years (Panel a). In the UK, the mortgage market has recently been dominated by mortgages of one to five year duration (Panel b). In contrast in Sweden, variable rate mortgages (which includes mortgages of fixed duration of less than one year) is the most widespread product (Panel c).

Cross-country variation in the typical mortgage duration is best thought of an an exogenous variable, due to institutional features of the financial sector, for example. However, in most countries the mortgage product is also a choice variable. This can lead to variation in the average duration of new mortgages over time within a country. In our three comparison countries this is most visible for Canada. Just prior to and at the the onset of the pandemic there was an uptick in the share of longer duration mortgages. Demand for these reduce in 2021, with variable rate mortgages becoming more common. This peaked in 2022, just prior to the rate tightening. As rates began to rise three-five year duration mortgages became more common. While less extreme, Sweden and the UK also exhibited a shift towards variable rate mortgages in 2022.

Finally, we can summarize these shares as an expected duration of mortgage length. To do the we assign an average length to each share and computed the expected value. This is shown in Panel d. The patterns confirm the approximate ordering of mortgage duration across the three countries. Sweden has the lowest typical duration of 1.6 years on average. Next is the UK: 2.7 years and Canada 3 years. Canada expected duration is the most volatile. We will use this targets in the calibration of our quantitative model in Section 6.

Figure 1 – Mortgage market product shares

(A) Canada (B) Sweden



(C) United Kingdom (D) Expected duration

Notes: Measure is shares of new loans issued. Data for Canada from Bank of Canada. Data for Sweden and United Kingdom from European Mortgage Federation.

2.2 Mortgage market and the transmission of monetary policy

Next we study the implications for monetary policy of the mortgage market structure. In particular, we compare how the share of variable rate mortgages in an economy affects its response to plausibly exogenous monetary policy shocks. Our analysis follows Almgren *et al.* (2022). They use local projections for Euro area countries to a shared monetary policy shock, to compare the output responses across countries to the hand to mouth share of households. Here we focus on the how output and house prices response to a monetary policy shock vary with the variable mortgage rate share. We use high-frequency monetary policy shocks identified around a short window around the monetary policy announcement (Nakamura and Steinsson (2018), Gertler and Karadi (2015)). This provides exogenous variation the interest rate not associated with the outcome variables. The benefit of the cross country specification is that by focusing on Euro area countries, experiencing a common shock we are controlling for variation that could be driven by the size and size of the set of shocks used to identify the response or time variation in the interest rate elasticity.[1] The underlying assumption is that the high frequency monetary policy shocks are uncorrelated with other shocks the economy that affect output of house prices. Of course variation across countries in the mortgage markets could be correlated with the true driver of cross country response variation.

2.2.1 Specification

The specification follows Jordà (2005) and Stock and Watson (2018). We estimate a local projections instrumental variables (LPIV) model. For each country n we estimate impulse response functions with the following set of h equations:

$$y_{n,t+h} - y_{n,t-1} = \alpha_n^h + \beta_n^h \hat{i}_t + \sum_{j=1}^{p} \Gamma_{n,j}^h X_{t-j} + u_{n,t+h} \tag{1}$$

$$i_t = c + \rho Z_t + \sum_{j=1}^{p} D_{n,j}^h X_{t-j} + e_t \tag{2}$$

Equation (1) is the outcome equation of interest. The dependent variable y_n is either log GDP or the log real house price in country n. The coefficients β_n^h capture the impulse response of country n in period $t+h$ to an interest rate shock in period t. We also include a set of lagged controls X. Equation (2) captures the implementation of the high frequency instrumental variables approach. The instrument is the change in the Euro Overnight Index Average (EONIA) in a 45 minute window around the monetary policy announcement. We convert this series to a monthly frequency following Gertler and Karadi (2015).[2]

Our main outcome of interest is the maximum response: $\max_h \beta_n^h \hat{i}_t$ to an expansionary monetary policy shock, $\hat{i}_t < 0$ within a 30 month window.

[1] A related concern would be that the size of the average monetary policy response was related to the mortgage market structure of an economy. Using shared monetary policy shocks avoids this issue.

[2] This involves cumulating shocks over days in a month and dividing by the number of days. We then take the difference in exogenous announcements between month t and $t-1$.

2.2.2 Data

For the main data sources we follow Almgren *et al.* (2022). We run specifications at a monthly frequency. Output is real GDP interpolated to monthly observations with industrial production. For the monetary policy rate we use the Euro Overnight Index Average (EONIA). For the instrument we use changes in the EONIA Overnight Index Swap. This is derivative which allows the buyer to exchange a fixed interest rate for the floating overnight rate and captures changes in expectations about monetary policy. We include a control for the price level with the Harmonized Consumer Price Index (HCPI). For real house prices we use the Bank of International Settlements real house price index. This is available at a quarterly frequency, so we interpolate to a monthly frequency with the HCPI. We estimate the local projections between 2000 and 2016 and compute the maximum response in the 30 months following the shock.

For the share of variable rate mortgages we use data from the European Mortgage Federation and European Central Bank on the share of mortgage lending with a variable interest rate. This is defined as lending with a rate fixed for less than a year.[3] For each country we take the average share of variable rate mortgages between 2000 and 2019. We then take the mean of the EMF and ECB share, although in practice these are highly correlated.

2.2.3 Results

Figure 2 presents the results. Panel a compares the peak output response to a 150 basis point cut in the monetary policy rate, with the share of variable rate mortgages in a country. [4] We see a strong positive relationship. Euro area countries where variable rate loan mortgages are more common are associated with a stronger response to monetary policy. This is intuitive as at is means the countries where monetary policy most quickly affects household's borrowing in the mortgage market experience the largest output responses. The correlation is slightly less strong than that found between the peak output response and the hand-to-mouth share, as measured in the Eurosystem Household Finance and Consumption survey (0.78).

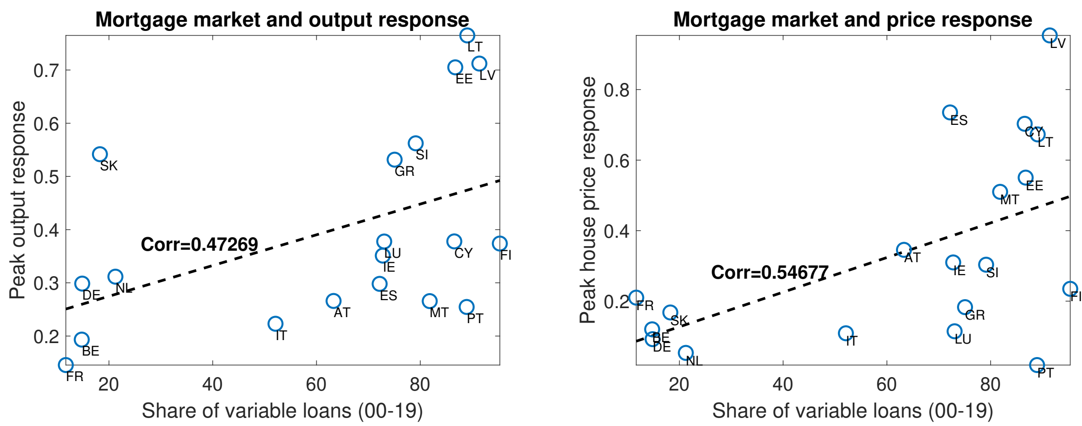
Panel b looks at the impact on the housing market. We see the average peak house price response to a monetary policy shock is of the same magnitude as the peak output

[3]The EMF data is available on an annual basis since 2000, although the start date varies by country. The ECB data is available on a monthly basis since 2003.

[4]The output response coefficient are exactly those from Almgren *et al.* (2022). The estimated model is linear so the sign is purely indicative.

FIGURE 2 – Mortgage structure and monetary policy response

(A) Output (B) House price

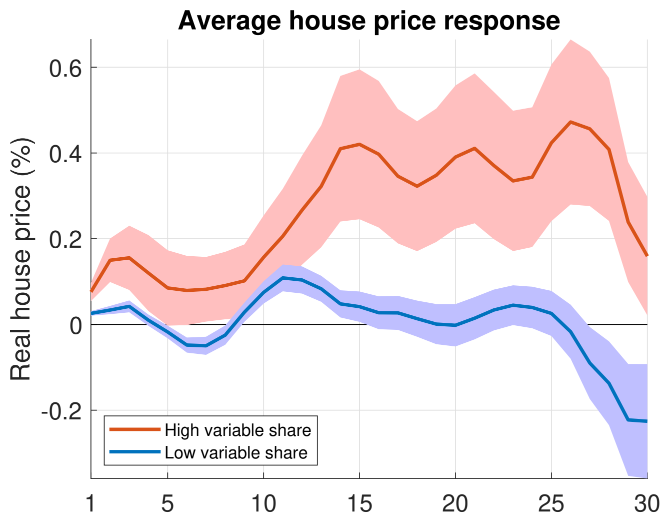


response. Again we find evidence of a strong positive correlation between the share of variable loans at the peak house price response (0.55 for house prices versus 0.47 for output).

Panel b presents stronger evidence of the set of countries that have a fairly low share of variable rate mortgages having much smaller house price responses. This includes Slovakia, Germany, the Netherlands, Belgium and France. In fact, there is evidence of a fairly strong split between countries that have either a low share of variable rate mortgages or a high share. To explore this further we partition the countries into the with the above and below median share of variable mortgages. We average the outcomes across countries within these two groups and compute the impulse response for the composite. The results are presented in Figure 3. The Figure confirms the correlation seen across countries. For low variable share countries on average the response to a monetary policy response is small, with a peak about one year are the shock. For high variable rate countries on average the response is much stronger, both on impact and after one year. The delayed response could reflect that many variable rate mortgages are still fixed for some short horizon.

Overall the section has provided motivating evidence that adjustable or variable rate mortgages are a pervasive feature of many economies outside the US. These mortgage differences are fairly stable across time, albeit household do change their mortgage choice in response to big shocks. The mortgage market seems important for the transmission of monetary policy. Within the Euro area, countries with a higher share of variable rate

FIGURE 3 – High and low variable rate mortgage share



mortgages respond more strongly to monetary policy shocks. This effect is evident for both the output response and house price response.

3 Model

In this section, we develop a heterogeneous agents model with housing and mortgages. To investigate the effect of the housing channel in the transmission of monetary policy, we include the following key ingredients: (1) a frictional housing market that endogenizes the price and liquidity of the housing market; (2) long-term nominal mortgages that generate nominal rigidity in household budget constraint and redistribution across borrowers and lenders; and (3) endogenous credit constraints and default risk.

The economy is populated by *(i)* a measure one of infinitely lived households, *(ii)* real estate brokers that facilitate transactions in the housing market, *(iii)* banks that issue long-term adjustable rate mortgages, and *(iv)* government sponsored enterprises that provide insurance to the banks against the default risk of mortgages. Time is discrete.

Below, we present the details of the model. Wherever non-essential, the technical details and equations are relegated to appendix A.

3.1 Households

There is a continuum of infinitely lived households that are subject to uninsurable idiosyncratic labor productivity risk. Their labor productivity z_t follows an exogenous finite state Markov according to the transition matrix $\Gamma(z_{t+1} \mid z_t)$. Households have preferences over non-durable consumption c and housing services s. Preferences are time-separable and the future is discounted at rate β. The expected lifetime utility of a household is given by:

$$\mathbb{E}_0 \sum_{t=0}^{\infty} \beta^{t-1} \frac{\left[(1-\phi_h)c_t^{1-\gamma_h} + \phi_h c_{h,t}^{1-\gamma_h}\right]^{\frac{1-\sigma}{1-\gamma_h}}}{1-\sigma}.$$

We use the CES aggregator between the consumption and the housing services. The parameters β, σ, and γ_h measure the discount factor and relative risk aversion, and elasticity of substitution between consumption and housing services, respectively. ϕ_h determines the share of housing services in total consumption.

The households enjoy housing services c_h either by owning and occupying a house or by renting from a competitive market in the form of apartment space. Owner-occupied housing comes in a set of discrete sizes, $h \in \mathcal{H} = \{h_1, h_2, ...h_n\}$. Living in an owner-occupied house of size h generates a service flow of $c_h = h\omega_h$, whereas living in a rental unit of the same size generates a service flow of $c_h = h$. $\omega_h \geq 1$ captures the motives towards ownership beyond those that are explicitly modeled. Homeowners are not allowed to rent out their housing unit to a tenant.

Households can save in a risk free bond, b_{t+1} at a price of q_t^B. Renters are not allowed to borrow. Homeowners can borrow in the form of long term, adjustable rate nominal mortgage contracts. In other words, homeownership allows households to extend their borrowing limit. Mortgage size and the mortgage interest rate in period t are denoted by M_t and r_{mt}, respectively.

3.2 Real estate brokers and the housing market

There is a fixed supply of housing in the economy that does not depreciate. Homeowners are allowed to sell their houses *provided that they have the ability to pay off any outstanding mortgage debt.* Houses are sold in a decentralized market subject to search frictions. Search is directed: A seller with a house size of h decides on the posting price x_s to put it on the market. She then meets a real estate broker who has entered the (x_s, h)-submarket by paying an entry cost of κh. A meeting between a real estate broker and a seller happens with probability $\tilde{p}_t(\theta_t(x_s, h))$, where $\theta_t(x_s, h)$ is the tightness of the submarket for houses of size h that are listed at a price of x_s in period t. Homeowners that try and fail to sell their houses pay a utility cost ξ.

After buying the houses from sellers, real estate brokers turn around and sell them to buyers in a centralized market. Real estate brokers have access to a technology that allows them to splice houses into a few smaller houses as well as to combine several into a larger unit. The implication of this assumption is that houses in the buying market are priced per unit, i.e., renters (including people who just sold their house) can purchase houses from the real estate brokers at a unit price p_t^H. Therefore, a renter buys a house of size h at price $p_t^H h$. To keep the problem simple, we do not allow homeowners to own multiple houses at the same time. If they want a house of different size, they must first sell their existing house in the frictional market. Buyers immediately move into their house and switch from apartment-dweller ("renter") status to homeowner status. Note that brokers are not permitted to carry housing inventories into future periods, but inventories *do* arise in equilibrium from the portion of the housing stock that owners put on the market but fail to sell.

Directed search and block-recursive structure We assume free entry of real estate brokers in every market. Letting $\alpha_t(\theta_t(x_s,h)) = \frac{\tilde{p}_t(\theta_t(x_s,h))}{\theta_t(x_s,h)}$ denote the probability that a broker finds a seller in period t, the free entry condition can be written as:

$$\kappa h = \overbrace{\alpha_t(\theta_t(x_s,h))}^{\text{prob of match}} \overbrace{(p_t^H h - x_s)}^{\text{broker revenue}} \tag{3}$$

for all markets with $\theta_t(x_s,h) > 0$. The revenue to a broker of purchasing a house is $p_t^H h - x_s$. Therefore, brokers continue to enter the submarket (x_s,h) until the cost κh exceeds the expected revenue.

The use of directed search and real estate brokers borrows a key idea from the labor search literature. As in Menzio and Shi (2010) and Menzio and Shi (2011), directed search with risk-neutral agents on one side of the market (real estate brokers in this model) gives rise to the simple condition in (3). This condition pins down the tightness of each market independent of household characteristics that decide to trade in that market, as shown in (4). The latter is important, because it allows us to solve market tightnesses as a function of p_t^H, without having to solve the maximization problem of households.

$$\theta_t(x_s,h) = \alpha_t^{-1}\left(\frac{\kappa h}{p_t^H h - x_s}\right) \tag{4}$$

This feature would not arise in random search models with bargaining. In such models, the outcome of bargaining depends on the characteristics of market participants (e.g. wealth and income of households). Price posting solves this problem. Free entry of risk-neutral agents insures a simple relationship between price and liquidity that is independent of household characteristics. These insights were previously used in Hedlund (2016b), Hedlund (2016a), Karahan and Rhee (2013), and Garriga and Hedlund (2020) to study different issues about housing.

Apartments We assume that apartment space can be produced using the final good. In particular, landlords have access to a linear technology that converts one unit of the final good into A_h units of apartment space (and vice versa). Market for apartments is competitive. Letting r_h denote the rental price of a unit of apartment, the technology implies that $r_h = \frac{1}{A_h}$. Thus a renter who rents a_h units of apartment space pays $r_h a_h$ units of final good as rent. It is important to note that the rental rate is pinned down by the technology and does not respond, among others, to changes in house prices. We also assume that the largest apartment one can rent is smaller than the maximum size of owner-occupied house ($\overline{a} \leq h_1$), which implies a partial segmentation in the housing market. This is going to be one of the reasons why households would become home owners.

3.3 Mortgages and banks

Banks offer long-term, fixed-rate mortgage contracts. The contract is characterized by a nominal face value, M_{t+1}, the price at origination, q^0_{mt}, and the amortization rate r_{mt}. A household receives nominal funds $q^0_{mt} M_{t+1}$ when taking out the loan and could pay it off the subsequent period by paying M_{t+1}. However, mortgages are long-term and have no pre-defined maturity date. Borrowers are free to choose how quickly to pay down their mortgage so long as they keep making a minimum payment, which is a pre-specified fraction of the loan; i.e. $M_{t+1} \leq (1-\chi)M_t$. Thus, $1/\chi$ controls the effective duration of the mortgage. To summarize, a borrower with an existing contract amount of M_t that chooses $M_{t+1} \leq (1-\chi)M_t$ has to make a mortgage payment of $(1 + r_{mt})M_t - M_{t+1}$. In addition to making a payment (or paying off) the loan, borrowers also have the option to refinance by originating a new loan and paying off the existing one.

Banks take into account two types of risks when issuing loans. First, borrowers have the default option, in which case they lose their house, incur a utility cost ξ_f, and have their debt discharged.[5] In the event of foreclosure, the bank sells the repossessed house (REO properties) in the frictional decentralized housing market (as individual sellers do) and incurs a loss γ^{REO}, proportional to the selling price.[6] When the bank sells a foreclosed house, it absorbs all losses but must pass along all profits to the borrower in the (unlikely) event that sales revenues exceed the remaining mortgage balance. The value to a lender of repossessing a house of size h is given by equation (6) in appendix A.

Second, as explained above, households also have the option of prepayment and refinancing the loan by paying off their old mortgage and taking out a new one. Banks have to price in these risks and determine the price of mortgage q^0_{mt} accordingly. Thus, mortgage prices depend on borrower characteristics. The recursive equation that determines the mortgage pricing is given by equation (5):

Mortgage pricing Mortgage prices for the amount of M_{t+1} for the household with risk-free saving b_{t+1}, house size h_t, and idiosyncratic labor productivity z_t satisfy the following recursive relationship:

$$
\begin{aligned}
q_{mt}(M_{t+1}, b_{t+1}, h_t, z_t)M_{t+1} = \frac{1}{(1+r_{mt})}\mathbb{E}\Bigg\{ & \overbrace{\tilde{p}_{t+1}(\theta_{t+1}(x_{st+1}, h_t))M_{t+1}}^{\text{sell + repay}} + \overbrace{[1-\tilde{p}_{t+1}(\theta_{t+1}(x_{st+1}, h_t))]}^{\text{no sale (do not try/fail)}} \\
& \times \Bigg[\underbrace{d_{t+1}\min\{P_{t+1}J_{REO}(h), M_{t+1}\}}_{\text{default + repossession}} + Refi_{t+1}M_{t+1} \\
+(1-d_{t+1}-Refi_{t+1}) & \Bigg(\underbrace{M_{t+1} - \frac{M_{t+2}}{(1+r_{mt+1})}}_{\text{borrower payment net of servicing costs}} + \underbrace{q_{mt+1}(M_{t+2}, b_{t+2}, h_t, z_{t+1})M_{t+2}}_{\text{continuation value of new } M''} \Bigg) \Bigg] \Bigg\}
\end{aligned}
\tag{5}
$$

where P_{t+1} is the price level and x_{st+1}, d_{t+1}, b_{t+2}, and M_{t+2} are the policy functions for list price, mortgage default ($\in \{0, 1\}$), bonds, and new mortgage balance next period, respectively. At origination, $q^0_{mt} = \frac{1}{(1+\zeta)}q_{mt}$. If the borrower never sells or defaults, mortgage prices in the steady state reduce to $q_{mt}(M_{t+1}, b_{t+1}, h_t, z_t) = \frac{1}{(1+r_{mt})}$.

[5]The utility cost is meant to represent, among other things, the stigma associated with foreclosure and non-monetary moving costs.

[6]This cost is meant to capture the various costs to the banks of selling foreclosed houses.

3.4 Timing of events

Below, we describe the timing of the events within a period.

1. Shocks: In the beginning of the period households learn about their idiosyncratic productivity and choose how much to work.

2. Market for house selling: Homeowners decide whether to put their houses up for sale and if so, at what price. Real estate brokers enter the various submarkets by paying the entry cost. Sellers meet with real estate brokers and transfer the ownership of their house.

3. Default decisions: Homeowners who have not sold their houses make default decisions. Banks take the ownership of the foreclosed houses and try to sell it to real estate brokers. Homeowners that do not default on their mortgage debt, choose the mortgage payment for the current period. This decision also encompasses the refinancing decision.

4. Market for house buying: Renters, including those that recently sold their houses, decide whether to buy a house. Buyers also decide on how much mortgage debt to take out, if any.

5. Consumption and savings: Households choose how much to consume and how much to save using the risk free bonds.

For household's dynamic problem see appendix A.

4 Calibration

We assume the economy is in steady state in period $t = 0$ and calibrate it to the US economy prior to Covid-19 pandemic. The calibration puts emphasis on matching key housing moments related to sales, time on the market, and foreclosures, as well as important dimensions of the joint distribution of assets, housing wealth, and mortgage debt. Some parameters are drawn from the literature or from external sources, but the remainder are determined jointly in the calibration.

4.1 Parameters set outside the model

Income process Using administrative data, Guvenen *et al.* (2016) estimate a canonical income process for the life cycle annual earnings risk which consists of a random walk and an i.i.d transitory component. Since our model is not a life-cycle model, we cannot directly use this income process in our calibration. Instead, we target the variance of log earnings in the working age population implied by this income process, which is 80 log points. More specifically, we first set the variance of transitory shocks to 0.16.[7] Second, in order to have a stationary distribution of earnings, we set the persistence parameter of persistent component ρ to 0.99, which is close to a random walk. Next, we choose the variance of innovations to the persistent component σ_η^2 by targeting the variance of log earnings in the population. In particular, out of 80 log points, transitory shocks account for 16 log points. Then, variance of persistent shocks is chosen to generate 0.64 unconditional variance:

$$0.64 = \frac{\sigma_\eta^2}{1-\rho^2} \Rightarrow \sigma_\eta^2 = 0.0127.$$

However these values are for annual earnings whereas our model period is a quarter. Therefore, we convert these annual values to their corresponding quarterly values. In particular, we estimate a quarterly income process such that the resulting aggregated annual income process has a transitory component with variance 0.16 and a persistent component with persistence 0.99 and variance 0.0127. Finally, we employ Rouwenhorst (1995) method to discretize the persistent and transitory components of the income process. We use 3 grid points for the transitory component and 7 for the persistent component.

Preference parameters Risk aversion is set to $\sigma = 2$. Preference parameter governing housing (ϕ_h), the value of housing services (ω_h), the intratemporal elasticity of substitution (γ_h), and the discount factor (β) are determined jointly in the calibration.

Technology Steady state TFP in the consumption good sector is set to normalize mean quarterly earnings to 0.25. The apartment technology A_h is set to generate an annual rent-price ratio of 3.5%.

Housing Market Matching function in the selling markets is governed by a Cobb Douglas function, i.e. $\tilde{p}(\theta) = \min\{\theta^\gamma, 1\}$. Substituting in the equation for market tightnesses

[7] Guvenen *et al.* (2016) estimate this parameter to be 0.25 for annual earnings. Since our model generates endogenous fluctuations in labor hours, and in turn in annual earnings, we calibrate this parameter to a smaller value of 0.16.

gives

$$\tilde{p}(\theta) = \begin{cases} 0 & \text{if } x_s > p^H h \\ \left(\frac{p^H h - x_s}{\kappa h}\right)^{\frac{\gamma}{1-\gamma}} & \text{if } (p^H - \kappa)h \leq x_s \leq p^H h \\ 1 & \text{if } x_s < (p^H - \kappa)h \end{cases}$$

The joint calibration determines the parameters κ, and γ. Holding costs (maintenance, property taxes, etc.) are set to 0.007 ($\eta = 0.007$).

Financial Markets To match values in the U.S. over the pre-pandemic period, the real risk-free rate is set to 0%, and the mortgage origination cost is set to 0.4%. The mortgage servicing cost ϕ is set to generate a 2% spread between the real mortgage rate and risk-free rate. The minimum payment is calibrated so that households can rollover their mortgage debt by paying interest only ($\chi = 0$). Lastly, the exogenous LTV limit is set to 125%, which makes it *non-binding* in the steady state.[8]

4.2 Joint calibration and model fit

The remaining parameters to be calibrated are the discount factor β, the share of housing in the utility function ϕ_h, the intratemporal elasticity of substitution γ_h, matching function elasticity γ, real estate market entry fee κ, size of the largest rental unit, smallest house size, utility cost of foreclosure ξ_f, and the efficiency loss that accrues to banks (γ^{REO}) are determined jointly in the calibration. The calibration targets various moments in the data that we explain below.

First, we target selected household portfolio moments calculated from the 2004 Survey of Consumer Finances (SCF) for prime-age households. Specifically, the calibration aims to match a homeownership rate of 62.7%, a median net worth of 1.06 (in terms of annual mean income), a mean value of housing (in terms of annual median income) of 3.37, a mean mortgage debt (in terms of annual median income) of 1.87, and a median mortgage debt (in terms of annual median income) of 1.55. In addition, we also target a host of moments about mortgage holders. More specifically, we target the fraction of homeowners that have a mortgage (82%), median loan-to-value ratio (LTV), the fraction of mortgage holders with an LTV larger than 70%, 80%, 90%, and 95%. We also target a quarterly foreclosure rate of 0.4%. Lastly, we target a set of moments about the housing

[8]At the peak of the housing boom in 2005, the popularity of cash-out refinancing led to many instances of new mortgages with loan-to-value ratios in excess of 100%. The foreclosure penalty and the REO discount γ^{REO} are determined in the joint calibration.

Table I – Targeted Moments and Model Fit

Moment	Model	Data
Home ownership rate	65.4%	65.1%
Housing Wealth (Owners)	3.85	3.91
Median net worth (rel. to mean income)	0.79	1.06
Mean housing (rel. to median income)	3.12	3.37
Mean mortgage debt (rel. to median income)	2.10	1.87
Median mortgage debt (rel. to median income	1.54	1.55
Fraction of homeowners with a mortgage	99%	82%
Median LTV	0.68	0.49
Percent with LTV>70%	44.7	28.5
Percent with LTV>80%	14.6	18.1
Percent with LTV>90%	9.6	9.4
Percent with LTV>95%	5.4	5.8
Foreclosure rate (%)	0.4	0.4
Mean buyer time on the market (weeks)	10.7	10.0
Mean seller time on the market (weeks)	17.1	17.3
Mean REO time on the market (weeks)	29	52
Turnover (share of housing stock transacted, %)	0.9	2.5

market. More specifically, we target the (mean) time it takes to buy a house, the time it takes to sell a house, and the fraction of the housing stock that is transacted every quarter. These set of moments are obtained from the National Association of Realtors. The calibration minimizes the percentage deviation from these moments and their model counterparts. The values of the targeted moments and the model's fit are reported in table I. Values of parameters that are set outside the model are shown in table II, and the values of internally calibrated parameters are reported in table III.

5 Steady-state properties of the calibrated model

We start by investigating the steady state properties of the calibrated model. We focus on the liquidity of the housing market induced by search frictions and how this liquidity affects consumption.

The illiquidity of the housing market induced by search frictions has several effects on the behavior of consumption at the individual level. First, illiquidity creates selling risk for homeowners, and in particular for homeowners with substantial outstanding mortgage debt. Panel 1 of figure 4 displays the optimal listing price as a function of leverage for a

Table II – Externally Calibrated Parameters

Parameter(s)	Interpretation	Value(s)	Source
Γ	Income process	see text	Guvenen *et al.* (2016)
σ	Risk aversion	2	Standard
ν	Maximum LTV	125%	

Note: This table reports the values for the parameters that are jointly calibrated within the model.

TABLE III – Internally Calibrated Parameters

Parameter(s)	Interpretation	Value(s)
β	Discount factor	0.95
ϕ_h	Taste for housing	0.4244
γ_h	Elasticity of substitution c, h	0.5
λ_s	Elasticity of matching fnc. in selling market	0.8922
λ_b	Elasticity of matching fnc. in buying market	0.0894
κ_s	Minimum house price that sells w. prob 1	0.7538
$\underline{h}$	Size of smallest house	2.9486
$\underline{h_r}$	Size of largest rental apartment	2.4287
ξ_F	Utility cost of foreclosure	0.0153
η	Efficiency loss due to foreclosure	1.53%

Note: This table reports the values for the parameters that are jointly calibrated within the model.

homeowner with zero liquid assets, a low level of income so that cash at hand is about one quarter's income, and a median sized house (worth 2.9 times annual income) and panel 2 shows the corresponding expected time to sell. This homeowner has a motive for selling and downsizing to smooth consumption. In case of an unsuccessful search for a buyer, the homeowner has the option to go to the bank, obtain a new mortgage, and extract equity, the value of which crucially depends on the outstanding mortgage debt. Panel 1 of figure 4 shows that, for low levels of mortgage debt (leverage ratio below 70%), the equity cushion allows this household to be patient and look for a good price for the house.

However, as leverage rises close to 75%–80%, the default risk rises (shown on panel 3), which manifests itself in the rising mortgage premium (panel 4), reducing the option value of going to the banks and asking to refinance. As a result, these homeowners become distressed sellers who optimally choose lower list prices ("fire sales") in search of liquidity. For homeowners with higher debt values (above 80% leverage), the constraint $x_s + y \geq \frac{m}{1+\pi}$ starts binding. As their equity cushion is non-existent, these debt-constrained sellers don't have the flexibility to price their house to sell quickly and end up having to list their unit at high prices. These homeowners experience debt overhang as their houses take longer to sell. Quantitatively, time on the market can exceed one year for the most indebted homeowners.

In fact, these debt-induced selling delays have ramifications for mortgage default behavior, the supply of credit, and ultimately, for consumption behavior. By increasing the risk that a financially distressed and indebted homeowner fails to sell their house, selling delays spill over into higher foreclosure risk. Panel 3 shows a heat map for mortgage default as a function of leverage and cash at hand. In standard Walrasian models of housing, only the "negative equity default" region exists, because having negative equity is a necessary condition for default. Intuitively, as long as the market clearing price is sufficiently high to repay the mortgage, owners with even a sliver of equity can always instantly sell their house to avoid default. However, longer endogenous selling delays in the model with housing search frictions have a direct impact on foreclosure activity. In short, having equity on paper is less relevant than being able to actualize that effort by selling at a particular price in a short time window.

As a result, endogenous housing illiquidity creates a new, graduated region of mortgage default, labeled as "illiquidity default" in panel 3. Notice that, depending on an owner's asset position, even having 6%, 10%, or 15% equity does not inoculate own-

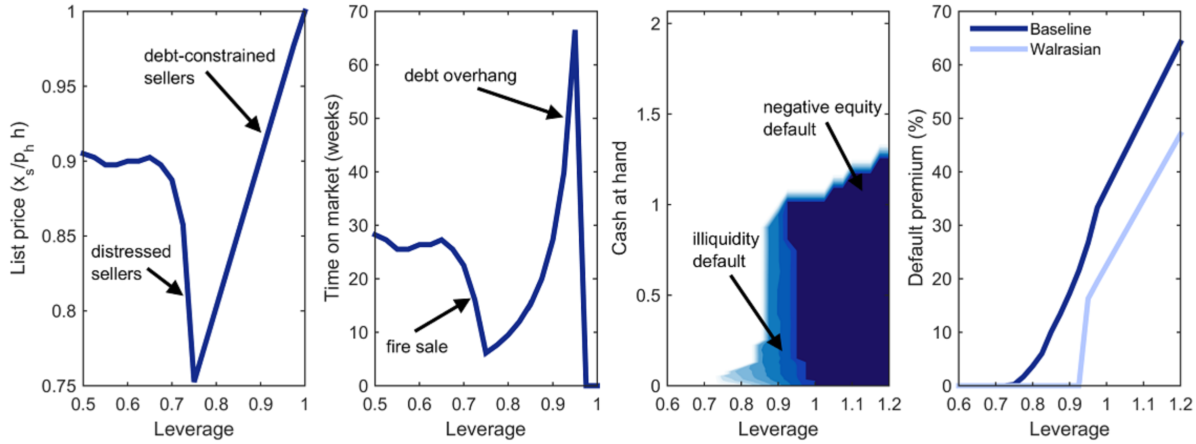


FIGURE 4 – (1) List price by LTV; (2) time on the market by LTV; (3) mortgage default heat map; (4) default premia.

ers against the risk of default. This behavior is consistent with empirical evidence on subprime mortgage data that finds repossession rates of 50% for delinquent mortgages with LTV ratios between 80% - 90% and 55% for delinquent mortgages with LTV ratios between 90% - 100%. In a Walrasian world, one would expect 0% repossession rates for such mortgages.

The heightened foreclosure risk that arises from housing illiquidity has a substantial effect on the supply of mortgage credit. Panel 4 of figure 4 plots sample default premia for new loans as a function of leverage. For clarity, a 10% default premium adds 10% to the cost of a loan over its lifetime. Default premia in the baseline economy with illiquid housing considerably exceed those in the Walrasian economy. This link between housing illiquidity and the availability of mortgage credit creates a powerful channel in the dynamic economy. If a shock hits the economy and drives down house prices, housing illiquidity will deteriorate endogenously and create longer selling delays. In turn, heightened time on the market increases foreclosures, leading banks to cut back on credit, which causes demand for housing to fall even further. In other words, endogenous housing illiquidity acts both as an amplification and propagation mechanism for economic shocks via the link between housing and mortgage market conditions.

Figure 5 plots some individual-level simulations to illustrate the mechanisms described above. In each case, we simulate the behavior of a homeowner who receives a constant stream of income. Panel 1 shows the path of mortgage leverage over time for a typical homeowner who does not experience any financial difficulty. Panel 2 shows the

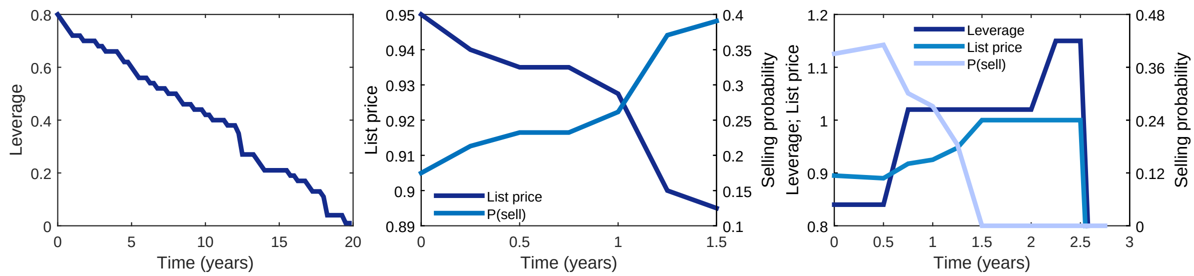


FIGURE 5 – Simulations over time of different individual homeowners who (1) pay down their mortgage; (2) use their equity cushion to cut their price; (3) engage in "distressed borrowing," raise their price, experience selling delays, and then default.

dynamic selling behavior of a homeowner who receives a sequence of low income realizations. This "distressed seller" lacks access to credit to extract equity but has sufficient equity to gradually lower the list price as financial duress intensifies. Lastly, panel 3 plots an example of "distressed borrowing" followed by debt overhang and default.

The illiquidity of housing, in conjunction with endogenous credit supply, generates substantial deviations in consumption behavior from standard incomplete markets models that assume households can costlessly access all of their wealth to smooth consumption. By explicitly modeling these important features of housing and mortgage markets, we allow monetary policy to affect consumption and output through changes in the liquidity of the housing market.

6 Quantitative Results

6.1 United States: fixed rate, adjustable rate comparison

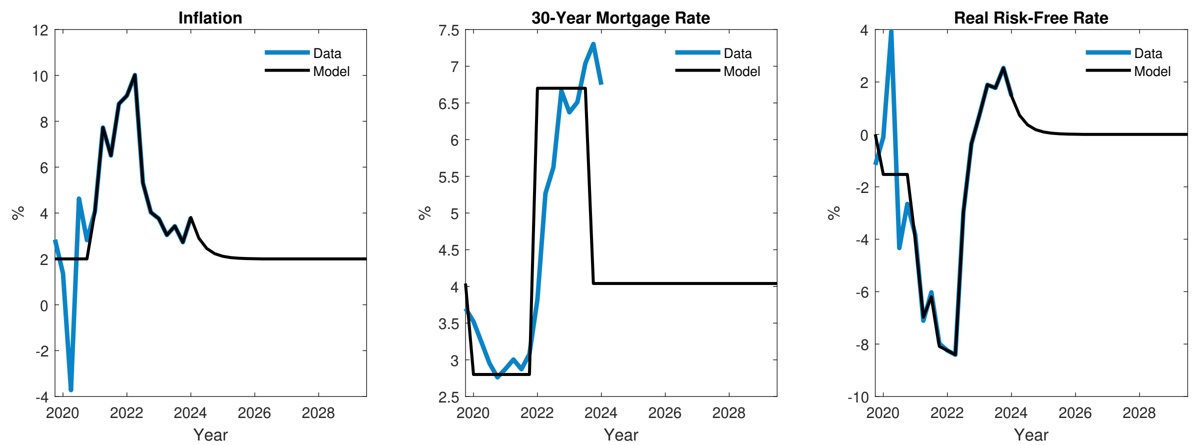
6.1.1 Great inflation shocks

The generate the dynamics of the pandemic recession and Great Inflation we feed in a series of shocks to the housing and labor market. We modeled the recession and recovery as three periods. Each period is a surprise and perfect foresight path.

Phase 1: The cut (2020). Initially the mortgage rate, r_{mt}, drops from 4 to 2.8 percent, and the real rate falls from 0 to -2 percent. Household perceive this to last 40 quarters. This is in keeping with the implied fall in market rates (see Appendix).

Phase 2: Inflation begins (2021). Inflation rises, but is perceived as temporary. We feed in actual values for 2021, with no change in monetary policy.

FIGURE 6 – Great Inflation shocks



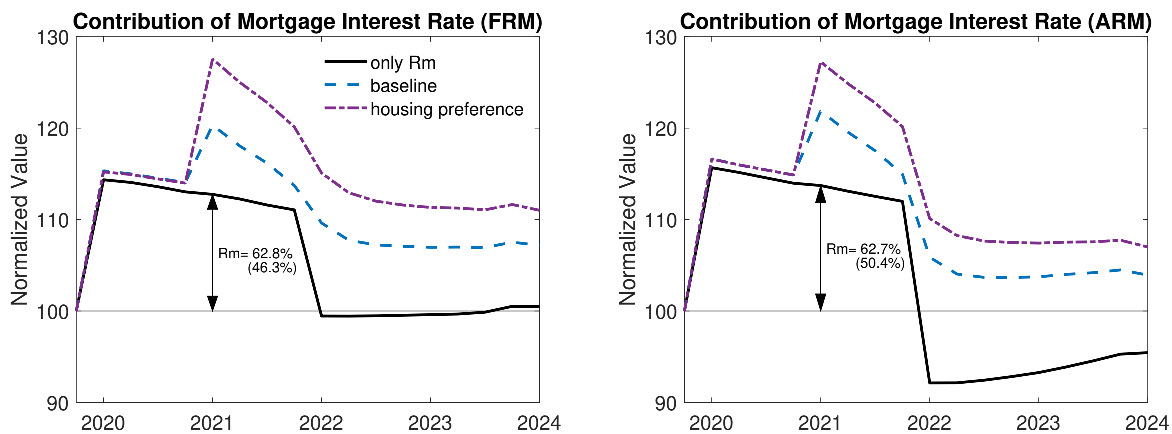
Phase 3: The Fed responds (2022-24). inflation continues to rise and is more persistent. The Fed tightens monetary policy. The mortgage rate rises to 6.8 percent, with an expected duration of 8 quarters. We feed in the real rate (the Fed Funds rate minus inflation) from the data.

As the mortgage rate is a state variable in the FRM case, we need to economize on possible values it can take. Here we choose three. For the mortgage rate we use Freddie Mac's 30-Year Fixed Rate Mortgage Average. For inflation we use annualized changes in the CPIU. We ignore some of the extreme changes in inflation that occurred in 2020. For the real rate we use the Fed Funds rate net of inflation. The path of these variables in the data and the series fed into the model are shown in Figure 6.

We also feed in labor market shocks to income and government transfers. For income we use quarterly hourly earnings for the private sector multiplied by the LFS employment rate, both from the OECD. This captures the intensive and extensive margin, we multiply all households' income by this productivity type shifter. For the transfers we sum unemployment insurance and other transfers (which captures the stimulus cheques) from the NIPA tables. We calculate the deviation from the pre-recession steady state in 2019 and calculate this as a fraction of the average income. We treat these as lump transfers received by all households. The paths of income and transfers are shown in Appendix B. The information is revealed to households on the same basis as the other shocks.

FIGURE 7 – Contribution of mortgage rates to house price movements

(A) Fixed rate mortgage (B) Adjustable rate mortgage



6.1.2 Contribution of mortgage rates to pandemic era house price movements

The first exercise is to decompose the total house price movements over the pandemic and great inflation period, to understand the contribution of mortgage rates. To do this we compare the path of house prices in the model when we feed in all the shocks to the case with only changes to the mortgage rate. The baseline model is shown with the dashed line on Figure 7. The model with only the changes in the mortgage rate is the solid black line. Panel a presents the results for fixed rate mortgages. The main point is that changes in the mortgage rate alone are able to account for a significant share of the movement in house prices over this period.

Upon the initial decline in rates in 2020, almost all of the increase in house prices occurs due to the decline in the mortgage rate. In 2021, the house price rises further as a result of the increase in inflation which lowers the real rate. In the model, this is when house prices reach their highest level. On impact in 2021, the mortgage rate alone accounts for 63 percent of the increase in house prices. When rates rise in 2022, the house price falls. With FRMs, the mortgage increase would return house prices to close to the steady state level. With ARMs, house prices would decline to almost 10 percent below their steady state level (Panel b of Figure 7). As discussed later, the baseline model with shocks to the interest rates, inflation, income and transfers is not able to fully match the increase in house prices during the pandemic. To match this, we add a housing preference shock which hits the economy in 2021, shown by purple line. However, even including the housing preference shock, mortgage rates are still a highly important driver of the increase in house prices. The mortgage cut explains 46 percent of the total increase in US house prices in the FRM model and 50 percent in the hypothetical economy with ARM mortgages.

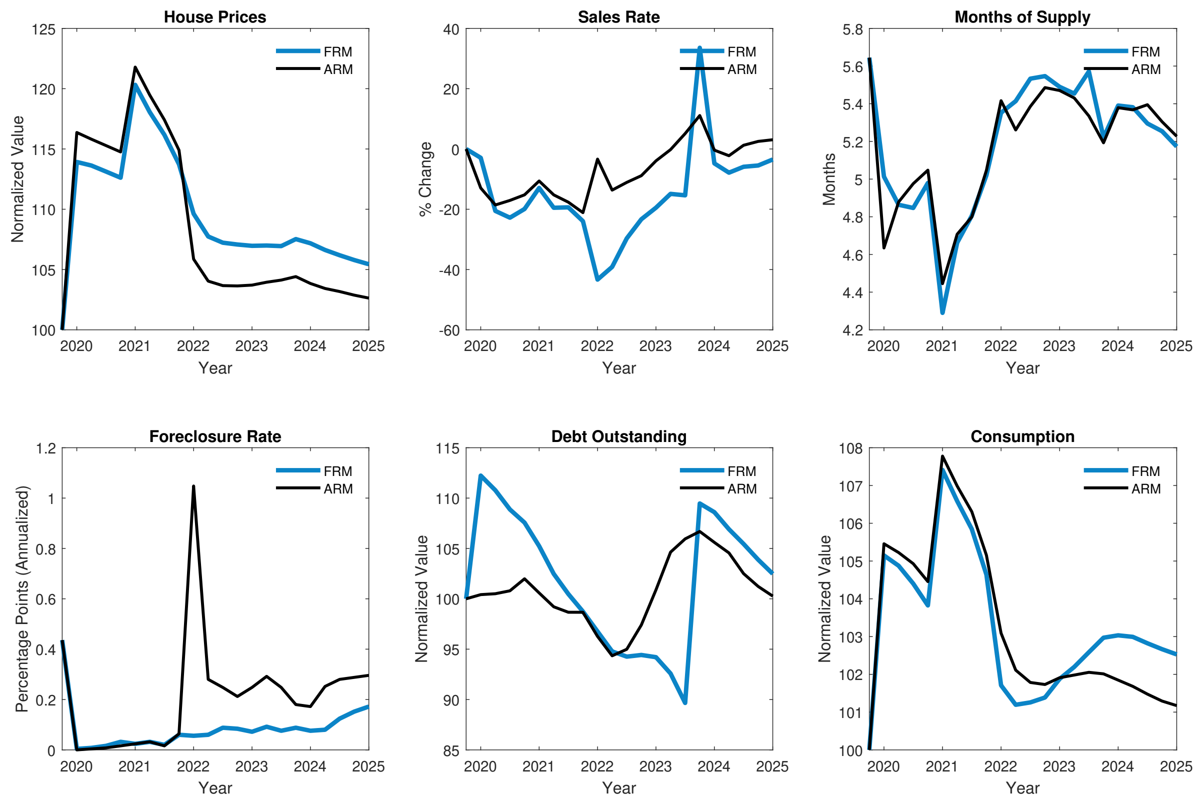
6.1.3 Great Inflation in US: Fixed Rate Mortgages versus Adjustable Rate Mortgages

We now study the role of the mortgage market in contributing to US house price dynamics. To do this we compare how various housing market margins respond to the shocks that hit the US economy under an FRM or ARM regime. The results are presented in Figure 8. As previously shown, under ARM the house price increases by more initially and displays less persistence upon rate tightening. We that see that upon impact, months of supply falls to a greater extent under ARM mortgages. In the ARM case, can benefit from the lower interest rate without refinancing. This can be seen in the Debt Outstanding panel, where we observe debt increase substantially under FRM, but only modestly under ARM.

When rates rise in 2022, the differences become more apparent. Under FRM, the sale rate drops further, whereas it begins to increase under ARM. The extra supply lowers house prices. There is also a dramatic spike in foreclosures under ARM, which remain depressed relative to the steady state under FRM. This highlights the importance of FRM in lowering the probability of distressed sellers, which avoids fire sales and prevents a large fall in house prices. Debt also has different dynamics after the rate increase. Under ARM debt begins to rise as larger mortgage payments are required to pay for the increase interest costs. In the FRM regime, most owners are not exposed to these large interest costs, they are also incentivized to not refinance as it would imply losing their preferable low fixed mortgage rate. Finally, we note the consumption patterns during the period are fairly counterfactual. This partly due to a high degree of complementarity between housing and consumption. However, we are abstracting from all pandemic era restrictions so it is not surprising that the model does not generate a consumption decline.

Equilibrium effects. It is interesting to consider the key role of general equilibrium effects for the result. We consider the counterfactual case with no change in house prices to the same shocks. As shown in Figure 9, Panel a if house prices do not rise there is a large increase in the homeownership rate. This indicates the main additional demand comes from marginal renters, who can afford to move into housing given the lower

FIGURE 8 – US: FRM versus ARM

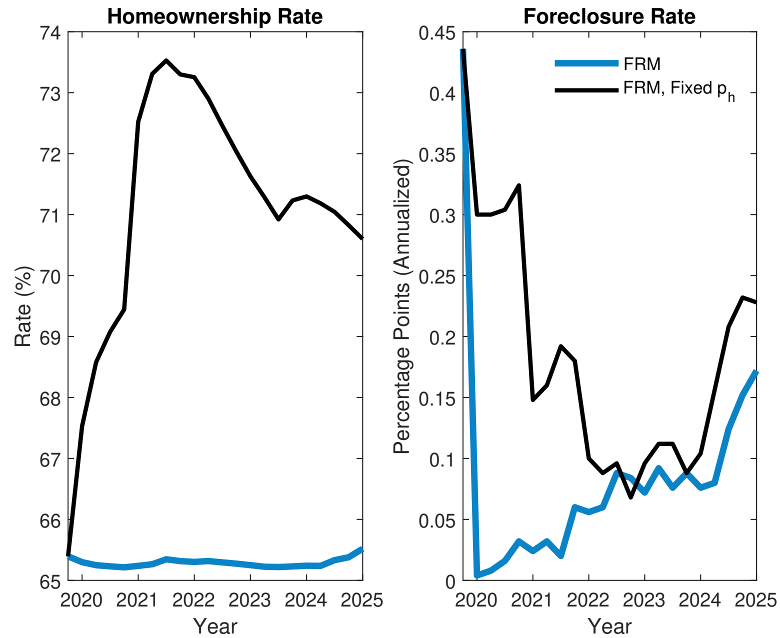


mortgage costs. The fall in the foreclosure rate is also less extreme. This emphasizes that foreclosure fall in to model not just due to the lower minimum interest costs. Instead by raising the price of the asset for underwater sellers reduces the chance of foreclosure. This also reduces fire sale behavior of these households, boosting house prices in equilibrium.

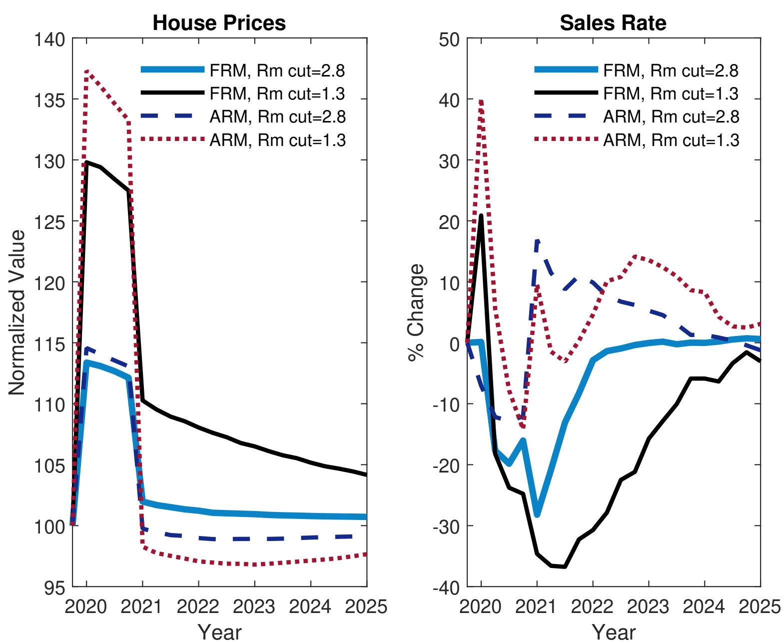
Path dependency. FRMs also generate substantial path dependency. To see this, we compare the impact of rate tightening under two different rate cuts. We consider the impact of an initial 1.3 percent with the baseline 2.8 percent. The results are presented in Figure 9, Panel b. The larger initial rate cut generates a bigger boom. After that we see the path dependency generated by FRM mortgage. While the mortgage rate returns to the steady state value (4 percent) in both cases the house price remains elevated following the bigger boom. The key driver of this difference is substantially depressed sales rate. In 2021, the sales rate is almost 40 percent below its steady state value following the big boom, but only 25 percent following the smaller rate cut. The increase in foreclosures is also smaller (not shown). The ARM model also exhibits some path dependency, but it much less than in the FRM example.

Figure 9 – Decomposing mechanism

(A) General equilibrium



(B) Path dependency



Search frictions We also investigate the importance of the endogenous housing market frictions for our main result. To do this we vary the parameters that govern the search market and consider counterfactual house price movements. We consider two alternatives. One where the matching function becomes highly elastic, such that variations in the posted price have a bigger impact on the matching probability. In particular, we set $\gamma_s = 0.99$ and $\gamma_b = 0.2$. Second, we lower the search cost, the disutility of a posting a house that fails to sell, to $\xi = 0.00014$. Finally, we consider the combination of both. The results are presented in Figure 10.

Increasing the elasticity of the matching function substantially reduces the volatility of house prices with respect to the mortgage rate shocks. The boom in prices in 2020 is close to zero. The size of the decline in prices is also smaller. The difference between the dynamics of the FRM and ARM mortgage market is still presence. One interpretation of this calibration is that it reduces the costliness of the matching friction for distressed sellers, as a smaller reduction in the posted price substantially increases the probability of selling. This rules out fire sale behavior. Removing the disutility cost of selling increases the magnitude of the initial boom. Households are now more willing to post a high price and face not selling, raising prices in equilibrium. One implication not considered here, but arguably consistent with the data and model, is that remote work made the cost of delayed selling lower and that this explains part of the boom in US house prices. Finally, we see that once the housing market is very elastic, lower search costs are no longer relevant as the probability of failing to sell is low.

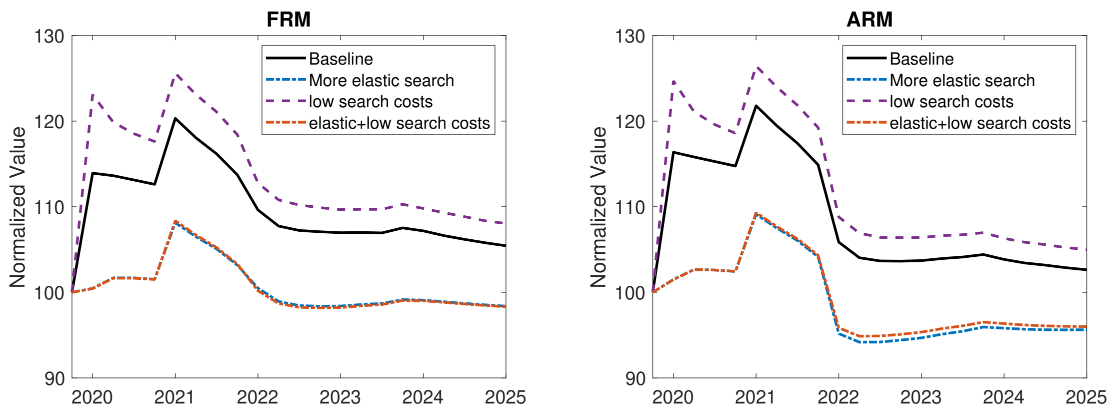
Overall, the decomposition shows that search frictions matter for house price dynamics and for the quantitative magnitude of the house price boom and decline. Interestingly, the relative behavior across ARM and FRM mortgage markets is fairly consistent. We still get evidence of lock in with FRMs. However, to quantitatively evaluate the contribution of the mortgage market structures to the Great inflation house price movements it is important to model these search frictions.

6.1.4 Mortgage lock-in

A further check on the model's dynamics is its ability to predict household's expected duration in their current house. A striking feature of the post-2022 data is a fall in the expected duration in the current house at longer horizons (>10 years) and an increase at shorter horizons (2-5 years). Prior to 2020, the level of these expected durations had been fairly constant. This is shown in Table IV, Panel a. The data comes from the NY

FIGURE 10 – Role of housing market search friction

(A) Fixed Rate Mortgage (B) Adjustable Rate Mortgage



Fed Survey of Consumer Expectations.[9]

We compare these trends to the expected duration in the model. These are computed by stimulating a panel of households and calculating whether a household moves in the next x quarters associated with each of the durations.[10] The results are presented in Table IV, Panel b. The model does a surprisingly good job of matching the patterns in the data. After 2022, the share of households that do not move in the next 10 year begins to fall, whereas there is an increase the expected duration at less than 2 years and between 6-10 years. The economic drivers for the change are quite intuitive. Initially, after the rate cut fewer households are forced to downsize, leading to a shift from <2 years to 2-5 years. After the rate increase, households immediately increase the expected duration at the 6-10 year duration, holding on to the low FRM rates. However, having held on to the low rates they are more likely to be allocated to a non-optimal house with the steady state policy functions (once Rm=Rm). Therefore, the share of households staying for more than 10 years begins to fall.

6.1.5 Household expectations

There is evidence to suggest household expectations about the rise in mortgage rates did not update as quickly as is implied by our baseline specification. Figure 11, Panel a shows the change in households expectations of the mortgage rate at the current, one-

[9] This is an annual survey where households report expectations in February.

[10] We do this separately for each of the three shock periods and paste the results together, therefore realized moved in the panel are consistent with household expectations.

TABLE IV – Owner's Expected Duration in the Current House

	Data			Model		
	2020	2024	Change	2020	2024	Change
$<$ 2 years	8%	16%	8 pp	9%	10%	1 pp
2–5 years	19%	28%	9 pp	16%	17.5%	1.5 pp
6–10 years	19%	18%	–1 pp	20.5%	20.5	0 pp
$>$ 10 years	54%	38%	-16 pp	54.5%	52%	-2.5 pp

year ahead and three-year ahead horizon. Changes are shown relative to the expectation in 2019. The data is from the NY Fed Survey of Consumer Expectations and is a measure of subjective expectations, rather than market implied rates. Expectations fell in 2020 and further in 2021. By 2022, expectations had begun to rise, but the one year forward expected mortgage rate was close to the 2019 level. There is an upward sloping yield curve, with mortgage rates expected to rise further in the future. In 2023, expectations then rose substantially at both in the near-term and three-year horizon.

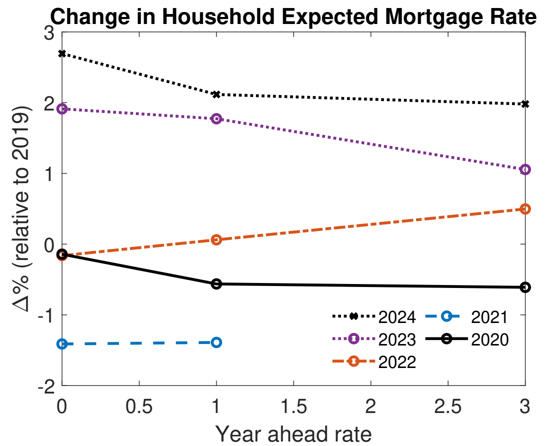
Our baseline specification has rates rise to 6.8 percent at the start of 2022. The evidence above suggests household expectations took a while to reach this level. To test this hypothesis, we introduce an additional shock to our model. In 2022, mortgage rates increase to 5.5 percent with duration expected to last for four quarters. In 2023, there is a further increase to 6.8 percent. All other shocks are revealed in 2022, as in the baseline. We introduce this in the model with a housing preference shock. The results are shown in Panel b. Unsurprisingly, the delayed rise in mortgage rates improves the model fit. The data is from the Case Schiller National House Price Index. During 2022, the house price is about 5 percent higher with delayed expectation. In 2023, it returns close to the path of the model with a housing preference shock, there is not much additional propagation. Overall, the improved fit of the model suggests a role for the delayed updating of household expectations in the model, particularly through to 20243. However, as households had updated their expectation of rates during 2023 it does not explain why prices continue to remain elevated.

6.1.6 Distributional gains

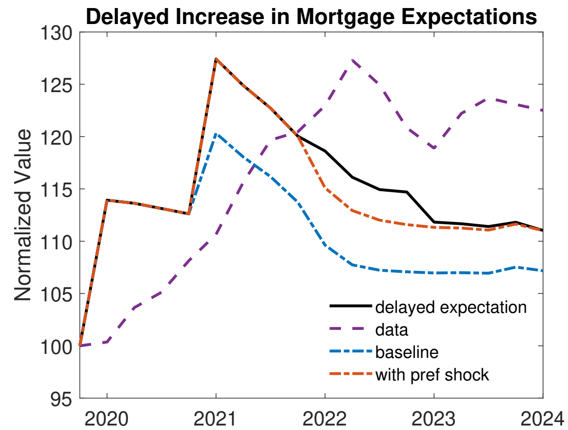
The mortgage rate loosening and tightening, and the resulting path of house prices, generates winners and losers across the distribution. Interestingly, the effect is non-

FIGURE 11 – Delayed household expectations

(A) Change in household mortgage expectations



(B) US fixed rate mortgage with four shocks



monotonic in income. Further, the magnitude of this welfare effect differs by the structure of the mortgage market. We compare the consumption equivalent gain of the set of shocks for the median household, the average owner and renter, and for low- and high-income owners. For this exercise we exclude the transfers which generate strong distributional patterns raising the welfare of low-income households. We also ignore housing preference shocks. The results including transfers is presented in Appendix B.

The on-impact effect of the arrival of new shocks is summarized in Table V. The FRM results are in the left panel, the ARM results are in in the right panel. The welfare value of a perfect foresight path occurs on impact when a new shocks arrive in 2020, 2021 and 2023.[11] The biggest winners of the period are low income homeowners. They benefit initially as prices rise, and this relaxes their credit constraints or the possibility of default. Home owners on average benefit, as does the median household. Renters suffer as the price of moving out of renting (a desirable outcome) has increased. Inflation further boosts the welfare of homeowners, by raising prices.

When rates increase, house prices drop, leading to an increase in the welfare of renters. With FRM mortgages the welfare of home owners remains fairly constant as their debt obligations have not increased and they are no more likely to face a forced sale. The pattern is different under ARMs. Initially, the welfare gains of the mortgage rate decline are larger, due to the greater increase in house prices and immediate decline

[11] After this welfare can change but excludes some past welfare gains or losses.

Table V – Distributional gains during Great Inflation

	FRM			ARM		
	2020	2021	2022	2020	2021	2022
Median	0.43	0.91	0.91	0.69	1.07	0.10
Owners						
average	1.16	1.44	1.68	1.51	1.67	0.72
bottom 25pct	1.68	1.87	1.86	2.10	2.12	1.06
top 10pct	1.05	1.31	1.59	1.37	1.53	0.58
Renters						
average	-0.91	-0.76	0.20	-0.91	-0.65	0.48

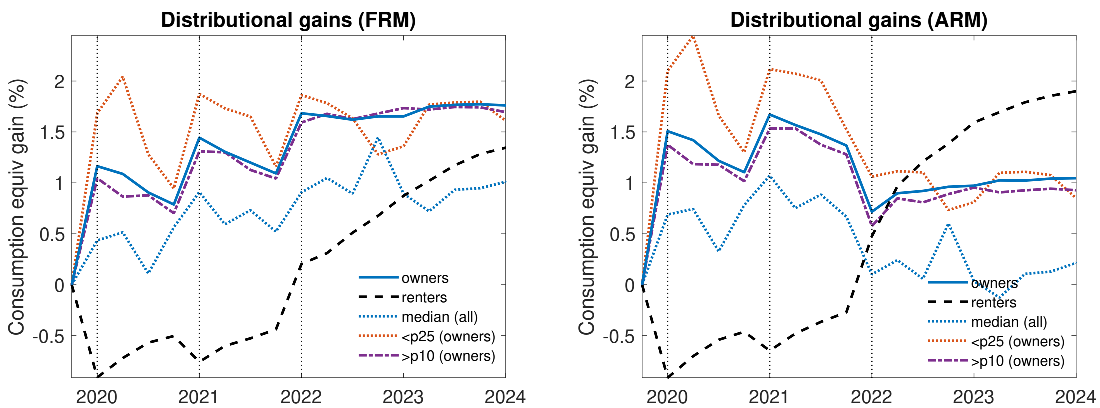
in the present value of the debt. After the tightening in 2022, with ARMs owners welfare falls by more. This is due to the larger fall in prices, which are below the steady state value, and also the increased minimum mortgage payments and increased probability of foreclosure. Conversely, the lower house prices raise renter welfare by more. Overall, FRMs raise welfare relative to ARMs, during a period of tightening. In 2022, under FRMs the median household has positive welfare relative to steady state, whereas under ARMs welfare has roughly returned to its steady state value. Figure 12 plots the paths of household welfare during the time period studied. The realization of shocks is shown with vertical lines. In these figures it is easy to see the persistence of welfare gains during the tightening period under the FRM regime.

6.2 Expected Duration

The Covid shock and rate tightening had a significant impact on households' housing choices. One important implication of this shift is the change in households' expected duration in their current houses. This expected duration partially captures how well households are matched to their current housing selections and provides insights into mortgage lock-in effects. For example, if rates temporarily increase while a household has a Fixed-Rate Mortgage (FRM), they are more likely to remain in their house in the short run to benefit from the lower mortgage rate. However, over time, households may become misallocated from their preferred housing stock. This misallocation will lower the expected duration at longer horizons when mortgage rates are anticipated to return

FIGURE 12 – Distributional gains

(A) Fixed Rate Mortgage (B) Adjustable Rate Mortgage



to lower levels and the value of holding the FRM diminishes.

Figure 13, Panel A shows owners' expected duration in their current houses as reported in the New York Federal Reserve's Survey of Consumer Expectations (SCE).[12] This shows the share of households expecting to stay in their current houses for less than 2 years, 2-5 years, 6-10 years, and more than 10 years. Prior to 2020, these shares remained remarkably stable, indicating they largely reflected life-cycle or income-related moving patterns. In 2022, however, they shifted dramatically. The share of households expecting to stay for less than 2 years and 2-5 years increased, while the share expecting to stay for more than 10 years fell substantially. We interpret these patterns as households expecting to remain in their houses while interest rates remain elevated but anticipating moves once mortgage rate lock-in effects dissipate.

The baseline model with FRMs successfully matches these empirical patterns. Panel B shows the response of model-implied duration for a panel of 100,000 households.[13] At the beginning of the recession, lower rates enabled households to remain slightly longer in their current houses, with a shift from the "<2 years" category to the "2-5 years" category. In 2022, after the tightening began, the share expecting to remain in their houses for less than 2 years and for 2-5 years initially fell before beginning to rise. Since

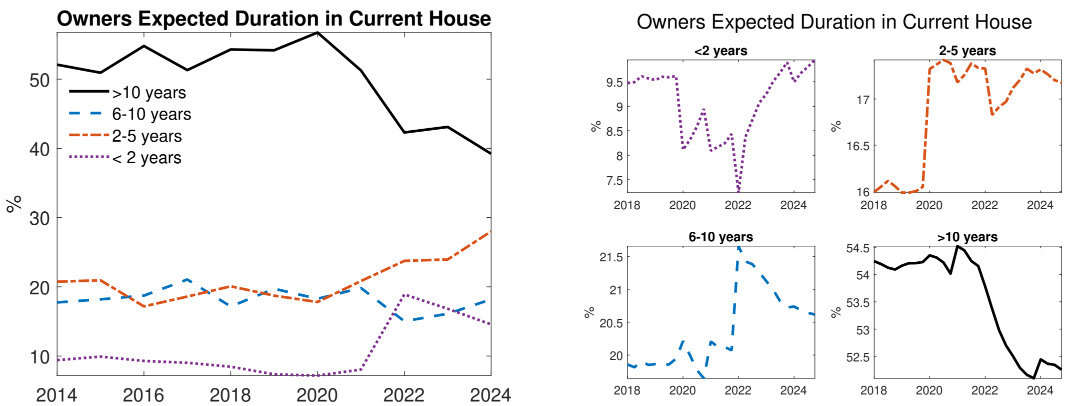
[12]Home tenure expectations are reported annually SCE Housing Survey. This survey takes place in February.

[13]To calculate the expected duration in the model we compute the actually probability of not selling in the time period under consideration, given the expected path of aggregates at time t under each MIT shock simulation.

the expected duration of higher mortgage rates in the model is 8 quarters, the 2-year period captures exactly the duration of the lock-in benefit. Crucially, over time, the share of households expecting to stay in their current houses for longer than 10 years falls substantially. These households are misallocated from their preferred housing size by the financial benefit of their lower current mortgage rates. While the magnitude in the model is not quite as large as in the data, the qualitative dynamics of expected duration align surprisingly well.

FIGURE 13 – Expected duration in current house

(A) Data (B) Model



6.3 Cross country comparison

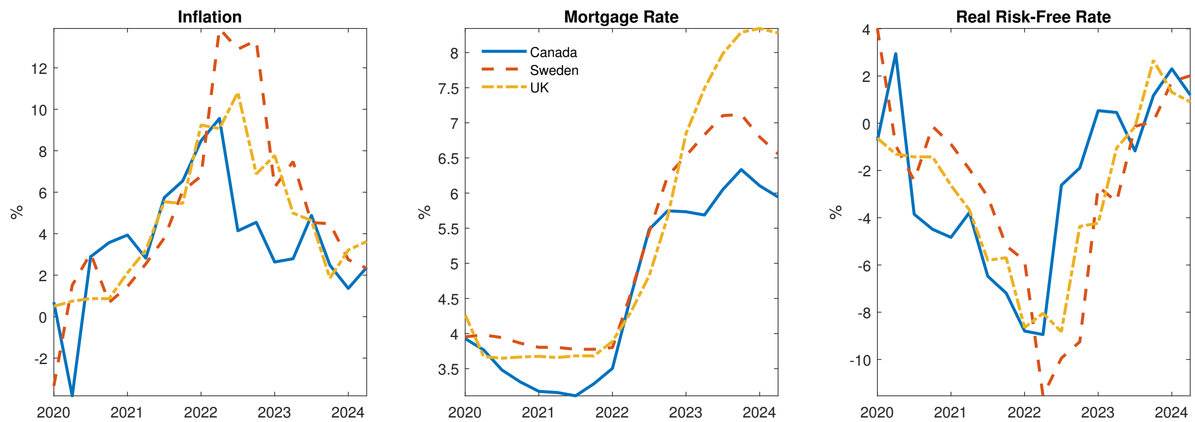
6.3.1 Calibration

We are also interested in how important different mortgage market settings are for explaining cross-country variation in house price dynamics during the Great Inflation.

6.3.2 Shocks

We feed in shocks on a similar basis to those calculated for the US to capture the dynamics of Canada, Sweden and the UK. Relative to the US, inflation peaked in Sweden and the UK a little later and mortgage tightening was also delayed. We try to capture these features and assume all countries experience 8 quarters at the highest rate level. The paths of inflation, mortgage rate and the risk-free rate are shown in Figure x. We also feed in income and transfers. Canada had transfers of a similar magnitude to the US, whereas there was a much lower level of transfers in Sweden and the UK. The European

FIGURE 14 – Cross country shocks



countries income fell by less during 2020, but Sweden has experienced a large real terms decline subsequently. The path of these shocks is presented in the Figure 14.

6.3.3 Model fit

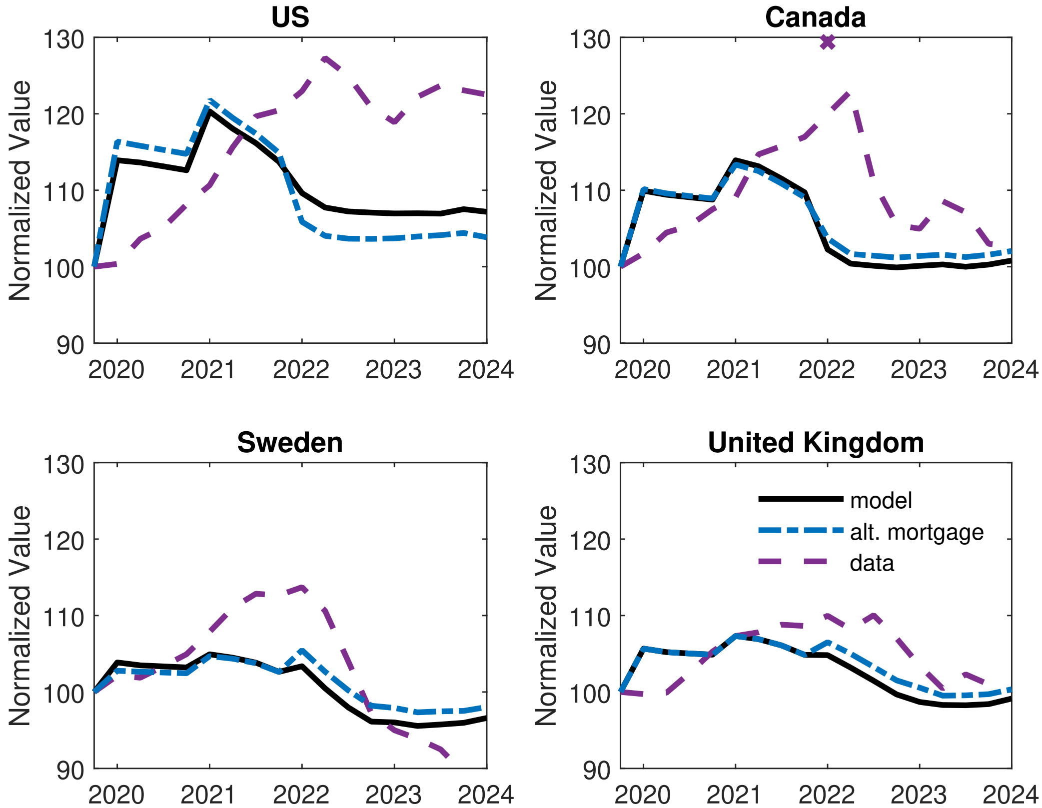
We now compare the path of house prices predicted by the model to that seen in the data. Figure 15 presents the results. The solid line is the baseline model, the dashed line is the data, while the dash-dotted line is the model with an alternative mortgage arrangement. For the US, the data is from the Case-Shiller index. For the other three countries is from the BIS. Overall, the model does a reasonable job of capturing the cross-country dynamics. Focusing on the baseline, in all four countries the model underpredicts the house price boom. However, it does correctly predict the US and Canada to have larger housing booms and for house price to fall to a low level in Sweden post 2022. The most persistence in high house prices in generated in the US, in keeping with the data. Table VI reports summary statistics for the model fit. An important measure is the share of the house price decline the model predicts.[14] In the US the model over predicts the decline, while in the three other comparators the model under predicts the decline relative to the data. On average for Canada, Sweden and the UK the model explains 48 percent of the decline in prices.[15]

The figure also reveals the importance of mortgage arrangements for the cross-country patterns. The "alternative mortgage" series is the ARM for the US and FRM for the other

[14]This is measured as the log difference between the max and minimum, post-peak and pre-2024 in the model and data.

[15]The explained decline is 100-deviation from the data. This is a convenient measure as it can deal symmetrically with over and under explanation.

FIGURE 15 – Cross country comparison of Great Inflation house price dynamics



three countries. Overall it is clear that the sequence of shocks, including the strength of the mortgage rate tightening is more important for understand the variation across countries than the mortgage arrangements per se. The largest difference is seen in the US where FRM do appear to be an important factor for explaining persistently high house prices. However, while the contribution of FRM versus ARM is modest in the other cases, in every country the true mortgage arrangement do move the model closer to the data. In Table VI, we compare deviation from the data for each country for the decline in house prices under the true and alternative mortgage arrangements. The ratio of these gives a measure of the additional explanation provided by the implementing the correct mortgage arrangements. It is positive for all for countries, i.e. a better fit. This ranges from 81 percent in the case of the UK to 8 percent in the case of Sweden. On average the correct mortgage arrangements closes the deviation to the data by 40 percent.

Table VI – Cross country model fit and mortgage contribution

	Boom			Decline					
	Data	Model	Dev	Data	Model		Dev		Mortgage
					base	alt	base	alt	contribution
United States	27.3	20.3	25.6	-6.8	-11.8	-16.1	-72.4	-136.0	46.8
Canada	23.0	13.9	39.4	-18.0	-13.1	-11.4	27.2	37.1	26.5
Sweden	13.7	4.9	64.0	-24.0	-9.4	-8.0	61.1	66.6	8.4
United Kingdom	10.0	7.3	27.1	-9.1	-8.8	-7.6	3.2	17.1	81.4
|Average|	18.5	11.6	39.0	14.5	10.8	10.8	41.0	64.2	40.8

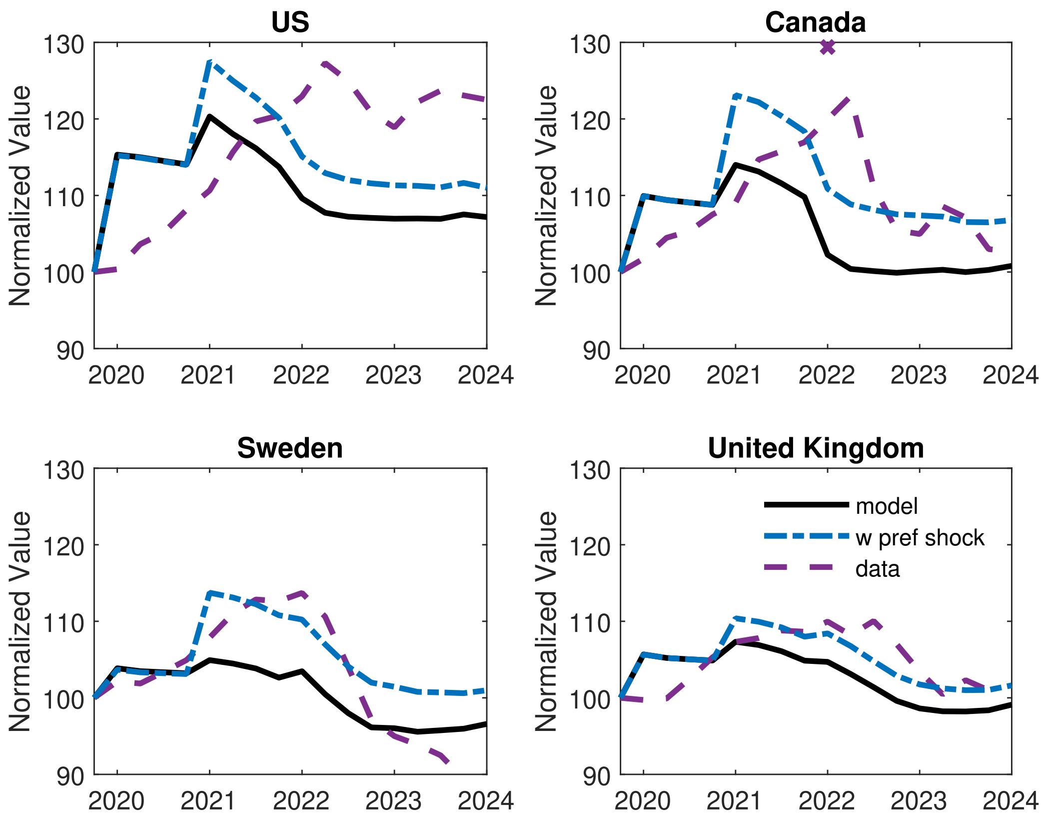
Finally, we introduce a housing preference shock to all four countries. As in the US case, this is chosen to match the maximum increase in house prices, arrives in 2021 and is expected to last for 12 quarters. The results are shown in Figure 16. With the addition of the housing preference shock the model is able to do a very good job of matching the path of house prices for all four countries. It does a particularly good job of capturing the dynamics of Canada and the UK, where the data is match almost perfectly.

6.4 Policy implication: speed of tightening

The mortgage structure of the economy also has implications for the preferred path of interest rates during a monetary tightening. In particular, we consider two policy alternatives: a shorter or longer tightening horizon. The short horizon closely replicates the behavior of the monetary authority in our baseline US experiment, abstracting from other economic shocks that hit the economy in this period. We examine under which mortgage regimes a smaller rate increase with a longer tightening window would be favorable, holding all else equal.

Figure 17 Panel a, presents the paths of the policy variables. Initially, the nominal and mortgage rates are cut. Households expect that, given the monetary policy stance, inflation will soon increase and persist for 8 quarters. After one year (in quarter 5), a new shock arrives. The monetary authority raises rates, and inflation is expected to return to steady state before interest rates also return to their steady state level. In the short policy case, the mortgage rate increases to 6.7 percent for 8 quarters. In the longer tightening experiment, the policy and mortgage rates are held at their higher levels for

Figure 16 – Cross country comparison with housing preference shock



twice as long, but the size of the tightening is less severe. We assume both policies induce the same path of inflation. To calculate the increase in rates required under the longer tightening horizon, we impose an equivalent on-impact effect on inflation as implied by a standard New Keynesian Phillips Curve. We require that for a short rate increase $R_{m,t+i} - R_{m,ss}$, the longer duration increase $\hat{R}_{m,t+i} - R_{m,ss}$ is given by:

$$\hat{\pi}_t = -\sum_{i=1}^{8} \beta^i (R_{m,t+i} - R_{m,ss}) = -\sum_{i=1}^{16} \beta^i (\hat{R}_{m,t+i} - R_{m,ss})$$

The welfare results of these two policies are shown in Panel B. The initial cut in rates raises welfare under both mortgage regimes, as previously demonstrated in Table V. Upon tightening, welfare declines, with a more pronounced decrease in the ARM case. The solid line shows the response under a shorter tightening horizon, while the dashed line represents the longer tightening horizon.

In the ARM case, welfare is relatively unaffected by the choice between the two rate-cutting scenarios. A policy maker would be indifferent between implementing a short or long horizon policy under this mortgage structure. However, under FRMs, a shorter tightening regime is clearly preferred. As shown in the Appendix, under this scenario, house prices fall by less and less persistently, while consumption remains higher. The shorter period of tightening allows constrained households with high Marginal Propensity to Consume (MPC) to avoid the cost of higher rates. Under long tightening, these households are more likely to face the necessity of moving or refinancing. Ex-post, later in the horizon as inflation subsides, the longer horizon can increase welfare as lower house prices allow renters to more easily move into housing. However, these discounted future gains are not large enough to offset the immediate welfare cost of the extended tightening schedule.

7 Conclusion

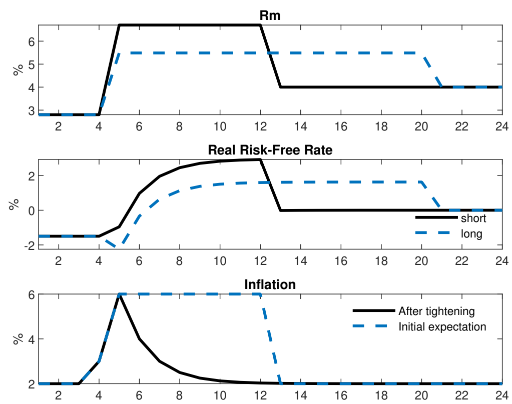
In this paper we study the role of mortgage market structures in shaping economic responses to the unprecedented interest rate and inflation dynamics of 2021-2024. First, we demonstrate that mortgage rate movements during the pandemic era were a significant driver of housing market activity. Our model suggests that 45-60% of the house price boom in the United States can be attributed to mortgage rate cuts earlier in the pandemic. This finding underscores the potent impact of monetary policy on housing markets, particularly in environments of extreme interest rate volatility.

Second, our cross-country analysis reveals that economies dominated by ARMs exhibit greater sensitivity to interest rate changes. This heightened sensitivity helps explain the larger house price busts observed in countries like Sweden and Canada compared to the United States. Furthermore, FRM regimes generate more pronounced path dependence in house prices. The lock-in effect from the low-rate period dampens price declines as rates rise, contributing to the resilience of US house prices in the face of aggressive monetary tightening. This path dependence has important implications for the transmission of monetary policy and the design of optimal policy responses.

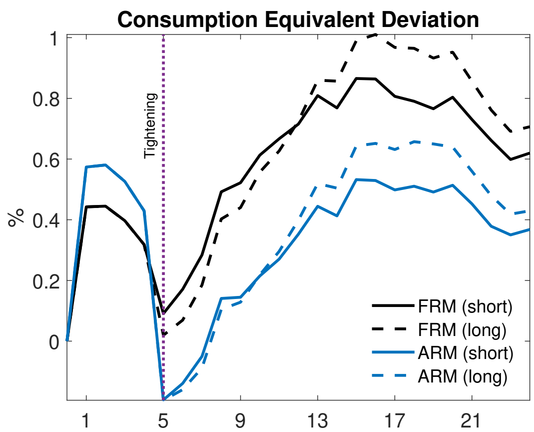
Our results also shed light on the distributional consequences of these dynamics. Low-income homeowners emerged as the largest beneficiaries of the initial low-rate environment, particularly in FRM regimes where these gains persisted even as rates rose. However, renters generally lost out as surging house prices reduced affordability, high-

FIGURE 17 – Policy experiment

(A) Policy path



(B) Welfare



lighting the complex equity implications of monetary policy operating through housing markets.

These findings have significant implications for policymakers. The welfare costs of monetary tightening are generally larger in ARM regimes, as households face more direct pass-through of higher interest rates. Moreover, our analysis suggests that the optimal tightening schedule may differ across mortgage regimes, with FRM-dominant economies potentially benefiting from a strategy of tighter but shorter-duration policy tightening.

While our model captures many key aspects of the recent housing market dynamics, it also points to the importance of other factors. Labor market conditions, shifts in housing preferences, and expectations formation all play roles in explaining the full extent of observed price movements and market activity.

In conclusion, this paper demonstrates the crucial importance of mortgage market structures in determining the transmission of monetary policy and the evolution of housing markets during periods of economic turbulence. As central banks navigate the challenges of inflation and interest rate normalization, a nuanced understanding of these mechanisms will be essential for crafting effective policy responses and managing their distributional impacts. Future research could further explore the implications of these findings for financial stability, optimal mortgage design, and the long-term evolution of housing markets in different institutional contexts.

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A Details of the model

This section presents the technical details that were omitted in the main text.

Value to banks of repossessing a house The value to a lender of repossessing a house of size h is

$$J^t_{REO}(h) = R^t_{REO}(h) - \eta h + \frac{1}{1+r_{t+1}} J^{t+1}_{REO}(h)$$
$$R^t_{REO}(h) = \max\left\{0, \max_{x_s \geq 0} \tilde{p}_t(\theta_t(x_s,h)) \left[(1-\gamma^{REO})x_s - \left(-\eta h + \frac{1}{1+r_{t+1}} J^{t+1}_{REO}(h)\right)\right]\right\} \quad (6)$$

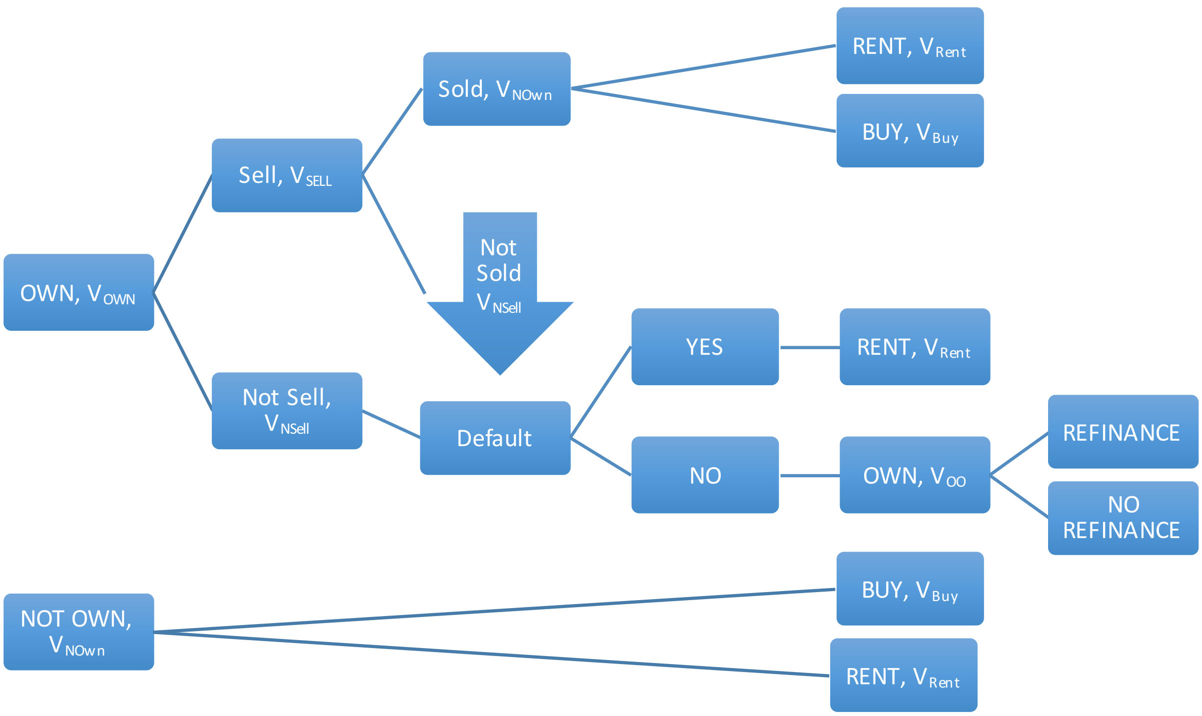
where η is the cost of holding onto the house (maintenance, property taxes, etc.) and $R^t_{REO}(h)$ is the option value of trying to sell the house in period t.

Household's Dynamic Problem Households take the paths of prices $\{P_t, w_t, p^H_t, r_{ht}, r_{mt}, r_t\}_{t\geq 0}$, mortgage price functions $\{q_{mt}(.)\}_{t\geq 0}$, lumpsum transfers $\{T_t\}_{t\geq 0}$ as given. Household dynamic problem can be summarized by the timeline shown in Figure 18.

Value function of a household who owns a house in the beginning of the period and has already decided to keep it in her portfolio involves decisions of consumption, labor supply, bond holdings, refinance, and mortgage debt payment:

$$\begin{aligned}
V^t_{OO}(a_t, M_t, h_t, z_t) &= \max_{M_{t+1}, b_{t+1}, c_t, l_t \geq 0} u(c_t, h_t, l_t) + \beta_L \mathbb{E}\left[V^{t+1}_{own}(a_{t+1}, M_{t+1}, h_{t+1}, z_{t+1})\right] \\
&\text{subject to} \\
P_t c_t + q^B_t b_{t+1} + M_t &\leq a_t + \frac{M_{t+1}}{1+r_{mt}} \text{ if } M_{t+1} \leq (1-\chi)M_t \\
P_t c_t + q^B_t b_{t+1} + M_t &\leq a_t + q^0_{mt} M_{t+1} \text{ if } M_{t+1} > (1-\chi)M_t \\
a_{t+1} &= P_{t+1} w_{t+1} z_{t+1} l_{t+1} + b_{t+1} \\
h_{t+1} &= h_t
\end{aligned}$$

FIGURE 18 – Timeline



Value function of a household who buys a house:

$$\begin{aligned}
V^t_{Buy}(a_t, z_t) &= \max_{h_t, M_{t+1}, b_{t+1}, c_t, l_t \geq 0} u(c_t, h_t, l_t) + \beta_L \mathbb{E}\left[V^{t+1}_{own}(a_{t+1}, M_{t+1}, h_{t+1}, z_{t+1})\right] \\
\text{subject to} & \\
P_t c_t + q^B_t b_{t+1} + p^H_t h_t &\leq a_t + q^0_{mt} M_{t+1} \\
a_{t+1} &= P_{t+1} w_{t+1} z_{t+1} l_{t+1} + b_{t+1}
\end{aligned}$$

Value function of a household who rents:

$$\begin{aligned}
V^t_{Rent}(a_t, z_t) &= \max_{b_{t+1}, s_t, c_t, l_t \geq 0} u(c_t, h_t, l_t) + \beta_L \mathbb{E}\left[V^{t+1}_{NOwn}(a_{t+1}, z_{t+1})\right] \\
\text{subject to} & \\
P_t c + q^B_t b_{t+1} + P_t r_s s_t &\leq a_t \\
s_t &\leq \bar{s} \\
a_{t+1} &= P_{t+1} w_{t+1} z_{t+1} l_{t+1} + b_{t+1}
\end{aligned}$$

Default decision (when household defaults it is always foreclosed and banks do not come after liquid assets of the household):

$$V^t_{NSell}(a_t, M_t, h_t, z_t) = \max_{d_t \in \{0,1\}} d_t(V^t_{Rent}(a_t, z_t) - \chi_f) + (1 - d_t)V^t_{OO}(a_t, M_t, h_t, z_t)$$

Buying decision a household who doesn't own a house (either recently sold or never owned):

$$V^t_{NOwn}(a_t, z_t) = \max_{Buy_t \in \{0,1\}} Buy_t V^t_{Buy}(a_t, z_t) + (1 - Buy_t)V^t_{Rent}(a_t, z_t)$$

Choosing a list price x_s for a household who wants to sell her house:

$$\begin{aligned} V_{SELL}(a_t, M_t, h_t, z_t) &= \max_{x_{st}} -\xi + \tilde{p}_t(\theta_t(x_s, h))V^t_{NOwn}(a_t + x_{st} - M_t, z_t) \\ &+ \tilde{p}_t(\theta_t(x_s, h))V_{NSell}(a_t, M_t, h_t, z_t) \end{aligned}$$

Selling decision of a household which defines V_{OWN}:

$$V_{OWN}(a_t, M_t, h_t, z_t) = \max_{\varsigma_t \in \{0,1\}} \varsigma_t V_{SELL}(a_t, M_t, h_t, z_t) + (1 - \varsigma_t)V_{NSell}(a_t, M_t, h_t, z_t)$$

B Details of the quantitative analysis

Figure 19 – Labor market shocks

(a) Labor market (b) Transfers (c) Disposable income

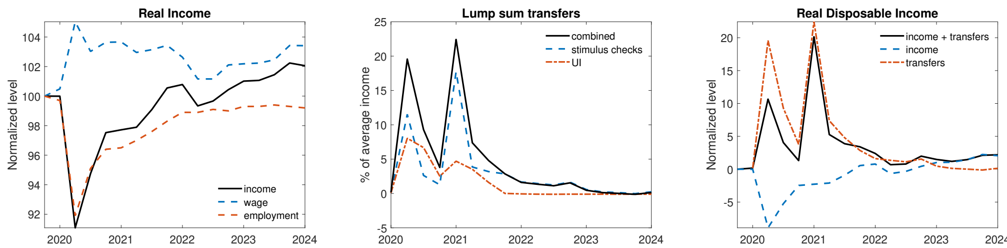


Figure 20 – Policy duration additional figures