Asymmetric effects of monetary policy in regional housing markets*

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Abstract

The responsiveness of house prices to monetary policy shocks depend both on the nature of the shock; expansionary versus contractionary and on city-specific housing supply elasticities. We test the hypothesis that expansionary monetary policy shocks have a larger impact on house prices when supply elasticities are low on 263 US metropolitan areas and find supporting evidence. We also test whether contractionary shocks are orthogonal to supply elasticities, as implied by downward rigidity of housing supply, and find supporting evidence. A final theoretical conjecture is that contractionary shocks should exercise a greater impact on house prices than expansionary shocks, as long as supply is not perfectly inelastic. For areas with a high housing supply elasticity, our results are in line with this conjecture. However, for areas with an inelastic housing supply, we find that expansionary shocks have a greater impact on house prices than contractionary shocks. We provide evidence that this is related to a momentum effect that is more pronounced when house prices are increasing than when they are falling.

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

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

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1 Introduction

How do house prices respond to changes in the central bank policy rate? The answer is central for understanding the drivers of house price fluctuations. It is also important for the discussion of whether central banks should use the interest rate to enhance financial stability, especially if financial stability considerations come at the cost of achieving macroeconomic stability. However, answering this question is non-trivial. First, even if house prices are not directly part of the central bank's reaction function, the interest rate may respond to house prices indirectly through their impact on consumption and employment (see e.g., Mian et al. (2013) and Mian and Sufi (2014)). Furthermore, while monetary policy is conducted at a national level, housing markets are regional (Ferreira and Gyourko, 2012). This means that changes in the policy rate may have differential effects across smaller areas within the same country. Finally, there are reasons to believe that the effect on house prices of changes in the policy rate 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.

To deal with potential reverse causality and to identify exogenous shifts in monetary policy, we make use of the narrative monetary policy shocks of Romer and Romer (2004). They extracted the change in the Fed's target interest rate at each meeting of the Federal Open Market Committee. They then regressed 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 exogenous monetary policy shocks, which have been widely used to study the transmission of monetary policy shocks to the real economy, see e.g. Coibion (2012) and Ramey (2016).[1] To study regional variations in the transmission of monetary policy shocks to house prices, we interact the Romer and Romer shock with the housing supply elasticities calculated

[1] We use an updated version of the Romer and Romer (2004) narrative shock series extending through 2007. To update the Romer and Romer shock, we use the code and data provided by Wieland and Yang (2016).

by Saiz (2010), which are estimated as functions of both regulatory and physical land constrains.

We ask the following questions: *(i)* Do differences in city-specific housing supply elasticities matter for how house prices respond to exogenous monetary policy shocks? *(ii)* Is the impact on house prices of monetary policy shocks asymmetric? Surprisingly, to the best of our knowledge, these questions remain unanswered. In this paper, we aim to fill this gap by estimating impulse responses for house prices to monetary policy shocks using panel data and local projection methods (Jordà, 2005). Our sample covers 263 US Metropolitan Statistical Areas (MSAs) over the period 1983Q1-2007Q4.

Our results are consistent with the view that expansionary monetary policy shocks have a considerably greater impact on house prices in markets with inelastic housing supply. For congested areas, such as Miami, Los Angeles and San Francisco, we estimate that house prices increase by almost seven percent two years after a monetary policy shock that lowers the interest rate by one percentage point. For construction elastic areas, such as Kansas City, Oklahoma City and Indianapolis, the same effect is estimated to be below three percent. We find that the effect on house prices of a contractionary shock of similar magnitude is independent of the housing supply elasticity. This is consistent with housing supply being rigid downward, which holds irrespective of local regulatory restrictions and topographical constraints. Finally, we find that whether expansionary or contractionary shocks have the strongest impact on house prices depend on local housing supply elasticities. For MSAs with low housing supply elasticities, expansionary monetary policy shocks are found to have a markedly larger effect on house prices than contractionary shocks. However, in areas with a high housing supply elasticity, the effect of expansionary shocks is muted, leading to a stronger impact of contractionary shocks.

From the view of a standard supply-demand framework with durable housing, contractionary shocks should have a greater impact on house prices than expansionary shocks unless supply is perfectly inelastic. For many US metro areas, our results show the opposite. We find that this can be attributed to a momentum effect that is more pronounced when house prices are increasing. Following the seminal paper by Case and Shiller (1989), momentum in house prices has been accepted as a key feature of the housing market, and Glaeser et al. (2014) listed predictability of house price changes by past house price changes as one of three stylized facts about the housing market. Consistent with this, we find strong evidence of a momentum effect in our sample. Moreover, we document that this momentum effect is particularly strong when house prices are increasing. Resultantly, expansionary monetary policy shocks, which *ceteris paribus* lead to an increase in house prices, triggers a momentum effect that puts additional pressure on house prices. Since the initial response in house prices is greater the lower is the elasticity of supply, this momentum effect will be more pronounced in congested areas. When house prices are falling, we find this momentum effect to be much weaker. Therefore, the same reinforcing mechanism is not at work following contractionary monetary policy shocks. As a result of this, the effect of expansionary shocks may be greater than, equal to, or smaller than the effect of contractionary shocks, depending on the elasticity of housing supply. For very inelastic areas, such as Miami, San Francisco and Los Angeles, expansionary shocks have almost twice the effect on house prices relative to contractionary shocks. On the contrary, contractionary shocks exercise a stronger impact on house prices in Kansas City, Oklahoma City and Indianapolis – areas with a high housing supply elasticity. In the case of Indianapolis, the effect of contractionary shocks is three times as large as that of expansionary shocks.

Several explanations have been put forward to explain why house prices exercise momentum effects, including variations in time on market due to search frictions (Head et al. (2014)), information frictions (Anenberg (2016)), extrapolative expectation formation (Case and Shiller (1987); Glaeser et al. (2008); Gelain and Lansing (2014); Glaeser and Nathanson (2017)), heterogenous beliefs and existence of momentum traders (Piazzesi and Schneider (2009); Burnside et al. (2016)), as well as strategic complementarities (Guren (2017)). While we are agnostic about the exact mechanism leading to a momentum effect, we show that a simple extension of the standard supply-demand model with durable housing that allows house price expectations to be different depending on whether house prices are increasing or decreasing can explain why supply inelastic areas may respond more to expansionary monetary policy shocks. To shed some light on the empirical relevance of this, we use data collected by Case et al. (2012), which measures house price expectations over the next year for four metro areas over the period 2003–2012. When distinguishing between periods of falling and increasing house prices, we find that current house prices are much better at predicting house price expectations in periods of increasing house prices, with an R^2 that is almost twice as large. While other mechanisms could also be relevant, we take these results as suggesting that parts of the asymmetric momentum can be explained by an asymmetric expectation formation.

There is a growing literature looking at the nexus between monetary policy and house prices (see e.g., Del Negro and Otrok (2007), Iacoviello (2005), Jarocinski and Smets (2008), Jordà et al. (2015) and Williams (2011, 2015)). What these papers have in common is that they are confined to studying aggregate effects on house prices, which masks the major heterogeneities existing across regional US housing markets.[2] For instance, while nominal house prices increased by more than 160 percent in some coastal areas of Florida and California from 2000 to 2006, they increased by less than 20 percent in inland open space areas of the Midwest. We add to this literature by documenting non-trivial heterogenous responses to a common exogenous monetary policy shock across regional markets, as well as documenting an economically important and sizeable asymmetry in the response to expansionary and contractionary monetary policy shocks.

Another branch of the literature has attributed regional variations in house price dynamics to heterogeneous supply side restrictions (see e.g., Green et al. (2005), Saiz (2010), Gyourko et al. (2008), Glaeser et al. (2008), Glaeser (2009), Huang and Tang (2012) and Anundsen and Heebøll (2016)). This literature has shown that house price

[2]One exception is Del Negro and Otrok (2007). They use a dynamic factor model on state level data to disentangle the relative importance of local and national shocks. They find that historically movements in house prices were mainly driven by local shocks. However, they highlight that the period 2001-2005 was different, as house prices during this period were mostly driven by national shocks. Although, they find the impact of common monetary policy shocks on house prices to be non-negligible, they are fairly small in comparison with the magnitude of the house price increase over this five year period.

booms tend to be larger in markets with an inelastic housing supply. Our results add to this literature by documenting a substantial heterogeneity in the transmission of monetary policy shocks that depends on housing supply elasticities.

Recent studies have documented an asymmetric effect of contractionary and expansionary monetary policy shocks (see Angrist et al. (2017), Tenreyro and Thwaites (2016) and Barnichon and Matthes (2016)) on the real economy. In particular, these papers find that an interest rate reduction is less effective in stimulating the real economy than an increase in the interest rate. Our results suggest that the opposite is true for house prices in many US metro areas. Combined, these results may pose a challenge to central banks if monetary policy is also used for financial stability considerations. The presence of heterogeneous regional shocks within a country may pose a challenge to monetary policy making in the first place, and a key question is whether monetary policy should pay attention to these regional disparities? Our findings suggest that monetary policy may contribute to amplify regional heterogeneity in the housing market.

Finally, several papers (e.g., Mian and Sufi (2009) and Favara and Imbs (2015)) have emphasized the role of lax lending standards as an explanation of regional differences in house prices. In all 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).[3]

Our results are robust to various sensitivity checks. Controlling for differences in regional economic conditions, institutional and regulatory differences by adding Census Division-by-quarter fixed effects do not materially affect our results. Using a balanced panel of 147 MSAs, covering the full sample period in our estimation, do not affect our conclusions. Finally, our results are robust to calculating impulse responses for each MSA separately, allowing for complete heterogeneity in coefficients. In this case, the house prices responses to contractionary and expansionary shocks are grouped according to local housing supply elasticities using the mean group estimator of Pesaran and Smith

[3]Favara and Imbs (2015) used this index as an instrument for credit supply.

(1995).

The rest of the paper is structured as follows. The next section motivates why heterogeneities and asymmetries may be of particular relevance in the housing markets. Section 3 presents the data we utilize and Section 4 documents our empirical findings on the heterogenous and asymmetric effects of monetary policy. We outline possible mechanisms that could generate our findings in Section 5, whereas several robustness and sensitivity checks are carried out in Section 6. The final section concludes.

2 Monetary policy shocks in a model with durable housing

To motivate why heterogeneities and asymmetries in the response to monetary policy shocks may be of particular relevance in a housing market context, we consider a very simple motivating framework, where house prices in a given area are determined by the intersection between demand and supply.

We follow Glaeser et al. (2008) and distinguish between the existing stock of houses and the supply of houses in the market at a particular point in time. The number of houses available for sale in area i at time t is denoted $S_{i,t}$, which consists of a proportion, ψ, of the existing stock of houses, $H_{i,t-1}$, put out for sale by existing home owners[4] and new investments, $I_{i,t}$. Similar to Glaeser and Gyourko (2005), we assume that investments are zero whenever prices are below construction costs and that housing is a durable good.

[4]This can be motivated as in Glaeser et al. (2008), where each homeowner with a certain probability receives a Poisson-distributed shock. If they receive the shock, they have to sell. Otherwise, they stay in the house. With a continuum of homeowners, the number of sales will be deterministic and proportional to the existing stock of houses. The housing stock is in turn determined by a standard law-of-motion of capital accumulation, so that the stock at t is equal to the sum of the non-depreciated stock from $t-1$ and new investments.

To capture these features, we postulate the following linear supply schedule:[5]

$$S_{i,t} = \begin{cases} \psi H_{i,t-1} & \text{if } PH_{i,t} \leq P_{i,t} \\ \psi H_{i,t-1} + \varphi_i \left(PH_{i,t} - P_{i,t} \right) & \text{if } PH_{i,t} > P_{i,t} \end{cases} \quad (1)$$

where $PH_{i,t}$ measures house prices, $P_{i,t}$ is the unit price of a composite input factor used to produce houses, while φ_i is an area-specific housing supply elasticity. With this setup, the supply curve is piecewise linear and kinked; only if the price exceeds the fixed cost of construction will supply increase. Hence, supply is assumed completely rigid downwards, motivated by the fact that housing is usually neither demolished nor dismantled (Glaeser and Gyourko (2005)).

We let housing demand be represented by a linear demand function:

$$D_{i,t} = v_0 r_t + v_1 Y_{i,t} + v_2 PH_{i,t} \quad (2)$$

where r_t is the interest rate, which is common across local markets and $Y_{i,t}$ is household income in area i.

To illustrate the conjectures of this skeleton model, assume that market i is characterized by house prices equal to construction costs at time 0 ($PH_{i,0} = P_{i,0}$), which also implies that $I_{i,0} = 0$ and hence that $S_{i,0} = \psi H_{i,-1}$. Then, market i is hit by an expansionary monetary policy shock at time 1. This will lead to a greater house price increase in supply inelastic markets. Figure 1 gives a visual illustration of this for the case of a market with a high supply elasticity and a market with a low supply elasticity. In this figure, the supply curve at time 0 is drawn with a kink at the equilibrium price, to reflect that houses are durable and that once they are built, they are usually not destroyed.

As seen, a positive demand shock (D_0 to D_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 adjustment that is taken by

[5] One could also motivate this by assuming that construction firms are idle when prices fall below construction costs, and that they otherwise maximize profits.

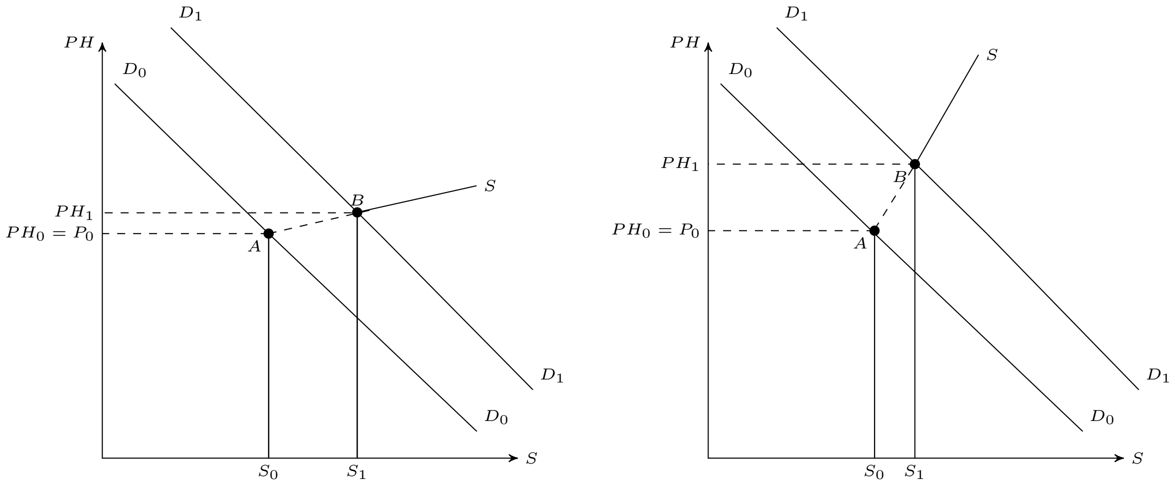
higher prices is larger the lower the supply elasticity. At the same time, the supply curve will now kink at point B instead of point A. Thus, the dotted part of the old supply curve is no longer relevant, since newly built houses are not destroyed, and a negative shock would lead to an adjustment along the vertical part of the supply curve.

In Figure 2, we show the effect of a contractionary monetary policy shock. Since supply is rigid downwards, this means that the demand curve shifts along the vertical part of the supply curve, independent of the supply elasticity. The conjecture is 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 is predicted to always be greater (in absolute value) than the increase in house prices following a similar sized expansionary shock – as long as supply is not completely inelastic, in which the supply curve would always be vertical. This asymmetry arises due to the durability of housing, and a similar conjecture comes out of the model of urban decline in Glaeser and Gyourko (2005). We summarize these conjectures below.[6]

Conjecture # 1: Expansionary shocks have a larger impact on house prices in markets with an inelastic housing supply.
Conjecture # 2: The effect of contractionary monetary policy shocks is independent of the supply elasticity.
Conjecture # 3: For any positive supply elasticity, contractionary shocks have a larger impact on house prices than expansionary shocks.

[6] In Appendix A, we derive the analytical expressions giving rise to these conjectures.

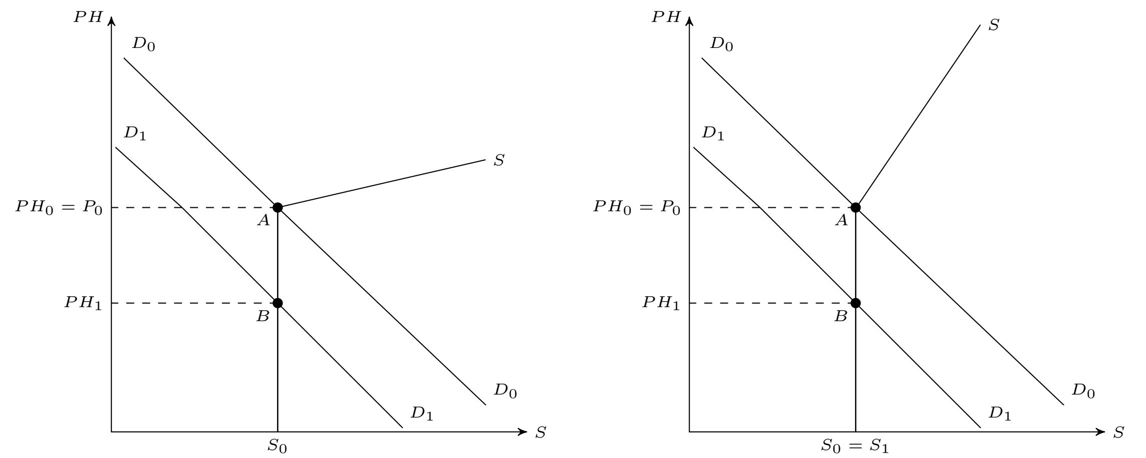
Figure 1: Expansionary monetary policy shocks



Market 1: High supply elasticity   Market 2: Low supply elasticity

Note: D_0 is the original demand curve, while D_1 is the demand curve after the interest rate reduction. The supply curve is given by S. The initial equilibrium is given by point A. The new equilibrium after the interest rate reduction is given at point B. The dotted part of the housing supply curve illustrates that housing supply is rigid downwards, so that the supply curve kinks at A before the shock and at B after the shock.

Figure 2: Contractionary monetary policy shocks



Market 1: High supply elasticity   Market 2: Low supply elasticity

Note: D_0 is the original demand curve, while D_1 is the demand curve after the interest rate increase. The supply curve is given by S. The initial equilibrium is given by point A. The new equilibrium after the interest rate increase is given at point B.

3 Data and descriptive statistics

Our data set includes 263 Metropolitan Statistical Areas (MSAs) in the United States, covering about 70 percent of the entire US population and all but two of the 50 US states (Hawaii and Alaska are not covered).[7] Following the Census Bureau, the US may be split into nine divisions: Pacific, Mountain, West South Central, West North Central, East North Central, East South Central, Middle Atlantic, New England and South Atlantic. Table 1 summarizes some information on the geographical dispersion of the MSAs covered by our sample across these divisions.

Table 1: Geographical distribution of MSAs in our sample

Census division	No. states	No. MSAs	Med. pop	Perc. pop.
Pacific	3	33	426	17
Mountain	8	21	289	7
West North Central	7	25	220	6
South West Central	4	33	390	12
East North Central	5	43	343	14
East South Central	4	18	402	5
New England	5	12	392	4
Middle Atlantic	3	25	427	14
South Atlantic	9	53	415	21
All	48	263	372	100

Note: The table summarizes the geographic distribution of the MSAs covered by our sample across US Census divisions. The table also shows median population in the MSAs in the different divisions, as well as the percentage of the total population covered by our sample of MSAs in each of the divisions. We use population data from 2007Q4.

The table shows that the MSAs are distributed across the entire country and that the median population size is broadly similar across census divisions. In addition to having a rich cross-sectional dimension, we also have a fairly long time series dimension for most of these areas. The sample runs through the period from 1983Q1 to 2007Q4

[7] Note that some of the MSAs belong to multiple states. The constraining factor in terms of MSA-coverage is the housing supply elasticities of Saiz (2010), which are available for 269 MSAs using the 1999 county-based MSA or NECMA definitions. The geographic data in Saiz (2010) are calculated using the principal city in the MSA, and we have matched those to the 2010 MSA definitions. For 6 MSAs, we were not able to match the Saiz data to the 2010 MSA definitions, as they no longer are the principal city in their new MSA.

($T = 100$) for 147 of the areas, and 227 MSAs are covered by 1987Q1. We have full coverage for all MSAs from 1998Q1. For a majority of the MSAs, the sample covers both the recent housing cycle and the previous boom-bust cycle (Glaeser et al., 2008) in the period 1982–1996.

Several data sources have been used to compile our data set, and the rest of this section describes the different data we utilize in our empirical analysis.

3.1 Monetary policy shocks

To measure exognous changes in monetary policy, we use 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 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, using the codes and data provided by Wieland and Yang (2016). The updated shock series ends in 2007Q4. Thus, our analysis is confined to study the transmission of conventional monetary policy shocks.[8] Moreover, Coibion (2012) showed that the effects of Romer and Romer identified monetary policy shocks on various variables are very sensitive to the inclusion of the period

[8]Due to the 5 year lag in the publication of the Greenbook forecasts, we could potentially have updated the Romer and Romer shock series until the end of 2011. However, there are two concerns with such an approach. First, when constructing the shocks, regressing the change in the Fed's target interest rate on the Fed's real-time forecasts of past, current, and future inflation, output growth, and unemployment would result in unreasonably large monetary policy shocks for the zero lower bound period. Second, such an approach would also imply that conventional and unconventional monetary policy shocks have similar effects on house prices.

of non-borrowed reserves targeting, 1979–1982. We therefore follow Coibion (2012) and exclude the period of nonborrowed reserve targeting, starting our estimation in 1983Q1.[9]

3.2 Housing supply elasticities

To explore regional heterogeneities in the response to monetary policy shocks, we use the MSA-specific supply elasticities calculated by Saiz (2010). These elasticities are based on both topographical measures of undevelopable land, as outlined in Saiz (2010), as well as regulatory supply restrictions based on the Wharton Regulatory Land Use Index (WRLURI) developed by Gyourko et al. (2008). WRLURI measures MSA-level regulatory supply restrictions, including complications related to getting a building permit etc., whereas the topographical measure captures MSA-level geographical land availability constraints.

3.3 House prices and control variables

Our source for the house price data is the Federal Housing Finance Agency. We also control for local differences in households' disposable income per capita and migration. Both income and house prices are deflated by MSA-specific CPI indices. Data on local CPI's, income and migration were collected from Moody's Analytics' *Economy.com* webpage.

Finally, to control for regional differences in credit constraints, we use 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. The index is constructed to capture regulatory changes govering geographic expansion for the US banking sector. Following the passage of the Interstate Banking and Branching Efficiency Act (IBBEA) in 1994 banks were allowed to 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

[9]Note that, for consistency, the Romer and Romer shock is also estimated on a sample from 1983 to 2007.

and 4. We follow Favara and Imbs (2015) and reverse the index, so that higher values refer to more deregulated states. As in Rice and Strahan (2010) and Favara and Imbs (2015), we assume that all states were fully restricted prior to 1994.

3.4 Descriptive statistics

Table 2 summarizes the average annual house price growth over the period 1983Q1 to 2007Q4 for the MSAs in our sample with a population exceeding one million. The table also shows the supply elasticity of Saiz (2010) for the same areas. It is clear that the areas with the highest annual house price growth have a lower supply elasticity than the areas with a low house price growth. The bottom part of the table shows summary statistics for both the supply elasticity and the average annual house price growth for all MSAs covered by our sample.

Table 2: House price growth and supply elasticities for MSAs with population above 1 million.

MSA	House price growth	Supply elasticity
Top 5 MSAs with population > 1,000,000:		
San Francisco-Redwood City-South San Francisco, CA	8.21	0.66
San Jose-Sunnyvale-Santa Clara, CA	8.12	0.76
Los Angeles-Long Beach-Glendale, CA	7.75	0.63
New York-Jersey City-White Plains, NY-NJ	7.67	0.76
Oakland-Hayward-Berkeley, CA	7.51	0.70
Bottom 5 MSAs with population > 1,000,000:		
Oklahoma City, OK	1.98	3.29
Houston-The Woodlands-Sugar Land, TX	2.26	2.30
Fort Worth-Arlington, TX	2.28	2.80
Dallas-Plano-Irving, TX	2.35	2.18
San Antonio-New Braunfels, TX	2.64	2.98
Summary stats all MSAs:		
10^{th} percentile	3.09	0.86
25^{th} percentile	3.91	1.21
Median	5.01	1.79
75^{th} percentile	6.24	2.59
90^{th} percentile	7.34	3.57
Mean	5.03	2.04
Standard deviation	1.53	1.04

Note: The table shows summary statistics for the supply elasticity of Saiz (2010) and for the average annual growth in nominal house prices over the period 1983Q1-2007Q4. The upper part of the table shows the average annual growth in house prices and supply elasticities for MSAs with a population exceeding 1 million. The first five are the MSAs with the highest average growth in house prices over this period. The next five are the MSAs with the lowest growth in house prices over the same period. The lower part of the table shows the distribution of average annual growth in nominal house prices and the supply elasticity over the same period for all MSAs for which data are available for the full sample period.

4 Asymmetric effects of monetary policy shocks

The supply-demand framework with durable housing that we outlined in Section 2 suggests that expansionary monetary policy shocks should have a greater impact on house prices in areas with an inelastic housing supply, whereas the response to contractionary shocks should be similar across areas, due to the downward rigidity of housing supply. The model also suggested that contractionary shocks will have a greater impact on house prices than expansionary shocks.

To investigate the empirical relevance of these conjectures, we consider a reduced form version of the supply-demand model. In the reduced form, the supply elasticity is interacted with all variables appearing in the supply-demand model.

Our *modus operandi* is the local projection framework of Jordà (2005). We use this framework to estimate the cumulative percentage response to house prices h quarters after a monetary policy shock, for $h = 0, 4, 8$ and 12. The advantage of using the local projection approach is that it allows us to study non-linear effects of monetary policy, which would be vastly complicated – and maybe even infeasible – in a standard VAR framework. In addition, our parameters of interest – the impulse-response functions of house prices following a monetary policy shock – are confined to one equation in the underlying VAR system, i.e., the house price equation.

4.1 Baseline specification

Our baseline empirical specification takes the following form:

$$\begin{aligned} ph_{i,t+h} - ph_{i,t-1} = \alpha_i &+ \beta_h^{Exp.} RR_t^{Exp.} + \beta_h^{Exp.,El.} Elasticity_i \times RR_t^{Exp.} \\ &+ \beta_h^{Cont.} RR_t^{Contr.} + \beta_h^{Cont.,El.} Elasticity_i \times RR_t^{Contr.} + \mathbf{\Gamma}' \boldsymbol{W}_{i,t} + \varepsilon_{i,t} \end{aligned} \tag{3}$$

where $ph_{i,t+h} - ph_{i,t-1}$ is the cumulative change in log house prices after h quarters, RR_t

is the Romer and Romer (2004) shock, $Elasticity_i$ is the time-invariant supply elasticities calculated by Saiz (2010), with a higher value indicating a more elastic housing supply.

We let $RR_t^{Exp.}$ denote a variable measuring expansionary shocks, and it is calculated as $RR_t^{Exp.} = RR_t \times I(RR_t \geq 0)$, where $I(RR_t \geq 0)$ is an indicator variable taking the value one for expansionary monetary policy shocks and a value of zero otherwise. Contractionary shocks are measured by $RR_t^{Contr.} = RR_t \times (1 - I(RR_t \geq 0))$.

With this notation, $-\beta_h^{Exp.}$ is the cumulative effect on house prices after h quarters following an expansionary monetary policy shock, whereas $\beta_h^{Cont.}$ measures the effect of a contractionary monetary policy shock after h quarters.

The vector $\boldsymbol{W}_{i,t}$ contains a set 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 the branching deregulation index used in Favara and Imbs (2015). For the lagged variables, we include four lags.

Regression results are displayed in Table 3. Consistent with *Conjecture I*, we find that expansionary monetary policy shocks lead to higher house prices, but that the effect is lower for areas with a high housing supply elasticity. Supporting *Conjecture II*, we find that the effect of contractionary shocks have a negative impact on house prices, and that this effect is independent of the housing supply elasticity.

Regarding *Conjecture III*, it is clear that the answer depends on the housing supply elasticity. Figure 3 shows the responses in house prices to an expansionary monetary policy shock (upper panel) and to a contractionary monetary policy shock (lower panel) of one percentage point for the MSAs covered by our sample after two years ($h = 8$).[10] The maps are constructed so that the color spectrum in the two panels have the same range in absolute value, and with a darker color indicating a greater response in house prices.

We see that expansionary shocks have a greater effect than contractionary shocks in

[10]For the contractionary shocks, the response in house prices for area i is calculated as $\beta_h^{Contr.} + \beta_h^{Contr.,El.} Elasticity_i$, whereas the response to house prices in area i following an expansionary shock is given by $-(\beta_h^{Exp.} + \beta_h^{Exp.,El.} Elasticity_i)$.

most areas. In particular, for very congested areas, such as San Francisco (CA) and Miami (FL), expansionary shocks have more than twice the impact on house prices relative to contractionary shocks, which is at odds with the simple demand-supply story. That said, it is also evident that there are several areas in which the effect of a contractionary shock exceeds that of an expansionary shock. Considering construction elastic areas, such as Dayton (OH) and Kansas City (MO), the effect of expansionary shocks is smaller than contractionary shocks. Table B.1 in Appendix B shows the effect of both contractionary and expansionary shocks after two years for MSAs with a population above 1 million. The areas are ranked according to their supply elasticity. The results in that table reveals that the effect of expansionary shocks is greater than the effect of the contractionary shocks for most of the large MSAs included in our sample.

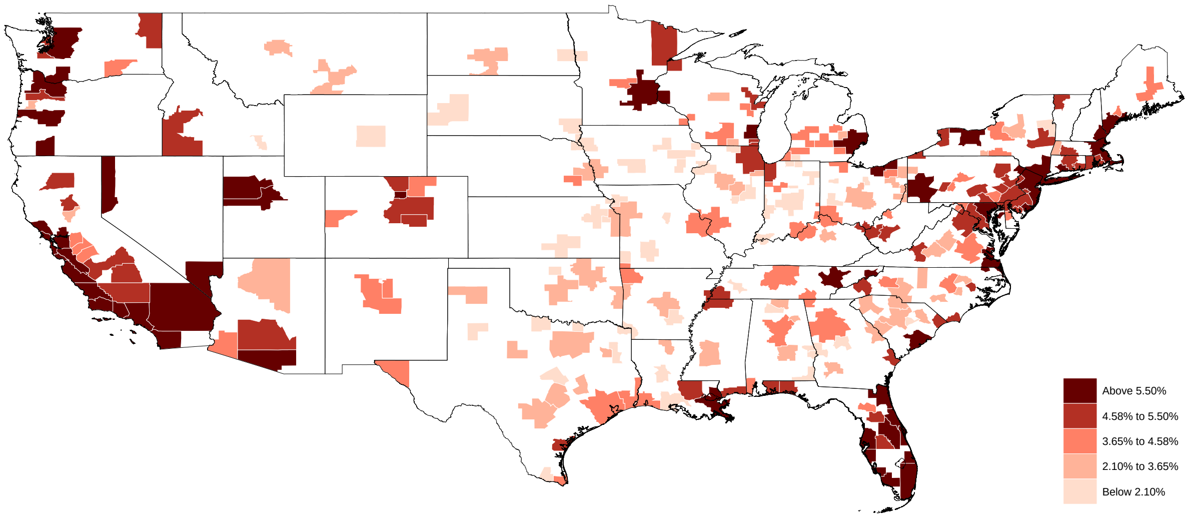
Table 3: Asymmetric and heterogeneous effects of monetary policy shocks on house prices.

	Dependent variable is $ph_{i,t+h} - ph_{i,t-1}$			
Indep. Var.	h=0	h=4	h=8	h=12
Contr. MP shock	-0.08	-0.80	-3.53***	-6.29***
	(0.29)	(0.67)	(1.16)	(1.77)
Contr. MP shock	0.12	-0.06	0.20	0.42
× Elasticity	(0.13)	(0.23)	(0.38)	(0.54)
Exp. MP shock	-0.18	2.85***	7.81***	8.13***
	(0.22)	(0.67)	(1.01)	(1.33)
Exp. MP shock	0.11	-0.59***	-1.59***	-2.07***
× Elasticity	(0.08)	(0.23)	(0.33)	(0.46)
Observations	23,212	22,160	21,108	20,056
MSAs	263	263	263	263
R^2	0.214	0.341	0.334	0.319
MSA FE	YES	YES	YES	YES
Controls	YES	YES	YES	YES

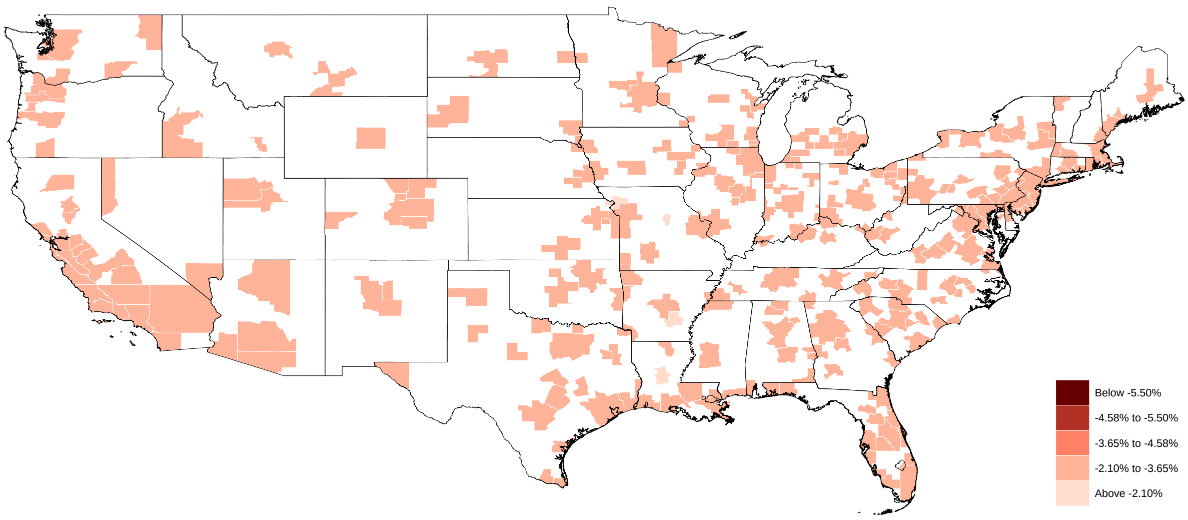
Note: The table shows the effect on house prices of contractionary and expansionary monetary policy shocks when accounting for different supply elasticities. The dependent variable is the cumulative log changes in the FHFA house price index at horizon $h = 0, 4, 8$ and 12. Results are based on estimating equation (3) using a fixed effect estimator and the data set cover a panel of 263 US MSA's countries over the period 1983q1–2007q4. 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 robust to heteroskedasticity and autocorrelation are reported in absolute value in parenthesis below the point estimates. The asterisks denote significance levels: * = 10%, ** = 5% and *** = 1%.

Figure 3: Regional variation in the response to monetary policy shocks

Expansionary



Contractionary



Note: The effect of an expansionary and a contractionary monetary policy shock for MSA's with different housing supply elasticity after 8 quarters.

4.2 Controlling for Census Division-by-quarter fixed effects

In our baseline specification, we control for state-specific changes in branching deregulation using the time-varying index of branching deregulation constructed by Rice and Strahan (2010). To control for other common regional shocks affecting geographically close MSAs, we add Census Division-by-quarter fixed effects to our baseline specification. These are are dummies for all 9 Census Divisions for all quarters spanned by our sample, and the modified specification takes the following form:

$$ph_{i,t+h} - ph_{i,t-1} = \alpha_i + \eta_{k,t} + \beta_h^{Exp.,El.} Elasticity_i \times RR_t^{Exp.} + \beta_h^{Cont.,El.} Elasticity_i \times RR_t^{Contr} + \mathbf{\Gamma} \boldsymbol{W}_t + \varepsilon_{i,t} \quad (4)$$

where $\eta_{k,t}$ is the Census Division-by-quarter fixed effects. Note that we cannot include the non-interacted variables for expansionary and contractionary monetary policy shocks in this case. This is because a linear combinations of these two variables would be perfectly collinear with the linear combination of the Census Division-by-quarter fixed effects. This specification therefore does not allow us to say anything about the absolute response to expansionary and contractionary shocks. That said, we can still test the two conjectures that expansionary shocks have a more muted response in supply elastic areas and that the effect of contractionary shocks is independent of the supply elasticity.

Results are reported in Table 4. Our results are robust to controlling for Census Division-by-quarter fixed effects. In particular, the interaction term between expansionary shocks and the elasticity is highly significant at all horizons, except contemporaneously. This suggest that expansionary shocks have a greater impact on house prices the lower is the elasticity of supply. On the contrary, the interaction between contractionary shocks and the elasticity is insignificant at all horizons. This adds support to our finding that the effect of contractionary shocks is independent of the housing supply elasticity.

Table 4: Asymmetric and heterogeneous effects of monetary policy shocks on house prices when controlling for Census Division-by-quarter fixed effects.

Horizon	Expansionary shock	Contractionary shock	No. Obs.
0	0.06	-0.04	23,212
	(0.1)	(0.12)	
4	-0.55***	-0.39	22,160
	(0.21)	(0.25)	
8	-0.97***	-0.24	21,108
	(0.34)	(0.36)	
12	-1.12**	0.23	20,056
	(0.48)	(0.45)	

Note: The table shows the effect on house prices of contractionary and expansionary monetary policy shocks when accounting for different supply elasticities and controlling for Census Division-by-quarter fixed effects. The dependent variable are the cumulative log changes in the FHFA house price index at horizon $h = 0, 4, 8$ and 12. Results are based on estimating equation 3 using a fixed effect estimator and the data set cover a panel of 263 US MSA's countries over the period 1983Q1–2007Q4. 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. We also control for Census Division-by-quarter fixed effects. Standard errors robust to heteroskedasticity and autocorrelation are reported in absolute value in parenthesis below the point estimates. The asterisks denote significance levels: * = 10%, ** = 5% and *** = 1%.

5 Momentum effects and asymmetric effects of monetary policy

Following the seminal article by Case and Shiller (1989), numerous articles have documented that aggregate house price changes are autocorrelated (see e.g., Cutler et al. (1991), Røed Larsen and Weum (2008), Head et al. (2014)). The momentum in house prices has been accepted as a key feature of the housing market and Glaeser et al. (2014) listed predictability of house price changes by past house price changes as one of three stylized facts about the housing market.

Several explanations have been put forward to explain why this momentum effect occurs in the housing market, including variations in time on market due to search frictions (Head et al. (2014)), information frictions (Anenberg (2016)), extrapolative expectation formation (Case and Shiller (1987); Glaeser et al. (2008); Gelain and Lansing (2014); Glaeser and Nathanson (2017),Armona et al. (2016)), heterogenous beliefs and existence of momentum traders (Piazzesi and Schneider (2009); Burnside et al. (2016)), as well as strategic complementarities (Guren (2017)).

We are agnostic about the exact source leading to the momentum effect, but the presence of momentum effects may be important to understand why expansionary monetary policy shocks can lead to a larger response in house prices than contractionary monetary policy shocks. A momentum effect that is symmetric over the housing cycle would contribute to further strengthen the conjecture that contractionary shocks hit harder than expansionary shocks. Any asymmetry in the momentum effect could, however, lead to different conclusions. In particular, a momentum effect that is more dominant in a booming market than in a falling market could lead to the opposite conjecture, namely that expansionary shocks have a greater impact on house prices than the contractionary shocks – which is consistent with the findings in this paper. If the momentum effect is more pronounced when house prices are increasing, positive demand shocks are amplified relatively more than negative demand shocks. Thus, even though the initial response to a negative demand shock is greater, the total effect of a positive demand shock may be greater.

To investigate whether there are evidence that the momentum effect is asymmetric, we estimate a simple AR(4)-model for house price growth, allowing the coefficients on lagged house price appreciation to have additional effect whenever house prices are increasing. Table 5 report the sum of the AR-coefficients both for the case where we do not distinguish between periods of increasing and decreasing house prices, and for the case where we allow the momentum to differ depending on whether house prices are increasing or decreasing. These results support the notion of a momentum effect that is far more pronounced when house prices are increasing.

Table 5: Asymmetric momentum effects.

Momentum	0.57	0.31
	(0.02)	(0.04)
Additional momentum		0.41
when $\Delta ph_{i,t} > 0$		(0.05)
MSAs	263	263
Observations	23,212	23,212
Adj. R^2	0.18	0.20

Note: The table reports the sum of coefficients on lagged house price appreciation based on estimating an AR(4)-model for house price growth. The first column shows the case of symmetric coefficients, whereas the second column shows coefficients when we allow for an additional momentum effect when house prices are increasing.

5.1 Monetary policy shocks in a model with durable housing and asymmetry in the extrapolative expectation formation

While we are agnostic about the exact mechanism leading to a momentum effect, we shall concentrate on the case of extrapolative expectation formation. In particular, we shall investigate how an expectation rule that differs depending on whether house prices are increasing or falling affect the conjectures of the simple supply-demand model.

Assume that expectations affect demand, so that a modified version of the original demand curve takes the following form:

$$D_{i,t} = v_0 r_t + v_1 Y_{i,t} + v_2 PH_{i,t} + \eta E_t \left(PH_{i,t+1}\right) \tag{5}$$

Assume also that expectations about future house prices are determined in the following way:

$$E_t \left(PH_{i,t+1}\right) \leq \begin{cases} \kappa_1 PH_{i,t} & \text{, when } PH_{i,t} > PH_{i,t-1},\ \kappa_1 > 1 \\ \kappa_2 PH_{i,t} & \text{, when } PH_{i,t} \leq PH_{i,t-1},\ \kappa_2 < \kappa_1 \end{cases} \tag{6}$$

Without loss of generality, we shall assume that $\kappa_2 = 0$, which can be interpreted as expectations playing no role when house prices are falling. However, in a booming market, people expect house prices to continue to increase in the future, which is captured by $\kappa_1 > 1$.

By inserting the expectation process in equation (6) into equation (5), we obtain a modified demand curve:

$$D_{i,t} = \begin{cases} v_0 r_t + v_1 Y_{i,t} + (v_2 + \eta\kappa_1)\, PH_{i,t} & \text{, when } PH_{i,t} > PH_{i,t-1} \\ v_0 r_t + v_1 Y_{i,t} + v_2 PH_{i,t} & \text{, when } PH_{i,t} \leq PH_{i,t-1} \end{cases} \tag{7}$$

Extending the supply-demand model to allow for asymmetric extrapolative expectation formation leads to some interesting mechanisms that are displayed in Figure 4 and Figure 5. We assume that we start out at point A, which also means that the demand curve will have a kink at this point.

In Figure 4, we illustrate the case of an expansionary monetary policy shock, shifting the demand curve out. The interest rate reduction leads to higher house prices and the new equilibrium is at point C. In the model without asymmetric extrapolative expectation formation, the new equilibrium would be at point B. In both models an expansionary monetary policy shock will have a greater impact in supply inelastic markets. However, in the model with asymmetric and extrapolative execrations formation, there will be an amplifying effect of the shock due to the price-to-price feedback loop (the movement from B to C). This effect is greater the lower is the elasticity of supply. Turning to Figure 5, we illustrate the effect of a contractionary monetary policy shock, leading to a downward shift in the housing demand curve. The effect of the interest rate increase is the same, irrespective of whether we allow for extrapolative expectation formations or not. Thus, the conjecture is still that the price drop is independent of the supply elasticity.

Furthermore, for the elastic market, the effect of the contractionary shock is still greater than the effect of the expansionary shock. However, for the inelastic market, the interest rate reduction has a greater impact on house prices than the interest rate increase. Thus, this simple model extension suggest that depending on the supply elasticity, an expansionary monetary policy shock may have a larger or smaller impact on house prices than a contractionary monetary policy shock. We summarize the main conjectures from this model below.[11]

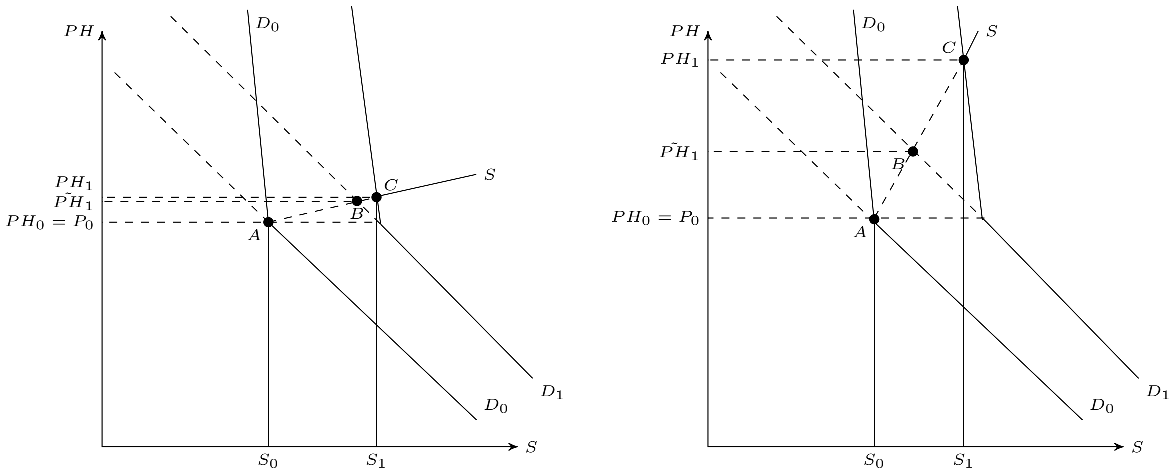
Conjecture # 1: Expansionary shocks have a larger impact on house prices in markets with an inelastic housing supply. The higher is the parameter of extrapolation ($\eta\kappa_1$), the greater is the response to an expansionary shock. The additional acceleration due to extrapolation is greater the lower is the elasticity of supply.

Conjecture # 2: The effect of contractionary monetary policy shocks is independent of the supply elasticity.

Conjecture # 3: An expansionary shock will have a greater effect than the contractionary shock *if and only if* $\varphi_i < \eta\kappa_1$. Thus, there are positive elasticities for which expansionary shocks have a greater impact on house prices than contractionary shocks. Furthermore, the range of elasticities for which this holds increases in $\eta\kappa_1$.

[11] In Appendix A, we derive the analytical expressions giving rise to these conjectures.

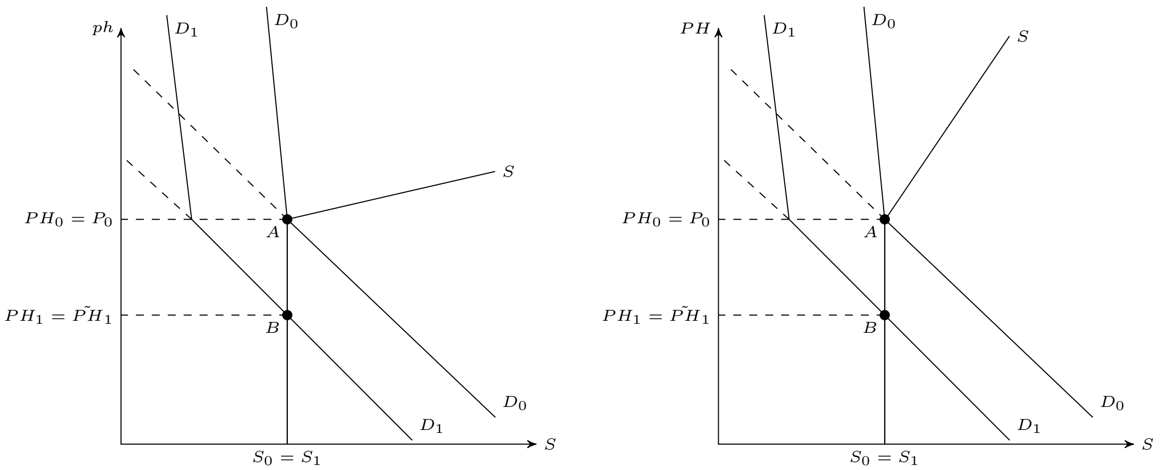
Figure 4: Expansionary monetary policy shocks with momentum effects



Market 1: High supply elasticity　　Market 2: Low supply elasticity

Note: D_0 is the original demand curve, while D_1 is the demand curve after the interest rate reduction. The supply curve is given by S. The initial equilibrium is given by point A. The new equilibrium after the interest rate reduction is given at point C. The dotted part of the housing supply curve illustrates that housing supply is rigid downwards. The dotted part of the demand curves illustrates how the demand curve would look in the case where there is no momentum effect. Point B shows the equilibrium that would prevail in the absence of a price-to-price feedback loop.

Figure 5: Contractionary monetary policy shocks with momentum effects



Market 1: High supply elasticity　　Market 2: Low supply elasticity

Note: D_0 is the original demand curve, while D_1 is the demand curve after the interest rate increase. The supply curve is given by S. The initial equilibrium is given by point A. The new equilibrium after the interest rate increase is given at point B. The dotted part of the demand curves illustrates how the demand curve would look in the case where there is no momentum effect.

5.2 Empirical evidence of asymmetry in extrapolative expectation formation

We use data from Case et al. (2012) which measures house price expectations based on a series of surveys of homebuyers in four metropolitan areas over the period 2003–2012. Consistent with their finding, we see that the data show 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.

Figure 6 shows a scatter plot of the Case et al. (2012) data, where we distinguish between periods of increasing (Panel 1) and falling (Panel 2) house prices. The figure shows a remarkable asymmetry in expectation formation. In periods of positive house price appreciation, there is strong evidence that homebuyers expect prices to continue to increase also in the future. However, when house prices are falling, the effect that house prices are expected to continue to fall is far less pronounced. The survey data therefore suggest that current house prices are much better at predicting house price expectations in periods of increasing house prices than in periods of falling house prices, with a R^2 that is almost twice as large.

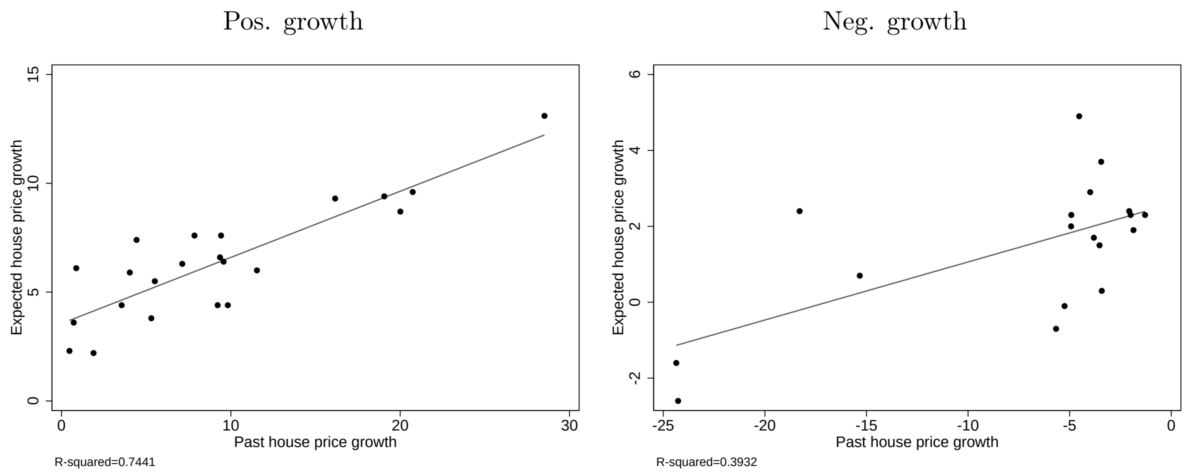
To formally address the asymmetries in expectation formation, we estimate the following model by OLS:

$$E_{i,t}\left(\Delta ph_{i,t+1}\right) = \alpha_i + \beta^{+} I(\Delta ph_{i,t} \geq 0)\Delta ph_{i,t} + \beta^{-} I(\Delta ph_{i,t} < 0)\Delta ph_{i,t} + u_{i,t} \qquad (8)$$

with $E_{i,t}\left(\Delta ph_{i,t}\right)$ denoting the expected increase in housing prices at time t over the next 12 months and $\Delta ph_{i,t}$ measuring the annual price increase at time t.

The results reported in Table 6 show strong evidence of asymmetry in expectation formation, which is consistent with our finding of a momentum effect that is more important when house prices are increasing. In particular, the extrapolation of current house price

Figure 6: Survey evidence on asymmetric expectations.



Note: The two figures show scatter plots of house price expectations and positive and negative house price growth, respectively. Data taken from Case et al. (2012) and measures house price expectations based on a series of surveys of homebuyers in four metropolitan areas over the period 2003–2012

Table 6: Asymmetric expectation formation.

Indep. Var.	*Dep. Var.:* $E_{i,t}(\Delta ph_{i,t+1})$	
	(I)	(II)
Current house price growth	0.27***	0.18***
	(0.02)	(0.04)
Current house price growth		0.16**
when $\Delta ph_{i,t} > 0$		(0.07)
Observations	40	40
R^2	0.84	0.86

Note: The table shows results from estimating equation (8). That is regressing expected house prices on current house prices and allowing for an additional effect when house prices increase. 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%.

growth is more pronounced in periods of increasing house prices. The presence of such asymmetries can explain why expansionary shocks are found to have a greater impact on house prices than contractionary shocks in most MSAs.

6 Robustness and sensitivity checks

6.1 MSA-by-MSA analysis

In our baseline model, we account for heterogeneity through the intercept term (MSA-specific fixed effects). While the panel approach has some advantages, a drawback is that only the intercept is allowed to vary along the cross-sectional dimension. As has been highlighted by e.g., Pesaran and Smith (1995); Im et al. (2003); Pesaran et al. (1999); Phillips and Moon (2000), the pooling assumption of equal slope coefficients may often be disputed as well. To investigate whether our results are sensitive to this assumption, we have estimated separate models for each MSA. For MSA i, we estimate the following specification:

$$ph_{i,t+h} - ph_{i,t-1} = \alpha_i + \beta_{i,h}^{Exp.} RR_t^{Exp.} + \beta_{i,h}^{Cont.} RR_t^{Cont.} + \mathbf{\Gamma}_i \boldsymbol{W}_{i,t} + \varepsilon_{i,t} \qquad (9)$$

with N MSAs and H horizons, this gives us two $N \times H$ matrices of the response to contractionary and expansionary shocks. We then group the MSAs into five equally sized groups, depending on their supply elasticity. For each group, we calculate the mean group estimator of Pesaran and Smith (1995). Thus, the mean group estimators for quintile q at horizon h is given by:

$$\beta_{q,h}^{Exp.} = \frac{1}{N_q} \sum_{j \in q} \beta_{j,h}^{Exp.}$$

$$\beta_{q,h}^{Cont.} = \frac{1}{N_q} \sum_{j \in q} \beta_{j,h}^{Cont.}$$

None of our conclusions are materially affected by this alternative econometric approach, and results are summarized in Table B.2 in Appendix B.

6.2 Balanced panel

In our baseline results, reported in 4, we use an unbalanced panel. For 147 of the areas, we have data for the full period, whereas the starting point for the rest of the MSAs varies. To explore sensitivity to this, we repeated our analysis on a balanced panel for the full data sample (1983Q1-2007Q4), covering 147 MSAs. Our results are not affected by this, see Table B.3 in Appendix B.

6.3 Asymmetric momentum and supply elasticities

We have also explored whether the momentum effect depends on the supply elasticity. To this end, we estimate MSA-specific models allowing for a different effect of lagged house prices in a booming market. We then collected the sum of coefficients for the common momentum term and the sum of coefficients for the additional momentum term in booming market for each MSA. We then regressed these variables on the supply elasticity. Results from this exercise are summarized in Table B.4 in Appendix B.

The intercepts are highly significant in both specifications, suggesting that the result of an additional momentum effect in a booming market is maintained in the cross section. Second, the additional momentum effect is, if anything, somewhat stronger in markets with a low supply elasticity. Thus, allowing for MSA-specific momentum effect would further strengthen our argument that asymmetries in the momentum effect could cause expansionary shocks to have a greater impact on house prices than contractionary shocks.

7 Conclusion

We have analyzed the effects of contractionary and expansionary monetary policy shocks in regional housing markets. Consistent with theory, we find that expansionary shocks have a substantially greater impact on house prices in markets with an inelastic housing supply. We also find that, due to the durability of housing, the effect of a contractionary shock is independent of the elasticity of housing supply. Finally, our results indicate that for most elasticities, the effect of an expansionary shock is greater (in absolute value) than the effect of a contractionary shock. Our results suggest that this is related to a momentum effect that is more important when house prices are increasing than when they are falling, and that this may be attributed to an asymmetric and extrapolative expectation formation.

Our results have direct bearing on the discussion on the trade-offs faced by monetary policymakers when it comes to real economic stability and financial stability. In particular, previous results have shown a greater impact of contractionary monetary policy shocks on the real economy. We find the opposite to be true for most housing markets. Therefore, reducing the interest rate in order to stimulate the real economy may not be very effective, but at the same time it may contribute to amplify the volatility of house prices – particularly so in supply inelastic areas. At the same time, an increase in the interest rate may have a large impact on the real economy without affecting house prices to the same extent as an expansionary monetary policy shock.

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A Analytical expressions for conjectures from baseline and extended supply-demand models

Baseline model

Boom

In a booming market, the equilibrium house price and housing quantity are given by equating supply and demand in the regime where investments respond to the deviation between house prices and construction costs:

$$PH_{i,t} = \frac{1}{\varphi_i - v_2}\left(v_0 r_t + v_1 Y_{i,t} - \psi H_{i,t-1} + \varphi_i P_{i,t}\right)$$
$$S = \frac{\varphi_i}{\varphi_i - v_2}\left(v_0 r_t + v_1 Y_{i,t} + v_2 P_{i,t}\right) - \frac{v_2 \psi}{\varphi_i - v_2} H_{i,t-1}$$

It follows from this that the response in house prices and quantity to an interest rate reduction are given by:

$$-\frac{\partial PH_{i,t}}{\partial r_t} = -\frac{v_0}{\varphi_i - v_2} > 0$$
$$-\frac{\partial S_{i,t}}{\partial r_t} = -\frac{\varphi v_0}{\varphi_i - v_2} > 0$$

Thus, a lower interest rate contributes to higher house prices and a larger supply. Furthermore, the higher is the elasticity of supply, the larger is the quantity reaction and the lower is the house price reaction.

Bust

In a falling market, the equilibrium house price and housing quantity are given by equating supply and demand in the regime where investments are zero:

$$PH_{i,t} = -\frac{1}{v_2}\left(v_0 r_t + v_1 Y_{i,t} - \psi H_{i,t-1}\right)$$
$$S = \psi H_{i,t-1}$$

The response in house prices and quantity to an interest rate increase are therefore given by:

$$\frac{\partial PH_{i,t}}{\partial r_t} = -\frac{v_0}{v_2} < 0$$
$$\frac{\partial S_{i,t}}{\partial r_t} = 0$$

Thus, a higher interest rate leads to lower house prices, but no change in quantity. Furthermore, the price response in the bust is independent of the supply elasticity, since supply is perfectly downward rigid in all markets during a bust.

Finally, the boom response in house prices (in absolute value) is greater than the bust response *if and only if*:

$$\frac{v_0}{\varphi_i - v_2} < -\frac{v_0}{v_2}$$
$$\frac{1}{\varphi_i - v_2} > -\frac{1}{v_2}$$
$$-v_2 > \varphi_i - v_2$$
$$\varphi_i < 0$$

which is logically impossible for any positive supply elasticity. Thus, a simple demand-supply framework suggest that the price response following a contractionary monetary policy shock will be greater than the price response to an expansionary monetary policy shock for any positive supply elasticity.

Model with asymmetry in expectation formation

Boom

In a booming market, the reduced form house price and housing quantity equations in the period of a shock are given by:

$$
\begin{aligned}
PH_{i,t} &= \frac{1}{\varphi_i - \upsilon_2 - \eta\kappa_1}\left(\upsilon_0 r_t + \upsilon_1 Y_{i,t} - \psi H_{i,t-1} + \varphi_i P_{i,t}\right) \\
S &= \frac{\varphi_i}{\varphi_i - \upsilon_2 - \eta\kappa_1}\left(\upsilon_0 r_t + \upsilon_1 Y_{i,t} + (\upsilon_2 + \eta\kappa_1) P_{i,t}\right) - \frac{(\upsilon_2 + \eta\kappa_1)\psi}{\varphi_i - \upsilon_2} H_{i,t-1}
\end{aligned}
$$

It follows from this that the response in house prices and quantity following an interest rate reduction are given by:

$$
\begin{aligned}
-\frac{\partial PH_{i,t}}{\partial r_t} &= -\frac{\upsilon_0}{\varphi_i - \upsilon_2 - \eta\kappa_1} > 0 \\
-\frac{\partial S_{i,t}}{\partial r_t} &= -\frac{\varphi \upsilon_0}{\varphi_i - \upsilon_2 - \eta\kappa_1} > 0
\end{aligned}
$$

These are similar to the results in the model without extrapolative house price expectations when $\kappa_1 = 0$, but the higher is κ_1, the greater is the price response – and more so the lower is the elasticity of supply.

Bust

In a bust, the reduced form house price and housing quantity equations are still given by:

$$PH_{i,t} = -\frac{1}{v_2}\left(v_0 r_t + v_1 Y_{i,t} - \psi H_{i,t-1}\right)$$
$$S = \psi H_{i,t-1}$$

It follows from this that the response in house prices and quantity following an interest rate increase are given by:

$$\frac{\partial PH_{i,t}}{\partial r_t} = -\frac{v_0}{v_2} < 0$$
$$\frac{\partial S_{i,t}}{\partial r_t} = 0$$

Thus, the price response in the bust is independent of the supply elasticity, since supply is perfectly downward rigid in all markets during a bust.

From this, it follows that the boom response in house prices (in absolute value) is greater than the bust response *if and only if*:

$$\frac{v_0}{\varphi_i - v_2 - \eta\kappa_1} < -\frac{v_0}{v_2}$$
$$\frac{1}{\varphi_i - v_2 - \eta\kappa_1} > -\frac{1}{v_2}$$
$$-v_2 > \varphi_i - v_2 - \eta\kappa_1$$
$$\varphi_i < \eta\kappa_1$$

Thus, there are positive supply elasticities for which the response to an expansionary shock is greater than the response to a contractionary shock. Furthermore, the greater is the price-to-price feedback loop, as measured by $\eta\kappa_1$, the greater is the range of elasticities for which this is true.

B Tables and figures

Effect of expansionary and contractionary monetary policy shocks in the largest MSAs

Table B.1: Effect of contractionary and expansionary monetary policy shocks after two years, MSAs with population > 1 million

Rank	MSA name and state	Elasticity	Exp.	Contr.
1	Miami-Miami Beach-Kendall FL	0.6	6.87	-3.41
2	Los Angeles-Long Beach-Glendale CA	0.63	6.82	-3.4
3	Fort Lauderdale-Pompano Beach-Deerfield Beach FL	0.65	6.78	-3.4
4	San Francisco-Redwood City-South San Francisco CA	0.66	6.76	-3.39
5	San Diego-Carlsbad CA	0.67	6.75	-3.39
6	Oakland-Hayward-Berkeley CA	0.7	6.7	-3.39
7	Salt Lake City UT	0.75	6.63	-3.38
8	New York-Jersey City-White Plains NY-NJ	0.76	6.61	-3.37
9	San Jose-Sunnyvale-Santa Clara CA	0.76	6.61	-3.37
10	New Orleans-Metairie LA	0.81	6.53	-3.36
11	Chicago-Naperville-Arlington Heights IL	0.81	6.53	-3.36
12	Virginia Beach-Norfolk-Newport News VA-NC	0.82	6.52	-3.36
13	West Palm Beach-Boca Raton-Delray Beach FL	0.83	6.5	-3.36
14	Boston MA	0.86	6.45	-3.35
15	Seattle-Bellevue-Everett WA	0.88	6.41	-3.35
16	Riverside-San Bernardino-Ontario CA	0.94	6.32	-3.34
17	New Haven-Milford CT	0.98	6.27	-3.33
18	Tampa-St. Petersburg-Clearwater FL	1	6.23	-3.33
19	Cleveland-Elyria OH	1.02	6.19	-3.32
20	Milwaukee-Waukesha-West Allis WI	1.03	6.18	-3.32
21	Jacksonville FL	1.06	6.13	-3.31
22	Portland-Vancouver-Hillsboro OR-WA	1.07	6.12	-3.31
23	Orlando-Kissimmee-Sanford FL	1.12	6.04	-3.3
24	Newark NJ-PA	1.16	5.98	-3.29
25	Pittsburgh PA	1.2	5.9	-3.28
26	Baltimore-Columbia-Towson MD	1.23	5.85	-3.28
27	Detroit-Dearborn-Livonia MI	1.24	5.84	-3.28
28	Las Vegas-Henderson-Paradise NV	1.39	5.61	-3.25
29	Rochester NY	1.4	5.59	-3.24
30	Minneapolis-St. Paul-Bloomington MN-WI	1.45	5.52	-3.24
31	Hartford-West Hartford-East Hartford CT	1.5	5.44	-3.23
32	Denver-Aurora-Lakewood CO	1.53	5.39	-3.22

Continued on next page

Table B.1 Effect of contractionary and expansionary monetary policy shocks after two years, MSAs with population > 1 million

(*Continued from previous page*)

Rank	MSA name and state	Elasticity	Exp.	Contr
33	Washington-Arlington-Alexandria DC-VA-MD-WV	1.61	5.26	-3.2
34	Phoenix-Mesa-Scottsdale AZ	1.61	5.25	-3.2
35	Philadelphia PA	1.65	5.2	-3.19
36	Memphis TN-MS-AR	1.76	5.01	-3.17
37	Buffalo-Cheektowaga-Niagara Falls NY	1.83	4.91	-3.16
38	Raleigh NC	2.11	4.47	-3.1
39	Dallas-Plano-Irving TX	2.18	4.36	-3.09
40	Nashville-Davidson–Murfreesboro–Franklin TN	2.24	4.26	-3.07
41	Houston-The Woodlands-Sugar Land TX	2.3	4.16	-3.06
42	Louisville/Jefferson County KY-IN	2.34	4.1	-3.05
43	St. Louis MO-IL	2.36	4.07	-3.05
44	Grand Rapids-Wyoming MI	2.39	4.02	-3.04
45	Cincinnati OH-KY-IN	2.46	3.91	-3.03
46	Atlanta-Sandy Springs-Roswell GA	2.55	3.76	-3.01
47	Columbus OH	2.71	3.51	-2.98
48	Fort Worth-Arlington TX	2.8	3.37	-2.96
49	San Antonio-New Braunfels TX	2.98	3.08	-2.92
50	Austin-Round Rock TX	3	3.05	-2.92
51	Charlotte-Concord-Gastonia NC-SC	3.09	2.91	-2.9
52	Greensboro-High Point NC	3.1	2.9	-2.9
53	Kansas City MO-KS	3.19	2.75	-2.88
54	Oklahoma City OK	3.29	2.59	-2.86
55	Indianapolis-Carmel-Anderson IN	4	1.46	-2.72

Note: This table reports estimated effects of a contractionary monetary policy shock for all MSAs in our sample with a population above 1 million. The calculations are based on results reported in Table 3.

Results from MSA-by-MSA analysis

Table B.2: Asymmetric effects of monetary policy, grouping by quartiles.

	Expansionary shock:				
Horizon	Q1	Q2	Q3	Q4	Q5
0	0.148	0.085	0.489	0.602	0.22
	(0.196)	(0.18)	(0.296)	(0.235)	(0.234)
4	4.019	2.12	1.594	0.806	1.582
	(0.587)	(0.581)	(0.669)	(0.609)	(0.492)
8	8.801	5.656	3.732	2.652	2.255
	(0.914)	(0.897)	(0.915)	(0.898)	(0.661)
12	9.392	6.565	3.12	2.398	0.656
	(1.269)	(1.244)	(1.205)	(1.344)	(0.93)
	Contractionary shock:				
Horizon	Q1	Q2	Q3	Q4	Q5
0	-0.057	0.337	0.196	0.691	0.668
	(0.195)	(0.278)	(0.335)	(0.356)	(0.418)
4	-0.578	0.292	-0.269	-1.165	0.146
	(0.711)	(0.763)	(0.703)	(0.721)	(0.617)
8	-2.855	-2.247	-1.842	-2.773	-0.719
	(1.03)	(1.068)	(1.098)	(1.017)	(0.937)
12	-3.561	-4.635	-4.002	-3.762	-2.614
	(1.478)	(1.396)	(1.251)	(1.261)	(1.109)

Note: The table shows mean estimates of the effect of contractionary and expansionary shocks at different horizons when we group the areas into quartiles depending on their housing supply elasticity. The underlying model for each MSA allows for full heterogeneity in all coefficients, and are estimated using the mean group estimator of Pesaran and Smith (1995).

Results from balanced panel

Table B.3: Asymmetric and heterogeneous effects of monetary policy shocks on house prices using a balanced panel.

	Dependent variable is $ph_{i,t+h} - ph_{i,t-1}$			
Indep. Var.	h=0	h=4	h=8	h=12
Contr. MP shock	0.22	-0.08	-2.92*	-6.08**
	(0.44)	(1.02)	(1.72)	(2.63)
Contr. MP shock × Elasticity	-0.11	-0.81*	-0.69	-0.21
	(0.24)	(0.44)	(0.70)	(0.99)
Exp. MP shock	-0.17	4.00***	9.68***	11.08***
	(0.32)	(0.95)	(1.45)	(1.94)
Exp. MP shock × Elasticity	0.09	-1.32***	-2.65***	-3.81***
	(0.16)	(0.40)	(0.60)	(0.84)
Observations	13,961	13,373	12,785	12,197
MSAs	147	147	147	147
R^2	0.303	0.403	0.369	0.344
MSA FE	YES	YES	YES	YES
Controls	YES	YES	YES	YES

Note: The table shows the effect on house prices of contractionary and expansionary monetary policy shocks when accounting for different supply elasticities. The dependent variable are the cumulative log changes in the FHFA house price index at horizon $h = 0, 4, 8$ and 12. Results are based on estimating equation 3 using a fixed effect estimator and the data set cover a balanced panel of the 147 MSA's for which we have data over the full period 1983q1–2007q4. 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 robust to heteroskedasticity and autocorrelation are reported in absolute value in parenthesis below the point estimates. The asterisks denote significance levels: * = 10%, ** = 5% and *** = 1%.

Allowing for heterogeneity in momentum effects

Table B.4: Asymmetric momentum, MSA-by-MSA.

	Momentum	Additional momentum when $\Delta ph_{i,t} > 0$
Constant	0.53	0.33
	(0.07)	(0.07)
Elasticity	-0.12	-0.06
	(0.02)	(0.02)
Observations	263	263
Adj. R^2	0.09	0.02

Note: The table shows how the momentum effect and the additional momentum effect in a booming market are related to the housing supply elasticity. The results are based on a two-stage analysis, where we first estimate an AR(4)-model for house price appreciation, allowing the AR-parameters to be different when house prices are increasing, for each MSA in the data set. We then calculate the sum of coefficients on the two momentum terms and regress them on the housing supply elasticity. The first column displays results for the common momentum effect, whereas the second column shows results for the additional momentum effect in a booming market.