# Monetary Policy and Homeownership: Empirical Evidence, Theory, and Policy Implications*

Daniel A. Dias[†] João B. Duarte[‡]

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**Abstract**

We show that monetary policy affects homeownership decisions and argue that this effect is an important and overlooked channel of monetary policy transmission. We first document that monetary policy shocks are a substantial driver of fluctuations in the U.S. homeownership rate and that monetary policy affects households' housing tenure choices. We then develop and calibrate a two-agent New Keynesian model that can replicate the estimated transmission of monetary policy shocks to homeownership rates and housing rents. We find that the calibrated model provides an explanation to the "price puzzle" and delivers two important results with policy implications. First, the homeownership decision channel amplifies the redistributive effects of monetary policy, with contractionary shocks benefiting more outright homeowners and disadvantaging more renters and homeowners with a mortgage. Second, a monetary authority that reacts to a price index that includes housing rents generates excess house price, rents, and output volatility and larger real effects.

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[†]Board of Governors of the Federal Reserve System and CEMAPRE. Email: daniel.dias@frb.gov.

[‡]Nova School of Business and Economics. Email: joao.duarte@novasbe.pt.

# 1 Introduction

*"Like others, I think the recent inflation data are moderately encouraging. I continue to see risks. If you're not satiated with risks, I'll add one more, which is that if the housing market really weakens and people go back to renting, we could get the same phenomenon that we saw last year, by which rents are driven up and we get an effect working through shelter costs. So I agree with those who still view the risk to inflation as being tilted to the upside."*

— Ben Bernanke, *Meeting of the Federal Open Market Committee on August 7, 2007*

Does monetary policy play a role in homeownership decisions? If so, does it matter for the transmission of monetary policy? In this paper we address these two questions by empirically showing that monetary policy affects homeownership decisions and by providing model-based evidence that this is an important channel of transmission of monetary policy.

We first show that monetary policy shocks are an important driver of fluctuations in the homeownership rate and that monetary policy affects households' homeownership decisions. Next, we develop a two-agent New Keynesian model with a segmented housing market in which households choose to rent or buy that matches the empirical evidence. Using a calibrated version of this model, we additionally show that the homeownership decision channel substantially affects the transmission of monetary shocks to house prices, rents, and output and that the transmission of monetary policy through this channel amplifies the redistributive effects of monetary policy.[1]

To measure the relative importance of monetary policy shocks for homeownership fluctuations, we use aggregate U.S. data and estimate a proxy structural vector autoregression (SVAR) and a structural vector moving average (SVMA) identifying the monetary policy shocks with the high-frequency external instruments proposed by Jarociński and Karadi (2020) and Miranda-Agrippino and Ricco (2021).[2] With the SVAR we analyze the dynamics effects of monetary policy shocks on the variables included in the model and also estimate the importance of such shocks for variation of the variable. As in previous work, Dias and Duarte (2019), we find that in response to a contractionary monetary policy shock the homeownership rate falls and housing rents increase while house prices decrease.[3] In addi-

[1]Throughout the paper we use the terms "homeownership decision channel", "homeownership channel", and "housing tenure choice channel" interchangeably, and in all cases we are referring to the additional effects of monetary policy that occur from households choice between renting or owning the home they live in response to unexpected changes in monetary policy.

[2]Both instruments separate the effect on interest rates that is due to pure monetary policy surprises from the effect on interest rates that is due to new information about the Feds view of the economy.

[3]In previous research, Dias and Duarte (2019), we showed that the homeownership rate falls and housing rents increase after a contractionary monetary policy shock, in this paper we expanded on our previous results by showing that they are robust to using a more refined monetary policy instrument and by providing an estimate of the importance of monetary policy shocks for fluctuations in the aggregate homeownership

tion to the SVAR model, we also estimate an SVMA model because it allows us to estimate an upper and a lower bound for the relative importance of the monetary policy shock for homeownership rate dynamics without assuming invertibility of the model, as shown by Plagborg-Møller and Wolf (2021a). Using this methodology, we find that monetary policy shocks are an important driver of fluctuations in the aggregate rate of homeownership in the United States, accounting for as much as 34% of the long-run variation of this variable.

We then resort to the American Housing Survey (AHS) microdata to provide empirical evidence that monetary policy affects homeownership decisions at the household level and that it affects housing supply for rental and ownership. At the household and housing unit levels, we estimate simple logit models in which the dependent variable measures transition from renting to owning or from owning to renting. We find that in response to a 25 basis points contractionary policy shock, the rate of transition from renting to homeownership falls by about 15% and the rate of transition from homeownership to renting increases by 2.1%. At the same time, in response to the same contractionary monetary policy shock, the rate of transition of housing units from rental to ownership declines by 1% and rate of transition of housing units from ownership to rental increases by 3.4%. When looking at the two sides of the housing market, the relative demand for and the relative supply of rental units, we find that the response of the relative supply of rental units to a monetary policy shock is insufficient to meet the change in the relative demand for rental units to the same monetary policy shock.

To account for our empirical findings, we propose a standard two-agent New Keynesian model extended with a homeownership decision margin and adjustment costs on the relative supply of housing for renting *vis-a-vis* owning. These two additional features of the proposed model generate the key mechanism behind the channel of monetary policy transmission that operates through homeownership decisions. This mechanism is as follows. A positive interest rate surprise increases the cost of borrowing to finance a house purchase. A higher cost for purchasing a house incentivizes the marginal borrower to rent instead of owning. From a housing demand perspective, as more borrowers switch to renting, the aggregate demand for renting rises driven through this extensive margin adjustment. At the same time, from a housing supply perspective, landlords observing higher rents respond by investing in housing stock for renting. However, because of adjustment costs, the supply of rental housing responds less than proportionally to the increase in demand for renting. As a consequence, housing rents may increase in equilibrium. One feature of this model is that it can generate a temporary increase in measures of inflation like the consumer price index (CPI) or personal consumption expenditures (PCE) price index fol-

rate.

lowing a contractionary monetary policy shock, a result that is known in the literature as the "price puzzle" (Sims (1992)). This temporary increase of the CPI or PCE occurs when the increase in rents due to a contractionary monetary shock is large enough to offset the decline in the price of the other goods and services included in these measures of inflation.

We calibrate the model to match a set of data moments related to long-run dynamics. We then evaluate the model by comparing its impulse response functions to the untargeted empirical counterpart obtained from the proxy SVAR and find that the calibrated model matches well the empirical results concerning the monetary transmission to the selected variables. We additionally show that for the model to match the empirical findings it must both have a housing tenure choice margin and a segmented housing market. Without one of these two features, the response of housing rents would be the opposite of what we find in the data.

The calibrated model is then used to show that the new homeownership channel of monetary policy transmission we uncover in this paper has important implications for monetary policy. We find that monetary policy shocks generate redistribution between homeowners with a mortgage and renters by affecting the price-to-rent ratio. We also find that borrowers (homeowners with a mortgage and renters) are worse-off when facing contractionary monetary policy shocks relative to savers (outright homeowners and landlords). The reason is that borrowers face increased costs to finance a house purchase and higher rents, and savers, by owning the housing stock for renting, benefit from higher house rents revenue. The existence of redistributive effects between savers and borrowers from monetary policy is well known, but we show in the paper that these effects are amplified by the homeownership channel of monetary policy. As such, a monetary authority that wishes to balance its goals of price stability and maximum employment with social welfare should take the results in this paper in consideration when setting monetary policy.

Moreover, we find that the homeownership channel of transmission of monetary policy has implications for how central banks respond to measured inflation. Namely, we find that a monetary authority that reacts to price indexes that include housing rents, such as the consumer price index (CPI) or the personal consumption expenditures index (PCE), generates more house price, rents, and output volatility and larger real effects than a monetary authority that targets a measure of inflation without housing costs. Because the response of housing rents to monetary policy shocks goes in the opposite direction of all other nominal final goods prices, the CPI (or the PCE) falls less than actual inflation. By using the CPI (or the PCE) as a measure of inflation, the interest rate adjustment towards the steady state is slower than otherwise would need to be if the monetary authority were responding to measures of inflation that exclude rents/shelter. This happens because the monetary authority needs to be more aggressive to push down the apparently more persistent inflation when measured by the CPI. Hence, targeting the CPI leads to higher volatility in the economy and larger output losses than when the monetary authority targets inflation measures that exclude housing costs.

The rest of the paper is organized as follows: in section 2 we discuss our results in light of existing literature and how we contribute to it; in section 3 we provide empirical evidence on the effect of monetary policy on the level of aggregate homeownership and on the effect of monetary policy on the decision to own or rent; in section 4 we present a model that can account for the main empirical patterns shown in section 3; in section 5 we describe the calibration of the model and compare the results obtained with the model with the empirical results obtained in 3; in section 6 we present the results on interest rate transmission, on the redistributive implications, and the consequences for monetary policy; in section 7 we provide some concluding remarks.

# 2 Related Literature and Contribution

The paper contributes to three large strands of the literature: the literature on monetary policy transmission, the literature on housing and macroeconomics, and the literature on the determinants of housing tenure choices. We contribute to the literature on monetary policy transmission by introducing and studying a new channel of monetary policy - the homeownership decision channel of monetary policy.[4] The literature on channels of transmission of monetary policy is extensive and very dynamic, with new channels being frequently identified. As summarized in Mishkin (1996), the more *traditional* channels of monetary policy include the interest rate channel, the exchange rate channel, the equity price channel, and the credit channel. More recently, however, new channels have been identified. Examples of these more *novel* channels of monetary policy are the risk-taking channel (examples of papers discussing this channel include Jiménez et al. (2014), Bruno and Shin (2015), and Morais et al. (2019)), the deposits channel (Drechsler et al. (2017)), and the floating rate channel (examples of papers discussing this channel include Garriga et al. (2017), Ippolito et al. (2018)).

There has also been recent work linking monetary policy transmission to features of the housing market, and our paper is mainly related to this area of the literature. For instance, using the Euro Area area as a lab, Corsetti et al. (2021) shows that the strength of monetary transmission strongly correlates with the country's homeownership rate and the

[4]As in Bernanke and Gertler (1995), we think of a transmission channel of monetary policy as being *a set of factors and institutional features of the economy that amplify and propagate conventional interest rate effects*.

fraction of adjustable rate mortgage contracts. Using U.S. data, Beraja et al. (2019) and Eichenbaum et al. (2022) note that the effect of monetary policy in the economy through the refinancing of mortgages, which usually results in mortgage payment savings for borrowers, depends on the distribution of savings in the economy and how much people can save in total by refinancing. The results in these two papers imply that monetary policy is path-dependent, meaning that the effect of today's monetary policy shocks may depend on the history of these shocks. Another implication of these two papers is that the effect of monetary policy through the mortgage refinancing channel is heterogeneous and time-varying, with the potential gains from refinancing varying across agents and over time. Hedlund et al. (2017) model the joint distribution of housing and mortgage debt in the context of a heterogeneous New Keynesian model to study how monetary policy shocks transmit through the housing market. Their main results are that housing prices are relevant for aggregate consumption dynamics. Monetary policy has asymmetric effects on economic activity, with responses to contractionary shocks being stronger than expansionary monetary policy shocks, and that monetary policy is more effective in a high-loan-to-value environment.

In a more empirical contribution, Cloyne et al. (2019) shows that monetary policy transmission at the household level depends on the housing tenure status of the household, with the critical difference coming from the effects on consumption of outright homeowners (those without any mortgage) and of homeowners with a mortgage or renters. We contribute to this literature by showing that monetary policy affects households' tenure choice decisions and that frictions in housing supply for ownership and renting affect the relative price of houses and rents. We show that when monetary policy loosens (tightens), more (less) households move from renting to owning and that fewer (more) households move from owning to renting. This result is consistent with the aggregate homeownership rate increasing (decreasing) after an expansionary (contractionary) monetary policy shock, as shown in previous work (Dias and Duarte (2019)) and confirmed again in the current paper. One consequence of these effects on house prices and rents is that shelter-related expenses, either mortgage payments or rents, change for some households, affecting the income available for consumption of non-shelter goods or services. One noteworthy difference in our work relative to that of Cloyne et al. (2019) is that we that find housing rents increase in response to a contractionary monetary policy shock, while they find that housing rents fall. A possible explanation for this different finding most probably stems from the different datasets used. While they use microdata at the household level, we use aggregate data. This paper focuses on aggregate housing rents because they constitute a significant component of CPI, thus affecting inflation dynamics.

We also contribute to the literature on housing and macroeconomics by proposing a model that allows studying the implications of changes in the aggregate level of homeownership for business cycle dynamics. The literature on housing and macroeconomics is also extensive, covering many aspects of how housing interacts with the overall macroeconomy. An excellent summary of this literature is that of Piazzesi and Schneider (2016). Within this literature, our paper is closest to Iacoviello (2005) and Iacoviello and Neri (2010), but with a key difference in how the supply of housing for renting and for ownership is modeled. In terms of the modeling choices we make, our approach is similar to contemporary and separate work by Greenwald (2018).[5] While Greenwald (2018) focuses on how the structure of the mortgage market influences the propagation of macroeconomic shocks, whereas we are primarily interested in how monetary policy propagates through its effects on housing tenure decisions. Unlike most of the literature on housing and macroeconomics, in our paper we consider a segmented housing market where transaction costs and nominal rigidities prevent the supply of housing for rental and ownership from quickly adjusting to changes in demand.[6] With a segmented housing market, the price of houses in the short run can be different from the discounted value of rents, which means that there may be fluctuations in the house price-to-rent ratio.

In addition to the modeling contribution, we also contribute to the literature on housing and macroeconomics by providing estimates of the importance of monetary policy shocks for fluctuations in the homeownership rate. Using the methodology of Plagborg-Møller and Wolf (2021a), we estimate that monetary policy shocks can account for as much as 34% of the long-run variation in the homeownership rate. To put this value in perspective, Plagborg-Møller and Wolf (2021a) estimate that monetary policy shocks account for close to 0% of the variation in consumer price growth. Our application estimates that monetary policy shocks can account for at most 30% of the variation of consumer price growth, but this result depends on the monetary policy instrument used. Using the Miranda-Agrippino and Ricco (2021) instrument, we find much lower importance of monetary policy shocks for consumer price growth variation, which is more in line with the results in Plagborg-Møller and Wolf (2021a). As such, our results show that monetary policy is likely to be at

[5]To generate a distribution of homeowners and renters, we also embed the household heterogeneity in a single family using the assumption of market completeness within the family. This simplifying assumption was first suggested by Ragot (2018).

[6]One paper that also allows for a segmented housing is Sommer et al. (2013). In this paper, the authors carefully model the U.S. housing market to study the effects of fundamentals on house prices and rents. Sommer et al. (2013)' model is richer than ours, but this higher richness comes at the cost of not being as tractable as ours and therefore either impossible or very difficult to use for the analysis of business cycle dynamics. Another paper that shows how segmented housing markets affect housing price dynamics is Greenwald and Guren (2021).

least as important for fluctuations in the aggregate homeownership rate as it is for the rate of inflation.

We also contribute to the literature on the determinants of housing tenure arrangements by providing evidence that monetary policy is one driver of the choice between owning or renting a home. This literature focuses typically on structural factors such as tax regimes or life-cycle motives as forces driving the choice between owning or renting - see for example Henderson and Ioannides (1983) or Weiss (1978). We contribute to this literature by providing a factor that can explain fluctuations in the timing of housing tenure decisions (for example, why specific cohorts of the population transitioned from renting to ownership earlier/later than other cohorts) but also provides a source of fluctuations in rents, which, as shown in Sinai and Souleles (2005), can be an essential factor for households choosing to own instead of renting.

Finally, the model we propose provides an explanation for the "price puzzle" (Sims (1992)) through the effect of monetary policy on housing rents. Namely, with rents moving in the same direction of interest rates, and because the shelter component of the consumer price index (or personal consumption expenditures index) is almost entirely based on the price of rents (directly through the cost of rental housing or indirectly through the way rents from the rental market are used to calculate the owner's equivalent rent), it is possible to see in the short run a rise (decline) in consumer prices when interest rates rise (decline). As such, for some parameterizations of the model, the rise in housing rents following a contractionary monetary policy shock can be sufficiently high to offset the decline in the prices of other goods or services. In such a case, the aggregate consumer price index (not inflation as defined in the model) may rise in response to a contractionary monetary policy shock (i.e., the "price puzzle").

# 3 Empirical Evidence of the Effect of Monetary Policy on the Aggregate Homeownership Rate and on Housing Tenure Decisions

In this section, we use U.S. aggregate-, household-, and housing-unit-level data to study the effects of monetary policy on the homeownership rate and on households' and housing unit owners' housing tenure choice decisions.

## 3.1 Monetary Policy and the Homeownership Rate - Evidence from Aggregate U.S. data

We use U.S. aggregate data to analyze how monetary policy affects the aggregate homeownership rate in the U.S. economy and how important it is for this variable and also to study the dynamic effects of monetary policy shocks on several macroeconomic variables. This analysis takes the results in Dias and Duarte (2019) as the starting point and expands on them. We first introduce the relevant methodologies and then present and discuss the results.

### 3.1.1 Methodology

To identify the effects of monetary policy on the variables of interest, we use a proxy SVAR model and an SVMA model with instrumental variables. This part first discusses the monetary policy instrument we use and then presents the two econometric methodologies used.

**Instruments.** To identify the effect of monetary policy on key variables of interest, we use two high-frequency monetary policy instruments. The first one is the instrument developed by Jarociński and Karadi (2020) and the second one is the instrument constructed by Miranda-Agrippino and Ricco (2021).

Unlike previous high-frequency monetary policy instruments, both of these instruments separate the effect on interest rates due to pure monetary policy surprises from the effect on interest rates that is due to new information about the Fed's view of the economy. To separate the monetary news from economic outlook news embedded in the Fed's communications, Jarociński and Karadi (2020) simultaneously look at high-frequency movements in interest rates and equity prices during a narrow window of time (10 minutes before and 20 minutes after the communication) around the Fed's policy announcement. These authors' idea is that news about monetary policy and news about the state of the economy have distinct effects on interest rates and equity prices. While a pure monetary shock has a negative correlation with equity prices – when monetary policy loosens, *ceteris paribus*, equity prices rise, and vice-versa –, information about the economy shock makes interest rates and equity prices move in the same direction – when interest rates fall because the Fed perceives a negative economic outlook, equity prices are also expected to decline because equity prices are supposed to reflect future profits which correlate positively with the performance of the economy, and vice versa. With a similar objective to that of Jarociński and Karadi (2020), but using a different approach, the instrument proposed by Miranda-Agrippino and Ricco (2021) instead isolates the pure monetary surprises from the information channel by projecting market-based monetary surprises around policy announcements on their lags and on the central banks' information set formed by the Greenbook forecasts.

These two monetary policy instruments are widely used in the macroeconomics literature, and, therefore, we do not expand much on the details of the two instruments' construction. The reader interested in the details underlying the construction and justification for the validity of these instruments can find this information in Jarociński and Karadi (2020) and in Miranda-Agrippino and Ricco (2021). However, it is helpful to formally define the external instruments, as the definition will be useful for discussing the econometric methodologies used.

For a variable $Z_t$ to be a valid instrument, it must simultaneously meet the relevance and exogeneity conditions:

1. **Relevance**: $E[\epsilon_{i,t} Z_t] \neq 0$
2. **Exogeneity**: $E[\epsilon_{j,t} Z_t] = 0 \ \forall \ i \neq j$

Additionally, it is also useful to express the instrument as a (linear) function of the structural shock and measurement error, as done in Plagborg-Møller and Wolf (2021a):

$$Z_t = \alpha \epsilon_{i,t} + \sigma_v \nu_t \tag{1}$$

With $\alpha \neq 0$, $\sigma_v \geq 0$, and $\nu_t$ a white noise random variable. The expression in equation 1 will be particular relevant for the discussion of the forecast variance decomposition methodology.

**Proxy SVAR Model.** We use a proxy SVAR model to study the dynamic effects of a monetary policy shock on the variables of interest. An SVAR model for $Y_t$, an $n \times 1$ vector of observable time series variables, with $p$ lags can be written as:

$$Y_t = A_0 + A_1 Y_{t-1} + A_2 Y_{t-2} + ... + A_p Y_{t-p} + H\varepsilon_t. \tag{2}$$

This expression can be re-written in a more succinct way by using the lag-operator notation:

$$A(L)Y_t = H\varepsilon_t, \tag{3}$$

In equation 3, $A(L) = I_n - \sum_{l=0}^{p} A_l(L^l)$ and each matrix $A_l(L^l)$, for $l \geq 1$, is an $n \times n$ matrix of coefficients associated with lag $l$, $H$ is an $n \times n$ matrix of impact coefficients, and

$\varepsilon_t$ is a vector of $n$ structural shocks. This equation characterizes all the dynamics of the variables in the model. As usual, the structural shocks are assumed to have a linear effect on the variables included in the model and to be uncorrelated at all leads and lags.

Our goal is to separate the effects of monetary policy shocks on the variables $Y_t$ in the model while controlling for any possible policy/feedback rule and other co-movements in the data. The elements in matrix $H$ are the contemporaneous effect of a change in the structural shock associated with that matrix element. For example, column $j$ of matrix $H$ corresponds to the contemporaneous effect of structural shock $j$ on each variable included in the vector $Y_t$. For ease of notation, as in Stock and Watson (2012), we assume that the monetary policy shock corresponds to the first column of $H$, and we denote it as $H_1$.

Given the definitions above, we can re-write the model in its structural vector moving average formulation:

$$Y_t = A(L)^{-1} H \varepsilon_t \tag{4}$$

Following equation 4, the impulse response function (IRF) of $Y_t$ to a monetary policy shock is given by

$$Y_t = A(L)^{-1} H_1 \tag{5}$$

All the parameters in $A(L)$ can be obtained by estimating equation 2 by ordinary least squares (OLS). Note that matrix $H$ is not directly estimable by OLS, and with OLS, we can only estimate the reduced form innovations $\eta_t = H\varepsilon_t$. To identify the monetary policy shocks that are included in $\eta_t$, we use the external instrument based on high-frequency identification of shocks approach as in Gertler and Karadi (2015) (with the obvious difference that we use the more refined monetary policy instruments of Jarociński and Karadi (2020) and Miranda-Agrippino and Ricco (2021)), which combines the external instrument approach to identification of structural shocks as in Stock and Watson (2012) and Mertens and Ravn (2013) with high frequency event studies around monetary policy announcements as in Kuttner (2001), Gurkaynak et al. (2005), Hamilton (2008), and Campbell et al. (2012). This approach will provide us with an estimate of the parameters in $H_1$, which we then use to identify the monetary policy shocks and the corresponding IRFs of all the variables in $Y_t$ to a monetary policy shock. All the details on the exact procedure can be found in Gertler and Karadi (2015).

**Dynamic Variance Decomposition Using SVMA Models with Instrumental Variables.** To understand the relative importance of different structural shocks for the dynamics of a variable of interest, we could have just used the same proxy SVAR model that we just discussed to compute the forecast error variance decomposition. However, as argued in Plagborg-Møller and Wolf (2021a), the results based on this approach would be highly dependent on certain assumptions, such as invertibility of the model. The forecast variance decomposition methodology proposed by Plagborg-Møller and Wolf (2021a) allows us to estimate bounds for the importance of monetary policy shocks on variables of interest without having to make many assumptions on the underlying economic model.

Plagborg-Møller and Wolf (2021a)'s approach to measure the relative importance of a structural shock for the dynamics of a particular macroeconomic variable is intuitively simple but difficult to present in a concise manner. Therefore, we only present the main ideas behind the method and refer the reader to the original paper for a more detailed exposition of the methodology and its implementation.

As a starting point, and for simplicity of exposition, following the exposure of the methodology in Plagborg-Møller and Wolf (2021a), we follow Plagborg-Møller and Wolf (2021a) and assume that SVMA representation of equation 4 has no dynamics and expand it by separating the structural shock $\epsilon_{1,t}$ from the other structural shocks.

$$Y_t = \Theta_{\cdot,1,0}\varepsilon_{1,t} + \sum_{j=2}^{n_\epsilon} \Theta_{\cdot,j,0}\varepsilon_{j,t} \tag{6}$$

Based on the expression in 6, the forecast variance ratio can be written as:

$$FVR_{i,0} = 1 - \frac{Var[Y_{i,t}|\epsilon_{1,t}]}{Var[Y_{i,t}]} = \frac{\Theta^2_{i,1,0}}{Var[Y_{i,t}]} \tag{7}$$

The expression for $FVR_{i,0,}$ can be re-written as a function of the instrument $Z_t$ (defined in equation 1):

$$FVR_{i,0} = \frac{1}{\alpha^2}\frac{Cov[Y_{i,t}, Z_t]^2}{Var[Y_{i,t}]} \tag{8}$$

While equation 8 provides an exact expression for the forecast variance ratio based on the observed instrument, because the estimation of $\alpha$ is infeasible, it is impossible to provide a point estimate of the forecast variance ratio. Plagborg-Møller and Wolf (2021a)'s key contribution is to show that, under the assumption that a valid instrument for the shock of interest exists and that it is possible to express the variables $Y_t$ as in 6, it is possible to construct informative bounds on the true forecast variance ratio.

To arrive at the lower bound for the true forecast error variance ratio, Plagborg-Møller and Wolf (2021a) note that $\alpha^2 \leq Var(Z_t) = \alpha^2 + \sigma_v^2$. This inequality implies that the quality of the instrument, measured by the signal-to-noise ratio $\frac{\alpha^2}{\sigma_v^2}$, will determine how tight or wide the lower bound for the true forecast variance ratio is. It is easy to see that $\alpha^{-2} \geq$

$(Var(Z_t) = \alpha^2 + \sigma_v^2)^{-1}$, and if $\sigma_v = 0$ (case of a perfect instrument) , then this lower bound exactly estimates $\alpha$, whereas if $\sigma_v$ is very large, the signal-to-noise ratio becomes very small pushing the lower bound of forecast variance ratio towards zero.

To derive the upper bound for the true forecast error variance ratio, Plagborg-Møller and Wolf (2021a) make the point that, the most that the variables included in $Y_t$ can explain of $Z_t$ (in the sense of a linear projection) is bounded above by what the structural shock $\epsilon_{1,t}$ can explain of the instrument $Z_t$ (this is a theoretical upper bound as the structural shock is not observed). That is, the explained sum of squares of a linear projection of $\epsilon_{1,t}$ on $Z_t$ is exactly $\alpha^2$, and, any linear projection of $Y_t$ on $\epsilon_{1,t}$ will be at most as high as $\alpha^2$. More formally, this means that $Var\{E[Z_t|Y_t]\} \leq \alpha^2$, and, consequently, $\alpha^{-2} \leq Var\{E[Z_t|Y_t]\}^{-1}$. When the model is invertible, that is, when the variables in $Y_t$ perfectly span the structural shocks, then the inequality binds and $\alpha^{-2} = Var\{E[Z_t|Y_t]\}^{-1}$.

Plagborg-Møller and Wolf (2021a) expand on these insights to derive upper and lower bounds for a more general case, which allows for rich dynamics of the variables. In the empirical application, we use the more general formulation of the interval estimation for the forecast variance ratios (and the corresponding confidence intervals).

#### 3.1.2 Results and Discussion

Having presented the most relevant aspects of the methodologies we use, we now turn to the results. In Figure 1, we show the estimated impulse response functions of the variables included in the VAR model – the federal funds rate, house rents, excess bond premium, the homeownership rate, house prices, consumer prices measured by the CPI, and GDP – to a 25 bps contractionary monetary policy shock. The federal funds rate, the excess bond premium, and the homeownership rate are expressed in levels, while the CPI, GDP, house prices, and house rents are expressed in log differences. For the variables expressed in levels, the results in Figure 1 are the non-cumulative impulse response functions, whereas for the variables expressed in log-differences, the results in the same Figure correspond to the cumulative impulse response functions. The results in this Figure are not new as we had obtained very similar results in previous work (Dias and Duarte (2019)). However, it is reassuring to see that the results are robust to using new monetary policy instruments – those proposed by Jarociński and Karadi (2020) and by Miranda-Agrippino and Ricco (2021) – that account for the information about the economy contained in monetary policy announcements relative to results based the instrument of Gertler and Karadi (2015) (which does not separate the pure monetary policy channel from the information channel of monetary policy). It is also reassuring to see that, as shown in Figure 1 the two monetary policy instruments yield qualitatively and quantitatively similar results.[7] Because the focus of the paper is on the effects of monetary policy on homeownership and housing tenure choices, and the results for the other variables are standard in the literature, we focus the discussion of the results that pertain to the effect of monetary policy on the homeownership rate, house rents, and house prices. As we had found in previous work, when the Fed unexpectedly tightens monetary policy, the homeownership rate declines and stays persistently lower for several years. At the same time, housing rents initially increase before adjusting down after some years. As for house prices, as shown previously, these decline after the monetary authority tightens its monetary policy. Altogether, we interpret these three results as evidence that monetary policy affects housing tenure choice decisions by affecting the relative cost of ownership relative to renting – in the following subsection, we use household- and housing unit-level data to test this hypothesis more formally.

For the other variables included in the model – the federal funds rate, the excess bond premium, GDP growth, and the growth rate of the consumer price index – our results are in line with those in the literature. In the case of the growth rate of the consumer price index, albeit with a lower magnitude in the case of the Miranda-Agrippino and Ricco (2021) instrument, the estimated impulse response functions show an initial increase in prices in response to a monetary policy shock (i.e., "price puzzle"). However, we are not too concerned with this result because, as discussed in Ramey (2016), small differences in the sample and identification can give rise to differences in the initial response of the consumer price index to monetary policy shocks.

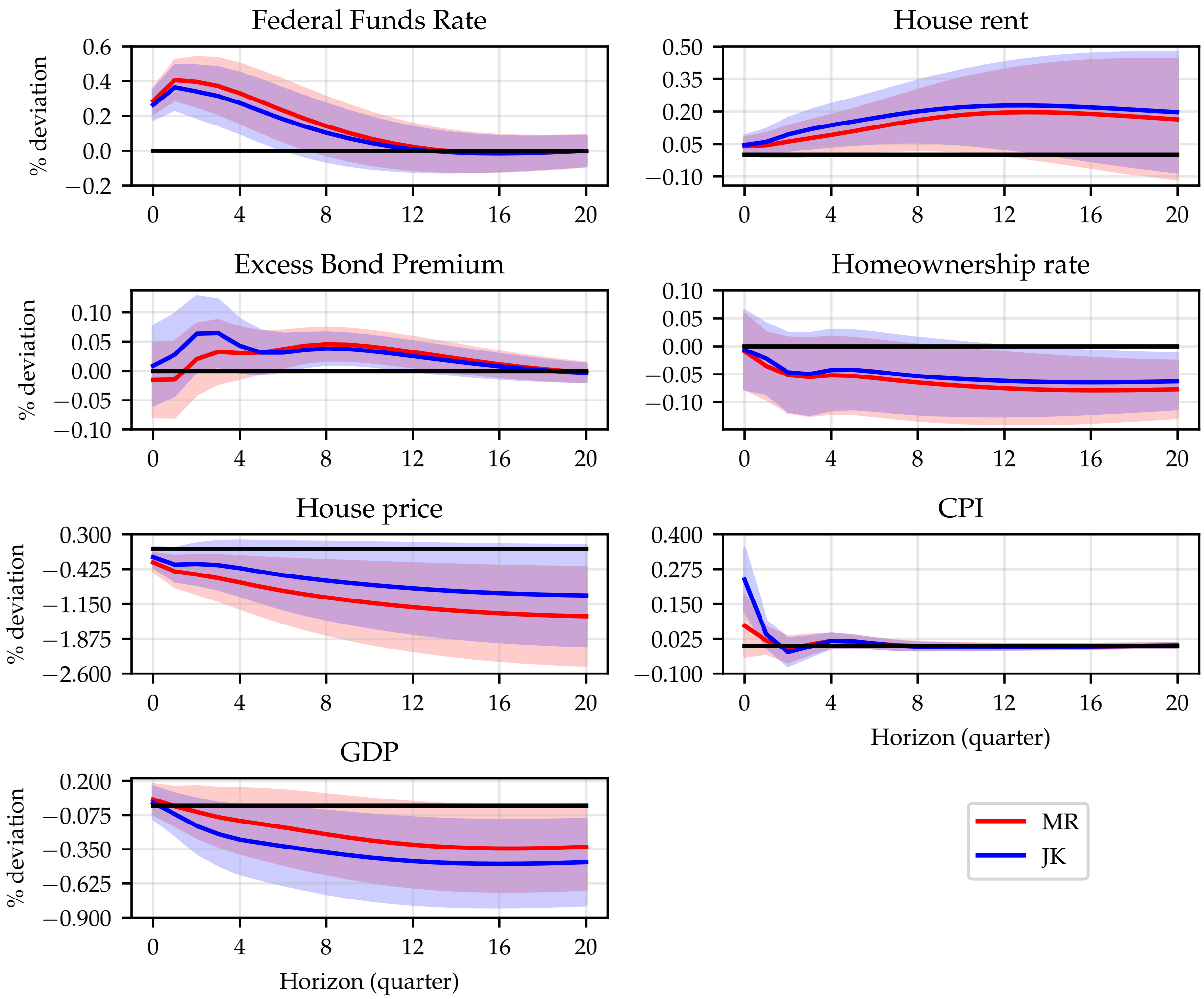
While Figure 1 shows that the homeownership rate, house prices, and housing rents respond strongly to monetary policy shocks, it is also important to know how much monetary policy shocks contribute to the variation in these variables. To answer this question, we use the dynamic variance decomposition methodology of Plagborg-Møller and Wolf (2021a) that we summarized earlier. The results of this decomposition are shown in Figure 2.[8]

We estimate that monetary policy shocks are an important driver of fluctuations in house prices and rents. In the short-run (in the first 1.5 years after the shock), monetary pol-

[7] In Appendix C we show results based on local projections using a proxy VAR model to identify the structural shocks. As expected, given the results of Plagborg-Møller and Wolf (2021b), showing the asymptotic equivalence between LP regressions and VAR models, the two methodologies yield very similar quantitative and qualitative results. Also, as observed with the VAR methodology, the results do not depend on the instrument used.

[8] In Appendix C we show the forecast error variance decomposition results based on the proxy VAR model that we used to obtain the impulse response functions shown in Figure 1. Overall, the two methodologies yield similar results.

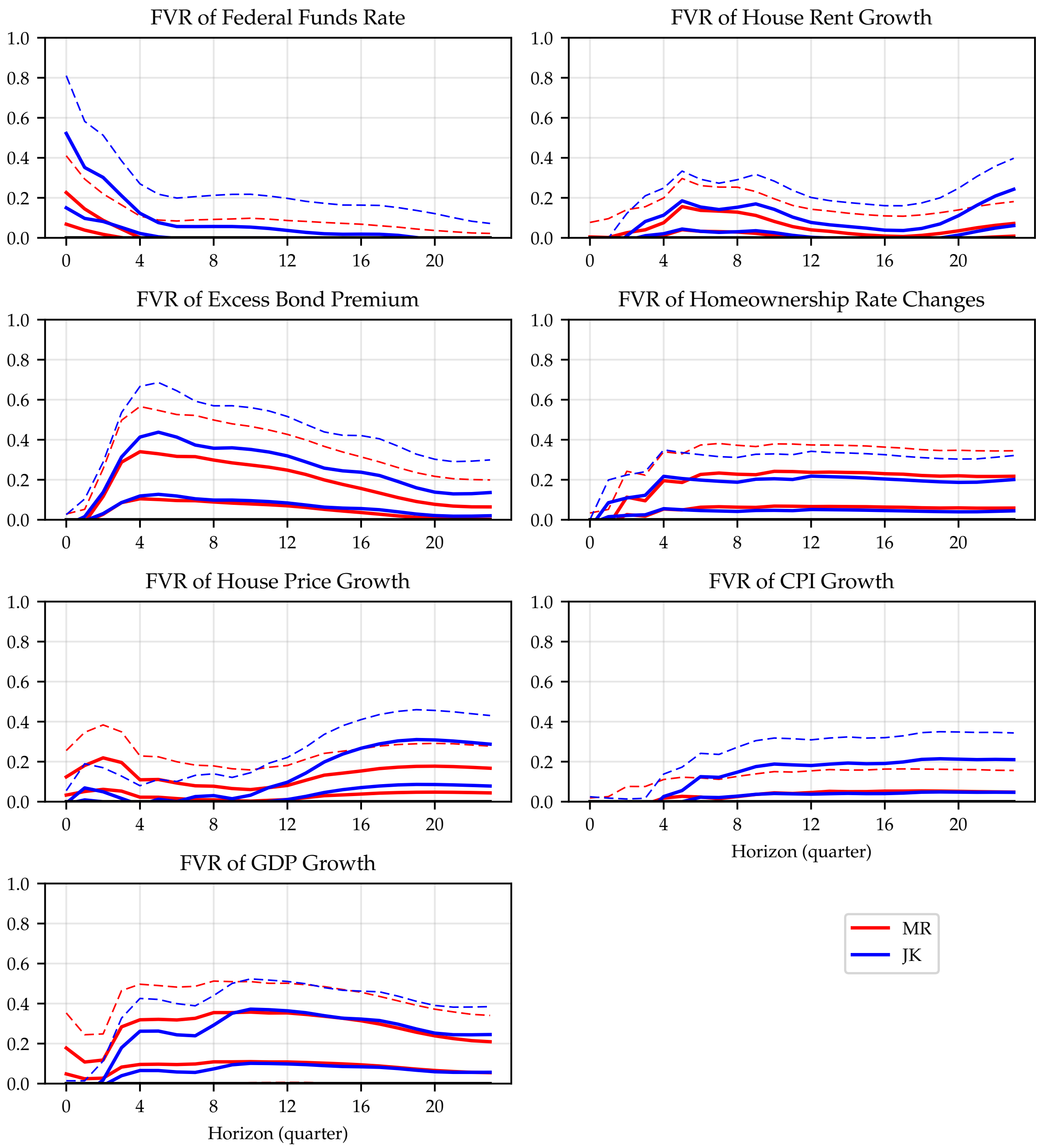
**Figure 1:** Impulse Response Functions of Select Macroeconomic Variables to a 25 bps Monetary Policy Shock




Note: The Figure shows the estimated impulse responses of the different variables included in the analysis to a 25 bps contractionary monetary policy shock. The results in the Figure are based on the proxy-SVAR methodology described in section 3, using the two alternative monetary policy instruments, that of Miranda-Agrippino and Ricco (2021) (in red) and that of Jarociński and Karadi (2020) (in blue), which were also described in the same section. Both instruments isolate the pure monetary surprises from the information content present in the Fed's communications. The solid lines are the impulse-response function point estimates, while the shaded areas are the 68% confidence intervals. The confidence intervals were computed from 1,000 draws using a parametric bootstrap as proposed in Stock and Watson (2018).

icy shocks can explain up to 40 percent of variations in rents, whereas in the medium-run (after 1.5 years), monetary policy shocks can explain as much as 43 percent of fluctuations in house prices. As for the homeownership rate, we estimate that monetary policy shocks can account for as much as 34 percent. This result is significant because the homeown-

**Figure 2:** Contribution of U.S. Monetary Policy Shocks to the Dynamic Variance of Select Macroeconomic Variables




Note: the Figure shows the forecast variance ratio of the different variables included in the analysis to a U.S. monetary policy shock based on the dynamic variance decomposition methodology of Plagborg-Møller and Wolf (2021a). The results are based in two alternative monetary policy instruments, that of Miranda-Agrippino and Ricco (2021) (in red) and that of Jarociński and Karadi (2020) (in blue). Both instruments isolate the pure monetary surprises from the information content present in the Fed's communications. The solid lines report the point estimates and the dashed lines the 90% confidence intervals for the identified sets of forecast variance across different variables and forecast horizons. The confidence intervals were computed from 1,000 draws using a bootstrap procedure as proposed in Kilian and Lütkepohl (2017).

ership rate tends to be a relatively slow-moving variable which is, as our results suggest, highly influenced by monetary policy shocks.

The results for the excess bond premium are the same as those found by Plagborg-Møller and Wolf (2021a). For GDP, we estimate that monetary policy shocks can be responsible for as much as 39 percent of the fluctuations in the rate of GDP growth - Plagborg-Møller and Wolf (2021a) obtained a similar result for industrial production. Unlike what Plagborg-Møller and Wolf (2021a) found for the rate of growth of the CPI when using the Jarociński and Karadi (2020) monetary policy shocks instrument, we estimate that monetary policy shocks can account for as high as 34 percent of fluctuation in the rate of growth of the CPI. However, when using the Miranda-Agrippino and Ricco (2021) monetary policy shock instrument, we estimate that monetary policy accounts for less than 15 percent of fluctuations in the rate of growth of the CPI, a result that is much more similar to the findings of Plagborg-Møller and Wolf (2021a). The fed funds rate is another variable for which we found substantial differences in results depending on the monetary policy instrument used. In particular, while based on the Jarociński and Karadi (2020) instrument, monetary policy shocks can explain close to 80 percent of the fed funds rate variation in the short run, based on the Miranda-Agrippino and Ricco (2021) instrument, monetary policy shocks are at most responsible for 40 percent of the variation in the fed funds rate in the short run. While understanding what may be driving these differences in the results is important, it is beyond the scope of our paper, and therefore we leave it for future research. At the same time, the most important results for this paper, namely those concerning the homeownership rate, housing rents, and house prices, the two instruments yield very similar results.

## 3.2 Monetary Policy and Housing Tenure Choice Decisions - Evidence from Household- and Housing Unit-Level Data

### 3.2.1 Data

We use the national American Housing Survey (AHS) data to test whether monetary policy affects housing tenure decisions. This survey is conducted by the U.S. Census every two years (in odd-numbered years) between May and September. The survey follows a sample of housing units and collects information on characteristics of the housing unit and the people (or household) living in that housing unit (in the case that the housing unit is not vacant). One key characteristic of the housing unit is its tenure status. That is, whether that house is owned by the person living in it or whether it is a rental. We also know whether a specific household is renting or is a homeowner with this information.

At the household level, we have information about the current tenure status through the information regarding tenure status of the housing unit. And, because the survey asks the household about its housing tenure status 12 months prior, we are also able to know whether a household switched tenure status in the last year. Unlike for housing units, the survey does not follow households over time.

The AHS data are available at a biennial frequency from 1973 to 2019. However, in our empirical exercises we only use 1991 to 2015. We restrict the sample to start in 1991 and end in 2015 because the monetary policy instrument we use, the high-frequency monetary instrument constructed by Jarociński and Karadi (2020), is only available for the period 1991 to 2016. In Appendix A we provide detailed information on the data we use and how we constructed the different variables.

An alternative source for studying housing tenure transitions is the Panel Study of Income Dynamics database. Bachmann and Cooper (2014) use this database to study housing tenure transitions in the U.S. market and compare their results to those obtained with the AHS database, and they report that the empirical patterns observed with the two databases are broadly similar. We chose to use the AHS database because it simultaneously allows us to study housing tenure decisions at the household level and changes in housing unit type - from rental to ownership and vice versa. One key difference between our study and that of Bachmann and Cooper (2014) is that these authors mostly look at transitions during the business cycle, whereas we look explicitly at household and housing unit tenure transitions related to changes in monetary policy.

To match the frequency of the AHS data, which are biennial, we construct a biennial monetary policy shock by summing the quarterly Jarociński and Karadi (2020) monetary policy shocks pertaining to the year of the survey and the year before. To be able to use an additional year of the AHS data, we decided to use only 4 quarters of data for the year 1991, as the Jarociński and Karadi (2020) monetary policy shocks are available for the period 1991 to 2016.

$$MP_t^{JK} = \sum_{q=-7}^{q=0} MP_{t,q}^{JK,quarterly} \tag{9}$$

For example, the monetary policy shock measure for 2005 is the sum of all the quarterly monetary policy shocks between 2004:Q1 and 2005:Q4 (8 quarters in total).

### 3.2.2 Methodology

To study the effect of monetary policy on household's tenure decisions and on housing unit owners, we estimate simple logit models in which the dependent variable measures transition from renting to owning or from owning to renting - both for households and housing units. For households rent-to-own transitions, the dependent variable is an indicator variable equal to 1 if the household is currently a homeowner but was a renter 12 months before, and 0 if the household is currently a renter and was also a renter before. For housing units rent-to-own transitions, the dependent variable is an indicator variable that takes the value 1 if the housing unit is now for ownership but two years prior was a rental unit, while it takes the value 0 if the housing unit is a rental unit currently and two years before.

In the case of the own-to-rent transitions of households, the dependent variable is an indicator variable equal to 1 if the household is currently a renter but was a homeowner 12 months before, and 0 if the household is currently a homeowner and was also a homeowner before. For own-to-rent transitions of housing units, the dependent variable is an indicator variable equal to 1 if the housing unit is currently a rental unit but was an owner-occupied unit two years before, and 0 if the housing unit is currently a rental and was also a rental before.

We estimate the following rent-to-own and own-to-rent equations:

$$\begin{aligned} Prob(HH_{i,t} = renter | HH_{i,t-1} = owner) &= Logit(\lambda + \gamma MP_t^{JK} + \delta D_{i,t}^{HH}) \\ Prob(HU_{i,t} = rental | HH_{i,t-2} = ownership) &= Logit(\lambda + \gamma MP_t^{JK} + \delta D_{i,t}^{HU}) \end{aligned} \tag{10}$$

$$\begin{aligned} Prob(HH_{i,t} = owner | HH_{i,t-1} = renter) &= Logit(\alpha + \beta MP_t^{JK} + \theta D_{i,t}^{HH}) \\ Prob(HU_{i,t} = ownership | HH_{i,t-2} = rental) &= Logit(\alpha + \beta MP_t^{JK} + \theta D_{i,t}^{HU}) \end{aligned} \tag{11}$$

$$\begin{aligned} Prob(HH_{i,t} = renter | HH_{i,t-1} = owner) &= Logit(\lambda + \sum \gamma_j MP_t^{JK} * d_{i,t}^{HH} + \delta D_{i,t}^{HH}) \\ Prob(HU_{i,t} = rental | HH_{i,t-2} = ownership) &= Logit(\lambda + \sum \gamma_j MP_t^{JK} * d_{i,t}^{HU} + \delta D_{i,t}^{HU}) \end{aligned} \tag{12}$$

$$\begin{aligned} Prob(HH_{i,t} = owner | HH_{i,t-1} = renter) &= Logit(\alpha + \sum \beta_j MP_t^{JK} * d_{i,t}^{HH} + \theta D_{i,t}^{HH}) \\ Prob(HU_{i,t} = ownership | HH_{i,t-2} = rental) &= Logit(\alpha + \sum \beta_j MP_t^{JK} * d_{i,t}^{HU} + \theta D_{i,t}^{HU}) \end{aligned} \tag{13}$$

In equations 10, 11, 12, and 13, the function Logit(.) is the standardized logit function $\frac{exp(.)}{1+exp(.)}$, $D_{i,t}^{HH} = \{d_{i,t}^{region}, d_{i,t}^{age\ ter}, d_{i,t}^{inc\ quar}\}$ and $D_{i,t}^{HU} = \{d_{i,t}^{region}\}$ are indicator variables for the U.S. region where the housing unit is located ($d_{i,t}^{region}$), the age tercile ($d_{i,t}^{age\ ter}$), or the income quartile ($d_{i,t}^{inc\ quar}$) the household belongs to - the superscripts "HH" and "HU" denote variables that are specific to the household and to the housing units transition regressions, respectively.[9] In the equations pertaining to household transitions, in addition to regional controls and interactions, we also include some household characteristics to better account for life-cycle motives for being a renter or a homeowner. Namely, we include information about the household's (or head of household's) age as older households are more likely to be homeowners. Similarly, we also control for household's income, as higher income households are more likely to be homeowners. Besides including controls for the region (households and housing units), age, and income (only households), we also allow the effects of monetary policy to depend on the region where the house is located (this interaction can be done in both housing unit and household transition equations) and on the age and income of the household (this interaction can only be done in household transition equations).

In addition to the more granular regressions at the household and housing unit levels, we also use the individual AHS data to construct aggregate measures of the share of renters and the share of housing units that are rentals.[10] These regressions will allow us to provide additional evidence for the effect of monetary policy on housing tenure decisions in addition to that from the results of the own-to-rent and rent-to-own transition based on equations 10, 11, 12, and 13.

We estimate the following linear models:

$$\Delta S_{j,t}^{renter} = \gamma + \lambda MP_t^{JK} + \kappa_j + \epsilon_{j,t} \tag{14}$$

$$\Delta S_{j,t}^{rental} = \gamma + \lambda MP_t^{JK} + \kappa_j + \epsilon_{j,t} \tag{15}$$

$$\Delta S_{t}^{renter} = \gamma + \lambda MP_t^{JK} + \epsilon_{t} \tag{16}$$

$$\Delta S_{t}^{rental} = \gamma + \lambda MP_t^{JK} + \epsilon_{t} \tag{17}$$

[9]The head of household age terciles and household income quartiles are based on the sample distribution of ages and incomes within each cohort of the AHS survey.

[10]In section A of the Online Appendix, we detail how we use the individual AHS data to construct the aggregate measures of the share of households that are renters and the share of housing units that are rentals.

In equations 14 and 15, the dependent variables are the change in the share of households that rent and the share of housing units that are rental units in the region and period, respectively. In these equations, $\kappa_j$ are region fixed effects. In equations 16 and 17, the dependent variables are the change in the share of households that rent and the share of housing units that are rental units in the period, respectively.

#### 3.2.3 Results and Discussion

We now turn to the discussion of the empirical results using the AHS data, starting with those in Tables 1 and 2.

Table 1 shows the effect of monetary policy shocks on the transitions from renting to owning for both households and housing units, while Table 2 shows the effect of monetary policy shocks on the transitions from renting to owning for both households and housing units. The two tables show that monetary policy shocks affect the decision of individual households and owners of housing units to transitions from renting to owning or from renting to owning. For both household and housing units, as shown in Table 1, the results shows that the probability of a household transitioning from renting to owning declines and also that the the probability of a housing unit switching from being rental to being owner occupied also declines. Similarly, as shown in Table 2, when monetary policy tightens, the probability of a household transitioning from owning to renting increases and also that the probability of a housing unit switching from being being owner occupied to being a rental also increases.[11] The results in Tables 1 2 are consistent with those based in aggregate data, which show that the aggregate homeownership rate falls when monetary policy tightens. The results in these tables also show that it's not just the relative demand for renting *vis-a-vis* owning that changes as a result of a monetary policy shock, the relative supply of houses for rental *vis-a-vis* for owner-occupied also change in response to the same shock.

To help with the interpretation of the results in Tables 1 and 2, we used the results from columns (1) and (4) from the two tables to calculate the marginal effect of a 25 basis points contractionary monetary policy shock on the transition probabilities from renting to owning and from owning to renting. The results from this exercise are shown in Table 3.

The results in this table suggest that changes in monetary policy conditions are particularly important for transitions of households from renting to owning, as the average rate of transition from renting to owning falls by close to 15% when monetary policy tight-

[11]Note that the transition probabilities for households and housing units are not directly comparable because of differences in time horizons. For household transitions the AHS dataset only provides information relative to one year prior to the survey, while for housing units transitions the information provided by the survey only allows to study transitions in two-year periods, corresponding to the frequency of the survey used in the construction of the AHS dataset.

**Table 1:** Effect of monetary policy shocks on the probability of a household becoming a homeowner and on the probability of a housing unit becoming owner occupied.

| Variables | Probability of becoming owner | | | Probability of becoming owner-occupied | |
|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) |
| MP Shock | -0.706 | -0.706 | -0.614 | -0.043 | -0.046 |
| | (0.257)*** | (0.260)*** | (0.252)** | (0.227) | (0.227) |
| Midwest | | 0.486 | 0.668 | | 0.202 |
| | | (0.038)*** | (0.053)*** | | (0.056)*** |
| South | | 0.518 | 0.649 | | 0.402 |
| | | (0.052)*** | (0.067)*** | | (0.039)*** |
| West | | 0.265 | 0.158 | | 0.193 |
| | | (0.050)*** | (0.071)** | | (0.050)*** |
| $2^{nd}$ age tercile | | | -0.102 | | |
| | | | (0.042)** | | |
| $3^{rd}$ age tercile | | | -0.285 | | |
| | | | (0.138)** | | |
| $2^{nd}$ income quartile | | | 0.987 | | |
| | | | (0.028)*** | | |
| $3^{rd}$ income quartile | | | 1.830 | | |
| | | | (0.036)*** | | |
| $4^{th}$ income quartile | | | 2.648 | | |
| | | | (0.027)*** | | |
| Constant | -2.057 | -2.404 | -3.686 | -2.699 | -2.923 |
| | (0.131)*** | (0.135)*** | (0.133)*** | (0.069)*** | (0.089)*** |
| $N$ | 222,386 | 222,386 | 222,386 | 120,284 | 120,284 |

Note: The Table shows results of logit regressions in which the dependent variable in columns (1)-(3) is a dummy variable that takes the value 1 if the household switched from renting to owning a house in the 12 months prior to the survey interview and 0 if it the household continues to rent; and, the dependent variable in columns (4)-(6) is a dummy variable that takes the value 1 if the housing unit switched from being a rental to being an owner-occupied house during the the two year period between surveys; the monetary policy shock was constructed with the high-frequency monetary shock instrument of Jarociński and Karadi (2020). Data for household transitions are biennial from 1991 to 2015 and from 1991 to 2013 for housing unit transitions. Standard errors clustered by period in parentheses. *, **, and *** denote statistical significance at 10%, 5%, and 1%.

ens by 25 basis points. However, the effects for other housing market transitions are not negligible. Overall, the results in this table also suggest that households are more responsive to monetary policy shocks than the owners of housing units. Namely, the demand for rental/ownership reacts faster to a monetary policy shock than the supply of housing for rental/ownership.

In the next three tables, we extend the results of Tables 1 and 2 by considering interactions of the monetary policy shock with region, age, and income indicator variables – we consider all interactions in the case of household transitions, but in the case of housing

**Table 2:** Effect of monetary policy shocks on the probability of a household becoming a renter and on the probability of a housing unit becoming a rental.

| Variables | Probability of becoming renter (1) | (2) | (3) | Probability of becoming rental (4) | (5) |
|---|---|---|---|---|---|
| MP Shock | 0.090 | 0.072 | 0.107 | 0.137 | 0.128 |
| | (0.192) | (0.190) | (0.214) | (0.070)* | (0.070)* |
| Midwest | | 0.187 | -0.030 | | -0.241 |
| | | (0.037)*** | (0.042) | | (0.027)*** |
| South | | 0.318 | 0.063 | | 0.093 |
| | | (0.062)*** | (0.063) | | (0.041)** |
| West | | 0.505 | 0.465 | | 0.354 |
| | | (0.051)*** | (0.057)*** | | (0.064)*** |
| $2^{nd}$ age tercile | | | -1.475 | | |
| | | | (0.028)*** | | |
| $3^{rd}$ age tercile | | | -2.671 | | |
| | | | (0.081)*** | | |
| $2^{nd}$ income quartile | | | -0.723 | | |
| | | | (0.037)*** | | |
| $3^{rd}$ income quartile | | | -1.531 | | |
| | | | (0.028)*** | | |
| $4^{th}$ income quartile | | | -2.322 | | |
| | | | (0.034)*** | | |
| Constant | -2.631 | -2.911 | -0.444 | -3.485 | -3.544 |
| | (0.127)*** | (0.098)*** | (0.103)*** | (0.034)*** | (0.046)*** |
| $N$ | 442,899 | 442,899 | 442,899 | 284,112 | 284,112 |

Note: The Table shows results of logit regressions in which the dependent variable in columns (1)-(3) is a dummy variable that takes the value 1 if the household switched from owning to renting a house in the 12 months prior to the survey interview and 0 if it the household continues to own; and, the dependent variable in columns (4)-(6) is a dummy variable that takes the value 1 if the housing unit switched from being owner-occupied house to being a rental during the the two year period between surveys; the monetary policy shock was constructed with the high-frequency monetary shock instrument of Jarociński and Karadi (2020). Data for household transitions are biennial from 1991 to 2015 and from 1991 to 2013 for housing unit transitions. Standard errors clustered by period in parentheses. *, **, and *** denote statistical significance at 10%, 5%, and 1%.

units we can only consider region interactions, as age and income are household-specific characteristics.

Table 4 shows the effect of monetary policy shocks on transition probabilities from renting to owning and from owning to renting for households and housing units interacted with indicator variables for the regions the house is located. For households, columns (1) and (3), there is little regional heterogeneity, as the effects are relatively similar for all re-

**Table 3:** Marginal effect of a monetary policy shock on the rent-to-own and own-to-rent transition probabilities

| | Rent-to-Own | | | | Own-to-Rent | | | |
|---|---|---|---|---|---|---|---|---|
| | No MP shock (1) | 25 bps MP shock (2) | Marginal effect (3) | % difference (4) | No MP shock (5) | 25 bps MP shock (6) | Marginal effect (7) | % difference (8) |
| **Households** | 11.3% | 9.7% | -1.7% | -14.6% | 6.7% | 6.9% | 0.1% | 2.1% |
| **Housing units** | 6.3% | 6.2% | -0.1% | -1.0% | 3.0% | 3.1% | 0.1% | 3.4% |

Note: The Table shows the effect of a 25 basis points monetary policy shock on the transition probabilities from renting/rental to owning/ownership and from owning/ownership to renting/rental for households and housing units. The values in columns (1) and (2) are obtained using the results shown in Table 1, while the results in columns (5) and (6) are obtained using the results shown in Table 2. Columns (3) and (7) are obtained by subtracting columns (2) and (1) and (6) and (5), respectively; columns (4) and (8) are obtained by dividing columns (3) and (1) and (7) and (5), respectively.

gions. In contrast, for housing units, columns (2) and (4), there is more heterogeneity, with housing units located in the Midwest being more reactive to monetary policy shocks than housing units located the other regions. What drives these differences is beyond the scope of this paper, but it is something worthwhile exploring further as there could be important differences across U.S. regions in the transmission of monetary policy through the homeownership channel.[12]

As already noted, we include information about head of household age and household income in some of the model specifications to control for life-cycle motives in the decision of becoming an owner/renter. In addition to controlling for these household characteristics, we also consider the possibility that monetary policy affects households housing decisions based on their age and income. Tables 5 and 6 show the results of the effect of monetary policy shocks on housing tenure decisions interacted with age and income information, respectively.

Column (1) in Table 5 shows that the effect of monetary policy on households decision to move from renting to owning increases with the household's age. This result suggests that some households pursue homeownership late into life, but, that the decision to become a homeowner is more sensitive to monetary policy conditions for older households. In the case of transitions from owning to renting, the results in column (2) show that younger households (those in the first and second terciles of the age distribution) are unlikely to move from being homeowners to being renters when monetary policy conditions change. This insensitivity may be due to most mortgages in the United States being fixed, which makes the cost of homeownership to be less responsive to changes in interest rates. However, results in column (2) show that households in the third tercile are quite responsive to

[12] Corsetti et al. (2021) show that cross-country differences in housing market characteristics are an important driver of heterogeneous pass-through of monetary policy to euro-area countries.

**Table 4:** Effect of monetary policy shocks on the probability of a household or housing unit changing housing tenure - interaction with U.S. region

| Variables | Prob. of becoming: | | | |
|---|---|---|---|---|
| | Owner (1) | Owner-occupied (2) | Renter (3) | Rental (4) |
| MP Shock*U.S. East | -0.658 | -0.016 | -0.100 | 0.056 |
| | (0.274)** | (0.362) | (0.213) | (0.164) |
| MP Shock*U.S. Midwest | -0.675 | -0.158 | 0.140 | 0.151 |
| | (0.298)** | (0.150) | (0.177) | (0.052)*** |
| MP Shock*U.S. South | -0.743 | -0.063 | 0.079 | 0.064 |
| | (0.284)*** | (0.261) | (0.213) | (0.101) |
| MP Shock*U.S. West | -0.719 | 0.053 | 0.103 | 0.257 |
| | (0.212)*** | (0.179) | (0.192) | (0.176) |
| Midwest | 0.483 | 0.175 | 0.221 | -0.225 |
| | (0.054)*** | (0.050)*** | (0.033)*** | (0.027)*** |
| South | 0.503 | 0.394 | 0.344 | 0.095 |
| | (0.064)*** | (0.046)*** | (0.067)*** | (0.036)*** |
| West | 0.255 | 0.204 | 0.534 | 0.386 |
| | (0.066)*** | (0.063)*** | (0.048)*** | (0.068)*** |
| Constant | -2.395 | -2.918 | -2.936 | -3.556 |
| | (0.137)*** | (0.098)*** | (0.093)*** | (0.043)*** |
| *N* | 222,386 | 120,284 | 442,899 | 284,112 |

Note: The Table shows results of logit regressions in which the dependent variable in column (1) is a dummy variable that takes the value 1 if the household switched from renting to owning a house in the 12 months prior to the survey interview and 0 if it the household continues to rent; the dependent variable in column (2) is a dummy variable that takes the value 1 if the housing unit switched from being a rental to being an owner occupied house during the the two year period between surveys; the dependent variable in column (3) is a dummy variable that takes the value 1 if the household switched from owning to renting a house in the 12 months prior to the survey interview and 0 if it the household continues to own; and, the dependent variable in column (4) is a dummy variable that takes the value 1 if the housing unit switched from being a owner-occupied house to being a rental during the the two year period between surveys; the monetary policy shock was constructed with the high-frequency monetary shock instrument of Jarociński and Karadi (2020). Data for household transitions are biennial from 1991 to 2015 and from 1991 to 2013 for housing unit transitions. Standard errors clustered by period in parentheses. *, **, and *** denote statistical significance at 10%, 5%, and 1%.

changes in monetary policy, and that, when monetary policy tightens some of these older households decide to sell and become renters. We see this result for older households as suggestive that some older households try to maximize sale value of their homes, and, once they see interest rates going up they decide to sell because they understand that house prices are likely to grow slower.

Turning now to the results pertaining to the interaction of monetary policy with household income, shown in Table 6. Column (1) in this table shows the results for the transition

**Table 5:** Effect of monetary policy shocks on the probability of a household changing housing tenure - interaction with the head of household age

| Variables | Prob. of becoming owner<br>(1) | Prob. of becoming renter<br>(2) |
|---|---|---|
| MP Shock*$1^{st}$ age tercile | -0.405<br>(0.232)* | -0.074<br>(0.247) |
| MP Shock*$2^{nd}$ age tercile | -0.716<br>(0.273)*** | 0.086<br>(0.199) |
| MP Shock*$3^{rd}$ age tercile | -1.358<br>(0.507)*** | 0.783<br>(0.217)*** |
| Midwest | 0.670<br>(0.053)*** | -0.030<br>(0.042) |
| South | 0.649<br>(0.067)*** | 0.064<br>(0.063) |
| West | 0.159<br>(0.071)** | 0.465<br>(0.057)*** |
| $2^{nd}$ age tercile | -0.153<br>(0.041)*** | -1.453<br>(0.031)*** |
| $3^{rd}$ age tercile | -0.455<br>(0.125)*** | -2.564<br>(0.074)*** |
| $2^{nd}$ income quartile | 0.986<br>(0.028)*** | -0.725<br>(0.038)*** |
| $3^{rd}$ income quartile | 1.830<br>(0.036)*** | -1.534<br>(0.029)*** |
| $4^{th}$ income quartile | 2.646<br>(0.026)*** | -2.323<br>(0.034)*** |
| Constant | -3.653<br>(0.126)*** | -0.467<br>(0.103)*** |
| $N$ | 222,386 | 442,899 |

Note: The Table shows results of logit regressions in which the dependent variable in column (1) is a dummy variable that takes the value 1 if the household switched from renting to owning a house between in the 12 months prior to the survey interview and 0 if it the household continues to rent; and, the dependent variable in column (2) is a dummy variable that takes the value 1 if the household switched from owning to renting a house in the 12 months prior to the survey interview and 0 if the household continues to own the house it lives in; the monetary policy shock was constructed with the high-frequency monetary shock instrument of Jarociński and Karadi (2020). Data are biennial from 1991 to 2015. Standard errors clustered by period in parentheses. *, **, and *** denote statistical significance at 10%, 5%, and 1%.

from renting to owning, and, despite some variation, there is no clear pattern with respect to the effect of monetary policy on households tenure choice decisions depending on income level. In contrast, the results in column (2), which are for the transition from owning to renting, show that only the households in the lowest income quartile are more likely to move from owning to renting once interest rates increase.

**Table 6:** Effect of monetary policy shocks on the probability of a household changing housing tenure - interaction with household income

| Variables | Prob. of becoming owner (1) | Prob. of becoming renter (2) |
|---|---|---|
| MP Shock*1$^{st}$ income quartile | -0.864 | 0.294 |
| | (0.302)*** | (0.164)* |
| MP Shock*2$^{nd}$ income quartile | -0.661 | 0.013 |
| | (0.254)*** | (0.235) |
| MP Shock*3$^{rd}$ income quartile | -0.421 | 0.035 |
| | (0.232)* | (0.246) |
| MP Shock*4$^{th}$ income quartile | -0.688 | 0.020 |
| | (0.263)*** | (0.293) |
| Midwest | 0.668 | -0.030 |
| | (0.053)*** | (0.042) |
| South | 0.649 | 0.064 |
| | (0.067)*** | (0.063) |
| West | 0.159 | 0.466 |
| | (0.071)** | (0.057)*** |
| 2$^{nd}$ age tercile | -0.101 | -1.476 |
| | (0.042)** | (0.028)*** |
| 3$^{rd}$ age tercile | -0.285 | -2.670 |
| | (0.138)** | (0.081)*** |
| 2$^{nd}$ income quartile | 1.021 | -0.761 |
| | (0.040)*** | (0.040)*** |
| 3$^{rd}$ income quartile | 1.904 | -1.566 |
| | (0.043)*** | (0.034)*** |
| 4$^{th}$ income quartile | 2.677 | -2.358 |
| | (0.036)*** | (0.035)*** |
| Constant | -3.729 | -0.418 |
| | (0.145)*** | (0.105)*** |
| $N$ | 222,386 | 442,899 |

Note: The Table shows results of logit regressions in which the dependent variable in column (1) is a dummy variable that takes the value 1 if the household switched from renting to owning a house between in the 12 months prior to the survey interview and 0 if it the household continues to rent; and, the dependent variable in columns (2) is a dummy variable that takes the value 1 if the household switched from owning to renting a house in the 12 months prior to the survey interview and 0 if the household continues to own the house it lives in; the monetary policy shock was constructed with the high-frequency monetary shock instrument of Jarociński and Karadi (2020). Data are biennial from 1991 to 2015. Standard errors clustered by period in parentheses. *, **, and *** denote statistical significance at 10%, 5%, and 1%.

The results from Tables 5 and 6 indicate that the transmission of monetary policy through the homeownership channel depends on household characteristics. In particular, we found younger households to be less sensitive to changes in monetary policy conditions than older households, while lower income households are more responsive to changes in interest rates than higher income households.

The last set of results in this section pertains to the estimation results of equations 14, 15, 16, and 17, which are shown in Table 7.

**Table 7:** Effect of monetary policy shocks on the aggregate share of renters and on the aggregate share of rental units

| Variables | Δ Renter share (percent) | | | Δ Rental share (percent) | | |
|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) | (6) |
| MP Shock | 2.41 | 2.41 | 2.49 | 2.82 | 2.82 | 2.82 |
| | (1.25)* | (1.29)* | (1.03)** | (1.83) | (1.89) | (1.05)** |
| $R^2$ | 0.08 | 0.08 | 0.08 | 0.11 | 0.11 | 0.14 |
| $N$ | 52 | 52 | 13 | 52 | 52 | 13 |
| Region FE | N | Y | N | N | Y | N |
| Data | U.S. Regional | U.S. Regional | U.S. Aggregate | U.S. Regional | U.S. Regional | U.S. Aggregate |

Note: The Table shows results of OLS regressions in which: the dependent variable in columns (1) and (2) is the change in the share of households in a given U.S. Census region (Northeast, South, Midwest, and West) that rent the place they live in; the dependent variable in column (3) is the change in the share of households in the Unite States that rent the place they live in; the dependent variable in columns (4) and (5) is the change in the share of housing units in a given U.S. Census region that are rentals; the dependent variable in column (6) is the change in the share of housing units in the Unite States that are rentals; the monetary policy shock was constructed with the high-frequency monetary shock instrument of Jarociński and Karadi (2020). Data are biennial from 1991 to 2015. Standard errors, in parentheses, are robust to heteroskedasticity and serial correlation. *, **, and *** denote statistical significance at 10%, 5%, and 1%.

The first three columns in Table 7 show results on the effect on monetary policy on the the change in the aggregate share of households that rent, while the last three columns show results on the effect on monetary policy on the the change in the aggregate share of housing units that are rentals. In line with the results concerning the effect of monetary policy on households and housing units transition probability from owning to renting and from renting to owning, the results in this table show that the renter share increases when monetary policy tightens and also that the share of housing units for renting also increase.

It is important to note once again that the household and housing unit results are not directly comparable because of differences in the time horizon considered for the transitions from rent to own and own to rent. Without taking this difference into consideration, the results in Table 7 could suggest that housing units adjust faster than households do in response to a monetary policy shock, because the coefficients in the last three columns are slightly larger than the coefficients in the first three columns. However, because the results for households only include transitions in the previous 12 months, while the results for housing units are based on a 2-year horizon, results in this table suggest that, similar to the results in Tables 1 and 2, households are more responsive to monetary policy shocks than housing units (i.e., the relative demand for rental housing is more responsive to monetary policy shocks than the relative supply of rental housing). This difference is likely the main reason for why housing rents increase (decrease) and the homeownership rate decreases (increases) when interest rates increase (decrease).

The results in this section, both based on aggregate and household and housing unit level data, provide strong evidence that monetary policy simultaneously affects house prices, house rents, and the aggregate homeownership rate by affecting the decision of individual households to rent or to own and also by affecting the decision of housing unit owners to rent or sell their properties. A question that remains to be answered is why do these findings matter. We address this question in the remainder of the paper.

# 4 Theory

To account for the empirical results presented in the previous section, we propose a two-agent New Keynesian model with a segmented housing market in which agents can choose between owning or renting. The proposed model builds on existing models that include a housing sector, such as those of Iacoviello (2005) and Iacoviello and Neri (2010), and extends them by incorporating a segmented housing market and the possibility of some households choosing between owning or renting the house they live in.

## 4.1 The Environment

The economy is set in discrete-time and features two types of families — borrowers and savers — each populated by a continuum of infinitely-lived households with measure one. The savers have full access to credit markets and behave as Ricardian agents. The borrowers face a collateral constraint along the lines of work by Campbell and Hercowitz (2005), Iacoviello (2005), Iacoviello and Neri (2010), and Calza et al. (2013). Hence, the borrowers borrowing limit is a function of the value of their house. In our theoretical environment, the borrowers' borrowing constraint is always binding. Consequently, they are assumed to behave in a "hand-to-mouth" fashion. Also, the households belonging to the borrowers family differ in their preferences concerning owning a house: they receive extra utility from these services for the same quantity of housing services if they own a house instead of renting one. For simplicity, we assume that only the households belonging to the borrowers family need to choose between owning or renting.[13]

[13]This assumption does not affect the qualitative nature of how the tenure choice channel affects the monetary policy transmission dynamics. It only has quantitative implications.

We assume that the housing stock in the economy is fixed, but that the share of housing for ownership/rental can be adjusted in response to changes in demand for the two types of housing (for ownership and for rental). Real estate brokers provide housing rental services buying them from landlords and selling them with a markup. The brokers are the source of rigidity in housing rents. The landlords buy/sell housing stock for owning and rent it to the brokers, subject to adjustment costs. The latter can be motivated by higher maintenance costs for renting, less favorable tax treatment relative to owning, and the necessity of rehabilitation work. These housing stock adjustment costs are the source of housing market segmentation in our model.

Finally, in terms of the supply of final goods, we assume that wholesale firms produce them with a constant return to scale technology that uses the labor of both agents (borrowers and savers) as its only inputs. Consumers buy the final good from retailers, who sell the wholesale goods with a markup but can only adjust the prices of their goods at random times (as in Calvo (1983)). Therefore, retailers are a source of nominal rigidity in this economy. We assume that savers own all types of firms in the economy. The savers' problem is standard. The savers', the wholesalers', and the retailers' problems are the same as in Iacoviello (2005). The only difference is that the savers in our model also own the brokers and the landlords.

## 4.2 Households

The households' utility function is standard and is the same for both borrowers and savers. Households get utility from consuming the final good and housing services, but they get disutility from working.[14] The instantaneous utility function is given by

$$u(c, h, L) = \ln c + \frac{h^{1-\phi}}{1-\phi} - \frac{L^{\eta}}{\eta}.$$

**Borrowers**

Households in the borrowers family can choose to own or rent a house every period. These households are heterogeneous regarding the utility they get from owning a house but they all get the same utility when renting. We assume that, for a given house size, these households get higher utility owning than when renting it. This difference in utility is given by $\rho_i$. We assume that, every period, each household receives an i.i.d. draw $\rho_i$ from CDF $F(\rho)$. Also, inspired by the work of Ragot (2018), we assume that each household

[14]We assume utility is separable in money balances, which results in the quantity of money having no implications for the rest of the model and, therefore, are ignored.

in the borrowers family trade a complete set of contracts for consumption and housing services within their own family, providing perfect insurance against idiosyncratic risk. The borrowers' social planner problem is one of maximizing the following lifetime utility function:

$$E_0 \sum_{t=0}^{\infty} (\beta')^t \left\{ \int_0^1 \ln c_t^i + (1 - I_t^i) \left( j^r \frac{(h_t^i)^{1-\phi^r}}{1-\phi^r} \right) + I_t^i \left( j^o \frac{(h_t^i)^{1-\phi^o}}{1-\phi^o} + \rho_t^i \right) - \frac{(L_t^i)^\eta}{\eta} di \right\},$$

subject to:

$$\int_0^1 c_t^i + I_t^i q_t \Delta h_t^i + (1 - I_t^i) h_t^i l_t + b_{t-1}^i \frac{R_{t-1}}{\pi_t} di = \int_0^1 b_t^i + w_t' L_t^i di$$
$$b_t^i \leq I_t^i E_t \left[ m q_{t+1} h_t^i \frac{\pi_{t+1}}{R_t} \right],$$

where $E_0$ is the expectation operator conditional on time zero information; $\beta \in (0, 1)$ is the discount factor; $c_t^i$ is consumption of borrower $i$ at time $t$; $I_t^i \in \{0, 1\}$ is an indicator function that takes the value of 1 if borrower $i$ decides to own and zero if she decides to rent; $h_t^i$ denotes housing services; $\rho_i$ is the utility that household $i$ receives when she chooses to own; $L_t^i$ are hours of work; $q_t$ denotes the real housing price; $l_t$ is the real housing rent; $R_t$ is the gross nominal interest rate; $\pi_t$ is the gross inflation rate; $w_t'$ is the real wage; $m$ is the loan-to-value ratio;and $b_t^i$ is borrowing in real terms.

**Proposition 1.** *If $\rho_i$ are i.i.d. draws from a continuous cdf $F(\rho)$, then:*[15]

*(i) for each household, the decision to own or to rent is determined by a single cutoff rule. Households with $\rho_t^i > \bar{\rho}_t$ choose to own, while households with $\rho_t^i < \bar{\rho}_t$ choose to rent, with $\bar{\rho}_t$ being the individual draw of the household that, for given prices, is indifferent between renting or owning a house. As such, in each period the share of homeowners is given $1 - F(\bar{\rho}_t) = \alpha_t$;*

*(ii) the consumption and hours of work allocations are the same across all borrowers;*

*(iii) housing services and bond holdings ($b_t^i$) allocations, although different between homeowners and renters, will be the same across renters and homeowners.*

According to Proposition 1, the problem of the borrowers' social planner can be rewritten as:

[15]The proof of Proposition 1 can be found in section B of the Online Appendix.

$$\max_{c'_t,h^o_t,h^r_t,b^o_t,b^r_t,L'_t} E_0 \sum_{t=0}^{\infty} (\beta')^t \left\{ \ln c'_t + \alpha_t \left( j^o \frac{(h^o_t)^{1-\phi^o}}{1-\phi^o} \right) + (1-\alpha_t) \left( j^r \frac{(h^r_t)^{1-\phi^r}}{1-\phi^r} \right) - \frac{(L'_t)^{\eta}}{\eta} \right\},$$

subject to

$$c'_t + \alpha_t q_t h^o_t - \alpha_{t-1} q_t h^o_{t-1} + (1-\alpha_t) l_t h^r_t + \alpha_{t-1} b^o_{t-1} \frac{R_{t-1}}{\pi_t} = \alpha_t b^o_t + w'_t L'_t \tag{18}$$

$$b^o_t \leq E_t \left[ m q_{t+1} h^o_t \frac{\pi_{t+1}}{R_t} \right] \tag{19}$$

$$b^r_t = 0, \tag{20}$$

where the share of homeowners is given by:

$$\alpha_t = 1 - F(\bar{\rho}_t) \tag{21}$$

$$\text{with} \quad \bar{\rho}_t = u((c'_t)^*, (h^r_t)^*, (L'_t)^*) - u((c'_t)^*, (h^o_t)^*, (L'_t)^*) \tag{22}$$

The star superscript in equation 22 denotes that these are optimal allocations given prices and distributions of homeowners and renters. These optimal allocations are used by each household to decide whether they should rent or own a house.

The first order condition with respect to $L'_t$ is given by

$$(L'_t)^{\eta-1} = \frac{w'_t}{c'_t} \tag{23}$$

While the first order conditions with respect to $h^o_t$, $h^r_t$ and $b^o_t$ when combined with those related to consumption are:

$$\alpha_t j^o (h^o_t)^{-\phi^o} = \frac{\alpha_t q_t}{c^o_t} - E_t \left[ \frac{\alpha_t q_{t+1} \beta'}{c^o_{t+1}} - \lambda_t m q_{t+1} \pi_{t+1} \right] \tag{24}$$

$$j^r (h^r_t)^{-\phi^r} = \frac{l_t}{c^r_t} \tag{25}$$

$$\frac{\alpha_t}{c^o_t} = E_t \left[ \beta' \alpha_t \frac{R_t}{c^o_{t+1} \pi_{t+1}} \right] + \lambda_t R_t \tag{26}$$

The aggregate demand of borrowers that are homeowners is given by:

$$h'_t = \alpha_t h^o_t \tag{27}$$

**Savers**

In our setting, the savers' problem is standard. These agents do not need to choose between owning or renting; we assume they own a house and simply have to maximize their lifetime utility given the resources that are available to them:

$$E_0 \sum_{t=0}^{\infty} \beta^t \left( \ln c_t + j \ln h_t - \frac{(L_t)^\eta}{\eta} \right) \tag{28}$$

$$s.t.: \quad c_t + q_t(h_t - h_{t-1}) + b_t \frac{R_{t-1}}{\pi_t} = b_t + w_t L_t + F_t$$

In equation 28, $F_t$ are lump-sum profits received from brokers, landlords, and retailers. The first order conditions are given by:

$$\frac{1}{c_t} = \beta E_t \left[ \frac{R_t}{c_{t+1}\pi_{t+1}} \right] \tag{29}$$

$$\frac{q_t}{c_t} = \frac{j}{h_t} + \beta E_t \left[ \frac{q_{t+1}}{c_{t+1}} \right] \tag{30}$$

$$L_t^{\eta-1} = \frac{w_t}{c_t} \tag{31}$$

## 4.3 Housing Supply

The supply of housing for ownership and for renting plays a crucial role in the model. To start, we assume that the total stock of housing is fixed and is equal to $\bar{H}$.[16] The total stock of housing is then split into a part that is for ownership, $H_t^o$, and another part that is for rent, $H_t^r$, with $\bar{H} = H_t^o + H_t^r$. While the total housing stock is fixed, the split between housing for ownership and housing for renting can change over time in response to the relative price of each type of housing. In the model, it's the landlords who can make these adjustments. To adjust the housing stock mix, landlords either buy housing stock that is available for owning and rent it or sell housing stock that was available for rent. Finally, we assume that housing rents are sticky.[17] As the duration of rental contracts is typically longer

[16] We could have included a housing production sector in the model, but, besides complicating the analytics of the model a touch more, it wouldn't make too much difference for our conclusions. For our model, what matters is the relative supply of housing for renting and for homeownership and how fast these two stocks can adjust in response to changes in demand. Adding a housing constructions sector would have been more realistic, but, because housing construction takes time, it wouldn't have made the adjustment of relative supply of housing sufficiently fast for our results to go away.

[17] The assumption of sticky rents is in line with empirical observation, as shown in Gallin and Verbrugge (2019). However, in contrast to Gallin and Verbrugge (2019), whose main objective was to explain why rents are sticky, we consider a simple model of rent stickiness that assumes that only a fraction of housing rents can be adjusted every period as in a standard Calvo price setting assumption. This simplification should not

than a single period, we assume that only a fraction of these contracts changes prices every period. To model this rent stickiness, we assume that there are real estate brokers who buy housing services from the landlords and sell them at a markup to households. The markup can be motivated by management costs and real estate brokers' fees.

**Landlords**

There is a unit mass of landlords that own the housing stock for renting. They competitively rent each unit of their housing stock for $l_t^L$ to real estate brokers that resell the housing services at $l_t = X_t^r l_t^L$, where $X_t^r$ is the brokers' markup. They invest/disinvest by buying/selling housing stock and converting it into renting stock. However, when they invest/disinvest, they face adjustment costs. In particular, we assume that the adjustment costs depend on the size of the investment relative to the current stock of renting housing and that they are convex. The adjustment costs are given by

$$\zeta_t = \psi \left( \frac{I_t^r}{H_{t-1}^r} \right)^2 q_t \frac{H_{t-1}^r}{2} \tag{32}$$

In our model, the adjustment costs are motivated by transaction and construction costs faced by landlords. One example of transaction costs that a landlord faces when buying a house is the taxes levied. Moreover, landlords need to pay for maintenance and rehabilitation expenses when placing a house for renting.

Consider the problem of a landlord that owns the capital stock for renting $H_{t-1}^R$ at time $t$. The representative landlord's problem is:

$$\max_{I_t^r, H_t^r} E_0 \sum_{t=0}^{\infty} \Lambda_t \left( \frac{l_t}{X_t^r} H_t^r - q_t I_t^r - \psi \left( \frac{I_t^r}{H_{t-1}^r} \right)^2 q_t \frac{H_{t-1}^r}{2} \right)$$

$$s.t.: \quad H_t^r = I_t^r + H_{t-1}^r \tag{33}$$

where $\Lambda_t = \prod_{\tau=0}^{t} \frac{\pi_\tau}{R_{\tau-1}}$ is the saver's relevant discount factor. Given that the total housing stock is fixed, the housing stock for owning is given by

$$H_t^o = \bar{H}_t - H_t^r. \tag{34}$$

The first-order conditions of the landlords for $I_t^r$ and $H_t^r$ are given by

have material implications for our results.

$$\mu_t = q_t + \psi q_t \frac{I_t^r}{H_{t-1}^r} \tag{35}$$

$$\mu_t = \frac{l_t}{X_t^r} + E_t \left[ \frac{\pi_{t+1}}{R_t} \frac{\psi}{2} q_{t+1} \left( \frac{I_{t+1}^r}{H_t^r} \right)^2 + \frac{\pi_{t+1}}{R_t} \mu_{t+1} \right] \tag{36}$$

In equations 35 and 36, $\mu_t$ is the Lagrangian multiplier associated with the law of motion of the housing for renting stock. This quantity is the shadow value of the constraint, which corresponds to how much the landlord would value having the constraint relaxed.

Note that, the landlords act as arbitrageurs in the housing market, with their actions guaranteeing that, in the steady state, the price of housing is equal to the sum of the present value of all future rents: $q = \frac{l}{X_{ss}^r(1-\beta)}$. In the short run, however, there may be deviations from this no arbitrage condition due to housing mix adjustment costs and rent stickiness. On the one hand, since housing prices are not sticky, but rents are, the sluggish adjustment of rents will imply that there will be deviations from the no-arbitrage condition in the short run. On the other hand, adjustment costs will also prevent the housing for renting stock from adjusting fast enough when faced with different demand conditions, contributing to deviations from the no-arbitrage condition between ownership and renting in the short run.

**Real Estate Brokers**

We assume that the housing rental sector is monopolistic competitive and that there is nominal rigidity in this sector, with prices following Calvo-style contracts. Real estate brokers play the role of intermediaries in the housing rental market. They rent the landlord's housing stock, differentiate it at no cost, and rent it to households at a markup over the marginal cost. The CES aggregates of these housing services are converted back into homogeneous housing services by households. Each period, a fraction $1 - \theta^r$ of real estate brokers set prices optimally, while a fraction $\theta^r$ cannot do so. These assumptions deliver the following housing-rental Phillips curve:

$$\pi_t^l = \pi_t \frac{l_t}{l_{t-1}} \tag{37}$$

$$\ln \pi_t^l = \beta E_t \ln \pi_{t+1}^l - \kappa^r \ln \frac{X_t^r}{X_{ss}^r} \tag{38}$$

where $\pi_t^l$ is the gross nominal housing rent inflation and $\kappa^r = (1 - \theta^r)(1 - \beta\theta^r)/\theta^r$.

## 4.4 Final Goods Sector

The final goods sector has two types of firms, competitive wholesale firms that produce wholesale goods and monopolistic competitive retailers who sell the goods to consumers.

### Wholesalers

Wholesale firms hire labor to produce wholesale goods. They solve:

$$\max \frac{Y_t}{X_t} - w_t L_t - w_t' L_t' \tag{39}$$

where $X_t$ above is the markup of final goods over wholesale goods. The production technology is:

$$Y_t = A_t L_t^{\nu} (L_t')^{1-\nu}. \tag{40}$$

The first-order conditions of the wholesalers are

$$w_t = \nu \frac{Y_t}{L_t X_t} \tag{41}$$

$$w_t' = (1-\nu) \frac{Y_t}{L_t' X_t}. \tag{42}$$

### Retailers

Retailers face monopolistic competition and implicit costs of adjusting nominal prices following Calvo-style contracts (this is a similar assumption to how real estate brokers can adjust housing rents). Retailers buy wholesale goods $Y_t$ from wholesale firms at price $P_t^w$ in a competitive market, differentiate the goods at no cost, and sell them at a markup $X_t = P_t / P_t^w$ over the marginal cost. The CES aggregates of these goods are converted into homogeneous consumption goods by households. A fraction of retailers $\theta$ can set prices optimally each period, while a fraction $1-\theta$ cannot choose prices optimally. These assumptions deliver the following consumption-sector Phillips curve:

$$\ln \pi_t = \beta E_t \ln \pi_{t+1} - \kappa \ln \frac{X_t}{X_{ss}} \tag{43}$$

where $\kappa = (1-\theta)(1-\beta\theta)/\theta$.

### 4.5 Consumer Price Index

In our model there are two goods that are consumed: final goods and housing services. The inflation rate of a consumer price index that follows the price changes of both goods is given by:

$$\ln \pi_t^{CPI} = (1-\omega)\ln \pi_t^l + \omega \ln \pi_t = (1-\omega)\ln \frac{l_t}{l_{t-1}} + \ln \pi_t, \tag{44}$$

where $\omega$ is the steady-state consumption share of total expenditure. Equation 44 shows how a measure of inflation, such as the CPI, that both includes the prices of consumption and shelter, both reflects changes in inflation ($\pi_t$) and relative prices of goods ($\frac{l_t}{l_{t-1}}$). This relative price effect would be present in any model with multiple goods, but this effect becomes particularly important if relative prices change in response to monetary policy. If the housing services expenditure share $(1-\omega)$ responded quickly to changes in the relative price of renting, then the CPI would provide a more precise measure of inflation. When real rents increase, the expenditure share on housing services falls as household substitute housing services with consumption of final goods. This assumes that all agents substitute housing services consumption when housing rents increase, but that is not necessarily the case as we will shown. Importantly, there are two practical reasons as to why the expenditure share used in CPI does not get adjusted quickly following a monetary policy shock. First, the expenditure shares that are used as weights in the construction of the CPI are only updated every two years. Second, even if these expenditure shares were updated more frequently, they would not just be reflecting the effects of monetary policy shocks, but of all shocks hitting the economy. As such, the expenditure shares would be adjusting to offset the effect of monetary policy on rents. For these two reasons, we chose to use fixed expenditure shares in CPI inflation following a monetary policy shock, as is done in practice.

### 4.6 Interest Rate Rule

As is standard in this literature, the monetary authority sets the gross nominal interest rate according to a Taylor rule:

$$R_t = R_{t-1}^{r_R} (\pi_{t-1}^{CPI})^{(1-r_R)r_\pi} \left(\frac{Y_{t-1}}{Y_{ss}}\right)^{(1-r_R)r_Y} R_{ss}^{1-r_R} \epsilon_t^R \tag{45}$$

where $R_{ss}$ and $Y_{ss}$ are the steady-state real interest rate and output, respectively. The rule allows for interest rate inertia via the parameter $r_R > 0$. Also, the interest rate reacts to past

(CPI) inflation and output. The strength of the reaction of interest rates to deviations of inflation and output from steady state is determined by the parameters $r_\pi$ and $r_Y$, respectively. Finally, $\epsilon_t^R$ is a white noise shock that captures interest rate surprises.

### 4.7 Equilibrium

The equilibrium in this economy is a sequence of allocations $\{c'_t, h'_t, L'_t, h^r_t, h^o_t, \alpha_t, \rho_t, c_t, h_t, b_t, b^o_t, b^r_t, L_t, H^o_t, H^r_t, I^r_t, Y_t, \zeta_r\}_{t=0}^{\infty}$ and a sequence of values $\{w'_t, w_t, q_t, l_t, \pi_t, \pi_t^{CPI}, R_t, \pi^l_t, X_t, X^r_t, \mu_t, \lambda_t\}_{t=0}^{\infty}$ satisfying equations (18) - (45) and the following market clearing conditions:[18]

$$\text{Goods market:} \quad c_t + c'_t = Y_t - \zeta_t \tag{46}$$

$$\text{Housing rental market:} \quad H^r_t = (1 - \alpha_t) h^r_t \tag{47}$$

$$\text{Housing homeownership market:} \quad H^o_t = h_t + h'_t, \tag{48}$$

given $\{h_{-1}, h'_{-1}, \alpha_{-1}, P_{-1}, R_{-1}\}$ and the sequence of monetary shocks $\{e^R_t\}_{t=0}^{\infty}$, together with the relevant transversality conditions.

### 4.8 Model Solution

We chose to use a second-order perturbation method around the steady state to solve the model because, for households to choose between owning or renting, they need to compare the utility they get from owning a house with that of renting[19]. Using a second-order approximation is crucial, because it is well known in the literature (see Kim and Kim (2003)) that first-order approximations give inaccurate solutions to welfare analysis as these don't consider second moments.

## 5 Calibration and Model Evaluation

In this section we calibrate the model described in the previous section by choosing parameters that allow the model to match a set of data moments pertaining to the U.S. economy. We then evaluate the model calibration by comparing outcomes of the model with empirical results that were not targeted in the calibration and show the importance of the inclusion in the model of a housing tenure choice and a segmented housing market to match the empirical results presented in section 3.

[18]The bonds market is suppressed because of Walras's law.

[19]The second-order perturbation does not yield higher precision than a first-order perturbation for inflation measures though, because they are already written using a linear approximation

## 5.1 Calibration

The calibrated parameter values are presented in Table 8. For the heterogeneous extra utility received when owning a house distribution $F(\rho)$, we chose the uniform functional form, so that $\rho_t^i \sim U(0, b)$. As a consequence, the share of borrowers that are homeowners is given by:

$$\alpha_t = 1 - \frac{\bar{\rho}_t}{b}. \tag{49}$$

In terms of preferences, we set the discount factor of savers $\beta = 0.99$ as is standard to match a quarterly interest rate of around 1%. As for the discount factor of the borrowers, we follow Iacoviello and Neri (2010) and set $\beta' = 0.97$. This value is also very close to the value used in Greenwald (2018). We set the savers' housing preference $j = 0.04$ to match the housing stock to GDP ratio of 1.35. The renters' and homeowners' housing preferences essentially regulate the steady-state housing share of total expenditure, so we set $j^r = 0.08$ and $j^o = 0.24$ to match the average housing weight in total expenditures in the CPI in 2019. The other housing preferences parameters $\phi^o$ and $\phi_r$ are the inverse price elasticity of intensive-margin demand for homeowners and renters housing, respectively. For the homeowners we set this elasticity $\phi^o = 1$ as in Iacoviello (2005), Iacoviello and Neri (2010) and Greenwald (2018), while for renters we set $\phi^r = 2$ based on Albouy et al. (2016), which estimates this inverse price elasticity to be somewhere between 1.5 and 2.24. We calibrate $\eta = 2$ so that the inverse Frisch elasticity is set to 1, as is standard in the literature. Given that we only model the homeownership decision for the borrowers, we jointly calibrate the lower and upper bound, $a = -0.4$ and $b = 0.1$, of the uniform distribution to match the U.S. average homeownership rate of hand-to-mouth agents reported in Kaplan et al. (2014) of approximately 50%.

We follow Kaplan et al. (2014)'s results and make the share of hand-to-mouth agents to approximately 32%, which implies that the share of hand-to-mouth agents that rent is 16% of the whole population. The average homeownership rate in the U.S. between 1983 and 2019 is approximately 65%, which means 35% of the households rent a house. Hence, 19% of the households rent a house but do not face liquidity constraints. In our model, we abstract from these agents because we assume that they have preferences towards owning that are always sufficiently far from the indifferent agent, thus yielding the impact of monetary surprises on housing tenure decisions of these agents to be negligible. Thus, in the model, we focus on explaining changes in the aggregate homeownership rate in response to monetary policy shocks rate solely coming from changes in the hand-to-mouth households' housing tenure choices.

**Table 8:** Parameter Values: Baseline Calibration

| Parameter | Name | Value | Internal | Target/Source |
|---|---|---|---|---|
| *Preferences* | | | | |
| $\beta$ | Saver discount factor | 0.99 | Y | Standard |
| $\beta'$ | Borr. discount factor | 0.97 | N | Iacoviello and Neri (2010) |
| $j$ | Saver housing preference | 0.04 | Y | Housing stock to GDP ratio of 1.35, Iacoviello and Neri (2010) |
| $j^r$ | Borr. that rents housing preference | 0.08 | N | Renters housing share of total expenditure in CPI |
| $j^o$ | Borr. that owns housing preference | 0.24 | N | Homeown. with outstd. mortgage housing share of total expenditure in CPI |
| $\eta$ | Labor disutility | 2 | N | Standard |
| $\phi^r$ | Inv. price elasticity of intensive-margin demand for rental housing | 2 | N | Albouy et al. (2016), Howard and Liebersohn (2021) estimates range = $[1.5, 2.24]$ |
| $\phi^o$ | Inv. price elasticity of intensive-margin demand for homeowner housing | 1 | N | Iacoviello (2005), Iacoviello and Neri (2010), Greenwald (2018) |
| $a$ | Lower limit of owning extra services | -0.4 | Y | U.S. average homeownership rate of hand-to-mouth households in Kaplan et al. (2014): 50%, $\alpha_{ss} = 0.5$ |
| $b$ | Upper limit of owning extra services | 0.1 | Y | U.S. average homeownership rate of hand-to-mouth households in Kaplan et al. (2014): 50%, $\alpha_{ss} = 0.5$ |
| *Housing sector* | | | | |
| $\psi$ | Rental housing stock adjustment cost | 1.6 | Y | Increase in rental units share two years after a 25bps monetary policy shock (Table 7, column 6) |
| $X^r_{ss}$ | Rental brokers markup | 2.2 | Y | Zillow, U.S. average price-to-rent ratio, $q_{ss}/(l_{ss} * 4) = 11.4$ |
| $\theta^r$ | Rents stickiness | 0.83 | N | Gallin and Verbrugge (2019) |
| $m$ | Loan-to-value ratio | 0.85 | N | Iacoviello and Neri (2010), Greenwald (2018) |
| $\bar{H}$ | Total housing stock | 1 | N | Normalization |
| *Final goods sector* | | | | |
| $\theta$ | Price stickiness | 0.84 | N | Iacoviello and Neri (2010) |
| $\nu$ | Savers labor income share | 0.79 | N | Iacoviello and Neri (2010), Kaplan et al. (2014) |
| $X_{ss}$ | Retailers markup | 1.15 | N | Iacoviello and Neri (2010) |
| $A$ | TFP | 1.057 | Y | $Y_{ss} = 1$ |
| *Monetary policy* | | | | |
| $\pi_{ss}$ | Steady state inflation | 1 | N | Iacoviello and Neri (2010) |
| $r_R$ | Taylor rule smoothing | 0.7 | N | Iacoviello and Neri (2010) |
| $r_Y$ | Taylor rule (GDP) | 0.13 | N | Iacoviello and Neri (2010) |
| $r_\pi$ | Taylor rule (CPI) | 1.5 | N | Standard |

Next, we turn to the calibration of parameters related to the housing sector. We set the parameter regulating the adjustment costs of the housing stock mix $\psi = 1.6$ to match the housing supply response to a 25 basis points average surprise over two years estimated from the AHS microdata. As reported in column 6 of Table 7, we find that the rental share increases by approximately 2.82 percentage points in response to a positive 100 basis points monetary policy shock. Consequently, a positive shock of 25 basis points corresponds to an increase of 0.7 percentage points in the rental share. With $\psi = 1.6$, a permanent shock of 25 basis points in the interest rate over two years gives a response in the rental share that matches our empirical findings. We set the share of real estate brokers that cannot adjust rents $\theta^r = 0.83$ to match the share of rents that do not change in 6 months reported in Table 1 of Gallin and Verbrugge (2019). The landlords first-order conditions in the steady-state imply that $q_t = l_t/(X^r_{ss}(1-\beta))$. We use this condition to calibrate $X^r_{ss} = 2.2$ such that we match the U.S. average price-to-rent ratio of 11.4. The loan-to-value ratio $m = 0.85$ is taken from Iacoviello and Neri (2010) and Greenwald (2018), and the total housing stock is normalized to 1.

For the final goods sector, we set the share of retailers that cannot adjust their prices on a given period to be $\theta = 0.84$, which is the same parameter value choice in Iacoviello and Neri (2010). We follow Iacoviello and Neri (2010) and Kaplan et al. (2014) and set the savers labor income share $\nu = 0.79$. The retailers markup is calibrated to $X_{ss} = 1.15$ as in Iacoviello and Neri (2010), and the TFP parameter $A$ is set such that output at the steady state is normalized to 1.

Finally, for the Taylor rule, we follow Iacoviello and Neri (2010) and set the steady-state inflation $\pi^{CPI}_{ss} = \pi_{ss} = 1$, the interest rate smoothing parameter $r_R = 0.7$, the response to output gap parameter $r_Y = 0.13$, and the response to inflation parameter $r_\pi = 1.5$.

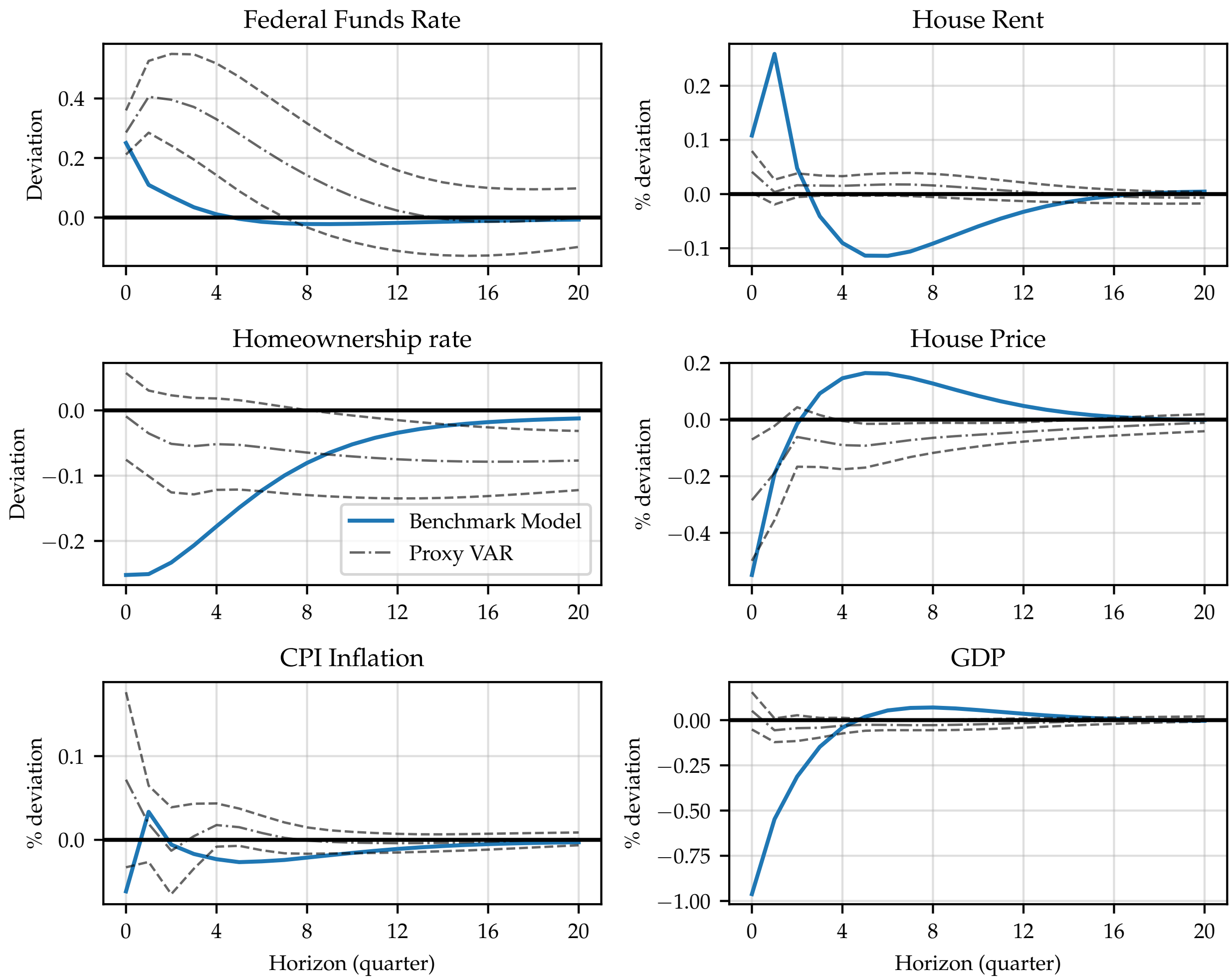
## 5.2 Model Evaluation

Having discussed the parameter values choices, we now evaluate the overall calibration of the model by comparing the responses of selected variables to a monetary policy shock in the model to those obtained with a proxy SVAR and that were presented in section 3.1.2. This comparison provides a credible test to our proposed theory because the calibration of the model does not target any of the empirical impulse response functions estimated with the proxy SVAR. Moreover, except for the housing supply dynamic response, the calibration of the model only targets long-run data moments.

In Figure 3, we show how the transmission of monetary policy shocks to the federal funds rate, house rents, homeownership rate, house price, CPI inflation and GDP implied by the model compares with that of the proxy SVAR.[20] The model matches the empiri-

[20]Since we are only modeling the borrowers' homeownership rate change, a 1 p.p. change in the share

**Figure 3:** Model vs. Proxy SVAR impulse response functions




Note: the Figure compares the model responses to a 25 basis point monetary policy shock to the untargeted empirical responses estimated with the proxy SVAR using the Jarociński and Karadi (2020) instrument to a shock of the same size. The dashed lines report the 68% confidence intervals for the proxy SVAR impulse response functions.

cal monetary transmission to the selected variables well, especially from a qualitatively point of view. Broadly consistent with our empirical findings, the model predicts that the homeownership rate and house prices fall while house rents rise following a contractionary monetary policy surprise. In the benchmark calibration of the model, the rise in rents is not enough make the CPI increase at impact, but it increases in the following period. This result is consistent with the well-known "price puzzle" (Sims (1992)), in which consumer prices rise after a contractionary monetary policy shock. Therefore, our model provides an

of $\alpha_t$ corresponds to a 0.32 p.p. change in the aggregate homeownership rate. For further details, see the discussion in section 5.1.

explanation for the "price puzzle" based on the effect of monetary policy shocks on house rents, and, consequently, on the shelter component of the CPI (or PCE).

While the model matches very well the empirical impulse response functions from a qualitatitve point of view, the model could be improved to better match the empirical response functions from a quantitative point of view. For example, a common way that is used in the literature to improve the quantitative fit of models like ours is the introduction of habit formation into households formation as in Iacoviello and Neri (2010). In our benchmark model we chose to not include habit formation or other features that could help with improving the model fit because: (i) the focus of the paper is on understanding the mechanisms involved in the homeownership decision channel of monetary transmission; and (ii) we want to keep the estimated empirical impulse responses untargeted in the calibration of the model so that we can use them in the evaluation of the calibration. It is our view that a more stripped-down model makes the illustration of the mechanism sharper.

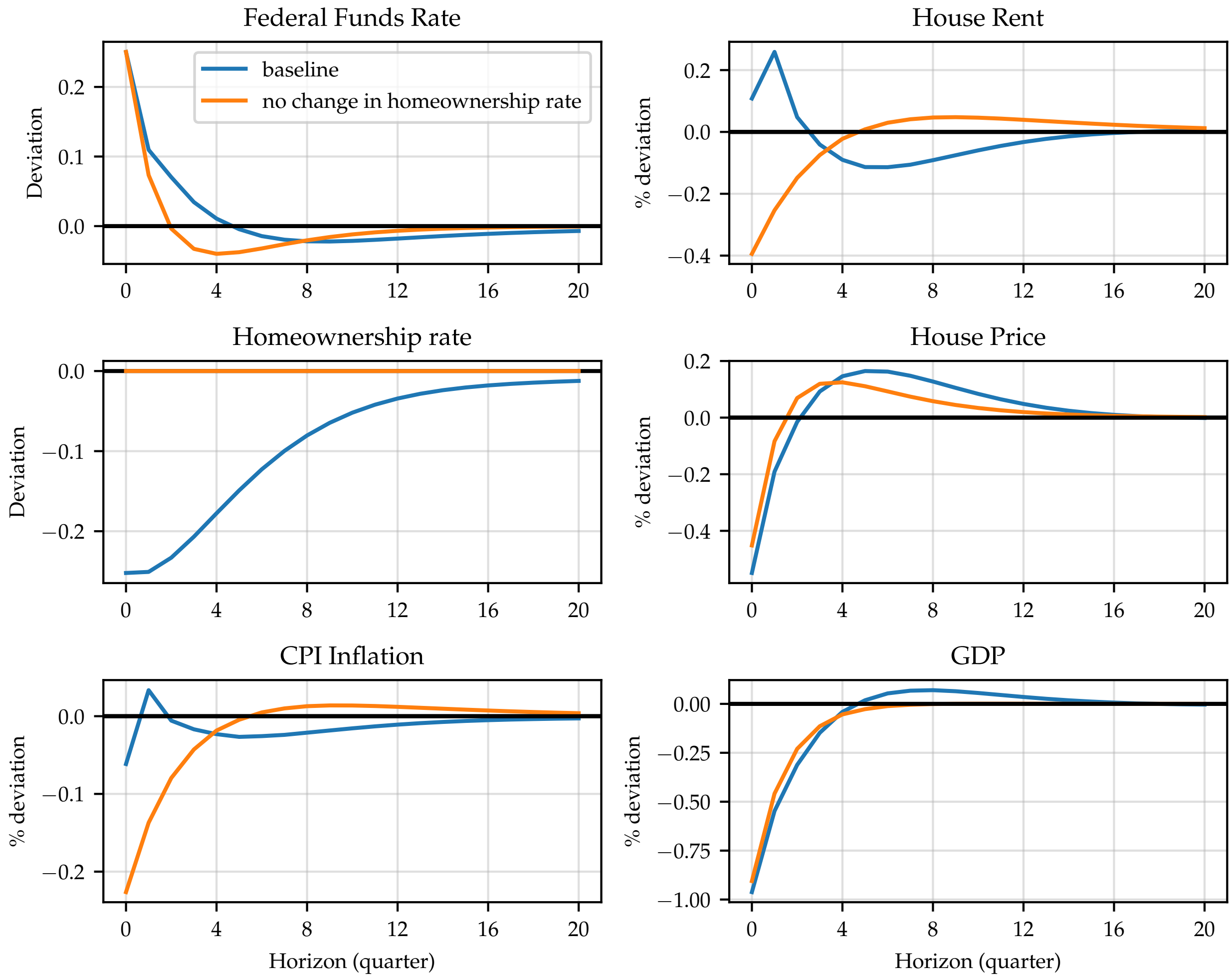
## 5.3 The Role of the Housing Demand and Supply in Matching the Empirical Results

To show the importance of the homeownership decision margin and of a segmented housing market, we compare the transmission of monetary policy when these elements are present in the model to when they are not.

**Homeownership Decision** Starting with the homeownership decision margin, to compare the transmission of a 25-bps contractionary monetary policy shock when borrowers are able to switch between ownership and rental to when they are not, we make the share of homeowners and renters to be constant. In Figure 4, we show the results of this experiment relative to the results obtained with the baseline specification of the model.

The results in Figure 4 show that, without a housing tenure choice margin, housing rents decline, and CPI inflation, which is a weighted average of housing and non-housing prices, declines much more than in the baseline model. For both variables, the model responses are at odds with the the empirical responses. Due to (CPI) inflation being less persistent in the model without a housing tenure choice margin, the federal funds rate declines faster when the hosing tenure choice margin is not present and goes below baseline much earlier than in the baseline. For the other variables, the differences are relatively minor and they are mostly the reflection of differences in the path of interest rates in the two models. House prices fall in both model specifications, but are somewhat more volatile when the housing tenure margin is present (fall by more at the beginning and increase by

**Figure 4:** Importance of the housing tenure choice margin for matching the empirical results

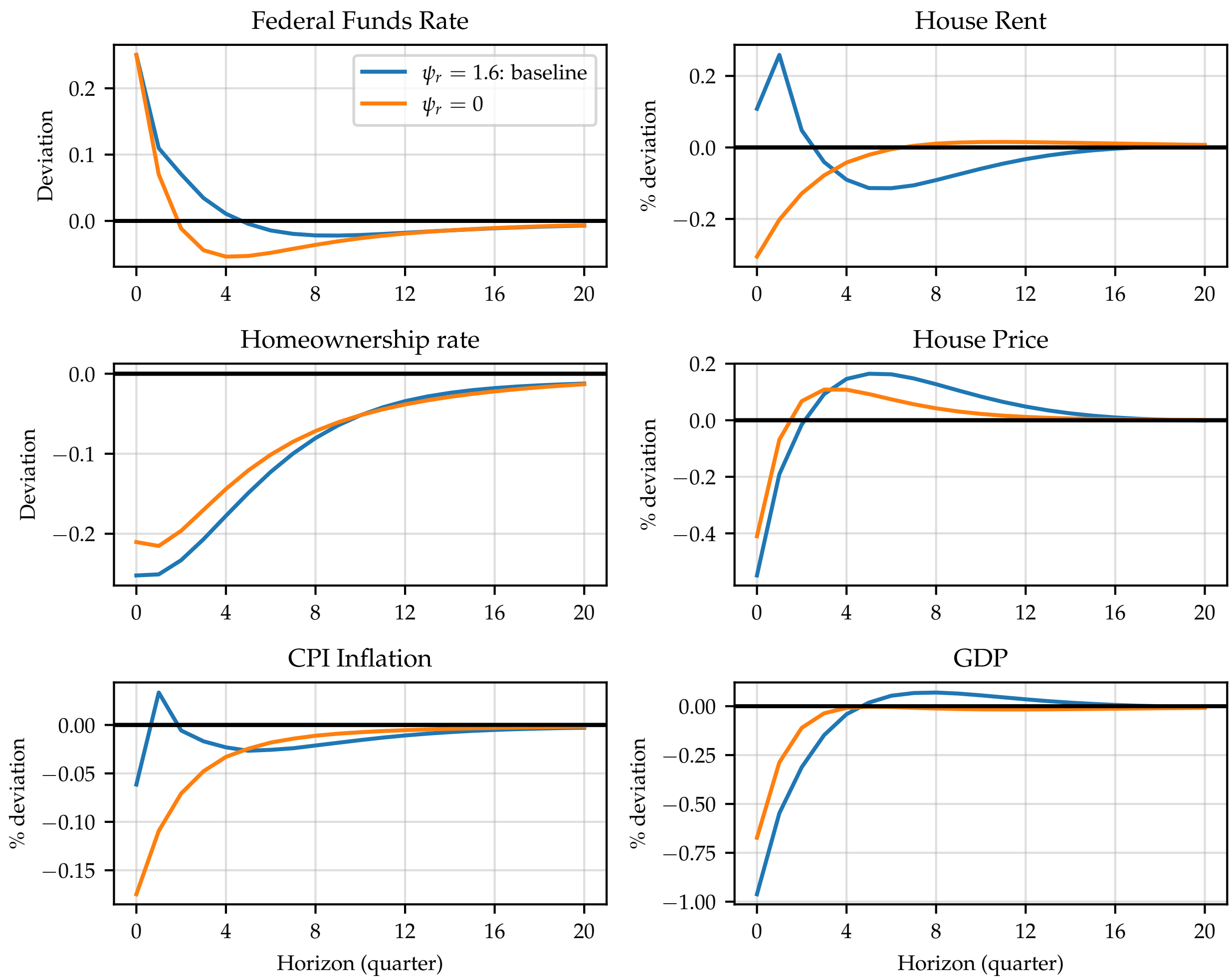



Note: this Figure shows the dynamics responses of macroeconomic aggregates to a 25 basis points positive shock in the nominal interest rate in the baseline calibration and in an alternative calibration in which the homeowner ship rate is constant and the adjustment costs are zero $\psi_r = 0$.

more later on). Similarly, the effects on GDP are relatively similar for both model specifications, but GDP is somewhat more volatile when the hosing tenure choice margin is present.

**Segmented Housing Market.** Turning now to the importance of a segmented housing market for matching the empirical results. Similarly to what we did for the case of the homeownership decision margin, to show the importance of the housing market being segmented for matching the empirical results, we simulate the model without any housing supply adjustment costs (this corresponds to setting the parameter $\phi_r = 0$) and compare the results with those based on the baseline model specification. The results of this exercise are shown in Figure 5.

**Figure 5:** Importance of a segmented housing market form matching the empirical results




Note: this Figure shows the responses of macroeconomic aggregates to a 25 basis points positive shock in the nominal interest rate for the baseline and for two alternative scenarios in which the adjustment cost parameter is set to $\psi_r = 0$ and $\psi_r = 100$.

Figure 5 shows that, without housing market segmentation ($\psi_r = 0$), the model is not able to match the empirical finding that housing rents increase in the short run following a contractionary monetary policy shock. When markets are not segmented, landlords facing higher demand for renting, immediately convert housing units available to homeownership for renting at no cost. As a consequence, supply of housing for renting increases and brings down housing rents in equilibrium.

Similar to the case without a housing tenure choice margin, when the housing market is not segmented (that is, the supply of housing for ownership and for rental can adjust as fast as needed in response to changes in demand), house rents decline after a contractionary monetary policy shock and so does CPI inflation. Also similar to the case without a housing tenure choice margin, the fed funds rate declines faster than in the baseline case and goes below steady sate two quarters after the initial shock. Because the housing tenure choice margin is available, the homeownership rate declines, likely reflecting some temporary fluctuations in the house price-to-rent ratio. In the model without a segmented housing market, house prices decline less than in the baseline model specification and so does GDP.

After having shown in this section how the model proposed in section 4 can match the empirical regularities shown in section 3, in the next section we discuss why these results matter and what implications there may be for monetary policy.

# 6 The Homeownership Decision Channel of Monetary Policy Transmission

In this section we discuss the mechanism underlying the homeownership decision channel of monetary policy and its implications for monetary policy.

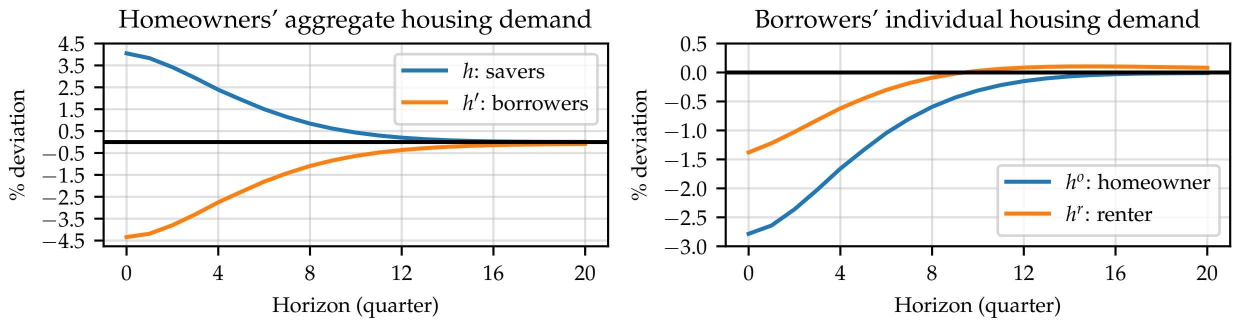
## 6.1 The Mechanism Underlying the Homeownership Decision Channel of Monetary Policy

To better understand how the homeowneship decision channel of monetary policy operates, we look at the responses of borrowers' and savers' housing demand, consumption and labor supply allocation to a monetary policy shock, and also at the response of housing supply to the same shock. Figure 6 shows the model responses of housing demand for borrowers and savers (panel a), housing supply (panel b), consumption and labor supply of borrowers and savers (panel c) to a 25-bps contractionary monetary policy shock.

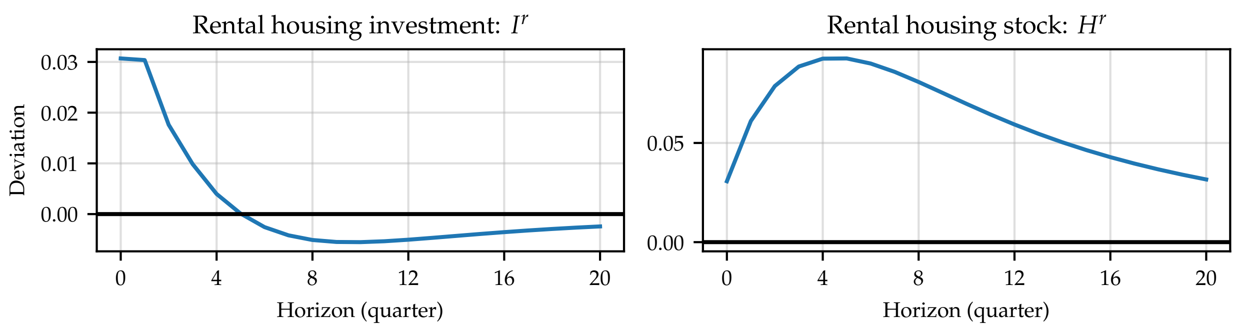
While in the model everything is moving simultaneously, it is useful to think about the dynamic effects of the monetary policy shock sequentially. When interest rates rise unexpectedly, the cost of homeownership for borrowers also rises. The higher cost of homeownership from higher interest rates makes some borrowers that were homeowners to become renters, which pushes up the demand for rental housing. Due to the increased demand for rental housing, rents increase, which also increases the income that savers get from the rental houses they own. The decline in borrowers' demand for housing for ownership pushes house prices down, while savers' higher income pushes their demand for housing up, which acts as a backstop for house prices thereby preventing them from falling further.

**Figure 6:** Model Impulse Response Functions of Housing Demand, Housing Supply, Consumption, and Labor Supply to a 25-bps Contractionary Monetary Policy Shock

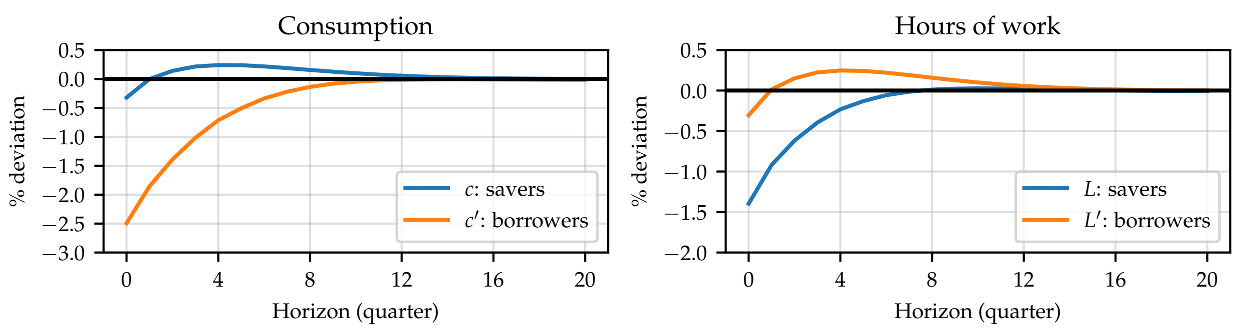
**(a)** Housing demand




**(b)** Housing supply




**(c)** Consumption and labor allocations




Note: this Figure shows in panels a), b), and c) the model responses to a 25-bps increase in the nominal interest rate in the benchmark calibration of the model of housing demand for borrowers and savers, housing supply, and consumption and labor supply of borrowers and savers, respectively.

As such, and as shown in panel a) of Figure 6, the amount of housing owned by borrowers declines after a contractionary monetary policy shock, while the amount of housing owned by savers increases.

Due to higher interest rates, the cost of homeownership, which is a function of house prices and interest rates, increases and as a result borrowers that are homeowners reduce the amount of housing services they consume. Higher rents also push down the consumption of housing services of renters, but by less than that that of homeowners because rents rise less than the homeownership cost. We know that rents rise less than the cost of ownership because otherwise there wouldn't be homeowners becoming renters as the results in Figure 3 show.

Following the increase in demand for rental housing and the decline of house prices, as shown in panel b) of Figure 6, landlords choose to increase their rental housing stock. This increase in the supply of housing for rental is insufficient to meet in the increase in demand, which explains the higher rents.

With respect to consumption and labor supply decisions of savers and borrowers (there is no difference in these allocation between borrowers that are homeowners and those that are renters), panel c) of Figure 6 shows that initially both savers and borrowers cut consumption and reduce labor supply. However, in the periods after the monetary shock, savers increase consumption above steady state values while borrowers' consumption remains below its steady state amount for more than 8 periods. For both savers and borrowers labor supply falls immediately in response to the contractionary monetary policy shock, but borrowers' labor supply quickly rises above steady state levels while savers' labor supply is below steady levels for a long period.

The differences between housing demand, consumption, and labor supply choices of borrowers and savers clearly suggest that a contractionary monetary policy shock in this model will be welfare improving for savers but welfare reducing for borrowers. In Figure 7 we summarize these changes in allocations in terms of consumption equivalent variation.

As expected from the results in panels a) and c) of Figure 6, but also because it is a well-established result in the literature, savers' welfare increases while borrowers' decreases (panel a) in Figure 7) following a contractionary monetary policy shock. Among borrowers, as could be expected from the results shown in panel a) of Figure 6, both renters and homeowners are negatively affected by a contractionary monetary policy shock but homeowners more than renters (panel b) of Figure 7).

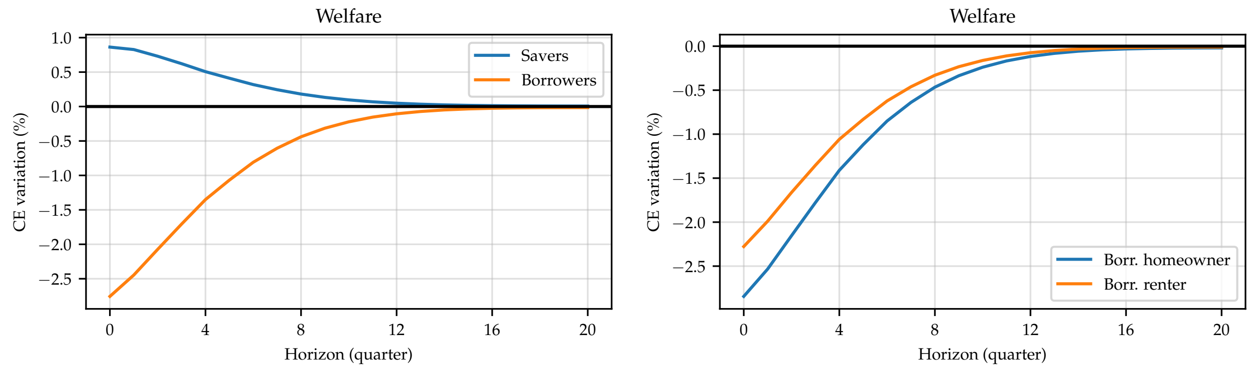
## 6.2 Implications for Monetary Policy

After having explained how monetary policy transmits when the homeownership decision channel of monetary policy is at play, we now discuss the implications for monetary policy.

**Figure 7:** Impact of a 25-bps contractionary monetary policy shock on welfare across agents

**(a)** Saver vs. borrower

**(b)** Borrower-homeowner vs. borrower-renter




Note: panel (a) shows the welfare change, measured in consumption equivalent variation, for borrowers and savers, following a contractionary monetary policy shock of 25 basis points; panel (b) shows the welfare change for borrowers-homeowners and borrowers-savers following the same shock as in panel (a).

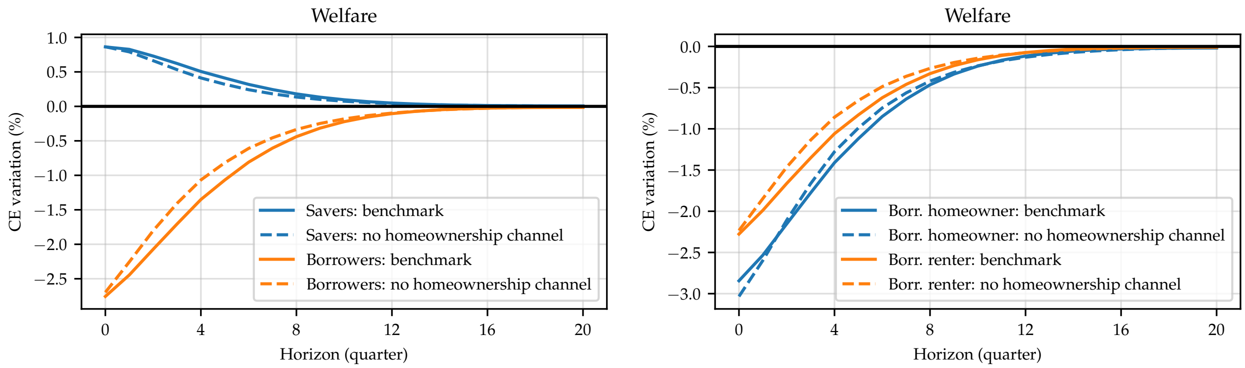
**Redistributive Effects** We have thus far shown that, in response to a contractionary shock, savers are better off while borrowers are worse off. This redistributive effect of monetary policy is well known, and therefore not specific to our model. What is important to know in the context of our model, is whether the homeownership channel of monetary policy amplifies or tapers such redistributive effect. To answer this question, we compare the welfare effects of a 25 basis points contractionary monetary policy shock under the baseline model and a model without the homeownership channel of monetary policy. In the model without the homeownership channel of monetary policy borrowers can't move between owning and renting and housing supply can be adjusted at no cost - these are the features that we showed in Section 5 to be necessary to match the empirical results, and thereby generate a homeownership decision channel of monetary policy. The results of this analysis are shown in panel a) of Figure 8

As can be seen in panel a) of this Figure, when the homeownership channel of monetary policy is at play, the redistributive effects of monetary policy between savers and borrowers get amplified. The dashed lines in panel a) of Figure 8 lie between the solid lines in the same panel, meaning that savers gain less and borrowers lose less in a model without the housing tenure choice of monetary policy than in a model with this channel. One implication for monetary policy is that it has stronger redistributive effects than previously thought, which could render different monetary policy choices once these differences are accounted for.

With regards to the differences of welfare among borrowers, panel b) of Figure 8 shows

**Figure 8:** Impact of a 25-bps contractionary monetary policy shock on welfare across agents with and without the housing tenure choice channel of monetary policy

**(a)** Saver vs. borrower **(b)** Borrower-homeowner vs. borrower-renter

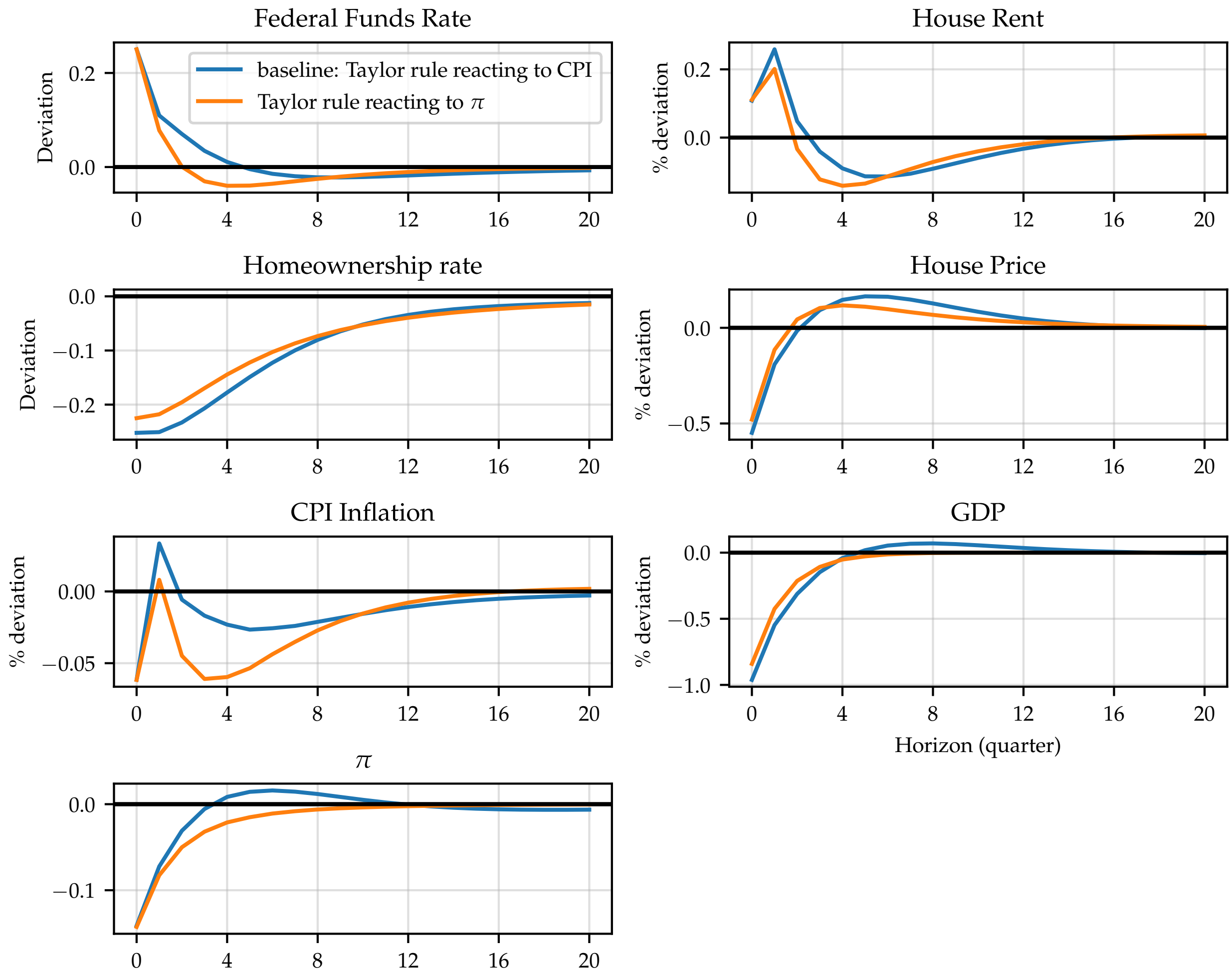



Note: panel (a) shows the welfare change, measured in consumption equivalent variation, for borrowers and savers, following a contractionary monetary policy shock of 25 basis points with and without the housing tenure choice channel of monetary policy; panel (b) shows the welfare change for borrowers-homeowners and borrowers-savers with and without the housing tenure choice channel of monetary policy following the same shock as in panel (a).

that renters lose more when the housing channel of monetary policy is at play. In cumulative terms, they lose 1.3 pp. in consumption equivalent variation because of the homeownership channel. This result comes from the fact that rents go up, which reduces their available income for consumption of other goods. For homeowners, the results are less clear cut. At impact, homeowners' welfare loss is lower because some homeowners decide to switch to renting when interest rates increase, which helps house prices decrease more when the housing tenure choice channel of monetary policy is in effect. As house prices start to rise again, and because house prices increase more in the baseline model, the welfare losses become larger when the housing tenure choice of monetary policy is present than when is not. In net terms the borrowers-homeowners lose 0.3 pp. more of consumption equivalent when the homeownership channel is present.

**A Taylor Rule with a Measure of Inflation Without Housing Costs** As shown in equation 45, when inflation is measured by CPI, movements in CPI reflect both changes in underlying inflation ($\pi_t$) and changes in rents (or the price of rents relative to that of consumption of other goods). Because rents move in the opposite direction to inflation in response to a monetary policy shock, monetary policy that responds to CPI will at times be responding to changes in relative price movements that were induced by monetary policy itself. To understand the implication from this feedback loop for monetary policy, we compare the effects of a 25 basis points monetary policy shock when the central bank follows a Taylor rule with inflation measured by CPI ($\pi_t^{CPI}$) and when the central bank follows follows a Taylor rule with a measure of inflation without housing costs ($\pi_t$).[21] The results of this exercise are shown in Figure 9.

**Figure 9:** Impulse responses when the central bank reacts to a measure of inflation without housing costs




Note: the Figure shows the response of macroeconomic aggregates to a monetary policy shock in the baseline calibration and modified version of the baseline in which the Taylor rule reacts to $\pi$, a measure of inflation that excludes housing costs, instead of $\pi^{CPI}$, a measure of inflation that includes housing costs.

Figure 9 shows that, relative to the baseline case (corresponding to a Taylor rule reacting to CPI), when the central bank responds to a measure of inflation without housing costs,

[21] In the context of our model, a measure of inflation without housing costs corresponds exactly to the underlying level of inflation in the economy, but, in practice, this does not need to be the case. What is most important is that the central bank follows a Taylor rule with a measure of inflation that doesn't include any component that moves in the same direction as interest rates.

real effects of monetary policy are smaller as GDP falls less and there is less GDP volatility (20% less) as GDP monotonically recovers towards steady following a monetary policy shock. At the same time, house prices and rents are both less volatile (24% and 28% less, respectively) when the central bank responds to a measure of inflation without housing costs than when the central bank responds to CPI. When the central bank follows a Taylor rule with a measure of inflation that excludes housing costs, interest rates are kept high for a shorter period of time and they return to steady faster than when the central bank follows a Taylor rule that targets CPI. With regards to the underlying inflation, measured by $\pi_t$, volatility is about the same when the monetary authority targets CPI or a measure of inflation without housing costs.

In addition to the different effects on GDP, house prices, rents, and the path of interest rates, when the central bank targets a measure of inflation without housing costs, in response to a monetary policy shock, the homeownership rate responds less, and CPI inflation responds more than when the central bank targets CPI.

Taken all together, the results in Figure 9 suggest that a central bank may be better able to achieve its goals by targeting a measure of inflation without housing costs than a measure of inflation that includes housing costs (such as the CPI).

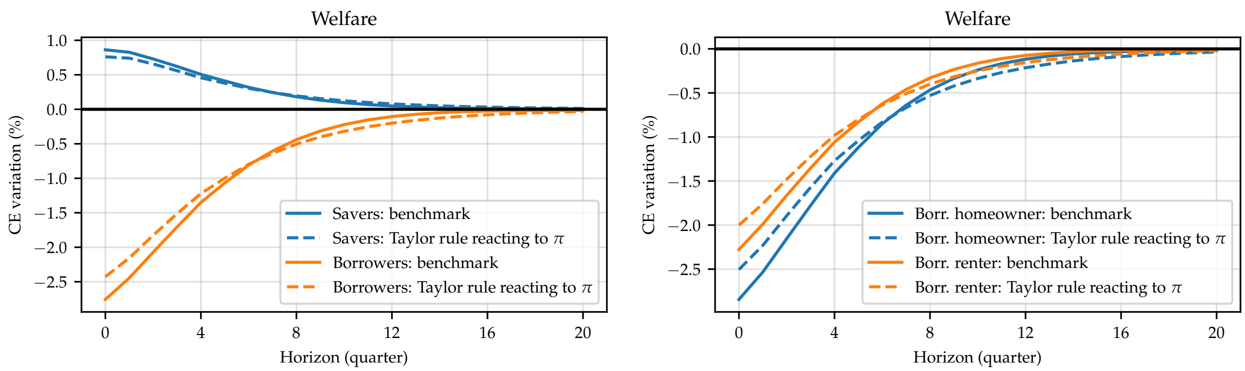
To quantify the welfare benefits from the central bank following a Taylor rule with measure of inflation without housing costs, we calculate the consumer equivalent variation after a monetary policy shock under the baseline case and the case of a Taylor rule with a measure of inflation without housing costs. The results of this exercise are shown in Figure 10.

This Figure shows that, when the central bank targets a measure of inflation without housing costs, the redistributive effects of monetary policy are smaller – borrowers lose less and savers gain less after a contractionary monetary policy shock. And, among borrowers, both renters and homeowners are less negatively affected by a contractionary monetary policy shock. In Figure 10, some of the welfare gains from the central bank targeting a measure of inflation without housing costs disappear after about 6 to 8 quarters after the monetary policy shock, but, even after accounting for this, the redistributive effects of monetary policy are still smaller and both renters and homeowners are better off.

It is important to note that the discussion of which inflation measure to target is only relevant only when the homeownership decision channel of monetary policy is at play. If monetary policy did not make households choose between owning or renting and the housing market was able to quickly adjust to changes in demand, housing rents would respond to monetary policy in the same way as other goods (Figures 4 and 5) there would not be a feedback loop from inflation to monetary policy that makes monetary policy less

**Figure 10:** Welfare effects of a 25-bps contractionary monetary policy shock when the central bank reacts to a measure of inflation without housing costs

**(a)** Saver vs. borrower **(b)** Borrower-homeowner vs. borrower-renter




Note: panel (a) shows the welfare change, measured in consumption equivalent variation, for borrowers and savers, following a contractionary monetary policy shock of 25 basis points when the Taylor rule targets $\pi^{CPI}$, a measure of inflation that includes housing costs, and when the Taylor rules targets $\pi$, a measure of inflation that excludes housing costs; panel (b) shows the welfare change for borrowers-homeowners and borrowers-savers when the Taylor rule targets $\pi^{CPI}$ and when the Taylor rules targets $\pi$ following the same shock as in panel (a).

effective and more costly from an output loss point of view.

# 7 Concluding Remarks

This paper shows that monetary policy transmits to the economy through its effects on households' homeownership decisions, and that this channel has implications for monetary policy.

To arrive at this conclusion, the paper first empirically shows that monetary policy shocks are an important driver of the aggregate homeownership rate and that this effect is due to monetary policy shocks affecting households decisions to transition from renting to owning and vice-versa. To account for these empirical facts, the paper proposes a two-agent New Keynesian model extended with a housing tenure decision and adjustment costs on housing supply. Using a version of the model calibrated to the U.S. economy, the paper shows that monetary policy effects on housing tenure decisions amplify the redistributive effects of monetary policy and that when the central bank targets a price index that includes housing costs (which are directly and indirectly measured by housing rents) it can generate excessive volatility of house prices, rents, and economic activity and monetary policy has larger real effects which produces larger losses in output.

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# Online Appendix for "Monetary Policy and Homeownership: Empirical Evidence, Theory, and Policy Implications"

## A Data Description

### A.1 Aggregate U.S. Data

In the aggregate data analysis portion of this paper, we use several publicly available macroeconomic variables. The table below lists and defines all these variables and provides the corresponding sources.

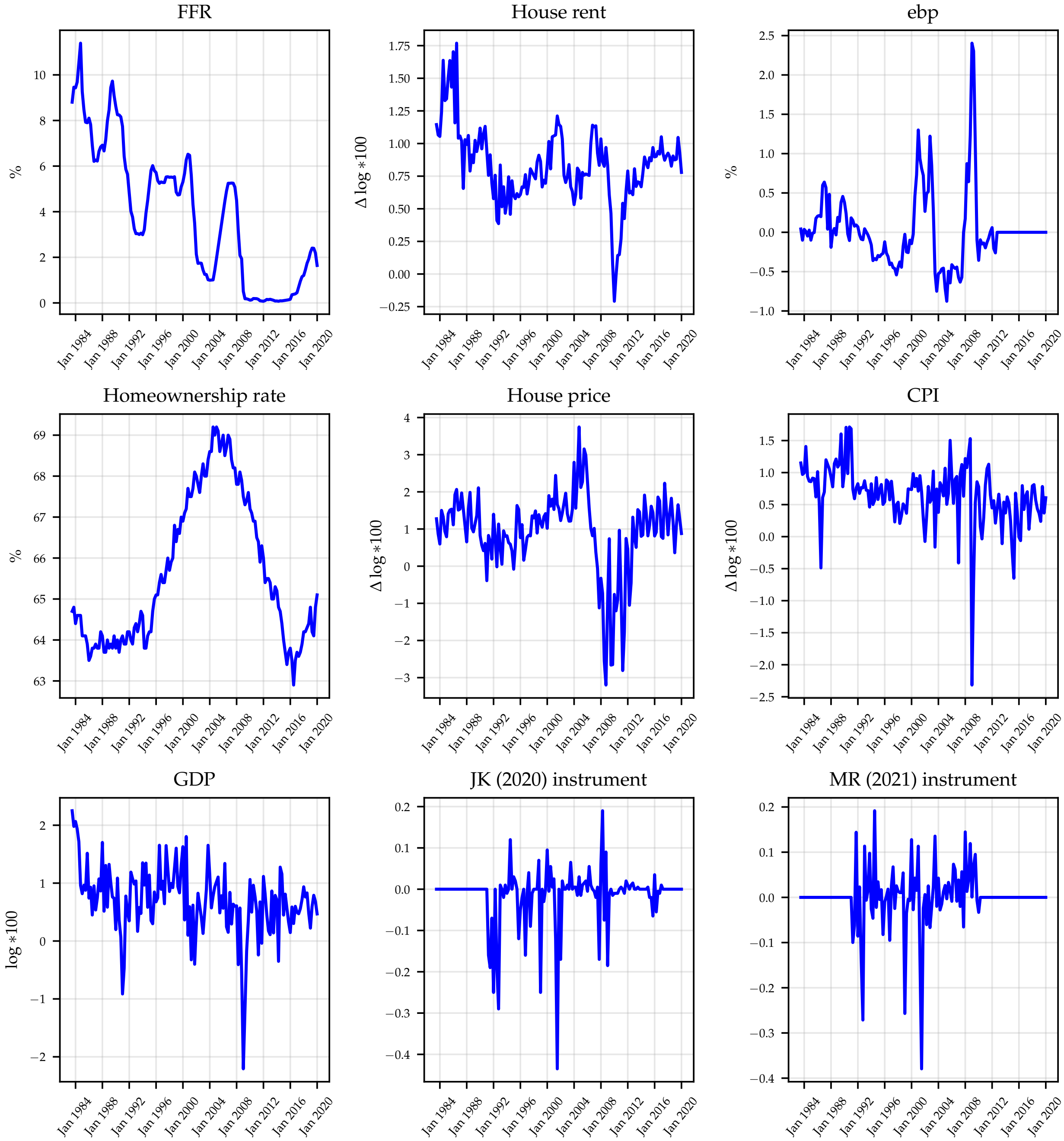
**Table A1:** Aggregate macroeconomic data

| Series | Source | Series Description | Sample |
|---|---|---|---|
| U.S. GDP | FRED | Quarterly data, Seasonally Adjusted | 1981:Q1 - 2017:Q4 |
| One-Year Rate | Own calculation | Quarterly average of the one-year rate monthly data, Seasonally Adjusted | 1981:Q1 - 2017:Q4 |
| Housing Prices (USSTHPI) | FRED | All-Transactions House Price Index for the United States, Index 1980:Q1=100, Not Seasonally Adjusted | 1981:Q1 - 2017:Q4 |
| Housing Rents | Own calculation | Quarterly average of the housing rents monthly data, Seasonally Adjusted | 1981:Q1 - 2017:Q4 |
| Homeownership Rate (RSAHORUSQ156SN) | FRED | Homeownership Rate for the United States, Percent, Seasonally Adjusted | 1981:Q1 - 2017:Q4 |
| Excess Bond Premium | | Gilchrist and Zakrajšek (2012) | 1990:Q1 - 2012:Q4 |
| JK monetary policy shock | Jarociński and Karadi (2020) | High frequency monetary policy shock instruments that separates monetary policy developments from economic outlook information from the Fed's communications | 1991:Q1 - 2016:Q4 |
| MR monetary policy shock | Miranda-Agrippino and Ricco (2021) | Same as JK monetary policy shock | 1990:Q1 - 2009:Q4 |

### A.2 Annual Housing Survey Data

With the exception of the monetary policy shock, all the data underlying the analysis of household tenure status and housing unit type transitions come from the publicly available Annual Housing Survey database that is compiled by the U.S. Census Bureau. This database has two main surveys, the national and the metro area surveys, and it covers a very large of aspects relating to U.S. household living arrangements and characteristics

**Figure A1:** Macroeconomic Variables and Instruments Time Series




Note: this Figure shows the time series data for all the variables and external instruments (Jarociński and Karadi (2020) and Miranda-Agrippino and Ricco (2021)) used in the estimation of the Proxy SVAR.

of the U.S. housing stock. For the analysis in this paper, we only used a small subset of variables which we list and describe how they were used in Table A2.

**Table A2:** Data from AHS database used in the analysis

| Variable used in analysis | Definition | Used variable(s) from AHS database |
|---|---|---|
| Housing unit type | Indicator variable for the housing unite tenure status. This variable takes the value 1 if the housing unit is deemed for rental and 0 if deemed for ownership. Other types of housing unit tenure status (e.g. ”Occupied without payment of rent”) were excluded from the sample. | “tenure” for years 1991, 1993, 1995, 1997, 1999, 2001, 2003, 2005, 2007, 2009, 2011, 2013, and 2015 |
| Housing unit rent-to-own transition | Indicator variable taking the value 1 if the housing unit was a rental unit 2 years before and is an owner-occupied unit currently, and the value 0 if the housing unit was a rental unit 2 years prior and still is a rental unit currently. | “tenure” for years 1991, 1993, 1995, 1997, 1999, 2001, 2003, 2005, 2007, 2009, 2011, 2013 |
| Housing unit own-to-rent transition | Indicator variable taking the value 1 if the housing unit was a owner-occupied unit 2 years before and is now a rental unit, and the value 0 if the housing unit was owner-occupied 2 years prior and still is owner-occupied. | “tenure” for years 1991, 1993, 1995, 1997, 1999, 2001, 2003, 2005, 2007, 2009, 2011, 2013 |
| Households rent-to-own transition | Indicator variable taking the value 1 if the household living in the housing unit was renting 1 year before and owns now, and the value 0 if the household was owning 1 year before and is owning now | “xaten” for year 1991, 1993, and 1995; “xten” for years 1997, 1999, 2001, 2003, 2005, 2007, 2009, 2011, 2013; “mgv1type” for year 2015. Combined with variable “tenure”, which provides information on current housing unit type |
| Households own-to-rent transition | Indicator variable taking the value 1 if the household living in the housing unit owned the house it lived in 1 year before and rents now, and the value 0 if the household was renting 1 year before and is renting now. | “xaten” for year 1991, 1993, and 1995; “xten” for years 1997, 1999, 2001, 2003, 2005, 2007, 2009, 2011, 2013; “mgv1type” for year 2015. Combined with variable “tenure”, which provides information on current housing unit type |
| Change in the aggregate household rental share | Difference between the number of all households that switched from owning to renting and the number of all households that switched from renting to owning divided by the total number of households in the year. $\frac{\sum_{i=1}^{N} Own\text{−}to\text{−}rent_i - \sum_{i=1}^{N} Rent\text{−}to\text{−}own_i}{N}$ | “xaten” for year 1991, 1993, and 1995; “xten” for years 1997, 1999, 2001, 2003, 2005, 2007, 2009, 2011, 2013; “mgv1type” for year 2015. Combined with variable “tenure”, which provides information on current housing unit type |
| Change in the aggregate share of rental units | Difference between the share of housing units in every year that is a rental. $\frac{\sum_{i=1}^{N_t} Rental_i}{N_t} - \frac{\sum_{i=1}^{N_{t-2}} Rental_i}{N_{t-2}}$ | “tenure” for years 1991, 1993, 1995, 1997, 1999, 2001, 2003, 2005, 2007, 2009, 2011, 2013 |
| Age tercile | Indicator variables taking the value 1 if the head of household’s age falls in a given age tercile for the sample of heads of household in a given year, and 0 otherwise. | “age” for years 1991, 1993, 1995, 1997, and 1999; “hhage” for years 2001, 2003, 2005, 2007, 2009, 2011, 2013, and 2015 |
| Income quartile | Indicator variables taking the value 1 if the housedhold’s income falls in a given income quartile for the sample of heads of household in a given year, and 0 otherwise. | “zinc2” for years 1995, 1997, 1999, 2001, 2003, 2005, 2007, 2009, 2011, and 2013; “hincp” for year 2015 |
| Region | Indicator variables taking the value 1 if housing unit is located in one of U.S. four administrative regions as defined by the U.S. Census Bureau: East, Midwest, South, and West. | “region” for years 1991, 1993, 1995, 1997, 1999, 2001, 2003, 2005, 2007, 2009, 2011, and 2013; “division” for year 2015 |

Note: the AHS database is available online here and the definition of each of the variables in the database can be found here.

Note: the AHS database is available online here and the definition of each of the variables in the database can be found here.

# B Proof of Proposition 1

Start with the borrowers’ social planner problem of maximizing:

$$E_0 \sum_{t=0}^{\infty} (\beta')^t \left\{ \int_0^1 \ln c_t^i + (1 - I_t^i) \left( j^r \frac{(h_t^i)^{1-\phi^r}}{1-\phi^r} \right) + I_t^i \left( j^o \frac{(h_t^i)^{1-\phi^o}}{1-\phi^o} + \rho_t^i \right) - \frac{(L_t^i)^\eta}{\eta} di \right\},$$

where $E_0$ is the expectation operator conditional on time zero information, $\beta \in (0,1)$ is the discount factor, $c_t^i$ is consumption of borrower $i$ at time $t$, $I_t^i \in \{0,1\}$ is an indicator function that takes the value of 1 if borrower $i$ decides to own and zero if she decides to rent, $h_t^i$ denotes housing services, $\rho_i$ is the extra utility i.i.d. draw from $F(\rho)$ that agent $i$ receives when owning a house and $L_t^i$ are hours of work, subject to

$$\int_0^1 c_t^i + I_t^i q_t \Delta h_t^i + (1 - I_t^i) h_t^i l_t + b_{t-1}^i \frac{R_{t-1}}{\pi_t} di = \int_0^1 b_t^i + w_t' L_t^i di$$
$$b_t^i \leq I_t^i E_t \left[ m q_{t+1} h_t^i \frac{\pi_{t+1}}{R_t} \right],$$

where $q_t$, $l_t$, $R_t$, $\pi_t$, $w_t'$, $m$ and $b_t^i$ denote the real housing price, real housing rent, gross nominal interest rate, gross inflation rate, real wage, loan-to-value ratio and borrowing in real terms, respectively.

The first order condition with respect to $c_t^i$ is

$$\frac{1}{c_t^i} = \gamma_t, \tag{B1}$$

where $\gamma_t$ is the Lagrange multiplier associated with the budget constraint. This condition implies that the optimal consumption is the same for all households. Let us denote this consumption by $c_t'$. Next, the first order for $L_t^i$ is the following:

$$(L_t^i)^{\eta-1} = \frac{w_t}{c_t'}. \tag{B2}$$

This condition implies that optimal hours worked will also be the same for all households. Hence, conditions B1 and B2 prove result (ii) of Proposition 1. Finally the first order condition for $h_t^i$ is given by:

$$\begin{cases} j^o (h_t^i)^{-\phi^o} = \frac{q_t}{c_t'} - E_t \left( \beta' \frac{q_{t+1}}{c_{t+1}'} + \lambda_t m_t q_{t+1} \pi_{t+1} \right) & \text{if } I_t = 1 \\ j^r (h_t^i)^{-\phi^r} = \frac{l_t}{c_t'} & \text{if } I_t = 0 \end{cases} \tag{B3}$$

where $\lambda_t$ is the Lagrange multiplier of the borrowing constraint. This last condition implies that the optimal housing services allocation $h_t^o$ will be the same across all homeowners $I_t = 1$, and that the optimal housing services allocation $h_t^r$ will be the same across all of those who rent $I_t = 0$. However, depending on house prices and rents, the housing allocations can be different between homeowners and renters. With this, we prove result (iii) of Proposition 1. We now turn to prove result (i). In each period, the borrowers' social planner will have each household $i$ owning a house instead of renting if and only if she receives higher instantaneous utility from it than otherwise:

$$I_t = \begin{cases} 1 & \text{if and only if} \quad j^o \frac{(h_t^i)^{1-\phi^o}}{1-\phi^o} + \rho_t^i > j^r \frac{(h_t^i)^{1-\phi^r}}{1-\phi^r} \\ 0 & \text{otherwise.} \end{cases} \tag{B4}$$

Because $\rho_t^i$ is drawn from a continuous cdf $F(\rho)$ with a non-negative support there will be a unique $\bar{\rho}_t$ that makes a household indifferent between owning and renting. Therefore, households with $\rho_t^i > \bar{\rho}_t$ choose to own a house, while those with $\rho_t^i < \bar{\rho}_t$ decide to rent a house. Hence, the share of homeowners will be given by $\alpha_t = 1 - F(\bar{\rho}_t)$.

# C Robustness Checks

## C.1 Local Projections

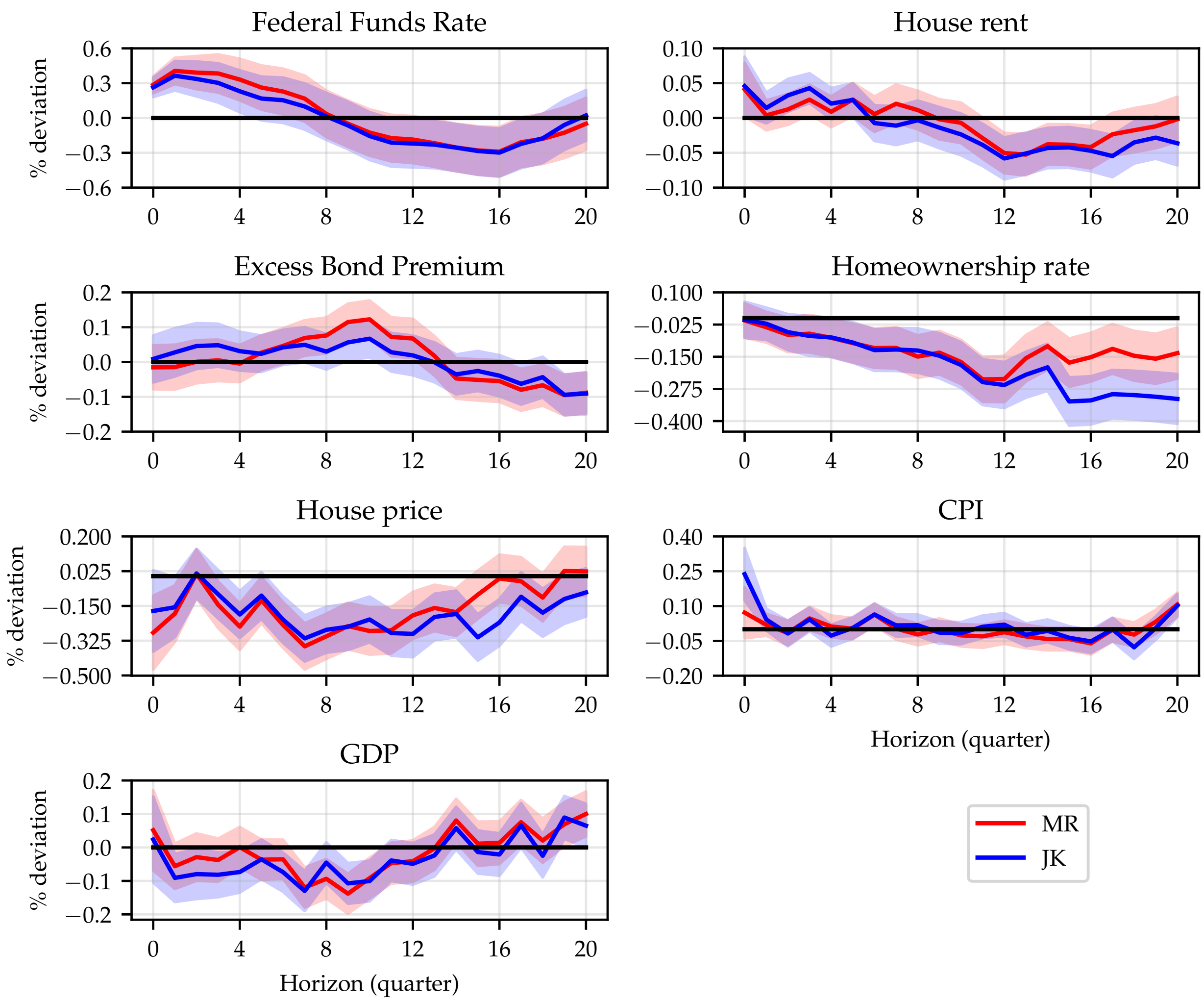
Jordà (2005) introduced the local projections (LP) method as an alternative to VAR models for the purpose of studying the dynamic effects of shocks on variables of interest. As shown in Plagborg-Mller and Wolf (2021), LP and VAR estimators are simply two dimension reduction techniques with common estimand but different finite-sample properties. In addition, Miranda-Agrippino and Ricco (2021) show that the different finite-samples are mostly related to a bias-variance trade-off, particularly at longer horizons: LP provide lower bias but higher variance when compared with VAR estimators. For the sake of robustness, we show how the dynamic responses of monetary shocks look like when estimated by LP and structural shocks are identified in the same way as with the SVAR. In Figure C1 we show the results based on LP. As expected, the results are qualitatively the same as those obtained with the SVAR model and that were presented in subsection 3.1.2 of the main text. The results are based on the two estimation methods are also very similar quantitatively.

## C.2 FEVD based on proxy SVAR

Instead of using the SVMA methodology of Plagborg-Møller and Wolf (2021a) to estimate the importance of a shock for forecast variance of the variables in the response in response to the monetary policy shock, we could have used the Proxy SVAR model to compute the forecast error variance decomposition (FEVD) of the variables in the model in response to the same monetary policy shock. While we prefer the result based on the SVMA methodology, we also computed the FEVD based on the proxy SVAR model. Figure C2 shows the forecast error variance decomposition (FEVD) estimates from the Proxy SVAR, which require the assumption of the model being invertible.

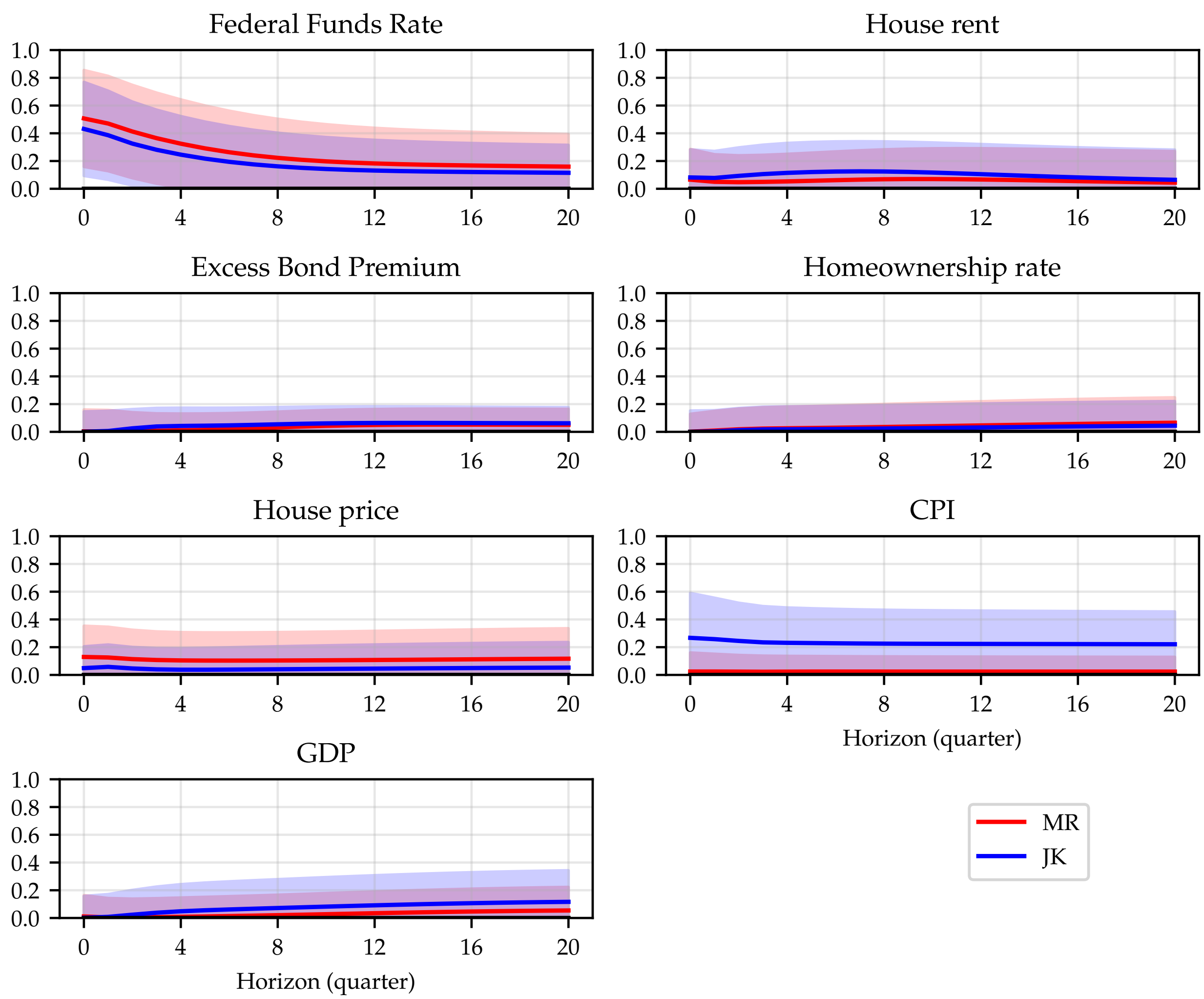
Notwithstanding the fact that the SMVA approach yields intervals for the forecast variance ratio whereas the proxy SVAR yields point estimates for the FEVD, we find that the results are broadly similar. Moreover, we also find that the results in Figure C2 are very similar for both instruments.

**Figure C1:** Impulse Response Functions of Select Macroeconomic Variables to a 25 bps Monetary Policy Shock Using Local Projections




Note: results in the figure are based on the local projections method (Jordà (2005)) combined with the proxy VAR approach to identify the impact effects of the monetary shock on the variables of interest (Miranda-Agrippino and Ricco (2021)); the monetary policy shock instrument used for the results displayed in red is that of Miranda-Agrippino and Ricco (2021) and the instrument used for those reported in blue is that of Jarociński and Karadi (2020) coming from their the poor man's sign restriction approach. Both instruments isolate the pure monetary surprises from the information content present in the Fed's communications. The solid lines report the impulse response functions point estimates, while the shaded areas report the 68% confidence intervals. The confidence intervals were computed from 1,000 draws using a parametric bootstrap as proposed in Stock and Watson (2018).

**Figure C2:** Contribution of Monetary Policy Shocks to the Forecast Error Variance of Select Macroeconomic Variables




Note: the forecast error variance decomposition of the monetary policy shock results in the figure are based on the proxy SVAR described in the methodology section of the paper; the monetary policy shock instrument used for the results displayed in red is that of Miranda-Agrippino and Ricco (2021) and the instrument used for those reported in blue is that of Jarociński and Karadi (2020) coming from their the poor man's sign restriction approach. Both instruments isolate the pure monetary surprises from the information content present in the Fed's communications. The solid lines report the point estimates, while the shaded areas report the 90% confidence intervals. The confidence intervals were computed from 1,000 draws using a parametric bootstrap as proposed in Stock and Watson (2018).