Asymmetric effects of monetary policy in regional housing markets*

Knut Are Aastveit† André K. Anundsen‡

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Abstract

The effectiveness of monetary policy in affecting house prices depend both on the nature of the shock; expansionary versus contractionary, and on local housing market characteristics. Standard supply-demand theory suggests that expansionary monetary policy shocks should have a greater impact on house prices in more inelastic markets. We confirm this conjecture studying 100 US MSAs with different supply elasticities. Moreover, due to the downward rigidity of housing supply, theory also suggests that contractionary shocks should have a greater impact on house prices than expansionary shocks. Our results support this view. However, we also document that a price-to-price acceleration mechanism is more important in a booming market. Taking this into account, we show that the total impact of an expansionary monetary policy shock is greater than the contractionary for most of the empirically observable elasticities in the US. For the most elastic areas, we find that contractionary shocks have a larger impact on house price dynamics.

Keywords: *House prices; Heterogeneity; Monetary policy; Non-linearity; Supply elasticities;*

JEL classification: *E32, E43, E52, R21, R31*

*This paper should not be reported as representing the views of Norges Bank. The views expressed are those of the authors and do not necessarily reflect those of Norges Bank. We thank Fabio Canova, Jean Imbs, Kevin Lansing, Juan Rubio-Ramirez and seminar participants at Banque de France, Board of Governors of the Federal Reserve System, Deutsche Bundesbank, Duke University, IMF, Norges Bank, University of Bozen/Bolzano and University of Zürich for useful comments.

†Norges Bank, Knut-Are.Aastveit@norges-bank.no

‡Norges Bank Andre-Kallak.Anundsen@norges-bank.no

1 Introduction

During the two decades leading up to the financial crisis, there was an unprecedented international house price boom accompanying the favorable economic situation in most industrialized countries. In many countries, this boom was succeeded by a significant bust, with real house prices falling by more than 30 percent in several countries. The consequences for the real economy following the bust in house prices have been severe, and it was one of the factors contributing to the deepest downturn in the world economy since the Great Depression (see e.g., Mian et al. (2013) and Mian and Sufi (2014)). The collapse culminated with the meltdown of the US housing market and financial system in the autumn of 2008 – the epicenter for the ensuing global financial crisis that is still putting a strain on global economic recovery.

The recent experiences have sparked a renewed interest in understanding the linkages between the housing market, macroeconomic activity and financial stability, and the link between monetary policy and financial stability has received much attention. Monetary policy may affect the financial system in several ways, but its impact on house prices may be of particular relevance. Standard economic theory suggests that monetary policy affects house prices through the user cost of housing, where a higher interest rate increases the user cost, thereby putting a downward pressure on housing demand and house prices. There are at least two nuances to this conjecture. First, there are reasons to believe that the effect of monetary policy on house prices is asymmetric. This is because the durability of housing implies that housing supply is rigid downwards (Glaeser and Gyourko, 2005), meaning that an interest rate increase should, *ceteris paribus*, have a larger impact on house prices than a corresponding reduction in the interest rate. Second, whereas monetary policy is conducted at a national level, housing markets are regional. This means that the effect of a monetary policy shock may be different across areas within the same country.

In this paper, we study the asymmetric and heterogenous effects of exogenous monetary policy shocks on house prices using a panel of 100 US MSAs over the period 1980Q1-2007Q4. We measure the monetary policy shock, using an updated version of the Romer and Romer (2004) narrative shock series, provided by Wieland and Yang (2016), and estimate impulse responses using panel data and local projection methods (Jordà, 2005). We ask the following two questions: (i) Is the effect of monetary policy dependent on local housing market conditions? (ii) Is the impact of monetary policy asymmetric?

We start by documenting a strong role of monetary policy in influencing aggregate house prices in the US. Following a one percentage point contractionary monetary policy shock, aggregate house prices decrease with about four percent after three to four years. These estimates are in line with the rapidly growing literature investigating the nexus between monetary policy and house prices (see e.g., Del Negro and Otrok (2007), Glaeser et al. (2012) , Goodhart and Hofmann (2008), Iacoviello (2005), Jarocinski and Smets (2008), Jordà et al. (2015) and Williams (2011, 2015)). That said, an aggregate investigation masks the major heterogeneities existing across regional US housing markets and national house price cycles are often driven by developments in certain regional markets, see e.g., Capozza et al. (2004), Glaeser et al. (2008) and Malpezzi and Wachter (2005) and Saiz (2010). For instance, while house prices increased by more than 160% in some coastal areas of Florida and California from 2000 to 2006, they increased by less than 20% in inland open space areas of the Midwest.

The presence of heterogeneous regional shocks within a country may pose a challenge to monetary policy making. A key question is whether monetary policy should pay attention to these regional disparities? The fact that monetary policy is common across regional markets may suggest that changes in monetary policy could have similar effects across member regions. However, on the other side, differences in regional economic conditions could impact the transmission of monetary policy, potentially amplifying regional heterogeneity. Many have for instance wondered whether the low interest rate environment that prevailed in the years before the 2008 crisis contributed to the house price booms experienced in many Western economies before the recent crash. Others, such as

Mian and Sufi (2009) and Favara and Imbs (2015) have emphasized the role of lax lending standards associated with securitization.In our estimations, we control for regional differences in credit supply by exploiting the time varying index of branching deregulation constructed by Rice and Strahan (2010). Favara and Imbs (2015) have used this index to show that an exogenous expansion in mortgage credit has significant effects on house prices, and in investigating the role of monetary policy this is a relevant control.

Another branch of the literature have attributed regional variations in house price dynamics to heterogeneous supply side restrictions see e.g., Malpezzi (1996), Green et al. (2005), Saiz (2010), Gyourko et al. (2008), Glaeser (2009), and Anundsen and Heebøll (2016), Huang and Tang (2012) and Glaeser et al. (2008) show that house price booms tend to be larger in markets with an inelastic housing supply. By adding MSA-dependent housing supply elasticities, as calculated by Saiz (2010), as an interaction variable in our model, we still find a strong role of monetary policy in affecting house prices. Furthermore, and consistent with the cross section studies alluded to above, the heterogeneity in the transmission of monetary policy is considerable. For instance, whereas the cumulative drop in house prices following a one percentage point contractionary monetary policy shock is estimated to be more six percent in Miami (FL) after four years, house prices in Dayton (OH) are predicted to fall by less than half a percent over the same period.

Recent studies have documented an asymmetric effect of contractionary and expansionary fiscal policy shocks (see Auerbach and Gorodnichenko (2012) and Owyang et al. (2013)) and monetary policy shocks (see Angrist et al. (2013) and Tenreyro and Thwaites (2016)) on the real economy. Due to the downward rigidity of housing supply, there are reasons to expect that house prices may respond asymmetrically to monetary policy shocks as well. In particular, theory suggests that contractionary shocks should have a greater impact on house prices than expansionary shocks. Consistent with theory, we estimate the *partial* effect of contractionary shocks to be greater than that of expansionary shocks. That said, our results show that the *total* effect of an expansionary shock is greater than that of a contractionary shock. This is because an expansionary shock triggers expectations about higher house prices in the future. As expected capital gains go up, demand for housing increases, putting additional pressure on house prices. We find that this price-to-price feedback loop is stronger in a booming market than in a market with falling house prices, which eventually implies that expansionary shocks have a greater impact on house prices than contractionary shocks. There are some nuances to this finding, however. We find that the increase in house prices following an expansionary shock is more than twice as high (in absolute value) as the fall in prices following a contractionary shock in Miami (FL) and San Francisco (CA) – both markets with an inelastic housing supply. For Dayton (OH), an area with an elastic housing supply, the effect of contractionary shocks are stronger. Thus, the asymmetric response to a monetary policy shock is tightly linked to region-specific housing supply elasticities. This is because the price-to-price feedback loop, which accelerates the expansionary monetary policy shocks, is stronger in the more inelastic markets, where the initial response to an increase in house prices is high. For most of the empirically observable elasticities in the US, we do find that the expansionary shocks have a greater impact than the contractionary shocks. This may be particularly important to keep in mind when then there are trade-offs between developments in economic activity, inflation and house prices.

Our investigation of the asymmetric transmission of monetary policy shocks to house prices continue as follows. The next section sketches a simple skeleton model that gives a theoretical foundation for our empirical investigation. Section 3 presents the data we utilize. Section 4 documents our empirical findings on the heterogenous and asymmetric effects of monetary policy. The final section concludes.

2 Theoretical motivation

Following Glaeser et al. (2008), we consider an economy consisting of several heterogeneous housing markets with different supply elasticities. Specifically, some regions are open space areas with no regulations on building permits, while other regions are naturally restricted, e.g. by mountains or water, or by the local regulatory framework. In particular, we will shed light on possible heterogeneities and asymmetries in the response to expansionary and contractionary monetary policy shocks.

In each period, the law of motion of capital accumulation for area i is given as:[1]

$$H_{i,t} \quad = \quad H_{i,t-1} + I_{i,t} \tag{1}$$

where $H_{i,t}$ is the housing stock at time t, while $I_{i,t}$ represents new investments in housing capital. We assume that investments are determined according to Tobin's Q theory (Tobin, 1969), i.e. new construction projects are initiated as long as the market price, $PH_{i,t}$, exceeds the marginal cost of construction, $MC_{i,t}$.

When considering heterogeneous areas of different sizes, the number of new construction projects initiated in each period will naturally depend on the size of the market in question. To take account of this, we assume that the marginal cost of investments is inversely proportional to the existing housing stock, i.e. there is a larger construction capacity in bigger markets. The marginal cost function for area i takes the following form:

$$MC_{i,t}(I_{i,t}) \quad = \quad C_{0,i} \left(I_{i,t}/H_{i,t-1} + 1 \right)^{1/\varphi_i} \qquad , \varphi_i > 0 \ \ \forall \ i$$

where φ_i is the time invariant area specific supply elasticity, while $C_{0,i}$ is a positive variable measuring fixed costs of housing construction (we disregard time varying construction costs for now). Setting the price equal to the marginal cost, we get the following investment function:

$$I_{i,t} \quad = \quad H_{i,t-1} \cdot \max \left\{ 0, \ \left(\frac{PH_{i,t}}{C_{0,i}} \right)^{\varphi_i} - 1 \right\} \tag{2}$$

Given a non-zero supply elasticity, it follows from 2 that there will be positive investments

[1] For now, we abstract from depreciation of the existing stock.

if and only if prices exceed the fixed costs of construction. Moreover, the size of the investment response depends on both the size of the market (as measured by $H_{i,t-1}$) and the supply elasticity. The two extreme cases are interesting: In a completely supply elastic market ($\varphi_i \to \infty$), a positive price-to-cost ratio implies that investments become infinite, while in a market where supply is completely inelastic ($\varphi_i \to 0$), investments will be zero and independent of house prices. From (1) and (2), we find that a log transformation (lower case letters) of the supply equation yields:[2]

$$h_{i,t} \quad = \quad h_{i,t-1} + \max\left\{0,\ \varphi_i \left(ph_{i,t} - c_{0,i}\right)\right\} \tag{3}$$

It follows that the log supply curve will be piecewise linear and kinked; only if the price exceeds the fixed cost of construction will supply increase as a function of the supply elasticity, φ_i, and the price-to-cost ratio (Tobin's Q). Hence, supply is assumed completely rigid downwards, motivated by the fact that housing is usually neither demolished nor dismantled (see also the discussion in Glaeser and Gyourko (2005)).

We follow custom when it comes to the modelling of the demand side. For each area, it is assumed that demand is determined in accordance with the life cycle model of housing, see e.g. Meen (1990, 2001) and Muellbauer and Murphy (1997), and the references therein. For area i, a logarithmic representation of the inverted demand function is given as:

$$ph_{i,t} \quad = \quad v_{0,t} i_t + v_{1,i,t} + v_2 h_{i,t} \qquad , v_0, v_2 < 0 \tag{4}$$

where the v_0 is the semi-elasticity of house prices with respect to the interest rate, $v_{1,i,t}$ measures other demand shifters, such as income and migration. The parameter v_2 measures the price elasticity of an increase in the number of houses (the inverse demand elasticity).

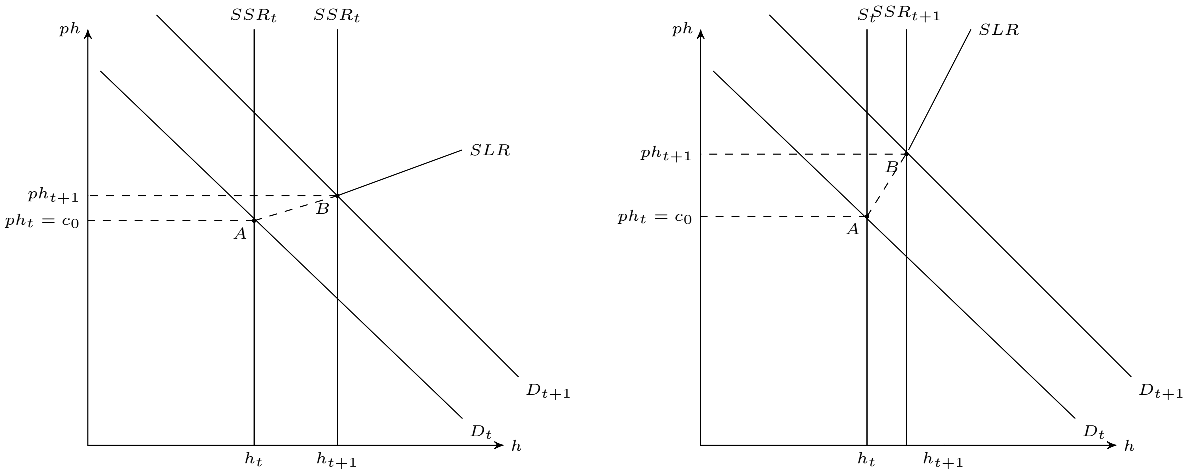
[2]This is seen by rewriting (1) using (2); $H_{i,t} = H_{i,t-1} \cdot \max\left\{1,\ \left(\frac{PH_{i,t}}{C_{0,i}}\right)^{\varphi_i}\right\}$ and then taking logs.

Let us assume that market i initially is in equilibrium ($ph_{i,t} = c_{0,i}$), which also implies that $I_{i,t} = 0$ and hence that $H_{i,t} = H_{i,t-1}$. Then, market i is hit by an expansionary monetary policy shock. This will lead to a greater increase in house prices in more inelastic markets. Figure 1 illustrates this results for the case of two markets with different supply elasticities (elastic and inelastic). In this figure, the short-run supply curve at time t is drawn as a vertical line due to the fact that increasing the housing stock is not done over night. The original long-run supply curve has a kink at point A – the market equilibrium. This is to capture the implication implied by our stylized model, namely that houses are durable and that once they are built, they are usually not destroyed.

As seen, a positive demand shock (D_t to D_{t+1}) primarily leads to quantity adjustments in supply elastic markets, while the shock is mostly absorbed in terms of higher prices in inelastic markets. To ensure market clearing, the part of the adjustments that has to be made in the form of higher prices will be larger the lower the supply elasticity. Thus, as expected, the conjecture of a standard supply-demand story is that expansionary shock has a greater impact on house prices the lower is the elasticity of supply. At the same time, the new short run supply curve will shift, leading to a new kink in the long-run supply curve at point B. Thus, the dotted part of the old long-run supply curve is no longer relevant, since we assume that the new houses that are built will not be destroyed. Thus, a negative shock would lead to an adjustment along the vertical part of the supply curve.

In Figure 2, we consider a contractionary monetary policy shock. Since supply is rigid downwards, this means that the demand curve shifts along a vertical supply curve, independent of the supply elasticity. The conjecture is therefore that the drop in house prices following a contractionary monetary policy shock is independent of the supply elasticity. Furthermore, the drop in prices following the contractionary shock will always be greater (in absolute value) than the increase in house prices following a similar sized expansionary shock – at least as long as supply is not completely inelastic, in which the supply curve would always be vertical.

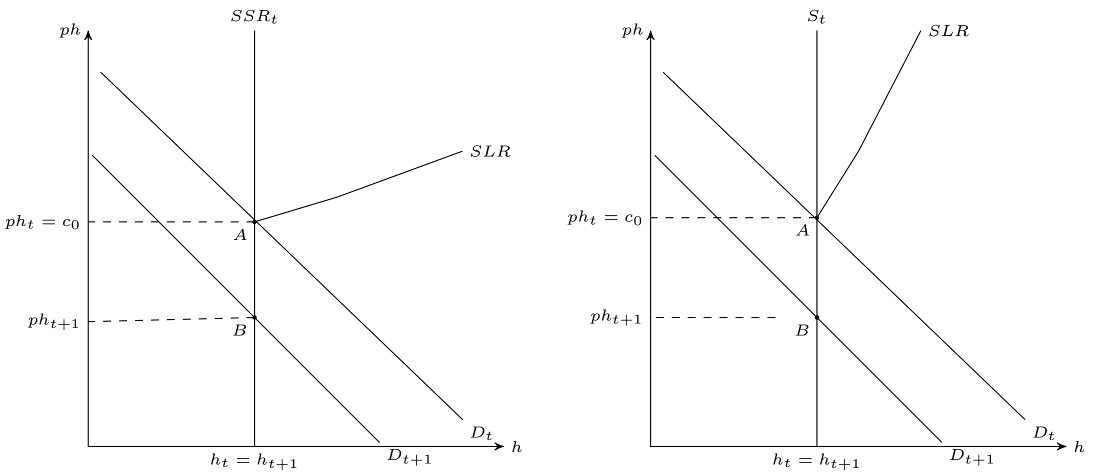
Figure 1: Expansionary monetary policy in supply-elastic vs. - inelastic markets



Market 1: Elastic supply Market 2: Inelastic supply

Note: D_t is the original demand curve, while D_{t+1} is the demand curve after the expansionary monetary policy shock. SSR_t is the original short-run supply curve and SSR_{t+1} is the short-run supply curve after the shock materializes. The long-run supply curve is given by SLR.

Figure 2: Contractionary monetary policy in supply-elastic vs. - inelastic markets



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We summarize these conjectures in Proposition 2.1

Proposition 2.1. *A lower supply elasticity will lead to a greater price increase following a positive monetary policy shock. When the demand shock is reversed, the price drop will be unrelated to the supply elasticity. A contractionary shock will have a greater impact on house prices than an expansionary shock as long as housing supply is not completely* *inelastic Proof: See Appendix A*

2.1 Price-to-price feedback loop

[INCOMPLETE SECTION]. Our basic idea is to introduce the following expectation mechanism:

$$E_t ph_{i,t+1} \leq \begin{cases} \kappa_0 + \kappa_1 ph_{i,t} & \text{, for } ph_{i,t} > ph_{i,t-1} \\ \kappa_0 & \text{, for } ph_{i,t} \leq ph_{i,t-1} \end{cases} \tag{5}$$

This will give the following dynamics for an expansionary MP shock:

1. Prices increase in t
2. In $t+1$ households expect prices to increase, which leads to increased demand and therefore additional price increase
3. The lower is the elasticity of supply, the more prices increase in both 1. and 2.
4. The implication is that house prices may increase a lot following an expansionary shock, especially when supply is inelastic

For a contractionary shock, we have:

1. Prices fall
2. Expected prices are independent of previous prices
3. Total impact on prices is the initial fall

As a result of this asymmetry, the expansionary shock may have a greater impact on house prices if the supply elasticity is low enough, and/or if κ_1 is high enough.

3 Data and descriptive statistics

3.1 Data

Our data set includes the 100 largest Metropolitan Statistical Areas (MSAs) in the United States, covering about 60 percent of the entire US population and all but four of the 50 US states.[3] Following the Census Bureau, the US may be split into four distinct regions: West, South, Midwest and Northeast, confer Figure 3. With reference to those regions,

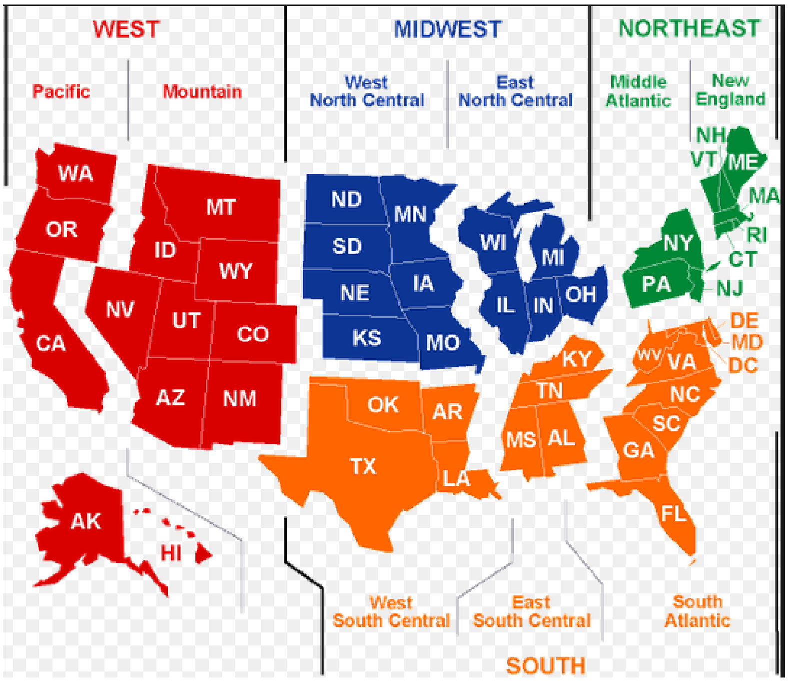


Figure 3: Main geographical regions in the US

our data set includes 25 areas in the West and the Midwest regions, while we have 20 MSAs situated in the Northeast and 30 in the South. In addition to having a rich cross-sectional dimension, we also have a fairly long time series dimension for each of these areas. The sample runs through the period from 1980q1 to 2010q2 ($T = 122$) for 82 of the areas, while the shortest samples (Fargo (ND-MN) and Sioux Falls (SD)) contain 95 observations. Thus, the sample covers both the recent housing cycle and the previous boom-bust cycle in the period 1982–1996 for a majority of the areas considered.[4]

[3]Note that some of the MSAs belong to multiple states.

[4]Here, we rely on the boom-bust cycle classification provided by Glaeser et al. (2008).

The house price data have been gathered from the Federal Housing Finance Agency (FHFA), while households' disposable income, the housing stock and the CPI index – used for the nominal-to-real transformations – have been supplied by Moody's Analytics.

We combine the MSA specific data with the Romer and Romer (2004) narrative monetary policy shock series. Romer and Romer propose a novel procedure to identify monetary policy shocks. First, they use the narrative approach to extract measures of the change in the Fed's target interest rate at each meeting of the Federal Open Market Committee (FOMC) between 1969 and 1996. They then regress this measure of policy changes on the Fed's real-time forecasts of past, current, and future inflation, output growth, and unemployment. The residuals from this regression constitute their measure of monetary policy shocks. The Romer and Romer shock series has gained acceptance as an exogenous indicator of monetary policy shocks and has been widely used to study the transmission of monetary policy shocks, see e.g. Coibion (2012), Ramey (2016). We use an updated version of the Romer and Romer (2004) narrative shock series, provided by Wieland and Yang (2016).

To account for regional heterogeneities, we use the MSA-specific supply elasticities calculated by Saiz (2010). These elasticities are based on both topographical measures of undevelopable land, outlined in Saiz (2010), as well as regulatory supply restrictions based on the Wharton Regulatory Land Use Index developed by Gyourko et al. (2008).

Finally, to control for regional regulatory differences in supply of credit, we use the time varying index of branching deregulation by Rice and Strahan (2010). Favara and Imbs (2015) have used this index to show that an exogenous expansion in mortgage credit has significant effects on house prices. The index is constructed to capture the regulatory changes the US banking sector has gone though regarding banks' geographic expansion (Kroszner and Strahan 2014). The deregulation waves culminated in 1994 with the passage of the Interstate Banking and Branching Efficiency Act (IBBEA). Banks could then operate across state borders without any formal authorization from state authorities. The Rice and Strahan (2010) index runs from 1994 to 2005 and takes values between 0 and 4: the index is reversed so that high values refer to deregulated states. In Rice and Strahan (2010), every state is assumed fully restricted in 1994. Prior to 1994 eight states permitted some limited interstate branching (i.e., Alaska, Massachusetts, New York, Oregon, Rhode Island, Nevada, North Carolina, and Utah). But the option to branch out of state lines was never exercised, except in a few cases (Rice and Strahan (2010)). We therefore assume that prior to 1994 all states were fully restricted.

4 Monetary policy shocks and house prices

4.1 Monetary policy shocks and house prices

The starting point for our empirical analysis is to encompass the findings of a strong effect of monetary policy on house prices, as documented in the literature. Our modus operandi is the local projection framework suggested in Jordà (2005). We use this framework to estimate the cumulative percentage response to house prices h quarters after a monetary policy shock, letting h run from 0 to 20. The advantage of using the local projection approach is that it allows us to study the various non-linearities we are interested in, which would be vastly complicated – and maybe even infeasible – in a standard VAR framework. In addition, our parameters of interest (the response in house prices to a monetary policy shock) are confined to one equation in the underlying VAR system, i.e., the house price equation. We start by considering a dynamic fixed effects model with no heterogeneity or asymmetries:

$$ph_{i,t+h} - ph_{i,t-1} = \alpha_{h,i} + \beta_h RR_t + \mathbf{\Gamma}'_h \boldsymbol{Z}_{i,t-1} + \varepsilon_{i,t+h} \tag{6}$$

where $ph_{i,t+h} - ph_{i,t-1}$ is the cumulative change in log house prices after h-horizons, RR is the Romer and Romer (2004) shock, while $\boldsymbol{Z}$ is a vector of control variables, including lagged changes in log house prices, lagged values of the log change in disposable income per capita, lagged changes in net migration rates and values of the branching deregulation index. For all variables, we include four lags. β_h measures the cumulative change in house prices h quarters after the monetary policy shock. Cumulative responses at h $= 2, 4, 8, 12$ and 16 are reported in Table 1 for a monetary policy shock that raises the interest rate by one percentage point. In the same table, we report cumulative effects on house prices for the same horizons following a shock to disposable income per capita of one percent.

It is evident that an exogenous increase in the Fed funds rate has a negative effect on house prices. While house prices are predicted to fall by a little less than one percent after 2 quarters, the fall is substantial – just below 4 percent – after four years. While sizeable, the effects we find are very much in line with estimates documented in the literature on international and US data (see Williams (2015) for an excellent overview).

We also see that our results imply that house prices increase by close to one percent when income increases by unity – implying a constant price-to-income ratio four years after income is permanently increased by one percent.

4.2 Regional variations in effectiveness of monetary policy

While our results are consistent with the literature documenting a strong role of monetary policy in affecting house prices, it is well known that the evolution of house prices differ substantially across US MSAs (see e.g., (Glaeser et al., 2008; Capozza et al., 2004; Malpezzi and Wachter, 2005)). Figure 4 displays the evolution of real house prices for four of the MSAs contained in our data set. The areas were chosen to illustrate four different types of housing markets, located in different regions of the US. Real house prices have moved quite differently in the four different areas, with a much more pronounced run-up (and subsequent bust) in San Francisco and Boston than in Houston and Wichita over the previous decade.

Our theory discussion suggested that local variations in housing supply elasticities may lead to different house price responses following a demand shock. To investigate whether

Table 1: Effect of monetary policy shock on house prices, symmetric and homogenous response.

	h=2	h=4	h=8	h=12	h=16
MP shock	-0.85***	-0.75***	-2.72***	-3.42***	-3.73***
	(0.16)	(0.19)	(0.32)	(0.45)	(0.56)
Income per capita	0.19***	0.23***	0.44***	0.54***	0.66***
	(0.04)	(0.05)	(0.08)	(0.12)	(0.15)
Branching Dereg.	0.00**	0.00*	0.01***	0.01***	0.02***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Net Migration	1.03***	2.55***	5.55***	8.03***	9.08***
	(0.23)	(0.34)	(0.55)	(0.75)	(0.88)
Observations	8872	8872	8872	8872	8872
MSAs	100.00	100.00	100.00	100.00	100.00
Within R^2	0.26	0.33	0.33	0.29	0.24

Notes: The dependent variable are the cumulative log changes in the FHFA house price index at horizon $h = 2, 4, 8, 12$ and 16. Results are based on estimating equation 6 using a fixed effect estimator and the data set cover a panel of 100 US MSA's countries over the period 1980q1–2007q4. Standard errors are clustered by MSA and reported in absolute value in parenthesis below the point estimates. The asterisks denote significance levels: * = 10%, ** = 5% and *** = 1%.

the supply elasticity has an impact on how monetary policy shocks are absorbed, we consider an equation of the following form:

$$ph_{i,t+h} - ph_{i,t-1} = \alpha_{h,i} + \beta_h \times RR_t + \beta_h^{El.} Elasticity_i \times RR_t + \mathbf{\Gamma}'\boldsymbol{W}_{i,t-1} + \varepsilon_{i,t+h} \qquad (7)$$

where $Elasticity_i$ is the time-invariant supply elasticities calculated in Saiz (2010), with a higher value indicating a more elastic housing supply. For a particular area, i, the cumulated response to house prices in period h following a monetary policy shock is given as $\beta_h + \beta_h^{El.} Elasticity_i$. The vector of controls include the same set of controls as previously, but also interactions of the other demand shifters (migration, branching deregulation and income) and the supply elasticity. This is because theory also suggests that the reaction to other demand shifters should be lower the lower is the elasticity of

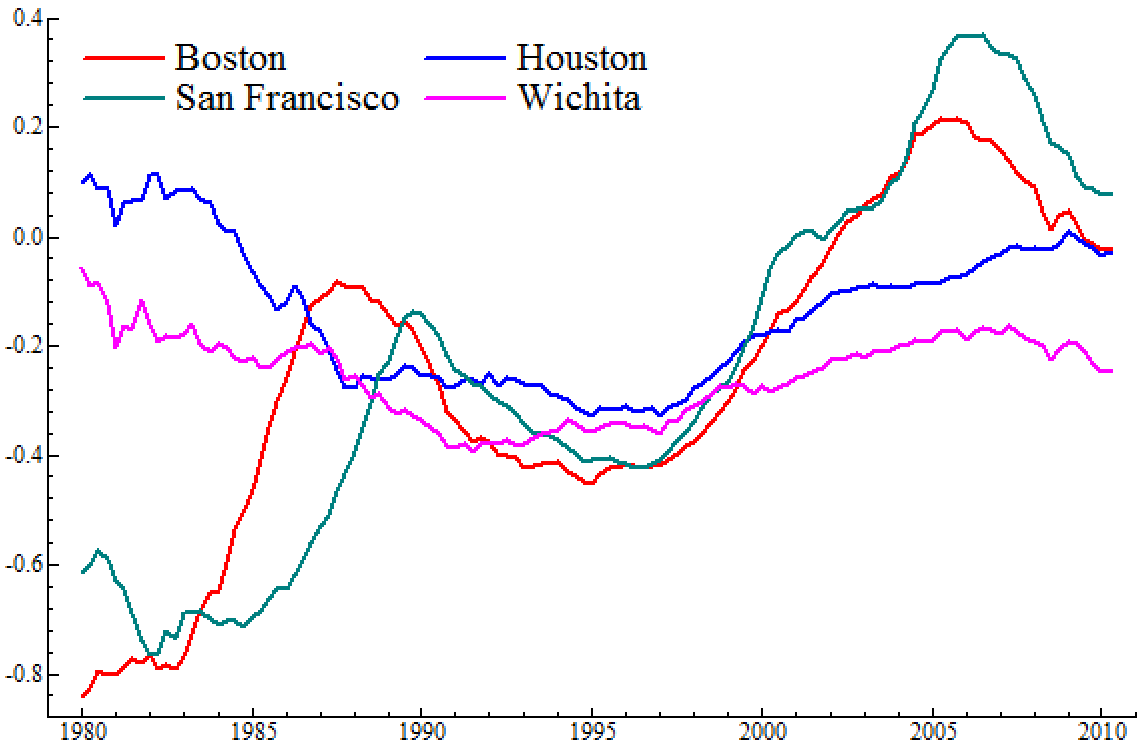


Figure 4: Log of real house prices, 1980q1-2010q2.

supply. Table 2 summarizes results from estimating (7).

We find that an exogenous increase in the policy rate has a smaller negative effect on house prices at all horizons the higher is the elasticity of supply, which is in line with the theory model. Consistent with this, we also find a smaller effect on house prices following an increase in per capita disposable income in more supply elastic areas.

In table 3 we have calculated the response for 5 different (and selected) MSAs with very different supply elasticites; Dayton, Kansas City, Scranton, San Francisco and Miami. While house prices are predicted to fall insignificantly and by less than 1 percent in Dayton 4 years after a contractionary monetary policy shock, house prices in Miami are precited to fall by almost 6 percent over the same horizon. Our results therefore suggest a substantial difference in house price responses for areas with different supply elasticities.

Table 2: Effect of contractionary monetary policy shock with different supply elasticities.

	h=2	h=4	h=8	h=12	h=16
MP shock	-1.11***	-1.81***	-4.79***	-6.42***	-6.96***
	(0.24)	(0.35)	(0.60)	(0.87)	(1.10)
MP shock × Elasticity	0.18*	0.60***	1.16***	1.67***	1.80***
	(0.10)	(0.14)	(0.22)	(0.31)	(0.39)
Income per cap.	0.32***	0.34***	0.69***	0.84***	1.13***
	(0.07)	(0.10)	(0.16)	(0.24)	(0.30)
Income per cap.× Elasticity	-0.07**	-0.07	-0.14**	-0.18**	-0.27**
	(0.03)	(0.04)	(0.06)	(0.09)	(0.11)
Branching Dereg.	0.00	0.00	0.01*	0.02***	0.04***
	(0.00)	(0.00)	(0.00)	(0.01)	(0.01)
Branching Dereg.× Elasticity	-0.00	0.00	-0.00	-0.00	-0.01**
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Net migration	0.48	1.69**	4.77***	7.27***	8.92***
	(0.46)	(0.66)	(1.08)	(1.47)	(1.78)
Net migration × Elasticity	0.29	0.47	0.41	0.41	0.07
	(0.20)	(0.30)	(0.50)	(0.69)	(0.85)
Observations	8781	8781	8781	8781	8781
MSAs	99.00	99.00	99.00	99.00	99.00
Within R^2	0.29	0.36	0.36	0.32	0.27

Notes: The dependent variable are the cumulative log changes in the FHFA house price index at horizon $h = 2, 4, 8, 12$ and 16. Results are based on estimating equation 7 using a fixed effect estimator and the data set cover a panel of 100 US MSA's countries over the period 1980q1–2007q4. The specification allows the response in house prices to differ depending on the elasticity of supply, as calculated in Saiz (2010). Standard errors are clustered by MSA and reported in absolute value in parenthesis below the point estimates. The asterisks denote significance levels: * = 10%, ** = 5% and *** = 1%.

Table 3: Effect of contractionary monetary policy shock for 5 selected MSAs.

	h=2	h=4	h=8	h=12	h=16
Dayton, OH (El. 3.64)	-0.45	0.36	-0.59	-0.35	-0.40
	(0.22)	(0.26)	(0.40)	(0.53)	(0.63)
Kansas City, MO (El. 3.19)	-0.53***	0.09	-1.11***	-1.10**	-1.21***
	(0.18)	(0.22)	(0.34)	(0.44)	(0.53)
Scranton, PA (El. 1.62)	-0.82***	-0.84***	-2.92***	-3.72***	-4.04***
	(0.14)	(0.19)	(0.33)	(0.47)	(0.60)
San Francisco, CA (El. 0.66)	-0.99***	-1.42***	-4.03***	-5.32***	-5.77***
	(0.1)9	(0.28)	(0.48)	(0.69)	(0.88)
Miami, FL (El. 0.60)	-1.00***	-1.45***	-4.10***	-5.42***	-5.88***
	(0.19)	(0.28)	(0.49)	(0.71)	(0.90)

Notes: The dependent variable are the cumulative log changes in the FHFA house price index at horizon $h = 2, 4, 8, 12$ and 16. Results are based on estimating equation 7. Results are reported for 5 selected MSA's: Dayton and Kansas (high supply elasticity), Scanton (median elasticity) and San Francisco and Miami (low elasticity). The asterisks denote significance levels: * = 10%, ** = 5% and *** = 1%.

4.3 Asymmetric effects of monetary policy

The durability of housing implies that the responses to contractionary and expansionary shocks may differ. In particular, if the demand responses to a contractionary and an expansionary monetary policy shock are equal (in absolute value), the simple demand-supply framework described in Section 2 suggests that the change in house prices will be larger for the contractionary shock. The key assumption for achieving this result is that housing supply is rigid downwards. To shed some light on this, we start by estimating a very simple panel model:

$$\Delta h_{i,t} = \alpha_i + \sum_{j=0}^{4} \beta_j^{Exp.} RR_{t-j}^{+} + \sum_{j=0}^{4} \beta_j^{Cont.} RR_{t-j}^{-} + \mathbf{\Gamma} \boldsymbol{Z}_{i,t-1} + \varepsilon_{i,t}$$

where $\Delta h_{i,t}$ is the change in the log of the housing stock, RR_t^{+} is a variable measuring expansionary shocks and is calculated as $RR_t^{+} = RR_t \times I(RR_t \geq 0)$, where $I(RR_t \geq 0)$ is an indicator variable taking the value one for expansionary shock and a value of zero otherwise. Contractionnary shocks are measured by $RR_t^- = RR_t \times (1 - I(RR_t \geq 0))$. Table 4 reports the sum of the coefficients, $\sum_{j=0}^{4} \beta_j^{Exp.}$ and $\sum_{j=0}^{4} \beta_j^{Cont.}$, following an expansionary shock and a contractionary shock, respectively. While there is a significant increase in the housing stock following an expansionary monetary policy shock, the housing stock does not change following a contractionary monetary policy shock. Thus, the results support the assumption of a downward rigid housing supply.

Table 4: Effects of contractionary and expansionary monetary policy shocks on the housing stock.

	Symmetry	Asymmetry
MP shock	-0.06***	
	(0.01)	
Exp. MP shock		0.13***
		(0.04)
Cont. MP shock		-0.01
		(0.04)

Notes: The dependent variable is the log change in the housing stock. Results are based on estimating equation 8 using a fixed effect estimator and the data set cover a panel of 100 US MSA's countries over the period 1980q1–2007q4. The specification allows the response in house prices to differ depending on whether the monetary policy shock is expansionary or contractionary. The table reports the sum of the coefficients, $\sum_{j=0}^{4} \beta_j^{Exp.}$ and $\sum_{j=0}^{4} \beta_j^{Cont.}$, following an expansionary shock and a contractionary shock, respectively. Standard errors are clustered by MSA and reported in absolute value in parenthesis below the point estimates. The asterisks denote significance levels: * = 10%, ** = 5% and *** = 1%.

Having established the empirical support of a downward rigid housing supply, we conjecture that a change in house prices will be larger for a contractionary monetary policy shock than for an expansionary monetary policy shock. To investigate the relevance of this conjecture, we consider a modified version of (6):

$$ph_{i,t+h} - ph_{i,t-1} = \alpha_{h,i} + \beta_h^{Exp.} RR_t^+ + \beta_h^{Cont.} RR_t^- + \mathbf{\Gamma}'_h \boldsymbol{Z}_{i,t-1} + \varepsilon_{i,t+h} \quad (8)$$

where RR_t^+ is a variable measuring expansionary shocks and is calculated as $RR_t^+ = RR_t \times I(RR_t \geq 0)$, where $I(RR_t \geq 0)$ is an indicator variable taking the value one for expansionary shock and a value of zero otherwise. Contractionnary shocks are measured by $RR_t^- = RR_t \times (1 - I(RR_t \geq 0))$. Thus, $-\beta_h^{Exp.}$ is the cumulative effect on house prices after h quarters following an expansionary monetary policy shock, while $\beta_h^{Cont.}$ measures the effect of a contractionary monetary policy shock. Estimating (8) for $h = 2, 4, 8, 12$ and 16, we obtain the results reported in the Table 5.[5]

The contractionary shock has an expected negative impact on house prices, while the expansionary shock exercises a positive impact on house prices. More intriguing, and in contrast to the simple demand-supply framework, we find that expansionary shocks have a greater impact on house prices than contractionary shocks. In particular, while an expansionary shock immediately leads an increase in house prices, it takes more than a year before a contractionary shock materializes into a drop in house prices. We will later investigate possible explanations of this, but one obvious explanation is that the demand response to an interest rate increase differ from that of a reduction in the interest rate.

Figure 5 summarizes the the cumulative responses for all horizons from zero to 20 following an expansionary and a contractionary shock, and – unsurprisingly – the figure mirrors the results reported in Table 5.

[5] Note that the effect of the expansionary shock is normalized to be $-\beta_h^{Exp.}$, such that it picks up the effect of a reduction in the interest rate of 1 percentage point.

Table 5: Effects of contractionary and expansionary monetary policy shocks on house prices.

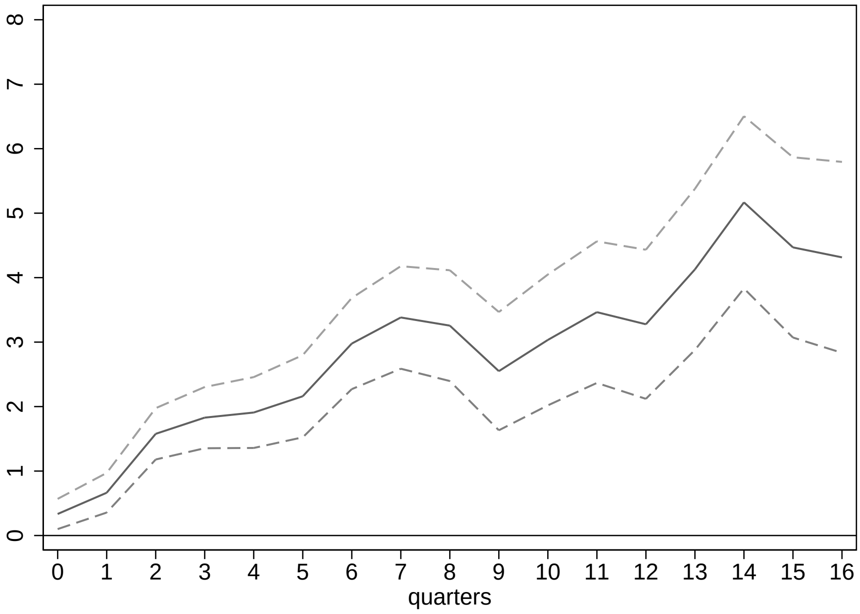
	h=2	h=4	h=8	h=12	h=16
Contr. MP shock	0.13	0.71**	-2.16***	-3.61***	-2.69***
	(0.30)	(0.35)	(0.56)	(0.75)	(0.93)
Exp. MP shock	1.58***	1.91***	3.26***	3.28***	4.31***
	(0.24)	(0.34)	(0.52)	(0.71)	(0.90)
Income per cap.	0.16***	0.20***	0.47***	0.60***	0.72***
	(0.04)	(0.05)	(0.08)	(0.12)	(0.16)
Branching Dereg.	0.00***	0.00**	0.01***	0.01***	0.02***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Net migration	1.02***	2.57***	5.63***	8.28***	9.45***
	(0.23)	(0.34)	(0.55)	(0.75)	(0.89)
MSAs	100.00	100.00	100.00	100.00	100.00
Within R^2	0.26	0.33	0.33	0.29	0.24
Observations	8872	8872	8872	8872	8872

Notes: The dependent variable are the cumulative log changes in the FHFA house price index at horizon $h = 2, 4, 8, 12$ and 16. Results are based on estimating equation 8 using a fixed effect estimator and the data set cover a panel of 100 US MSA's countries over the period 1980q1–2007q4. The specification allows the response in house prices to differ depending on whether the monetary policy shock is expansionary or contractionary. Standard errors are clustered by MSA and reported in absolute value in parenthesis below the point estimates. The asterisks denote significance levels: * = 10%, ** = 5% and *** = 1%.

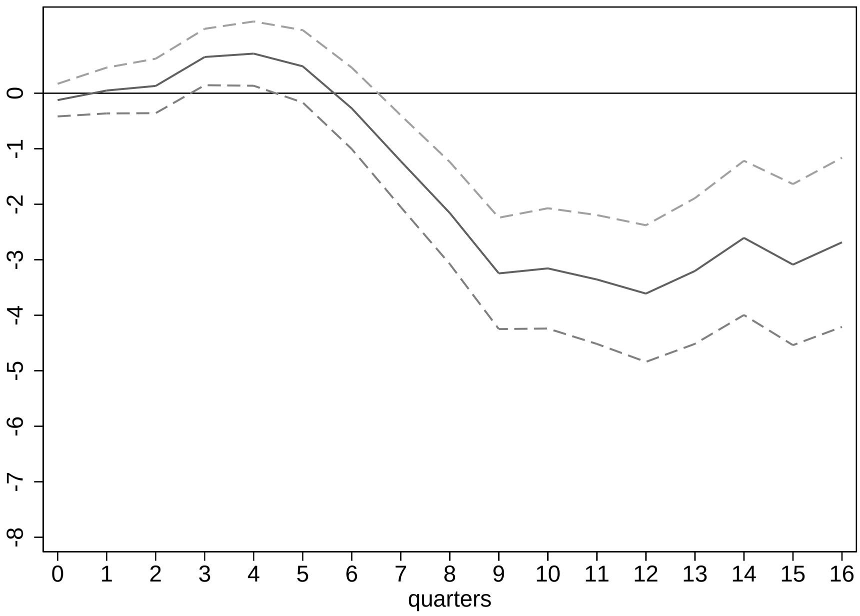
5 Understanding the source of asymmetries

5.1 Adaptive expectations and monetary policy asymmetries

An important theoretical element of housing price determination is the expectation about future housing price gains, which affects housing prices by altering the user cost of housing. An assumption we have made is that price expectations may be modeled by lagged house price appreciation, i.e. that expectations are formed adaptively. The assumption that housing price expectations are formed adaptively rather than rationally calls for some justification given the strong position that rational expectations have in modern macroeconomics.



Expansionary



Contractionary

Figure 5: Asymmetric effect on the aggregate house price from a 1 percentage point monetary policy shock. The first subfigure, labeled Expansionary, shows the response on aggregate house prices of a monetary policy shock that decrease the interest rate. The second subfigure, labeled Negative, refers to a monetary policy shock that decrease the interest rate.

Perhaps surprisingly, there is strong evidence in the literature that housing price expectations are formed in an adaptive manner, see e.g. Jurgilas and Lansing (2013)

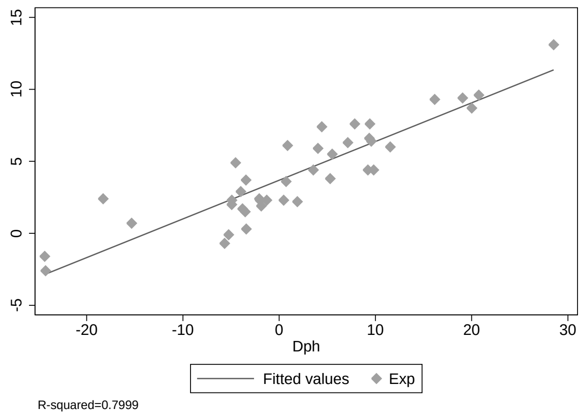


Figure 6: Expectations and lagged house price growth

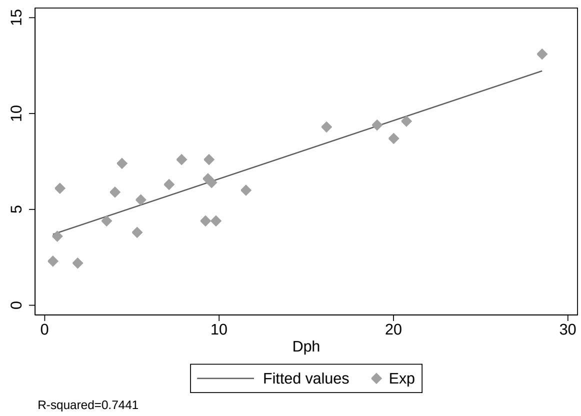
Case et al. (2012)

Figure 7: Scatter plot of house price expectations and lagged house price growth using data from Case et al. (2012).

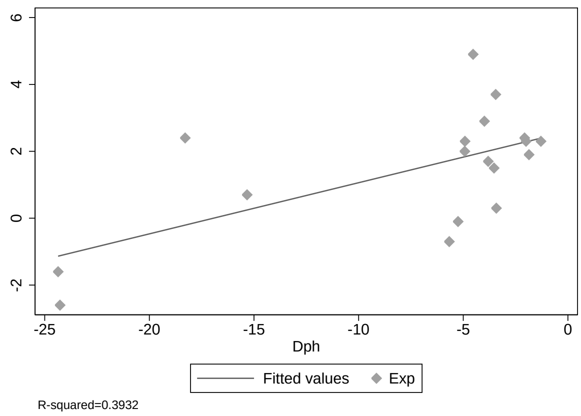
and the references therein. In particular, survey evidence from the US for the years 2006 and 2007 (Shiller (2008)) suggests that individuals in areas with increasing housing prices expected further increases, while the opposite was the case in areas with recent declines in home values. Strikingly, conducting a similar survey in the midst of the national housing bust (in the year 2008), Case et al. (2012) find that individuals living in previously booming areas now expected a decline in housing prices.

To shed some more light on this assumption, we have collected the Case et al. (2012) data, which measures house price expectations over the next year for four metro areas over the period 2003–2012. As suggested in Case et al. (2012), there is strong evidence that house price expectations for the coming year are explained by current house price appreciation. In fact, a regression of house price expectations on current house prices yields an R^2 close to 0.8. The strong relationship between house price expectations and current house price growth is illustrated in Figure 7.

What is also evident in this figure is that in periods of positive house price appreciation, the expectation is that prices will increase. However, it is not clear that periods of falling house prices are associated with an expectation of falling house prices. We illustrate this in Figure 8, where we reproduce the scatter plot above for periods of falling and increasing house prices. It is clear that current house prices is a much better predictor of house price expectations in periods of increasing house prices, with a R^2 that is almost twice as large.



Pos. growth



Neg. growth

Figure 8: Asymmetric expectations. Scatter plots of house price expectations and positive and negative house price growth, respectively. Data taken from Case et al. (2012).

To investigate the asymmetries a bit further, we estimate a simple model of the following form by OLS:

$$E_t\left(\Delta ph_{i,t+1}\right) = \alpha_i + \beta^{+} I(\Delta ph_t \geq 0)\Delta ph_t + \beta^{-} I(\Delta ph_t < 0)\Delta ph_t + u_t \qquad (9)$$

with $E_t\left(\Delta ph_t\right)$ denoting the expected increase in housing prices over the next 12 months and Δph_t measuring the annual price increase from period $t-1$ to period t.

The results, reported in Table 6, show strong evidence of asymmetry in expectation

Table 6: Asymmetric expectation formation.

	Symmetry	Asymmetry
House price growth	0.27***	
	(0.02)	
Pos. House price growth		0.34***
		(0.04)
Neg. House price growth		0.18***
		(0.04)
Observations	40	40
Within R^2	0.84	0.86

*Notes: The table shows estimation results for equation 9, where we report the sum of the coefficients, $\sum_{j=0}^{4} \beta_j^{+}$ and $\sum_{j=0}^{4} \beta_j^{-}$, respectively. Standard errors are clustered by MSA and reported in absolute value in parenthesis below the point estimates. The asterisks denote significance levels: * = 10%, ** = 5% and *** = 1%.*

formation. In particular, the extrapolation of current house price growth is more pronounced in periods of increasing house prices. The presence of such asymmetries may explain why we found the puzzling results in the previous sections, since a reduction of the interest rate leads to higher house prices. Since price expectations are formed adaptively, this means that demand will increase even more, putting an addition upward pressure on house prices and creating a price-to-price feedback loop. Our results suggest that this mechanism is less relevant in periods of falling house prices, which also means that the price-to-price feedback loop has lesser impact on house prices following an increase in the interest rate. Thus, although there may be a greater effect of a contractionary shock ceteris paribus, the stronger price acceleration mechanism in a booming market contributes to magnify the expansionary shock relatively more. Based on the these results, we can therefore form the following conjecture:

Conjecture # 1: An expansionary monetary policy shock may have a greater impact on house price growth than a contractionary monetary policy shock due to asymmetric expectation formation – especially if supply is inelastic

To investigate the conjecture, we estimate a modified version of equation (8), where we allow the coefficients on lagged house price appreciation to differ depending on whether current house price appreciation is positive or negative. Table 7 report the sum of the coefficients on the contractionary and the expansionary shock, as well as the sum of the coefficients on lagged house price appreciation. We report results both for the original case, where we allow for no asymmetry in expectation formation, and for the case where we allow for asymmetric expectation formation. In the case where we do not allow for asymmetric expectation formation, we find that expansionary shocks have a greater impact on house prices than contractionary shocks. This contrasts the predictions from the simple demand-supply framework alluded to in section 2, However, once we allow for asymmetric expectation formation, we find that the partial impact of an expansionary shock is smaller on house prices than a contractionary shock, in line with the predictions from the theoretical model in section 2. However, we also document that a price-to-price acceleration mechanism is far more pronounced in a booming market than in a bursting market. In fact the results suggest that when house price appreciation is negative, there is no adaptive expectation formation. In contrast, when house price appreciation is positive, the estimation results suggest that expectations are formed in a strongly adaptive manners. Taking this into account, the total impact of an expansionary monetary policy shock is greater than of a contractionary shock.

Table 7: Asymmetric expectation formation.

House price growth	0.29	
	(0.11)	
Pos. House price growth		0.72
		(0.07)
Neg. House price growth		-0.22
		(0.20)
Contr. Shock	-0.83	-1.33
	(0.33)	(0.48)
Exp. Shock	1.22	0.63
	(0.29)	(0.18)
MSAs	100.00	100.00
Observations	8872	8872
Within R^2	0.11	0.16

Notes:

5.2 Asymmetric effects of monetary policy with different supply elasticities

The theory model in section 2 suggests that while an expansionary monetary policy shock have a greater impact on house prices in areas with an inelastic housing supply, the response to a contractionary shock should be similar across areas, due to the downward rigidity of housing supply. We can therefore form the following conjecture:

Conjecture # 2: Expansionary shocks have a relatively larger impact on house prices than contractionary shocks when supply is inelastic.

We investigate this by allowing expansionary and contractionary shocks to have different effects for different supply elasticities. We consider a specification of the following form:

$$\begin{aligned} ph_{i,t+h} - ph_{i,t-1} = \alpha_i &+ \beta_h^{Exp.} RR_t^+ + \beta_h^{Exp.,El.} Elasticity_i \times RR_t^+ \\ &+ \beta_h^{Cont.} RR_t^- + \beta_h^{Cont.,El.} Elasticity_i \times RR_t^- + \mathbf{\Gamma W}_{i,t-1} + \varepsilon_{i,t} \end{aligned} \quad (10)$$

With this specification, the cumulative response to house prices in area i after h quarters following an expansionary monetary policy shock is given by $\beta_h^{Exp.} + \beta_h^{Exp.,El.} Elasticity_i$, which clearly varies by the supply elasticity as long as $\beta_h^{Exp.,El.}$ is different from zero. The following a contractionary shock is given by $\beta_h^{Contr.} + \beta_h^{Contr.,El.} Elasticity_i$. Regression results are displayed in Table 8.

First, we find that expansionary shocks have a greater effect on house prices in inelastic areas. On the contrary, in line with predictions from the theoretical models in section 2, the effect of a contractionary shock is independent of the supply elasticity.

Second, the effect of a expansionary monetary policy shock is substantially stronger than the effect of a contractionary monetary policy shock. However, there are nuances to this results. In Table 9 we report results for 5 selected MSAs with different elasticities.

For very inelastic markets, such as San Francisco and Miami, the expansionary shock has more than twice the impact on house prices as the contractionary shock, which is at odds with the simple demand-supply story. In contrast, when considering areas with very elastic housing supply, such as Dayton (OH) and Kansas City (MO), the effect of the expansionary shock is smaller than the contractionary shock. We ascribe the differences in results to expectation formation, as discussed in section 5.1. In markets with a low elasticity of supply, expansionary shocks may lead to expectations of substantial future price increases. Households understand that a high demand pressure in an inelastic market will lead to higher prices in the future, leading them to increase demand today in anticipation of future price increases. Thus, households that are eager to enter the market may increase their demand today in expectation of increasing prices in the future. At the same time, banks may be willing to extend more credit, since the value of their housing portfolio has increased. If price increases lead to expectations of further price increases, or to a relaxation of credit constraints, this can have a strong amplifying effect on demand (Glaeser et al., 2008; Bernanke and Gertler, 1989; Kiyotaki and Moore, 1997; Aoki et al., 2004; Iacoviello, 2005), resulting in large price increases in inelastic markets. On the other hand, an increase in the interest rate may have a relatively smaller impact on demand. These mechanisms will be less relevant in markets with a high supply elasticity, since people know that even in the face of an increase in house prices, there is still plenty of land to build on at a relatively low cost.

Figure 9 show the cumulative response in house prices following an expansionary (upper panels) and contractionary (lower panels) monetary policy shocks for markets with an elasticity below average (left panels) and for markets with an elasticity above average (right panels).

Table 8: Effect of contractionary and expansionary monetary policy shocks with different supply elasticities.

	h=2	h=4	h=8	h=12	h=16
Contr. MP shock	0.57	1.56**	-2.28*	-3.97**	-2.36
	(0.52)	(0.78)	(1.28)	(1.76)	(2.14)
Contr. MP shock × Elasticity	-0.18	-0.41	0.16	0.43	0.19
	(0.24)	(0.35)	(0.58)	(0.79)	(0.96)
Exp. MP shock	1.71***	3.57***	5.80***	7.30***	9.40***
	(0.47)	(0.67)	(1.07)	(1.45)	(1.75)
Exp. MP shock × Elasticity	-0.07	-0.90***	-1.36***	-2.07***	-2.57***
	(0.22)	(0.31)	(0.49)	(0.66)	(0.80)
Income per cap.	0.16**	0.15*	0.52***	0.69***	0.99***
	(0.06)	(0.09)	(0.15)	(0.20)	(0.24)
Income per cap.× Elasticity	0.00	0.02	-0.04	-0.08	-0.20*
	(0.03)	(0.04)	(0.06)	(0.09)	(0.10)
Branching Dereg.	0.01*	0.01	0.01	0.02**	0.04***
	(0.00)	(0.00)	(0.01)	(0.01)	(0.01)
Branching Dereg. × Elasticity	-0.00	-0.00	-0.00	-0.00	-0.01
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Net migration	1.00***	2.41***	5.76***	8.37***	9.90***
	(0.36)	(0.52)	(0.87)	(1.20)	(1.48)
Net migration × Elasticity	0.07	0.17	0.01	-0.02	-0.30
	(0.18)	(0.25)	(0.42)	(0.59)	(0.72)
Observations	8770	8780	8781	8781	8781
MSAs	99.00	99.00	99.00	99.00	99.00
Within R^2	0.35	0.40	0.38	0.34	0.29

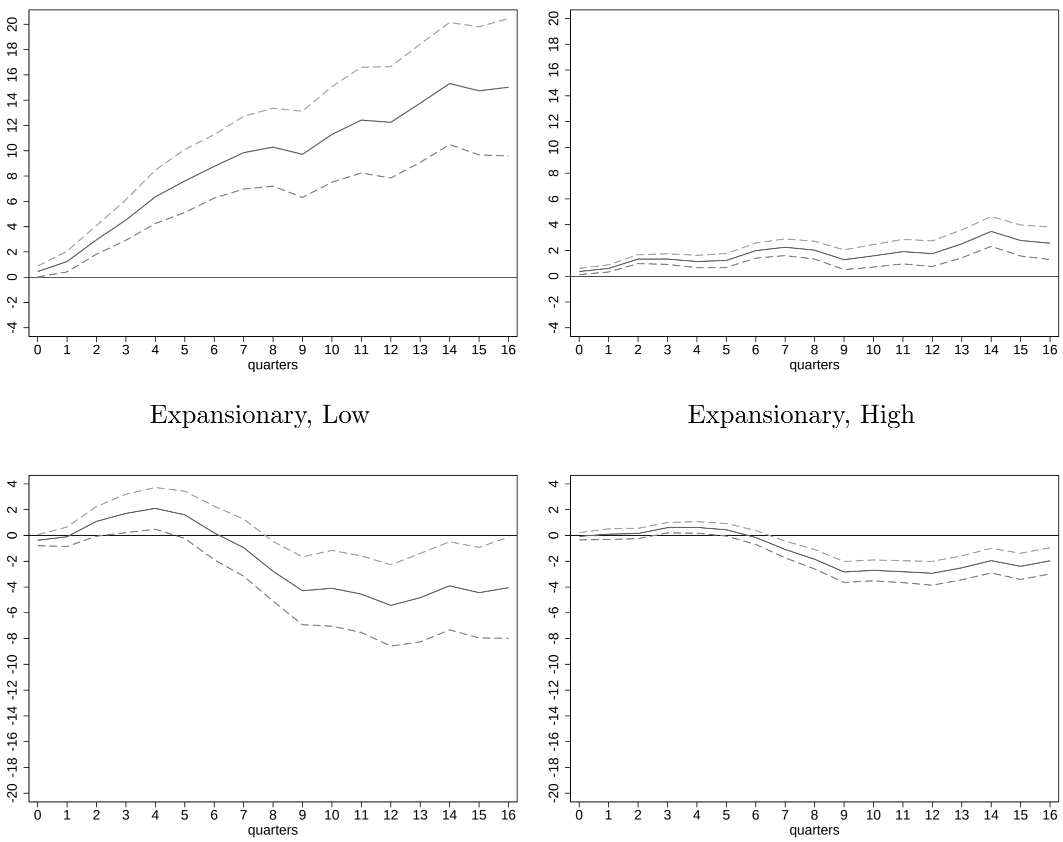
Notes: The dependent variable are the cumulative log changes in the FHFA house price index at horizon $h = 2, 4, 8, 12$ and 16. Results are based on estimating equation 10 using a fixed effect estimator and the data set cover a panel of 100 US MSA's countries over the period 1980q1–2007q4. The specification allows the response in house prices to differ depending on the elasticity of supply, as calculated in Saiz (2010), and whether the monetary policy shock is expansionary or contractionary. Standard errors are clustered by MSA and reported in absolute value in parenthesis below the point estimates. The asterisks denote significance levels: * = 10%, ** = 5% and *** = 1%.

Table 9: Effect of contractionary and expansionary monetary policy shocks with different supply elasticities.

	h=2	h=4	h=8	h=12	h=16
	Contractionary shock:				
Dayton	-0.08	0.07	-1.70	-2.41	-1.66
	(0.49)	(0.74)	(1.21)	(1.66)	(2.02)
Kansas	-0.00	0.26	-1.77*	-2.60**	-1.75
	(0.41)	(0.61)	(1.00)	(1.37)	(1.67)
Scranton	0.28	0.90**	-2.02***	-3.27***	-2.05**
	(0.28)	(0.42)	(0.68)	(0.94)	(1.14)
San Francisco	0.45	1.29**	-2.17**	-3.68***	-2.23
	(0.40)	(0.59)	(0.98)	(1.34)	(1.63)
Miami	0.46	1.31**	-2.18**	-3.71**	-2.24
	(0.41)	(0.61)	(1.00)	(1.37)	(1.67)
	Expansionary shock:				
Dayton	1.44***	0.31	0.86	0.24	0.05
	(0.45)	(0.65)	(1.02)	(1.39)	(1.68)
Kansas	1.48***	0.71	1.47*	0.69	1.20
	(0.37)	(0.53)	(0.85)	(1.15)	(1.39)
Scranton	1.59***	2.12***	3.60***	3.95***	5.24***
	(0.25)	(0.36)	(0.57)	(0.77)	(0.93)
San Francisco	1.66***	2.98***	4.90***	5.94***	7.70***
	(0.36)	(0.51)	(0.81)	(1.10)	(1.33)
Miami	1.66***	3.03***	4.99***	6.06***	7.86***
	(0.37)	(0.52)	(0.83)	(1.13)	(1.36)

Notes: The dependent variable are the cumulative log changes in the FHFA house price index at horizon $h = 2, 4, 8, 12$ and 16. Results are based on estimating equation 10 using a fixed effect estimator and the data set cover a panel of 100 US MSA's countries over the period 1980q1–2007q4. The specification allows the response in house prices to differ depending on the elasticity of supply, as calculated in Saiz (2010), and whether the monetary policy shock is expansionary or contractionary. Standard errors are clustered by MSA and reported in absolute value in parenthesis below the point estimates. The asterisks denote significance levels: * = 10%, ** = 5% and *** = 1%.

6 Conclusion



Expansionary, Low

Expansionary, High

Contractionary, Low

Contractionary, High

Figure 9: Asymmetric effect on house price from a 1 percentage point monetary policy shock for MSA's with different housing supply elasticity, as measured by Saiz (2010). Expansionary, Low refers to the effect of an expansionary monetary policy shock for MSA's with low supply elasticity, while Expansionary, High refers to the effect of an expansionary monetary policy shock for MSA's with high supply elasticity. Likewise, Contractionary, Low refers to the effect of an contractionary monetary policy shock for MSA's with low supply elasticity, while Contractionary, High refers to the effect of an contractionary monetary policy shock for MSA's with high supply elasticity.

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A Proofs for theory model

Proof of Proposition 2.1

The effects on house prices of an increase in a demand shifter $\hat{v}_{0,i,t} \in v_{0,i,t}$ are given by:

$$\left.\frac{\partial ph_{i,t}}{\partial \hat{v}_{0,i,t}}\right|^{M=B} = \frac{1}{1 - v_1\varphi_i} > 0$$

As a result, the differences in the price response for a *low* elasticity ($\underline{\varphi}$) and a *high* elasticity ($\overline{\varphi}$) market with $0 < \underline{\varphi} < \overline{\varphi} < \infty$ are given by:

1.

$$\left.\frac{\partial ph_{i,t}}{\partial \hat{v}_{0,i,t}}\right|^{M=B}_{\varphi_i=\underline{\varphi}} - \left.\frac{\partial ph_{i,t}}{\partial \hat{v}_{0,i,t}}\right|^{M=B}_{\varphi_i=\overline{\varphi}} = \frac{1}{1 - v_1\underline{\varphi}} - \frac{1}{1 - v_1\overline{\varphi}} = \frac{v_1\left(\underline{\varphi} - \overline{\varphi}\right)}{\left(1 - v_1\underline{\varphi}\right)\left(1 - v_1\overline{\varphi}\right)} > 0$$

To shift the demand curve back to its initial position in period $t+1$, we need a negative shock of size $\left.\frac{\partial ph_{i,t}}{\partial \hat{v}_{0,i,t}}\right|^{M=B}$. But, even though I_t drops to zero when $ph_{i,t+1} \leq c_{0,i}$, it is evident from (3) and (4) that ph_{t+1} will be affected also through the effect that $\hat{v}_{0,i,t}$ has on h_t. The total effect on ph_{t+1} of reversing the shock is given by:

$$\left.\frac{\partial ph_{i,t+1}}{\partial \hat{v}_{0,i,t}}\right|^{M=B} = -\left.\frac{\partial ph_{i,t}}{\partial \hat{v}_{0,i,t}}\right|^{M=B} + v_1 \left.\frac{\partial h_{i,t}}{\partial \hat{v}_{0,i,t}}\right|^{M=B} = -\frac{1}{1 - v_1\varphi_i} + v_1\frac{\varphi_i}{1 - v_1\varphi_i} = -1$$