Heterogeneous Effects of Mortgage Rates on Housing Returns: Evidence from an Interacted Panel VAR

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Abstract

This paper develops a theoretical and empirical framework to assess the heterogeneous effects of mortgage rates on housing returns when accounting for the zero lower bound regime of the policy interest rate and state-level supply and demand conditions. Based on an interacted panel VAR, estimated on a dataset comprising of all 50 U.S. states and the District of Columbia for a time period between January 1995 and December 2020, our empirical findings show that the response of housing returns to a mortgage rate shock is larger in magnitude when the federal funds rate is at its zero lower bound. Various supply and demand conditions, including housing permits, personal income, employment, and population, matter for the transmission of a mortgage rate shock to housing returns in local markets. A partial equilibrium model supports our empirical results.

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1 Introduction

In this paper, we build a simple partial equilibrium model of housing based upon Glaeser et al. (2008) to understand the effects of changes in mortgage rates on regional housing returns. The supply side of the model is composed of existing homeowners and developers, who sell old and new houses respectively. Housing demand is determined by new home buyers and their decision to purchase a home, which is influenced by the utility derived from living in a region and the expected capital gains from owning a home in the region. The equilibrium condition shows that mortgage rate shocks have heterogeneous effects on housing returns conditional on the monetary policy regime, local supply and demand factors, and their interactions. Based on these theoretical observations, we estimate an interacted panel vector autoregression (IPVAR) model, as outlined in Towbin and Weber (2013), to empirically test the impact of various housing supply and demand determinants at the state level, including housing permits, real personal income, employment, and population, on housing returns following a mortgage rate shock. Furthermore, the IPVAR approach allows us to account for the zero lower bound (ZLB) regime of the federal funds rate and measure its implications for a mortgage rate shock and its impact on housing returns in the presence of heterogeneous supply and demand forces.

Our empirical results show that the response of housing returns to a mortgage rate shock is amplified in the ZLB regime of monetary policy. At its maximum impact, the ZLB response is double the size of the non-ZLB response. In other words, if mortgage rates are lowered, housing returns expand by twice the amount when the policy rate is near its lower bound of zero. Furthermore, the mortgage rate shock is more persistent and its effects are longer-lasting in an environment where the federal funds rate is close to zero. These results are in line with the ongoing housing boom in the U.S., accompanied by declining mortgage rates throughout 2019-2020 and a cut in the federal funds rate to a range of 0-0.25 percent in early 2020, as a measure to combat the economic side effects of the Covid-19 pandemic. Allowing for supply and demand conditions and their interactions with the ZLB regime of monetary policy confirms the presence of heterogeneous effects of a mortgage rate shock on housing returns across regions. A negative mortgage rate shock triggers a larger increase in housing returns in states with lower housing permits or higher personal income, employment, and population, especially when the federal funds rate is near zero. The estimation results therefore provide strong evidence for a significant, heterogeneous response of housing returns to a mortgage rate shock and confirm the theoretical predictions derived from our simple partial equilibrium model.

Our findings can be traced back to the early contributions made by McAvinchey and Maclennan (1982) and Segal and Srinivasan (1985), both focus on the causes of remarkable cross-region variation in housing price inflation. McAvinchey and Maclennan (1982) examine the rate of housing price inflation across 11 geographic regions of the British housing market between 1967 and 1976. Performing regressions of linear functional form and allowing for supply (housing starts and completions) and demand factors (population and income growth), the study observes significant regional differences when it comes to the impact of mortgage rates. Using a sample of 51 metropolitan areas in the U.S. between 1975 and 1978, Segal and Srinivasan (1985) find that demand-side factors (income, population, and mortgage rates) have a significant influence on housing price inflation and 40% of the variations, which are unexplained by demand-side factors, can be attributed to supply-side factors (suburban growth restrictions on potentially developed land). A series of studies, including Bartik (1991), Poterba et al. (1991), Abraham and Hendershott (1996), Jud and Winkler (2002), Meese and Wallace (2003), Capozza et al. (2004), and Hwang and Quigley (2006), further investigate the dynamics of housing prices and the impact of supply and demand conditions. While these studies in the regional economics literature provide abundant evidence of heterogeneous responses of housing returns to a mortgage rate shock across geographic regions, none of them have considered the effects of monetary policy regime, and how it interacts with local supply and demand conditions.

The zero lower bound regime of monetary policy has become a hot topic for macroeconomic research over the last decade. Assessing the effect of monetary policy becomes more challenging in the aftermath of the Great Recession (Hamilton and Wu, 2012; Wu and Xia, 2016). Even though the goal of our paper is not to evaluate the monetary policy effects in a zero lower bound environment, we still find theoretical and empirical evidence of asymmetric effects of mortgage rates on housing returns between non-ZLB and ZLB regimes of monetary policy, and significant heterogeneity across geographic regions. Our paper is therefore related to a strand of literature which investigates the interplay between housing/real estate developments and the heterogeneous effects of monetary policy across regions. In addition to this, our research is also linked to another strand of literature which investigates the effectiveness of monetary policy over the business cycle.

Within the first strand of literature, the housing market has been identified as an important channel through which monetary policy impacts real economic activity with differential effects across regions. Monetary policy actions affect mortgage rates, which further affect disposable income and consumption through both direct (cash flow effect) and indirect (wealth effect) channels (Elbourne, 2008; Caplin et al., 1997; Beraja et al., 2019; Bernanke and Blinder, 1988; Bernanke and Gertler, 1995). Fratantoni and Schuh (2003) find that incorporating sources of heterogeneity along with housing yields greater cross-region differences in the effect of monetary policy. Furceri et al. (2019) provide empirical evidence of how asymmetries in the impact of monetary policy shocks across U.S. states can be explained by industry mix, share of small firms, share of small banks, and housing conditions. Regarding the impact of monetary policy on regional housing markets, Christidou et al. (2011) estimate VAR models for the period 1988-2009 and their results suggest that housing markets across U.S. states respond differently to a common monetary policy shock. Füss and Zietz (2016) provide further evidence on the heterogeneous effect of monetary policy on housing returns across metropolitan statistical areas (MSAs) by interacting MSA-specific demand and supply conditions with monetary policy.

The second strand of literature examines the effectiveness of monetary policy over the business cycle. Garcia and Schaller (2002) study the asymmetric effects of monetary policy during expansions and recessions with the help of an estimated Markov switching model. Interest rate changes are found to have a stronger impact on output growth during recessions compared to periods of expansion. The results are in line with the previous findings by Weise (1999), who estimates a nonlinear VAR model to show that money supply shocks have larger output and weaker price effects, when output growth is initially low. Similarly, Lo and Piger (2005) find strong evidence that monetary policy measures applied during recessions have a stronger impact on output compared to those applied during expansions.[1] In contrast, Tenreyro and Thwaites (2016) reach the opposite conclusion, that is, monetary policy is less effective during recessions.

[1] In the REITs market, Glascock and Lu-Andrews (2014) also find that macroeconomic factors have stronger effects on the pricing of REIT liquidity during recessions.

Regarding the asymmetric effects of mortgage rates on housing prices over the business cycle, Kim and Bhattacharya (2009) find that mortgage rates have a stronger impact on home prices when the housing market is in an upswing rather than in a downswing. In the light of this asymmetry, the study further finds strong support for Granger causality from mortgage rates to house prices.

While our paper is related to the asymmetry in the effects of mortgages rates on housing prices over the business cycle, we focus on the ZLB and non-ZLB regimes of monetary policy rather than general business cycles. We contribute to the existing literature in three dimensions. First, we present a simple theoretical model to analyze the response of housing returns to changes in mortgage rates whilst accounting for the monetary policy regime and regional supply and demand differences. Second, we use an IPVAR approach to empirically test and further investigate the predictions of our theoretical model by interacting supply and demand conditions with changing policy interest rate environments, which allows us to analyze the heterogeneous effects of a mortgage rate shock on housing returns. Third, the sample end date of our dataset is December 2020, which means that we include important information about recent housing market fluctuations during the Covid-19 pandemic into our study and therefore our findings add to the ongoing policy debate.

Our results hold important policy implications, given that the Federal Reserve is committed to its zero-interest-rate policy until 2024, as repeatedly signalled by chairman Jerome Powell,[2] but with current mortgage rates on the rise. In the light of our findings, this may result in negative ramifications for the housing sector. Although the U.S. housing market is experiencing surging prices at the time of writing this paper, the surge could be caused by the fiscal expansion during the Covid-19 pandemic and the prolonged effects of declining mortgage rates in both 2019 and 2020. As the economy remains in the ZLB environment and mortgage rates keep going up, we would expect a more pronounced contraction of housing returns at some point in time. Additionally, these developments unfold in a time where the U.S. economy suffers from the consequences of the Covid-19 pandemic. As a result of this, households face now a much more complex financial environment. For example, a household's financial situation may be altered due to job loss or as the mortgage forbearance ends. As more and more consumers are wondering if we are

[2]See the March 2021 Financial Times article "Fed Signals No Rate Rise Until At Least 2024 Despite Growth Upgrade" at https://www.ft.com/content/3d7704d3-a312-4294-95bc-90233f469ccd.

headed for a housing market crash, our results point out the importance of avoiding a rapid climb of mortgage rates in a near zero policy rate environment, which for example can be achieved through large scale asset purchases better known as quantitative easing. However, this will challenge the Fed's current plan of reducing its monthly purchases of mortgage-backed securities, given inflation pressures, before raising the policy rate.[3]

The structure of the paper is as follows. Section 2 derives a simple partial equilibrium model to illustrate the heterogeneous effects of a mortgage rate shock on local housing returns. Section 3 presents the data used for the estimation of our IPVAR model and discusses in detail the underlying VAR methodology. Section 4 analyzes the empirical results and impulse response functions of the estimated IPVAR framework. Section 5 concludes.

2 Heterogeneous effects of mortgage rates on housing returns

In order to illustrate how regional housing returns respond to a change in the mortgage rate, we tailor the simple partial equilibrium model of Glaeser et al. (2008) to incorporate heterogeneous expectations of house price growth. In this model, the house price in a region, or a state in our context, is jointly determined by supply and demand of the regional housing market. Housing supply is given by the total amount of old houses being sold by existing homeowners and new houses produced by developers. For the sake of simplicity, both types of housing are assumed to be physically identical. Housing demand comes from a group of potential new homebuyers, whose willingness to pay is determined by the utility gains from living in the region and the expected capital gains from owning a house in the same region.

Let $H(t)$ and $I(t)$ denote the stock of houses and the flow of new housing construction in the region at time t, respectively. The marginal cost of housing production is assumed to be a linear function of the size of construction $c_0 + c_1 I(t)$ where $c_1 > 0$. At any point in time, as long as there is new construction of housing, price and marginal cost must be equal in equilibrium, i.e., $P(t) = c_0 + c_1 I(t)$. As in Sun

[3]See the April 2021 Wall Street Journal article "Central Bank Will Begin Reducing Bond Purchases 'Well Before' Raising Interest Rates, Powell Says" at https://www.wsj.com/articles/central-bank-will-begin-reducing-bond-purchases-well-before-raising-interest-rates-powell-says-11618421656.

and Tsang (2019), an increase in c_1 can be interpreted as a negative supply shock that reduces housing production and a decrease in c_1 captures a positive supply shock. Existing homeowners in the region are assumed to receive a Poisson-distributed shock with probability λ in each period that forces them to sell their houses, leave the region, and receive zero utility for the rest of their lives. Under this assumption, housing supply at time t is given by $S(t) = \lambda H(t) + I(t)$.

There exist a fixed number of potential home buyers at any point in time. These potential buyers are heterogeneous in terms of their utility gains from living in the region. The utility of potential buyer i from living in the region, $u(i)$, is assumed to follow a uniform distribution on the interval $[\underline{u}, v_0]$ with density $1/v_1$, where $v_1 > 0$. Let $u^*(t)$ denote the utility of the marginal buyer at time t, potential buyers with utility above $u^*(t)$ choose to purchase a house in the region while others do not. Housing demand is therefore given by $D_t = (v_0 - u^*(t))/v_1$. Following Sun and Tsang (2019), we interpret an increase in v_1 as a negative housing demand shock and a decrease in v_1 as a positive demand shock. Given the mortgage rate r, potential buyer i's expected utility flow at time t is the sum of the utility gains from living in the region and the expected appreciation in house price:

$$\frac{u(i)}{r+\lambda} + E_t\left(\int_{x=t}^{\infty} e^{-(r+\lambda)(x-t)}\lambda P(x)dx\right) - P(t),$$

where $E_t(\cdot)$ denotes expectations as of time t. Potential buyers will keep moving into the region until the expected utility flow diminishes to zero.

Putting the supply and demand sides of the market together yields the following equilibrium conditions:

$$S(t) = D(t), \tag{1}$$

$$P(t) = c_0 + c_1(S(t) - \lambda H(t)), \tag{2}$$

$$P(t) = \frac{v_0 - v_1 D(t)}{r+\lambda} + E_t\left(\int_{x=t}^{\infty} e^{-(r+\lambda)(x-t)}\lambda P(x)dx\right). \tag{3}$$

Suppose that, at time t, the region has reached its long-run steady state with $H(t) = \frac{v_0 - rc_0}{\lambda v_1}$ and

$P(t) = c_0$. Following Glaeser et al. (2008), individuals are assumed to update their beliefs at discrete intervals. Let ϵ be the expected growth rate of house prices at time t. During a period when beliefs about the future are held constant, the expected house price follows $P(x) = P(t) + \epsilon \cdot (x - t)$ and Equation (3) becomes:

$$P(t) = \frac{\nu_0 - \nu_1 D(t)}{r + \lambda} + E_t \left(\int_{x=t}^{\infty} e^{-(r+\lambda)(x-t)} \lambda (P(t) + \epsilon \cdot (x - t)) dx \right). \tag{4}$$

Equalizing supply and demand of the regional housing market gives rise to the house price at time $t + 1$:

$$P(t+1) = c_0 + \frac{\epsilon \lambda c_1}{(rc_1 + \nu_1 + \lambda \nu_1)(r + \lambda)}. \tag{5}$$

The appreciation in house price, or housing return, from t to $t + 1$ is then given by:

$$\Delta P = \frac{\epsilon \lambda c_1}{(rc_1 + \nu_1 + \lambda \nu_1)(r + \lambda)}. \tag{6}$$

The marginal effects of mortgage rates on future housing returns can be derived as:

$$\frac{\partial \Delta P}{\partial r} = -\frac{\epsilon \lambda c_1 (2rc_1 + \lambda c_1 + \nu_1 + \lambda \nu_1)}{(rc_1 + \nu_1 + \lambda \nu_1)^2 (r + \lambda)^2}. \tag{7}$$

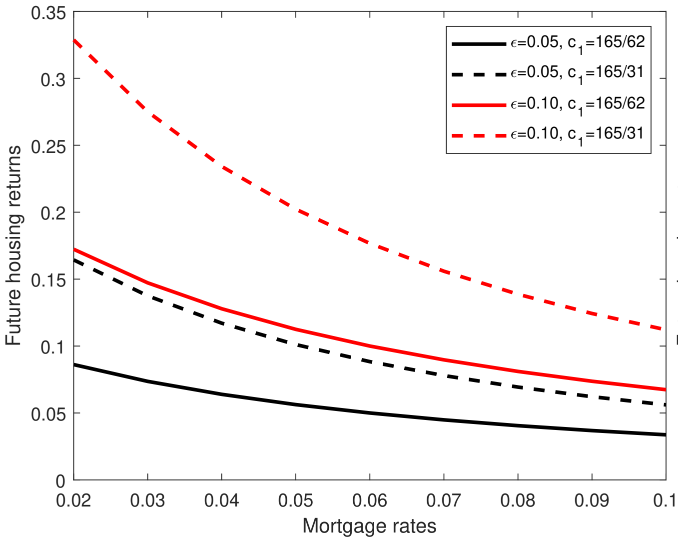
Equation (7) indicates that housing returns will increase (decrease) following a decline (rise) in the mortgage rate and the marginal effects depend on the size of the expected growth rate of house prices ϵ; they also depend on parameters c_1 and ν_1 that capture housing supply and demand conditions, as well as their interactions with ϵ. It has been shown in the literature, initially driven by the bull housing market in the 1970s, that nominal interest rates play an important role in the formation of house price appreciation expectations. The 1970s were a period of rising interest rates, accompanied by rising inflation, during which the demand for ownership was stimulated; see Frieden et al. (1977), Hendershott and Hu (1979), and Schwab (1982) among many others. As Harris (1989) points out, expectations of a future interest rate hike, increase the desire for home ownership and thereby the expected growth rate of house prices. Facing potentially higher interest rates in the future, risk averse households tend to purchase a home in order to fix future housing costs and hedge against rent risk; see Kau and Keenan (1980), Sinai and Souleles (2005), and Elgin and Uras (2014). Hence, the expected growth rate of house prices ϵ strongly relates to the monetary policy regime. When nominal interest rates are near zero, households tend to expect interest rates to be higher in the future. First, being around the lower bound of zero already, nominal interest rates have little to no room to be further reduced. Second, a monetary expansion is likely to result in inflation which will cause the central bank to raise interest rates afterwards. The expected growth rate of house prices ϵ therefore tends to be higher at the ZLB of nominal interest rates.

Given higher expectations of future house price growth at the ZLB regime of monetary policy, we have the following two hypotheses:

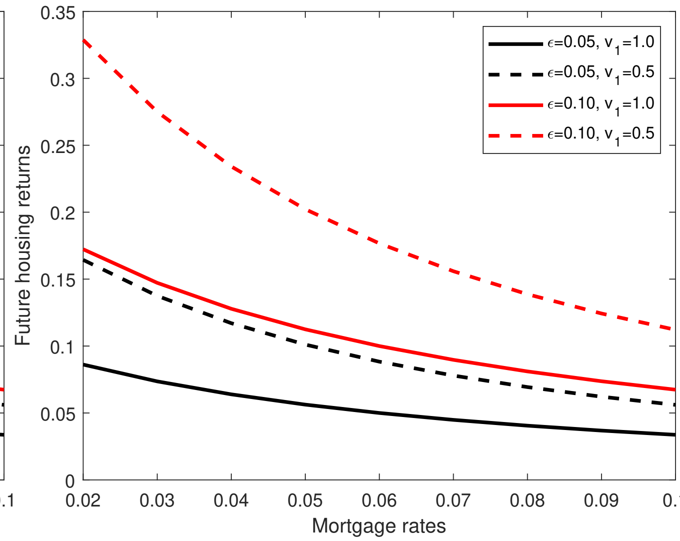
Hypothesis 1: A mortgage rate shock has heterogeneous effects on housing returns conditional on the monetary policy regime. Other things equal, the marginal effects of a mortgage rate shock on housing returns are larger at the ZLB of nominal interest rates.

Hypothesis 2: A mortgage rate shock has heterogeneous effects on housing returns conditional on the monetary policy regime, local supply and demand conditions, and their interactions.

To better illustrate the heterogeneous effects of a mortgage rate shock on housing returns, we calibrate the model parameters to reasonable values and plot future housing returns as shown in Equation (6) against hypothetical values of the mortgage rate in Figure 1.



(a) Effects of ZLB and supply conditions



(b) Effects of ZLB and demand conditions

Figure 1: Future housing returns and mortgage rates

In the baseline scenario, we choose $\lambda = 0.05$, $r = 0.06$, $\nu_1 = 1$, and $c_1 = 165/62$.[4] We consider an expected growth rate of house prices of $\epsilon = 0.05$ during normal times and a considerably higher expectation of $\epsilon = 0.10$ when nominal interest rates are stuck at the lower bound of zero. The solid lines in black and red in both panels depict the effects of mortgage rates on future housing returns in the non-ZLB and ZLB regimes of monetary policy, respectively. In line with our expectation, the red line is steeper than the black line, which indicates larger marginal effects in magnitude of a mortgage rate shock on housing returns at the ZLB of nominal interest rates.

Not all regions are impacted equally. To account for regional differences, we simulate a region with lower housing supply by doubling the parameter c_1 in Panel (a) and a region with higher housing demand by halving the parameter ν_1 in Panel (b), while leaving other parameters unchanged. The dashed lines in black and red outline the effects of mortgage rates on future housing returns in the non-ZLB and ZLB regimes of nominal interest rates, respectively. As Panel (a) shows, compared to the baseline region, housing returns are more responsive to a mortgage rate shock in the region with lower housing supply, especially in the ZLB regime of monetary policy. Similarly, Panel (b) suggests higher responsiveness of

[4]These values correspond to a 5% probability of selling the house and leaving the region in each period, a 6% mortgage rate, and a density one of a potential buyer's utility. The value of c_1 is selected to equalize the future housing return in Equation (6) and the expectation ϵ in the long-run steady state.

housing returns to a mortgage rate shock in the region with higher housing demand, especially in the ZLB regime of monetary policy.

3 Data and Methodology

To empirically test the hypotheses developed in the previous section, we utilize an IPVAR model and estimate the response of housing returns to a mortgage rate shock and its dependence on the ZLB regime of the policy interest rate and local housing supply and demand conditions. On the demand side, we choose three variables, namely real personal income, nonfarm employment, and population, which have been found to direct influence housing price appreciation, while on the supply side we use the number of housing permits; see Mayer and Somerville (2000), Strauss (2013), and the references discussed in the introduction.

3.1 Data description

We use monthly data of 50 U.S. states and the District of Columbia from 1995 to 2020. Our sample covers a long period of near zero federal funds rates from 2008 to 2015 and the ongoing ZLB that started in April 2020 following the global outbreak of Covid-19. Seasonally adjusted house price indices are obtained from Freddie Mac. Compared to other commonly referenced house price indices, such as the Federal Housing Finance Agency and the S&P/Case-Shiller indices, the Freddie Mac House Price Index includes not only purchase transactions but also appraisal values used for refinance transactions. The federal funds rate and the 30-year fixed rate mortgage average are retrieved from the Federal Reserve Economic Data; the former rate is only used for defining the ZLB dummy variable and the later is one of the endogenous variables in the IPVAR model. The number of housing permits is extracted from the Building Permits Survey conducted by the U.S. Census Bureau. The number of employees in the nonfarm sector is obtained from the U.S. Bureau of Labor Statistics. Personal income at quarterly frequency and population at annual frequency are obtained from the U.S. Bureau of Economic Analysis.[5] Both house

[5] Instead of using interpolation to match the frequency of all other variables, we use quarterly data of personal income and annual data of population for each month in a certain quarter or year. This is not of much concern given that our focus is to

price and personal income data are deflated with the chain-type price index for personal consumption expenditures obtained from the U.S. Bureau of Economic Analysis.

3.2 IPVAR model

In order to examine the conditional responses of housing returns to a mortgage rate shock, we estimate an Interacted Panel VAR, proposed by Towbin and Weber (2013), of the form:

$$\begin{pmatrix} 1 & 0 \\ \alpha_{0,it}^{21} & 1 \end{pmatrix} \begin{pmatrix} MR_t \\ HR_{it} \end{pmatrix} = \mu_i + \sum_{l=1}^{L} \begin{pmatrix} \alpha_l^{11} & 0 \\ \alpha_{l,it}^{21} & \alpha_{l,it}^{22} \end{pmatrix} \begin{pmatrix} MR_{t-l} \\ HR_{i,t-l} \end{pmatrix} + u_{it}, \tag{8}$$

where MR_t is the mortgage rate (i.e., the 30-year fixed rate mortgage average) in period t, which is common across states, and HR_{it} is the real housing return for state i in period t, calculated as the log difference of real house price. The vectors μ_i and u_{it} denote state-specific intercepts and independent and identically distributed shocks. L is the number of lags.

An implicit assumption imposed on Equation (8) is that the 30-year fixed rate mortgage average does not depend on state-level housing returns, i.e., $\alpha_{l,it}^{12} = 0$ for $l = 0, ..., L$. This exogeneity assumption tends to hold for two reasons. First, the mortgage rate is a national-level variable which is impacted by conditions of any single state to a negligible extent. Second, the mortgage rate is affected by the Fed's monetary policy, usually with a delay, and the literature has shown no evidence that the Fed responds to house price movements; see Sun and Tsang (2014). While mortgage rates vary across states, the magnitude of regional differences is small and statistically insignificant; see Ozanne and Thibodeau (1983), Jud and Epley (1991), and Kim and Bhattacharya (2009). We use the average 30-year mortgage rates in our IPVAR model in order to properly identify an exogenous mortgage rate shock. Section 4.3 provides a further discussion on this matter.

In Equation (8), $\alpha_{l,it}^{jk}$ $(l = 0, ..., L)$ are deterministically varying coefficients. To examine how responses of housing returns to a mortgage rate shock vary with the monetary policy regime and state-level housing supply and demand characteristics, we allow these coefficients to be linear functions of a ZLB_t dummy,

capture the heterogeneity of supply and demand conditions across states.

local housing supply and demand conditions X_{it}, and their interactions, i.e.,

$$\alpha_{l,it}^{jk} = \beta_{l,1}^{jk} + \beta_{l,2}^{jk} \cdot ZLB_t + \beta_{l,3}^{jk} \cdot X_{it} + \beta_{l,4}^{jk} \cdot ZLB_t \cdot X_{it}, \tag{9}$$

where ZLB_t is the zero lower bound dummy in period t that equals one if the federal funds rate lies in the 0% to 0.25% interval and zero otherwise; the variable X_{it} captures the supply and demand characteristics of the local housing market, namely the number of housing permits, real personal income, nonfarm employment, and population for state i in period t.

It is worth noting that we use the ZLB indicator with a stronger focus on the potential long-lasting effects of a mortgage rate shock. The ZLB dummy captures both the state of the macroeconomy and the monetary policy environment. This indicator is different from more short-lived recession indexes, such as the NBER recession indicator. The ZLB regime covers not only a severe recession but also the initial stage of an economic recovery from the recession, which better matches the period of time during which individuals raise expectations of house price growth in our partial equilibrium model presented in Section 2. Over our sample period, the ZLB indicator takes the value one between December 2008 and December 2015 and from April 2020 onward, which covers both the Great Recession and the ongoing Covid-19 recession. The only NBER recession excluded by the ZLB indicator is the Dot-com recession between March and November 2001, which is considerably less severe and shorter-lived than the later two recessions.

Table 1: Unit root test

Variable	Transformation	Unit root test
Mortgage rate	Linear trend removed	-2.878 (p=0.004)
Housing returns		1272.38 (p=0.000)
Housing permits	Log transformation of one plus the number of permits	837.481 (p=0.000)
Personal income	State-specific linear trend removed from log transformation	295.315 (p=0.000)
Employment	State-specific linear trend removed from log transformation	243.980 (p=0.000)
Population	State-specific linear trend removed from log transformation	132.914 (p=0.022)

The null hypothesis is defined as the presence of a unit root (assuming individual unit root process for panel data).

The mortgage rate variable is common to all states and, over our sample period, it exhibits a significant downward trend. We remove a linear trend from the mortgage rate data and the detrended mortgage rate is stationary according to the PP unit root test (Phillips and Perron, 1988). Housing returns are stationary based on the results of the Fisher-PP unit root test for panel data (Maddala and Wu, 1999; Choi, 2001); see Table 1. Housing permits, personal income, employment, and population are all log transformed. One is added to the number of housing permits before taking the natural log as there are zero-valued observations of housing permits in our sample for the District of Columbia. The log transformed housing permits variable does not have a linear trend and it is found to be stationary. We remove state-specific linear trends from the log-transformed personal income, employment, and population so that all housing demand and supply factors are stationary based on the Fisher-PP panel unit root test. This stationarity condition is particularly critical for interacted VAR results to be meaningful; see Towbin and Weber (2013). Note that, in order to capture the cross-state heterogeneity, we do not remove the level information in the data. The summary statistics of model variables are presented in Table 2.

Table 2: Summary statistics

Variable	Mean	SD	Min	Max	10th Pct	90th Pct
Mortgage rate	0.0556	0.0057	0.0429	0.0705	0.0430	0.0690
Housing returns	0.0016	0.0054	-0.0348	0.0345	-0.0336	0.0336
Housing permits	6.6335	1.3430	0.0000	9.9057	0.0000	9.8718
Personal income	11.9087	1.0430	9.9808	14.4503	9.9904	14.4429
Employment	7.4108	0.9883	5.4266	9.6738	5.4320	9.6722
Population	15.0910	1.0304	13.1523	17.4250	13.1539	17.4243

4 Empirical Results

4.1 ZLB vs non-ZLB regimes

We start with the ZLB versus non-ZLB responses of housing returns to a negative one-standard-deviation shock to the mortgage rate by setting $\beta_{l,3}^{jk} = \beta_{l,4}^{jk} = 0$ in Equation (9). We choose one lag for the VAR, based on the Schwarz information criterion. The model parameters are estimated using the method proposed by Towbin and Weber (2013). Given the inaccuracy of analytical standard errors which rely on first-order asymptotics, we use bootstrapped standard errors instead with 50 bootstrap iterations.

We evaluate the coefficients at both values of the ZLB dummy variable and then compute the impulse responses of housing returns to a negative one-standard-deviation shock, which is estimated to be 17.3018 basis points, in the mortgage rate. The impulse response functions and the bootstrapped 90% confidence intervals in both the ZLB and non-ZLB regimes are depicted in Figure 2. The horizontal axis of the impulse response functions shows the number of periods (months) that have passed after the impulse has been realized while the vertical axis measures the response of the variable of interest, i.e., housing returns. We also present the impulse responses (only in the first 20 periods to save space) and the corresponding percent deviations from the sample average of monthly housing returns in the appendix Table A1.

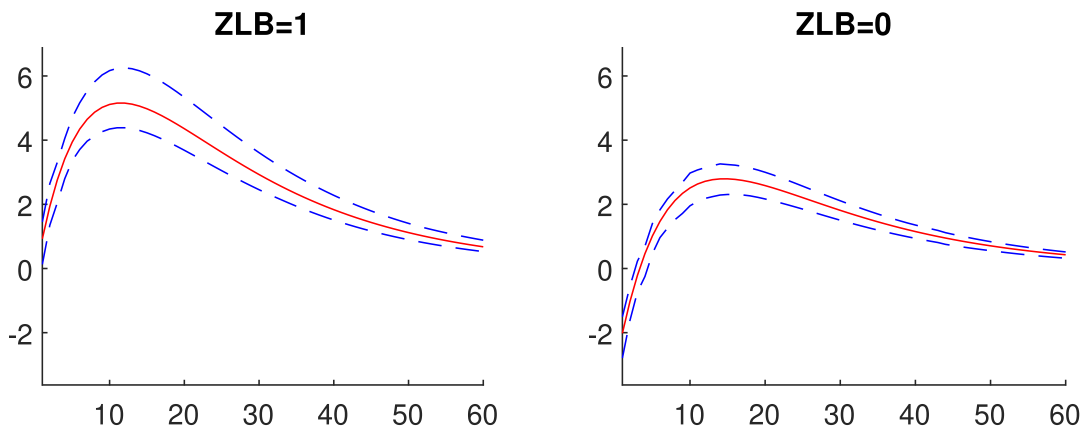


Figure 2: Responses of housing returns to a negative one-standard-deviation mortgage rate shock in ZLB and non-ZLB regimes

Figure 2 and Table A1 provide strong evidence for heterogeneous impacts of the mortgage rate shock on housing returns. The responses of housing returns to the mortgage rate shock are much stronger in the ZLB regime compared to the non-ZLB regime, a result in line with our first hypothesis. In the ZLB regime, housing returns increase right after the shock and the impact reaches its maximum about a year later when housing returns increase by 5.1550 basis points or about 31.45% deviation from the sample average. In the non-ZLB regime, however, the impact on housing returns is initially negative. It becomes positive a quarter later and reaches its maximum after another year. The maximum impact is only half the size of that in the ZLB regime.

The positive impact of a mortgage rate decrease on housing returns is long-lasting and large in magnitude when the policy rate is near zero. This finding is consistent with the ongoing housing market boom in the U.S. following the 2019-2020 period of falling mortgage rates and the lowering of the federal funds rate to near zero in early 2020 in response to the economic downturn caused by the global outbreak of Covid-19.[6] Given that the federal funds rate is likely to stay near zero until at least 2024, as repeatedly signalled by the Federal Reserve chairman Jerome Powell, the impact of the mortgage rate decrease in 2019 and 2020 on housing returns is expected to stay positive and outweigh the downward pressure caused by the recent surge in mortgage rates at least in the near future. As the positive impact dies down and the negative impact of rising mortgage rates, which started in February 2021, becomes more dominant at some point in time, housing returns will likely start to decline at a fast pace if the policy rate stays low. By analyzing a history of large price run-ups in U.S. state-level housing markets, Sun and Tsang (2019) find that a sharper run-up in house prices predicts a higher probability of a crash. In light of their finding, our results point out the importance of avoiding mortgage rates from climbing too fast in maintaining healthy housing markets following the ongoing boom. This brings challenges to the Fed when it comes to the plan of reducing its monthly bond purchases, given inflation pressures, before raising the policy rate. At the recent Federal Open Market Committee meetings, officials have started discussions/debates about reducing the pace of asset purchases.[7]

4.2 The effects of housing supply and demand factors

Having illustrated the difference in the housing return responses between two policy rate regimes, we then evaluate the effects of housing supply and demand factors, including the number of housing permits, real personal income, nonfarm employment, and population. While the ZLB regime is a dummy variable, our measures of housing permits, personal income, employment, and popuation are all continuous. We let the variable X be one of the these four factors at a time, estimate the model parameters, and compute the

[6]The article from the Wall Street Journal, https://www.wsj.com/articles/surging-u-s-home-prices-gaining-momentum-as-rally-intensifies-11613062810, shows that, according to the median sales price for existing homes in more than 180 metro areas tracked by the National Association of Realtors, the U.S. home prices are rising at an accelerating pace. The U.S. is experiencing the strongest housing boom in more than a decade.

[7]See the July 2021 Wall Street Journal article “Fed Officials See Earlier End for Bond Buying, Emphasize Patience" at https://www.wsj.com/articles/fed-debated-how-to-begin-pulling-back-on-stimulus-at-june-meeting-11625680801 and the August 2021 Wall Street Journal article “Fed Signals Asset Purchases Likely to Slow This Year" at https://www.wsj.com/articles/fed-debated-timing-mechanics-of-stimulus-pullback-at-july-meeting-11629309648.

impulse response functions at a Low (10th) percentile and a High (90th) percentile value of the X variable and in both policy rate regimes. The impulse responses and the bootstrapped 90% confidence intervals are depicted in Figure 3. While we observe a difference in the housing return responses evaluated at Low versus High values of each X variable in the non-ZLB regime, a greater difference stands out in the ZLB regime. In particular, housing returns increase by a larger extent following a negative mortgage rate shock in the case of less housing permits, higher personal income, higher employment, or larger population. We explore the role of these factors in detail one by one.

A. Housing permits

The effects of housing permits are shown in Table A2 in the appendix, where we report the responses of housing returns in the first 20 periods following a negative one-standard-deviation shock to the mortgage rate and the corresponding percent deviations from the sample average, evaluated at the 90th and 10th percentiles of housing permits in each policy rate regime. In line with Table A1, the impact of a negative mortgage rate shock on housing returns is generally larger when the policy rate is near zero. Not all states are impacted equally. In particular, when the policy rate is not constrained by the ZLB, housing returns decrease in the first several months following the shock, irrespective of the level of housing permits. When the policy rate is at the ZLB, a negative mortgage shock heightens housing returns right away by 3.2 basis points (or about 20% deviation from the sample average) and the impact reaches its maximum at 4.2 basis points (or about 25% deviation from the sample average) after half a year in states with High housing permits. In states with Low housing permits, however, the impact is small in size initially and then increases gradually and reaches its maximum a year after the shock when housing returns increase by more than 6 basis points (or 37% deviation from the sample average). The intuition behind this finding is straightforward. A mortgage rate decrease heats up housing demand and returns, and the effect strengthens when less housing units are allowed to be built, which restricts housing supply. These results confirm our hypothesis that a mortgage rate shock has heterogeneous effects on housing returns conditional on the state of the macroeconomy (captured by the ZLB of the policy rate), local supply conditions, and their interactions. Our results are consistent with the finding of Kishor and Morley (2015) at the metropolitan statistical area (MSA) level that MSAs with less elastic housing supply are more sensitive to mortgage rate changes.[8]

B. Personal income

Personal income also affects the response of housing returns to a negative shock to the mortgage rate; see the appendix Table A3. In the non-ZLB regime, housing returns decline in the first three months and increase thereafter. The impact of the mortgage rate shock on housing returns is long-lasting and reaches its maximum around 15 months after the shock, with a larger impact on states with higher personal income than those with lower personal income. In the ZLB regime, housing returns increase almost immediately following the negative mortgage rate shock and personal income tends to matter even more. In states with Low personal income, the maximum impact of the shock on housing returns is about 3.55 basis points (or 22% deviation from the sample average). In contrast, the maximum magnitude is 6.66 basis points (or 41% deviation from the sample average) in states with High personal income. Given that personal income is an important determinant of housing demand in local markets, an increase in personal income reinforces the surge in housing returns caused by lowered mortgage rates.

C. Employment

Table A4 in the appendix shows the effects of employment, another determinant of housing demand in local markets, on the responses of housing returns to a negative mortgage rate shock. When the federal funds rate is not near zero, housing returns decrease for 3 months and then start to increase, to a larger extent in states with higher employment. It takes around 15 months for the impact of the negative mortgage rate shock to reach a peak, irrespective of the level of employment. The shock leads to larger increases in housing returns when the policy rate gets stuck at zero, especially in states with High employment. In line with our expectation, an increase in employment also reinforces the surge in housing returns caused by lowered mortgage rates.

D. Population

Table A5 in the appendix shows the effects of population. Similar to personal income and employment, population also affects local housing demand positively. The table shows that a negative mortgage rate

[8] Kishor and Morley (2015) use the geography-based measure of Saiz (2010) and the regulation-based measure from the Wharton Regulation Index of Gyourko et al. (2008) to measure supply elasticity. However, there are no time-series data on these housing supply elasticities and only the cross-sectional variation could be exploited. Instead, we use time-varying housing permits to measure supply-side conditions of housing markets.

shock increases housing returns, to a larger extent in states with High population and during times when the policy rate is constrained by the zero lower bound. These results confirm our hypothesis that a mortgage rate shock has heterogeneous effects on housing returns conditional on the state of the macroeconomy, local demand conditions, and their interactions.

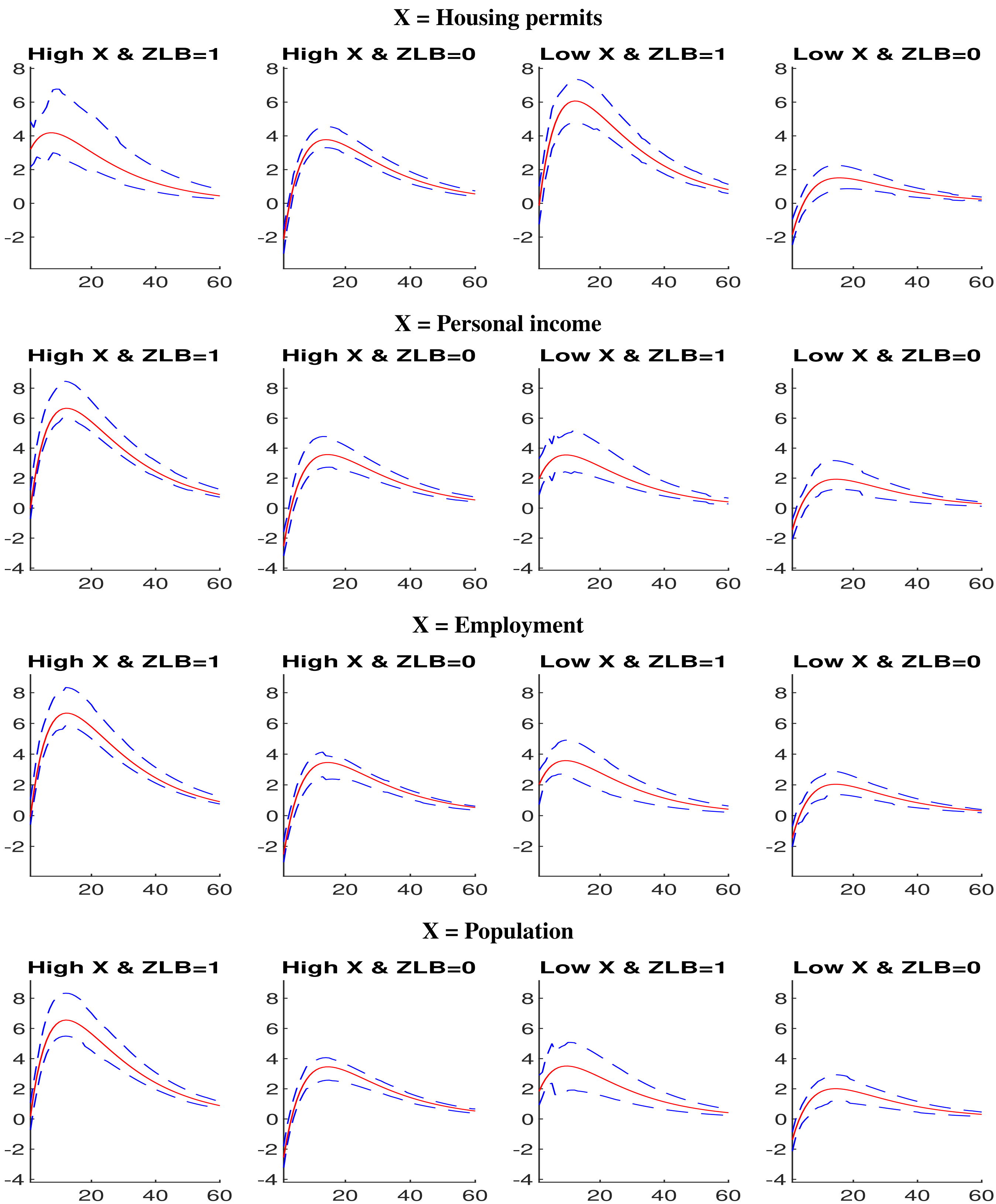


Figure 3: Impulse responses of housing returns to a negative one-standard-deviation mortgage rate shock and the effects of supply and demand factors

4.3 Further discussion: heterogeneous mortgage rates across states

We find strong evidence for heterogeneous effects of a mortgage rate shock on housing returns across U.S. states, conditional on the ZLB of the federal funds rate, local supply and demand factors, and their interactions. One might suspect that our results are driven by differential mortgage rates across regions, which could potentially be determined by local supply and demand factors, rather than heterogeneous responses of housing returns to changes in mortgage rates. While mortgage rates indeed vary across states, we use the 30-year fixed rate mortgage average, which is common to all states and non-responsive to state-level housing returns, in the IPVAR model so that an exogenous shock to the mortgage rate can be properly identified. In order to rule out the possibility that our results are driven by differential mortgage rates across states, we collect the state-level effective mortgage rate data (available only at annual frequency) between 1995 and 2018 from the Monthly Interest Rate Survey of the Federal Housing Finance Agency (FHFA). The sample ends in 2018 due to the discontinuation of FHFA's Monthly Interest Rate Survey in 2019. We present the summary statistics of state-level effective mortgage rates in Table 3. Results show that variation in effective mortgage rates is dominated by variation within states over time rather than that across states. In line with Ozanne and Thibodeau (1983), Jud and Epley (1991), and Kim and Bhattacharya (2009), differences in terms of mortgage rates across different regions are insignificant.

Table 3: Summary statistics of state-level effective mortgage rates

	Mean	Std. Dev.	Min	Max
Overall	5.8215	1.4201	3.5578	8.4600
Between		0.0814	5.6393	5.9915
Within		1.4178	3.5010	8.3506

We then regress the difference between state-level effective mortgage rates and the 30-year fixed rate mortgage average against local housing permits, income, employment, and population for each year between 1995 and 2018. We report the coefficients of determination from yearly cross-sectional regressions in Table 4.

Table 4: Coefficients of determination

Year	Adj. R^2	Year	Adj. R^2	Year	Adj. R^2	Year	Adj. R^2
1995	-0.0473	2001	-0.0633	2007	0.0333	2013	0.1262
1996	0.0090	2002	0.1543	2008	0.0502	2014	0.2712
1997	0.0473	2003	-0.0188	2009	0.1496	2015	0.2145
1998	0.0051	2004	0.0314	2010	0.0852	2016	0.3519
1999	0.1527	2005	0.0493	2011	0.0351	2017	0.4197
2000	0.0922	2006	0.1700	2012	-0.0075	2018	0.2356
Min	-0.0632	Max	0.4197	Median	0.0677	Mean	0.1061

The table shows that local supply and demand factors altogether have limited explanatory power for the cross-state variation in mortgage rates. Between 1995 and 2018, those factors explain an average of 10 percent of the variation in mortgage rates across states. Even though their explanatory power improves in recent years, the adjusted R^2 is mostly lower than 10 percent before 2014, including the years when the federal funds rate stays in the ZLB regime in the aftermath of the Great Recession.

It is worth noting that the test presented in this section is based on single-equation regressions. Our goal is not to explore what determines regional mortgage rates. Instead, we aim at examining what fraction of the variation in regional mortgage rates is driven by the four specific local supply and demand factors, i.e., housing permits, income, employment, and population. The result that these factors have limited explanatory power for the cross-state variation in mortgage rates provides further support for our finding of heterogeneous responses of housing returns to a mortgage rate shock across states. For discussions on regional variation of mortgage rates, see for example Ostas (1977), Morrell and Saba (1983), Jameson et al. (1986), and especially Jameson et al. (1990), who address the simultaneity bias of single equation models used in the context of studying regional differences in mortgage yields using a two-stage least squares approach.

5 Conclusion

This paper develops an empirical and theoretical framework to examine how the impact of a mortgage rate shock on housing returns is altered by local supply and demand conditions. We build a partial equilibrium model which shows that the effect of mortgage rate changes on the return of housing is dependent on the zero lower bound regime of the policy interest rate, local supply and demand conditions, and their interactions. This finding is supported by our empirical results, which originate from an IPVAR model estimated on data including 50 U.S. states and the District of Columbia for a period ranging from January 1995 to December 2020.

Our theoretical and empirical models draw a clear and unambiguous picture. Supply and demand conditions matter for the impact of mortgage rate fluctuations. This is especially true during times when the policy interest rate hits the zero lower bound. We find that the zero lower bound on the federal funds rate intensifies the housing return responses to a mortgage rate shock, with and without accounting for demand and supply factors in local housing markets. This paper has important policy implications in the post-Covid-19 era when the U.S. is experiencing a nationwide housing boom and a surge in mortgage rates, while the federal funds rate is expected to stay near zero at least until 2024.

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Appendix

Table A1: Responses of housing returns to a negative one-standard-deviation mortgage rate shock in ZLB and non-ZLB regimes

	ZLB=1		ZLB=0	
Period	Change	% deviation	Change	% deviation
1	0.9259	5.65 %	-2.0191	-12.32 %
2	1.9371	11.82 %	-1.0348	-6.31 %
3	2.7586	16.83 %	-0.2160	-1.32 %
4	3.4182	20.86 %	0.4609	2.81 %
5	3.9399	24.04 %	1.0163	6.20 %
6	4.3444	26.51 %	1.4678	8.96 %
7	4.6496	28.37 %	1.8307	11.17 %
8	4.8709	29.72 %	2.1180	12.92 %
9	5.0214	30.64 %	2.3411	14.28 %
10	5.1127	31.19 %	2.5098	15.31 %
11	5.1544	31.45 %	2.6325	16.06 %
12	5.1550	31.45 %	2.7165	16.57 %
13	5.1217	31.25 %	2.7679	16.89 %
14	5.0606	30.88 %	2.7922	17.04 %
15	4.9770	30.37 %	2.7939	17.05 %
16	4.8753	29.75 %	2.7769	16.94 %
17	4.7595	29.04 %	2.7447	16.75 %
18	4.6327	28.27 %	2.7002	16.47 %
19	4.4977	27.44 %	2.6457	16.14 %
20	4.3568	26.58 %	2.5833	15.76 %

The change is expressed in basis points.

Table A2: Responses of housing returns to a negative one-standard-deviation mortgage rate shock and the effects of housing permits

	X = Housing permits							
	High X & ZLB=1		High X & ZLB=0		Low X & ZLB=1		Low X & ZLB=0	
Period	Change	% deviation	Change	% deviation	Change	% deviation	Change	% deviation
1	3.2007	19.53 %	-2.1182	-12.92 %	-0.1370	-0.84 %	-1.8598	-11.35 %
2	3.5310	21.54 %	-0.8766	-5.35 %	1.2887	7.86 %	-1.1944	-7.29 %
3	3.7792	23.06 %	0.1509	0.92 %	2.4533	14.97 %	-0.6389	-3.90 %
4	3.9582	24.15 %	0.9954	6.07 %	3.3953	20.72 %	-0.1775	-1.08 %
5	4.0791	24.89 %	1.6836	10.27 %	4.1477	25.31 %	0.2033	1.24 %
6	4.1513	25.33 %	2.2387	13.66 %	4.7392	28.92 %	0.5153	3.14 %
7	4.1831	25.52 %	2.6806	16.35 %	5.1943	31.69 %	0.7686	4.69 %
8	4.1813	25.51 %	3.0263	18.46 %	5.5341	33.77 %	0.9720	5.93 %
9	4.1520	25.33 %	3.2906	20.08 %	5.7768	35.25 %	1.1328	6.91 %
10	4.1001	25.02 %	3.4861	21.27 %	5.9380	36.23 %	1.2575	7.67 %
11	4.0301	24.59 %	3.6237	22.11 %	6.0310	36.80 %	1.3518	8.25 %
12	3.9456	24.07 %	3.7127	22.65 %	6.0673	37.02 %	1.4204	8.67 %
13	3.8497	23.49 %	3.7612	22.95 %	6.0566	36.95 %	1.4673	8.95 %
14	3.7451	22.85 %	3.7761	23.04 %	6.0075	36.65 %	1.4961	9.13 %
15	3.6341	22.17 %	3.7631	22.96 %	5.9270	36.16 %	1.5099	9.21 %
16	3.5184	21.47 %	3.7273	22.74 %	5.8211	35.52 %	1.5111	9.22 %
17	3.3998	20.74 %	3.6729	22.41 %	5.6952	34.75 %	1.5021	9.16 %
18	3.2795	20.01 %	3.6037	21.99 %	5.5536	33.88 %	1.4846	9.06 %
19	3.1587	19.27 %	3.5227	21.49 %	5.4001	32.95 %	1.4603	8.91 %
20	3.0382	18.54 %	3.4326	20.94 %	5.2376	31.96 %	1.4306	8.73 %

The change is expressed in basis points.

Table A3: Responses of housing returns to a negative one-standard-deviation mortgage rate shock and the effects of personal income

	X = Personal income							
	High X & ZLB=1		High X & ZLB=0		Low X & ZLB=1		Low X & ZLB=0	
Period	Change	% deviation	Change	% deviation	Change	% deviation	Change	% deviation
1	-0.0167	-0.10 %	-2.5343	-15.46 %	1.9615	11.97 %	-1.4496	-8.84 %
2	1.5117	9.22 %	-1.2805	-7.81 %	2.4031	14.66 %	-0.7596	-4.63 %
3	2.7619	16.85 %	-0.2384	-1.45 %	2.7513	16.79 %	-0.1856	-1.13 %
4	3.7745	23.03 %	0.6224	3.80 %	3.0203	18.43 %	0.2889	1.76 %
5	4.5845	27.97 %	1.3280	8.10 %	3.2222	19.66 %	0.6782	4.14 %
6	5.2221	31.86 %	1.9010	11.60 %	3.3674	20.55 %	0.9946	6.07 %
7	5.7134	34.86 %	2.3609	14.40 %	3.4650	21.14 %	1.2490	7.62 %
8	6.0809	37.10 %	2.7246	16.62 %	3.5226	21.49 %	1.4505	8.85 %
9	6.3438	38.71 %	3.0064	18.34 %	3.5469	21.64 %	1.6071	9.81 %
10	6.5188	39.77 %	3.2190	19.64 %	3.5435	21.62 %	1.7257	10.53 %
11	6.6201	40.39 %	3.3731	20.58 %	3.5174	21.46 %	1.8120	11.06 %
12	6.6600	40.63 %	3.4779	21.22 %	3.4727	21.19 %	1.8713	11.42 %
13	6.6491	40.57 %	3.5415	21.61 %	3.4130	20.82 %	1.9078	11.64 %
14	6.5962	40.25 %	3.5705	21.78 %	3.3413	20.39 %	1.9254	11.75 %
15	6.5092	39.71 %	3.5709	21.79 %	3.2602	19.89 %	1.9271	11.76 %
16	6.3946	39.02 %	3.5477	21.65 %	3.1718	19.35 %	1.9159	11.69 %
17	6.2580	38.18 %	3.5053	21.39 %	3.0780	18.78 %	1.8940	11.56 %
18	6.1041	37.24 %	3.4471	21.03 %	2.9805	18.18 %	1.8635	11.37 %
19	5.9371	36.22 %	3.3765	20.60 %	2.8804	17.57 %	1.8261	11.14 %
20	5.7602	35.14 %	3.2960	20.11 %	2.7789	16.95 %	1.7832	10.88 %

The change is expressed in basis points.

Table A4: Responses of housing returns to a negative one-standard-deviation mortgage rate shock and the effects of employment

	X = Employment							
	High X & ZLB=1		High X & ZLB=0		Low X & ZLB=1		Low X & ZLB=0	
Period	Change	% deviation	Change	% deviation	Change	% deviation	Change	% deviation
1	-0.0745	-0.45 %	-2.5262	-15.41 %	2.0269	12.37 %	-1.4485	-8.84 %
2	1.4663	8.95 %	-1.3005	-7.93 %	2.4627	15.03 %	-0.7322	-4.47 %
3	2.7271	16.64 %	-0.2813	-1.72 %	2.8058	17.12 %	-0.1368	-0.83 %
4	3.7486	22.87 %	0.5608	3.42 %	3.0702	18.73 %	0.3550	2.17 %
5	4.5661	27.86 %	1.2514	7.64 %	3.2679	19.94 %	0.7581	4.63 %
6	5.2100	31.79 %	1.8126	11.06 %	3.4095	20.80 %	1.0855	6.62 %
7	5.7066	34.82 %	2.2633	13.81 %	3.5037	21.38 %	1.3482	8.23 %
8	6.0785	37.09 %	2.6201	15.99 %	3.5583	21.71 %	1.5560	9.49 %
9	6.3450	38.71 %	2.8969	17.67 %	3.5799	21.84 %	1.7171	10.48 %
10	6.5230	39.80 %	3.1061	18.95 %	3.5741	21.81 %	1.8385	11.22 %
11	6.6268	40.43 %	3.2581	19.88 %	3.5458	21.63 %	1.9266	11.75 %
12	6.6687	40.69 %	3.3619	20.51 %	3.4991	21.35 %	1.9865	12.12 %
13	6.6593	40.63 %	3.4254	20.90 %	3.4375	20.97 %	2.0228	12.34 %
14	6.6077	40.32 %	3.4552	21.08 %	3.3641	20.53 %	2.0394	12.44 %
15	6.5216	39.79 %	3.4570	21.09 %	3.2814	20.02 %	2.0396	12.44 %
16	6.4077	39.09 %	3.4357	20.96 %	3.1917	19.47 %	2.0264	12.36 %
17	6.2715	38.26 %	3.3955	20.72 %	3.0966	18.89 %	2.0021	12.22 %
18	6.1180	37.33 %	3.3400	20.38 %	2.9979	18.29 %	1.9690	12.01 %
19	5.9511	36.31 %	3.2722	19.96 %	2.8967	17.67 %	1.9286	11.77 %
20	5.7742	35.23 %	3.1948	19.49 %	2.7942	17.05 %	1.8827	11.49 %

The change is expressed in basis points.

Table A5: Responses of housing returns to a negative one-standard-deviation mortgage rate shock and the effects of population

	X = Population							
	High X & ZLB=1		High X & ZLB=0		Low X & ZLB=1		Low X & ZLB=0	
Period	Change	% deviation	Change	% deviation	Change	% deviation	Change	% deviation
1	0.1758	1.07 %	-2.5530	-15.58 %	1.8331	11.18 %	-1.3789	-8.41 %
2	1.6454	10.04 %	-1.3234	-8.07 %	2.2914	13.98 %	-0.6820	-4.16 %
3	2.8463	17.37 %	-0.3009	-1.84 %	2.6542	16.19 %	-0.1028	-0.63 %
4	3.8177	23.29 %	0.5442	3.32 %	2.9359	17.91 %	0.3754	2.29 %
5	4.5935	28.03 %	1.2374	7.55 %	3.1488	19.21 %	0.7672	4.68 %
6	5.2029	31.74 %	1.8008	10.99 %	3.3036	20.16 %	1.0852	6.62 %
7	5.6711	34.60 %	2.2534	13.75 %	3.4094	20.80 %	1.3402	8.18 %
8	6.0197	36.73 %	2.6118	15.94 %	3.4743	21.20 %	1.5417	9.41 %
9	6.2676	38.24 %	2.8902	17.63 %	3.5049	21.38 %	1.6977	10.36 %
10	6.4307	39.24 %	3.1006	18.92 %	3.5070	21.40 %	1.8151	11.07 %
11	6.5228	39.80 %	3.2537	19.85 %	3.4857	21.27 %	1.8999	11.59 %
12	6.5558	40.00 %	3.3585	20.49 %	3.4451	21.02 %	1.9574	11.94 %
13	6.5398	39.90 %	3.4228	20.88 %	3.3890	20.68 %	1.9919	12.15 %
14	6.4836	39.56 %	3.4532	21.07 %	3.3204	20.26 %	2.0072	12.25 %
15	6.3945	39.01 %	3.4556	21.08 %	3.2420	19.78 %	2.0066	12.24 %
16	6.2790	38.31 %	3.4348	20.96 %	3.1560	19.26 %	1.9929	12.16 %
17	6.1424	37.48 %	3.3950	20.71 %	3.0643	18.70 %	1.9685	12.01 %
18	5.9893	36.54 %	3.3399	20.38 %	2.9685	18.11 %	1.9354	11.81 %
19	5.8236	35.53 %	3.2724	19.97 %	2.8700	17.51 %	1.8953	11.56 %
20	5.6486	34.46 %	3.1953	19.50 %	2.7698	16.90 %	1.8498	11.29 %

The change is expressed in basis points.