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# Asymmetric Effects of Monetary Policy in Regional Housing Markets†

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*The responsiveness of house prices to monetary policy shocks depends on the nature of the shock—expansionary versus contractionary—and on local housing supply elasticities. These findings are established using a panel of 263 US metropolitan areas. Expansionary monetary policy shocks have a larger impact on house prices in supply-inelastic areas. Contractionary shocks are orthogonal to housing supply elasticities. In supply-elastic areas, contractionary shocks have a greater impact on house prices than expansionary shocks do. The opposite holds true in supply-inelastic areas. We attribute this to asymmetric housing supply adjustments.* (*JEL* E32, E43, E52, R21, R31)

How do house prices respond to changes in the central bank policy rate? The answer is central to 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—particularly in order to quantify the potential trade-off between financial and real economic stability. Establishing the effect of monetary policy on house prices is far from trivial. First of all, the effects of monetary policy changes on house prices may be different when rates are increased compared to when they are lowered. Such asymmetries can arise because of differential supply-side adjustments in face of positive and negative demand shocks (Glaeser and Gyourko 2005, 2018a), a differential pass-through of monetary policy

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shocks to mortgage rates depending on the level of competition in the banking sector (Scharfstein and Sunderam 2016), and downward rigidity in house prices due to loss aversion (Genesove and Mayer 2001) or down payment constraints (Stein 1995; Genesove and Mayer 1997). Secondly, it is well known that there are tremendous heterogeneities across regional housing markets (Ferreira and Gyourko 2012), which means that changes in the policy rate could have differential effects across local areas within the same country. Somewhat surprisingly, the asymmetric effects of monetary policy across regional housing markets remain unexplored.

In this paper, we aim to fill this gap by exploring (i) whether differences in city-specific housing supply elasticities matter for the responsiveness of house prices to exogenous monetary policy shocks and (ii) the extent of asymmetry in the response to expansionary and contractionary monetary policy shocks. We estimate 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 1983:I–2007:IV.

Although house prices are not directly part of the central bank's reaction function, they can affect the interest rate indirectly through their impact on consumption and employment (see, e.g., Mian, Rao, and Sufi 2013 and Mian and Sufi 2014). 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).[1] To study regional variations in the transmission of expansionary and contractionary monetary policy shocks to house prices, we interact the Romer and Romer (2004) shock with the housing supply elasticities calculated by Saiz (2010a).

Our results suggest 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 7 percent 2 years after a monetary policy shock that lowers the interest rate by 1 percentage point. For areas with higher housing supply elasticity, such as Kansas City, Oklahoma City, and Indianapolis, the same effect is estimated to be below 3 percent. In contrast, we find that the effect on house prices of a contractionary shock of similar magnitude is independent of housing supply elasticity. Finally, we find that whether expansionary or contractionary shocks have the strongest impact on house prices depends 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 high housing supply elasticity, the effect of expansionary shocks is muted, leading to a stronger impact of contractionary shocks. For very inelastic areas, such as Miami, San Francisco and Los Angeles, we find that expansionary shocks have almost twice the effect on house prices relative to contractionary shocks. On the contrary, contractionary shocks are estimated to exercise a stronger impact on house prices in Kansas City, Oklahoma City, and Indianapolis—areas with high housing supply elasticity. In the case of

[1] We use an updated version of the Romer and Romer (2004) narrative shock series extending through 2007. To update the Romer and Romer (2004) shock, we use the code and data accompanying Wieland and Yang (2020a).

Indianapolis, the effect of contractionary shocks is more than twice as large as that of expansionary shocks.

We argue that our results can be explained by differential supply-side adjustments in face of positive and negative demand shocks. Glaeser and Gyourko (2018a) argue the shape of the housing supply curve depends on house prices relative to minimum profitable construction costs (MPPC). In areas in which prices are close to MPPC, contractionary shocks should have a greater impact on house prices than expansionary shocks due to the durability of housing (Glaeser and Gyourko 2005). By combining data on house prices, MPPC, and housing supply elasticities, we find that areas in which prices are close to MPPC are typically supply elastic. This is consistent with our finding that contractionary shocks have a stronger impact on house prices in these markets. In supply-inelastic areas, prices are typically above MPPC. In that case, supply is not downward rigid. In contrast, it may actually be easier to adjust supply downward due to nonlinear adjustment costs (Topel and Rosen 1988) arising because expansions are constrained by regulations, availability of land, labor, and capital in intermediary firms. This is consistent with our finding that expansionary monetary policy shocks have a greater impact on house prices in supply-inelastic areas. An estimated housing supply equation yields results that support these findings further. We find that supply-elastic areas respond more to a house price increase than a decrease in house prices. For supply-inelastic areas, we find the opposite. Differential supply-side dynamics can therefore explain the asymmetric effects of monetary policy shocks on house prices.

A complementary explanation is that the pass-through of expansionary and contractionary shocks to mortgage rates is different and that it depends on competition in the banking sector (Scharfstein and Sunderam 2016). To investigate this, we exploit MSA-level data on Herfindahl-Hirschman indices (HHI) constructed by Acolin, An, and Wachter (2018a). This exercise reveals that increased banking competition amplifies the effects of expansionary monetary policy shocks. We find that expansionary shocks have a greater impact than contractionary shocks in supply-inelastic areas, when the level of banking competition is both high and low. This asymmetry is strengthened as competition increases. For supply-elastic areas, we find that contractionary shocks have a greater impact than expansionary shocks when banking competition is low. However, as competition is increased, the asymmetry is reversed. Time variation in banking competition therefore matters for both the direction and magnitude of the asymmetry.

As a third driver of asymmetry, we find support of a momentum effect that is more pronounced when house prices are increasing.[2] Consequently, expansionary monetary policy shocks, which ceteris paribus lead to an increase in house prices, trigger a momentum effect that puts additional pressure on house prices. When house prices are falling, we find this momentum effect to be much weaker. However, such differences in momentum effects cannot alone explain why contractionary shocks have

[2] 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.

a greater impact on house prices than expansionary shocks in elastic areas but the opposite effects holds true in inelastic areas.

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; Jarociński and Smets 2008; Kuttner 2014; Jordà, Schularick, and Taylor 2015; Williams 2011, 2015; and Füss and Zietz 2016). These papers are, however, confined to studying aggregate effects on house prices, which masks the major heterogeneities existing across regional US housing markets.[3] 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 nontrivial heterogeneous responses to a common expansionary monetary policy shock across regional markets, as well as documenting an economically important and sizeable asymmetry in the response to expansionary versus contractionary monetary policy shocks.

Another branch of the literature has attributed regional variations in the amplitude of boom-bust cycles in the housing market to heterogeneous supply-side restrictions (see, e.g., Green, Malpezzi and Mayo 2005; Saiz 2010a; Gyourko, Saiz, and Summers 2008; Glaeser, Gyourko, and Saiz 2008; Gyourko 2009; Huang and Tang 2012; and Anundsen and Heebøll 2016). This literature has shown that house price 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.

While our paper is the first to quantify the asymmetric effects of monetary policy on house prices, Tenreyro and Thwaites (2016); Barnichon and Matthes (2018); and Angrist, Òscar Jordà, and Kuersteiner (2018) have documented an asymmetric effect of contractionary and expansionary monetary policy shocks 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 is in curbing economic activity. Our results suggest that the opposite is true for house prices in many US metro areas. These 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. 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 amplifying 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.

The paper that is perhaps the closest to ours is Füss and Zietz (2016), who develop a state-space model to study how changes in the federal funds rate impact house prices in 94 MSAs. Similar to us, they find that monetary policy has stronger effects on house prices in supply-constrained MSAs. However, our paper differs

[3] 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 also find the impact of common monetary policy shocks on house prices to be nonnegligible, their estimates are fairly small in comparison with the magnitude of the house price increase over this five-year period.

from theirs in four important aspects. First, in contrast to Füss and Zietz (2016), we study the impact of monetary policy shocks—thereby isolating the impact of monetary policy on house prices. This is important because a change to the interest rate may in part reflect policymakers' responses to nonmonetary developments in the economy. Second, our study focuses on documenting an economically important and sizeable asymmetry in the response to expansionary and contractionary monetary policy shocks. In contrast, Füss and Zietz (2016) consider symmetric responses to interest rate changes. Third, we outline a range of possible mechanisms that can explain the asymmetric effects of monetary policy shocks on house prices. While we find little support for heterogenous responses of house prices following contractionary monetary policy shocks, we find substantial heterogeneity in the responses to expansionary monetary policy shocks. In particular, we find strong effects of expansionary monetary policy shocks on house prices in areas that are supply constrained and have high levels of competition in the banking sector. Fourth, we use a larger panel, consisting of 263 MSAs, and consider a longer time period spanning 1983–2007.

Our results are robust to various sensitivity and robustness checks. An alternative to the narrative monetary shocks of Romer and Romer (2004) are shocks identified using high-frequency surprises around policy announcements. We show that our results are robust to using the monetary shocks identified by Gertler and Karadi (2015a). Some papers have criticized the housing supply elasticities in Saiz (2010a) for being correlated with other city characteristics (Davidoff 2016) and losing power before 2000. Guren et al. (2021a) propose a new proxy for (the inverse of) housing supply elasticities that overcome these two challenges. We show that our results are robust to using the sensitivity measure by Guren et al. (2021a). 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. We also test the robustness of our results to adding controls for demographic differences and its interactions with the monetary policy shocks, and we account for potential news effects of monetary policy (Nakamura and Steinsson 2018) by controlling for Greenbook forecasts. Our results are robust to this. We follow Tenreyro and Thwaites (2016) and add the third power of the monetary policy shock, as well as its interaction with supply elasticities, to control for potential nonlinear effects. We also estimate our models on a balanced panel consisting of 147 MSAs. None of our conclusions are altered. 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 (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 market. Section II presents the data we utilize, and Section III documents our empirical findings on the heterogeneous and asymmetric effects of monetary policy on house prices. We investigate alternative mechanisms that can generate our findings in Section IV, whereas several robustness and sensitivity checks are carried out in Section V. The final section concludes.

## I. Theoretical Motivation for Asymmetry and Regional Differences

To motivate why heterogeneities and asymmetries in the response of house prices to monetary policy shocks may be of particular relevance, we discuss housing supply adjustments in face of demand changes. As argued by Glaeser and Gyourko (2018a), the shape and slope of the housing supply curve depends on house prices relative to MPPC, together with housing supply elasticities. The ratio of house prices to MPPC is akin to a Tobin's $q$—the ratio of market value to firm replacement cost.

In Figure 1 we show a housing supply curve that is consistent with the discussion in Glaeser and Gyourko (2018a).[4] In an area in which house prices are close to MPPC, the supply curve is piecewise linear and kinked (to the left of the vertical line in Figure 1). In this case, supply will only increase if house prices exceed MPPC. Hence, supply is assumed completely rigid downward and nearly vertical at the existing housing stock when prices are at or below MPPC (to the left of A). At this point, disinvestments are not possible—apart from natural depreciation of the existing stock—which is motivated by the fact that housing is usually neither demolished nor dismantled (Glaeser and Gyourko 2005). When $q$ is greater than one (to the right of A), the slope of the supply curve depends on local housing supply elasticities.

This kink in the supply curve implies that negative demand shocks (a shift from A to C) will lead to large price adjustments and only small quantity changes. This holds for both supply-elastic and supply-inelastic areas, since construction is no longer profitable once $q$ drops below one. However, if there is a positive demand shock—bringing $q$ above one—prices are expected to increase (a shift from A to B). The magnitude of the price increase depends on local housing supply elasticities. The lower the elasticity, the higher the price increase will be. This suggests that demand shocks have asymmetric effects on house prices in an area in which $q$ is close to one; negative demand shocks have a greater impact on house prices than positive demand shocks.

As argued by Glaeser and Gyourko (2018a), in an area in which house prices are systematically greater than MPPC (to the right of the vertical line in Figure 1), we are located far from the vertical portion of the housing supply curve. This implies that housing supply is adjusted either upward or downward in response to demand shocks. In this case there is no downward rigidity of housing supply. Values of $q$ above one reflect that there are barriers to investment.[5] Glaeser and Gyourko (2018a) argue that this is likely to be more driven by regulations and scarcity of land than standard adjustment costs for the housing market. Topel and Rosen (1988) incorporate adjustment costs into a model of housing supply in a dynamic profit maximizing setting. They argue that restrictions on building activity are more binding when supply is increased than when it is lowered, which may give rise to asymmetric adjustment costs. This nonlinearity could arise if expansions are more constrained by availability of land, labor, and capital in intermediary firms than by contractions.

[4] A similar supply curve is illustrated in Davis and Palumbo (2008).

[5] Since construction costs have not risen much over time, several papers have concluded that rising real house prices cannot be explained by higher physical construction costs; see, e.g., Davis and Heathcote (2007) and Davis and Palumbo (2008).

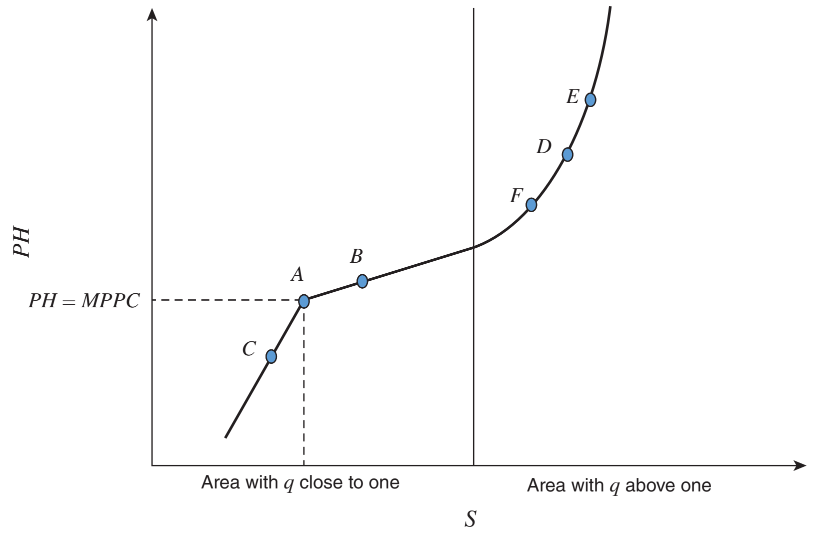


Figure 1. Supply Curve of Housing for Different Values of $q$

*Notes:* The figure shows the housing supply curve for an area in which $q$ is close to one (to the left of the vertical line) and an area in which $q$ is systematically greater than one (to the right of the vertical line). The figure is similar to the supply curve illustrated in Davis and Palumbo (2008).

This suggests that it may be easier to lower supply in face of negative demand shocks than to increase supply when demand increases. Davis and Heathcote (2005) focus directly on the scarcity of land and argue that land works just like a traditional convex adjustment cost on residential investment.[6]

With this supply curve, a negative demand shock (a shift from D to F) leads to lower house prices and lower investment activity, whereas a positive demand shock leads to higher prices and more investments (a shift from D to E). The lower the housing supply elasticity, the higher the house price response is. In the case of convex adjustment costs, supply is more easily adjusted downward than upward. This gives rise to an asymmetric response in house prices to demand shocks also in an area in which $q$ is well above one; contractionary shocks have a smaller impact on house prices than expansionary shocks do.

While supply-side adjustments following a negative demand shock should be independent of housing supply elasticities in areas in which $q$ is close to one, it is less clear that this also holds for areas in which $q$ is systematically above one. However, to the extent that regional variations in regulations and land restrictions—giving rise to differences in supply elasticities—are less important for slowing down construction, it seems plausible that downward adjustments in housing supply are

[6] Several studies have shown that costly reversibility implies that firms face higher costs in adjusting the capital stock downward than in adjusting it upward (Abel and Eberly 1994, 1996; Ramey and Shapiro 2001). While these studies are not focusing on the housing market, similar mechanisms may also be relevant for the construction sector. In such a case, housing supply will respond less to a negative demand shock than to a positive demand shock, generating a larger price response following a negative demand shock than following a positive demand shock.

also independent of supply elasticities in areas in which house prices exceed MPPC. We leave this open as an empirical question.

In sum, the direction of the asymmetry, as well as its relative magnitude, depends on prices relative to MPPC and local housing supply elasticities. The main predictions from the discussion above can be summarized by the following conjectures:

**Conjecture 1:** Positive demand shocks have a greater impact on house prices in markets with an inelastic housing supply.

**Conjecture 2:** Negative demand shocks have a greater impact on house prices than positive demand shocks do when $q$ is close to one. When $q$ is greater than one, positive demand shocks have a greater effect than negative demand shocks.

The conceptual framework above abstracts from how long it takes to build a house. The building process is multifaceted, and builders often face time-to-build constraints. Time-to-build considerations could affect the conjectures above if building dynamics are correlated with the timing of either positive or negative demand shocks.[7] Moreover, Oh and Yoon (2020) argue that the housing investment process can be best viewed through the lens of real option theory, where time to build could be delayed by uncertainty over future revenue. They show that when time to build increases due to construction bottlenecks, investment activity slows down. Furthermore, Paciorek (2013) finds that regulations lead to delays and higher building costs in more regulated areas relative to a less regulated areas. It is therefore likely that increased construction delays in highly regulated areas contribute to a higher $q$ and higher investment barriers.

## II. Data and Descriptive Statistics

Our dataset includes 263 MSAs in the United States, covering about 70 percent of the entire US population and all but 2 of the 50 US states (Hawaii and Alaska are not covered).[8] Following the Census Bureau, the United States 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.

[7] Since it takes time to build a house, one could imagine that there were lots of houses in the process of being built prior to a shock that were then finished being built right after the shock. In such a case the supply of houses would change at the same time as the shift in demand, possibly affecting the two conjectures above. While we cannot rule out such a scenario, there are few reasons to believe that either expansionary or contractionary monetary policy shocks should be strongly correlated with finished constructions.

[8] 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 (2010a), which are available for 269 MSAs using the 1999 county-based MSA or New England county metropolitan areas definitions. The geographic data in Saiz (2010a) are calculated using the principal city in the MSA, and we have matched those to the 2010 MSA definitions. For six MSAs we were not able to match the Saiz (2010a) data to the 2010 MSA definitions, as they are no longer the principal city in their new MSA.

Table 1—Geographical Distribution of MSAs in Our Sample

| Census division | Number of states | Number of MSAs | Median population | Percentage population |
|---|---|---|---|---|
| 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 | 20 |
| All | 48 | 263 | 382 | 100 |

*Notes:* 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 2007:IV.

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 1983:I to 2007:IV ($T = 100$) for 147 of the areas, and 227 MSAs are covered by 1987:I. We have full coverage for all MSAs from 1998:I. For a majority of the MSAs, the sample covers both the recent housing cycle and the previous boom-bust cycle (Glaeser, Gyourko, and Saiz 2008) in the period 1982–1996.

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

### A. *Monetary Policy Shocks*

To measure exogenous changes in monetary policy, we use the Romer and Romer (2004) narrative monetary policy shock series. Romer and Romer (2004) 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 (2004) series has been widely used to study the transmission of monetary policy shocks; see, e.g., Coibion (2012); Ramey (2016); Tenreyro and Thwaites (2016); and Coibion et al. (2017). We use an updated version of the Romer and Romer (2004) narrative shock series, using the codes and data provided by Wieland and Yang (2020b).[9] The updated shock series ends in 2007:IV. Thus, our

[9] We downloaded the replication file of Wieland and Yang (2020b) in October 2017 at the webpage of Johannes Wieland (https://johanneswieland.github.io/index.html).

analysis is confined to studying the transmission of conventional monetary policy shocks.[10] Moreover, Coibion (2012) showed that the effects of Romer and Romer (2004) identified monetary policy shocks on various variables are very sensitive to the inclusion of the period of nonborrowed reserves targeting, 1979–1982. We therefore follow Coibion (2012) and exclude the period of nonborrowed reserve targeting, starting our estimation in 1983:I.[11]

### B. *Housing Supply Elasticities*

To explore regional heterogeneities in the response to monetary policy shocks, we use the MSA-specific supply elasticities calculated by Saiz (2010a).[12] These elasticities are based on topographical measures of undevelopable land, as outlined in Saiz (2010a), as well as regulatory supply restrictions based on the Wharton Regulatory Land Use Index (WRLURI) developed by Gyourko, Saiz, and Summers (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.

### C. *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 CPIs, income, population, and migration were collected from Moody's Analytics' Economy.com webpage.[13] We provide a more detailed description of each data series and its original source in the Appendix.

Several papers (e.g., Mian and Sufi 2009 and Favara and Imbs 2015a) have emphasized the role of lax lending standards as an explanation of regional differences in house prices. To control for this, we use the time-varying index of branching deregulation constructed by Rice and Strahan (2010). Favara and Imbs (2015a) 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 governing geographic expansion for the US banking sector. Following the passage of the Interstate Banking and Branching Efficiency Act 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 and 4. We follow Favara and Imbs (2015a) and reverse the index so that higher

[10] Due to the five-year lag in the publication of the Greenbook forecasts, we could potentially have updated the Romer and Romer (2004) shock series until the end of 2014. 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.

[11] Note that for consistency, the Romer and Romer (2004) shock is also estimated on a sample from 1983 to 2007.

[12] The data were provided to us by Albert Saiz.

[13] The data were downloaded in February 2017.

Table 2—House Price Growth and Supply Elasticities for MSAs with Population above One 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: | | |
| Tenth percentile | 3.09 | 0.86 |
| Twenty-fifth percentile | 3.91 | 1.21 |
| Median | 5.01 | 1.79 |
| Seventy-fifth percentile | 6.24 | 2.59 |
| Ninetieth percentile | 7.34 | 3.57 |
| Mean | 5.03 | 2.04 |
| Standard deviation | 1.53 | 1.04 |

*Notes:* The table shows summary statistics for the supply elasticity of Saiz (2010b) and for average annual growth in nominal house prices over the period 1983:I–2007:IV. The upper part of the table shows average annual growth in house prices and supply elasticities for MSAs with a population exceeding one 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 supply elasticity over the same period for all MSAs for which data are available for the full sample period.

values refer to more deregulated states.[14] As in Rice and Strahan (2010) and Favara and Imbs (2015a), we assume that all states were fully restricted prior to 1994.

### D. *Descriptive Statistics*

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

[14] The data were downloaded in November 2016 from the replication files of Favara and Imbs (2015b) (https://www.openicpsr.org/openicpsr/project/112894/version/V1/view).

## III. Empirical Results

Based on the discussion in Section I, we would expect that expansionary monetary policy shocks should have a greater impact on house prices in areas with an inelastic housing supply. The response to contractionary shocks should be more similar across areas. This is due to the downward rigidity of housing supply in areas in which prices are close to the replacement cost and adjustment costs that make it more difficult to expand supply than to lower it in areas in which prices exceed the replacement cost. The discussion also suggested that asymmetries are expected and that the direction of the asymmetry depends on where we are located on the housing supply curve.

To investigate the empirical relevance of these conjectures, we consider a reduced-form house price specification in which supply elasticity is interacted with the monetary policy shocks and all other control variables. 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 nonlinear effects of monetary policy, which would be vastly complicated—and maybe even infeasible—in a standard vector autoregression (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.

Our baseline empirical specification takes the following form:

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

in which $ph_{i,t+h} - ph_{i,t-1}$ is the cumulative change in log house prices after $h$ quarters, $RR_t$ is the Romer and Romer (2004) shock, and $Elasticity_i$ are the time-invariant supply elasticities calculated by Saiz (2010a), 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 $RR_t^{Exp.} = RR_t \times I(RR_t \geq 0)$, in which $I(RR_t \geq 0)$ is an indicator variable taking the value one for expansionary monetary policy shocks and a value of zero otherwise. Contractionary shocks are measured by $RR_t^{Contr.} = RR_t \times \big(1 - I(RR_t \geq 0)\big)$.

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 (2015a). For the lagged variables, we include four lags.[15] We use Conley (1999, 2008) standard errors that are robust to both spatial correlation and autocorrelation.[16] We used Quantum Geographic Information System (QGIS) software to calculate latitudes and longitudes of MSA centroids and then used a distance of 100 miles as a cutoff for the spatial correlation. The geographic information system (GIS) data used for calculating latitudes and longitudes of MSA centroids are the 2019 TIGER/Line files located at the webpages of the US Census Bureau. The motivation for setting a 100-mile cutoff is that MSAs that are more distant are likely to belong to different commuting zones (Chetty and Hendren 2018). We use a kernel that decays linearly with distance in all directions to account for spatial correlation.

Regression results are displayed in Table 3. Consistent with Conjecture 1, we find that expansionary monetary policy shocks lead to higher house prices and that the effect is lower for areas with high housing supply elasticity. Our results also suggest that the effect of contractionary shocks has a negative impact on house prices and that this effect is independent of housing supply elasticity.[17]

We also find results consistent with Conjecture 2 in that the direction of the asymmetry depends on housing supply elasticity. Figure 2 shows the responses in house prices to an expansionary monetary policy shock (upper panel) and a contractionary monetary policy shock (lower panel) of 1 percentage point for the MSAs covered by our sample after 2 years ($h = 8$).[18] The maps are constructed so that the color spectrum in the two panels have the same range in absolute value, with a darker color indicating a greater response in house prices.

Expansionary shocks have a greater effect than contractionary shocks in most areas. In particular, for very congested areas, such as San Francisco, California, and Miami, Florida, expansionary shocks have more than twice the impact on house prices relative to contractionary shocks. 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, Ohio, and Kansas City, Missouri, the effect of expansionary shocks is smaller than that of contractionary shocks. Table A.1 in the online Appendix shows the effect of both contractionary and expansionary shocks after two years for MSAs with a population above one million. The areas are ranked according to their supply elasticity. The results in that table reveal that the effect of expansionary shocks is greater than the effect of contractionary shocks for most of the large MSAs included in our sample.

It is useful to compare the magnitude of our results to earlier studies. Kuttner (2014) argues that the impact of interest rate changes on house prices is quite modest and is considerably smaller than what the conventional user cost theory would suggest. He suggests that a 1 percentage point expansionary monetary policy shock would lead to house prices increasing somewhere between 0.8 and 2 percent. On the

[15] To investigate how sensitive our results are to the inclusion of these controls, we have reestimated the models without controls. All results remain intact.

[16] To estimate the standard errors, we have used the code developed by Hsiang (2010).

[17] These results are maintained if we consider nominal instead of real variables.

[18] For the contractionary shocks, the response in house prices for area $i$ is calculated as $\beta_h^{Contr.}$ since the interaction effect is estimated to be insignificant. The response to house prices in area $i$ following an expansionary shock is given by $-(\beta_h^{Exp.} + \beta_h^{Exp.,El.} Elasticity_i)$.

Table 3—Asymmetric and Heterogeneous Effects of Monetary Policy Shocks on House Prices

| | $h = 0$ | $h = 4$ | $h = 8$ | $h = 12$ |
|---|---|---|---|---|
| Exp. MP shock | −0.18 | 2.85 | 7.81 | 8.13 |
| | (0.23) | (0.83) | (1.37) | (1.94) |
| Exp. MP shock × El. | 0.11 | −0.59 | −1.59 | −2.07 |
| | (0.09) | (0.26) | (0.41) | (0.58) |
| Contr. MP shock | −0.08 | −0.80 | −3.53 | −6.29 |
| | (0.30) | (1.02) | (1.69) | (2.45) |
| Contr. MP shock × El. | 0.12 | −0.06 | 0.20 | 0.42 |
| | (0.12) | (0.30) | (0.49) | (0.69) |
| Observations | 23,212 | 22,160 | 21,108 | 20,056 |
| MSAs | 263 | 263 | 263 | 263 |
| $R^2$ | 0.260 | 0.458 | 0.495 | 0.511 |
| MSA fixed effects | Yes | Yes | Yes | Yes |
| Controls | Yes | Yes | Yes | Yes |

*Notes:* 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 Federal Housing Finance Agency (FHFA) house price index at horizon $h = 0, 4, 8$, and 12. Results are based on estimating equation (1) using a fixed effect estimator, and the dataset covers a panel of 263 US MSAs over the period 1983:I–2007:IV. The specification allows the response in house prices to differ depending on the elasticity of supply, as calculated in Saiz (2010b), and whether the monetary policy shock is expansionary or contractionary. We use Conley (1999, 2008) standard errors that are robust to both spatial correlation and autocorrelation by employing the code developed by Hsiang (2010). We use the QGIS software to calculate latitudes and longitudes of MSA centroids and set the cutoff distance for the spatial correlation at 100 miles. The kernel that is used to weigh the spatial correlations decays linearly with distance in all directions. The standard errors are reported in absolute value in parentheses below the point estimates. To calculate MSA centroids, we use 2019 TIGER/Line files for US CBSAs from https://www.census.gov/cgi-bin/geo/shapefiles/index.php.

contrary, Williams (2015)—who reviews 11 papers—finds that the average house price increase following a 1 percentage point expansionary monetary policy shock is 7 percent, but ranging from 1.7 percent to 10.8 percent. Our results are well within this range. Following a 1 percentage point expansionary monetary policy shock, we find the largest effect on house prices in Miami, Florida, with an increase of almost 7 percent after 2 years. Similarly, we find the effect after a contractionary shock to be just below 3.5 percent after 2 years.

## IV. Supply-Side Dynamics and Other Possible Explanations

### A. *Supply-Side Dynamics*

*Profitability Considerations and Housing Supply Elasticities.*—Glaeser and Gyourko (2018a) construct a biannual measure of median house prices relative to MPCC for several MSAs over the period 1985–2015.[19] We match their data with the data on housing supply elasticities in Saiz (2010b)—leaving us with 93 MSAs for

[19] We downloaded the data in October 2020 from the replication files of Glaeser and Gyourko (2018b) (https://www.openicpsr.org/openicpsr/project/116388/version/V1/view).

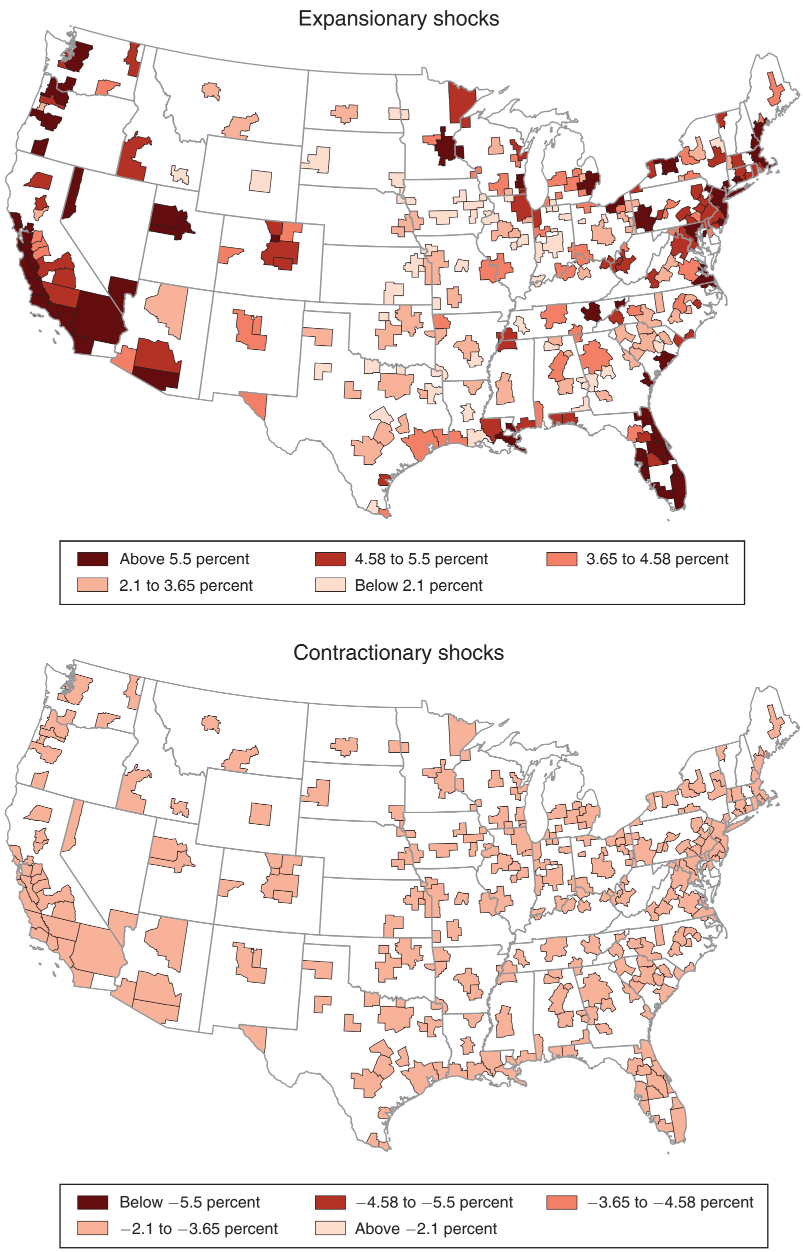


Figure 2. Regional Variation in House Price Response to Monetary Policy Shocks after Two Years

*Notes:* The effect of an expansionary (upper panel) and contractionary (lower panel) monetary policy shock on house prices for MSAs with different housing supply elasticity after eight quarters. To draw the geographical boundaries of MSAs and US states, we use the *maptile* code written by Meru Bhanot and Michael Stepner. We use 2019 GIS data for core-based statistical areas (CBSAs) and US states, downloaded from the National Historical Geographic Information System (NHGIS); see Manson et al. (2020a, b). While our dataset mostly contains MSAs, it also includes a few metro divisions (MDs). In order to include these MDs in the map, we need to match them with their corresponding CBSA codes. We do this by using delineation files for CBSAs, MDs, and CSAs from the US Census Bureau.

which we have data on both measures. The distribution of housing supply elasticities in this smaller sample resembles our larger sample of 263 MSAs, with a mean elasticity close to 2.[20]

We plot the MSA-level averages (across the years 1985–2007) of the ratio of house prices to MPPC, as constructed by Glaeser and Gyourko (2018a) versus the housing supply elasticities of Saiz (2010a) in Figure 3.

It is evident that high-elasticity areas have a lower average ratio of house prices relative to MPPC. For areas with an elasticity at or above the median, the average of this ratio is 0.81. This is suggesting that supply-elastic areas are more likely to be located near the vertical portion of the housing supply curve, i.e., that they see small supply-side adjustments in face of negative housing demand shocks. This is consistent with our finding that contractionary monetary policy shocks have a greater impact on house prices in supply-elastic areas. At the same time, the average ratio of house prices relative to MPPC is considerably higher—1.18—for areas with a below-median housing supply elasticity. These areas should be located further away from the kink, and—given asymmetric adjustments costs—they are expected to respond more to expansionary monetary policy shocks than contractionary ones—consistent with our findings.

*Housing Supply and House Price Growth*.—To further investigate the link between housing supply adjustments and the asymmetric effects of monetary policy shocks on house prices, we look at the link between housing starts and house price growth. We treat housing starts relative to the existing housing stock—the housing investment rate—as our dependent variable.[21] We regress the housing investment rate on house price growth, distinguish between periods when house prices are increasing and periods when they are falling, and interact house prices in both regimes with the housing supply elasticity.[22] We control for year-by-quarter fixed effects and lags of population growth as well as lags of housing vacancies. While detailed estimation results are shown in Table A.2 in the online Appendix, we have illustrated the main results in Figure 4.[23] The upper panel shows how different MSAs respond to an increase in house price growth of 1 percentage point, whereas the lower panel shows the response to a decrease in house price growth of 1 percentage point.

[20] In our full sample of 263 MSAs, the tenth and ninetieth percentiles are 0.86 and 3.57, respectively. In this smaller sample, they are 0.86 and 3.35, respectively.

[21] Somerville (2001) argues that the building process may be regarded as a compound option. However, he also notes that a building permit is perhaps the most clear real option, since it is a right but not an obligation to build. For this reason, we consider housing starts, which are the execution of a permit that has been granted.

[22] A reduced-form approach is less informative regarding the shape of the supply curve, since there will be two opposing mechanisms (see also Anundsen and Heebøll 2016); more supply-restricted areas are expected to see a smaller increase in housing supply for a given increase in house prices. However, they are expected to experience a greater house price increase, which has a stimulating effect on construction activity. We show a scatterplot of cumulative house price growth over our sample period versus cumulative housing starts relative to the existing stock over our sample period below in Figure A.1 in the online Appendix. It is clear that there is a clustering between the groups: areas with high supply elasticities have experienced relatively low house price growth, whereas areas with low elasticities have experienced relatively high house price growth. There is, however, little evidence that there are systematic differences in construction activity between the two groups.

[23] For a house price increase, the effect on housing starts for a given area is calculated as the sum of the coefficient on the uninteracted term and the coefficient on the interaction term multiplied by the area's housing supply elasticity. For a house price decrease, the effect only consists of the coefficient on the uninteracted term, since the interaction effect is estimated to be statistically insignificant.

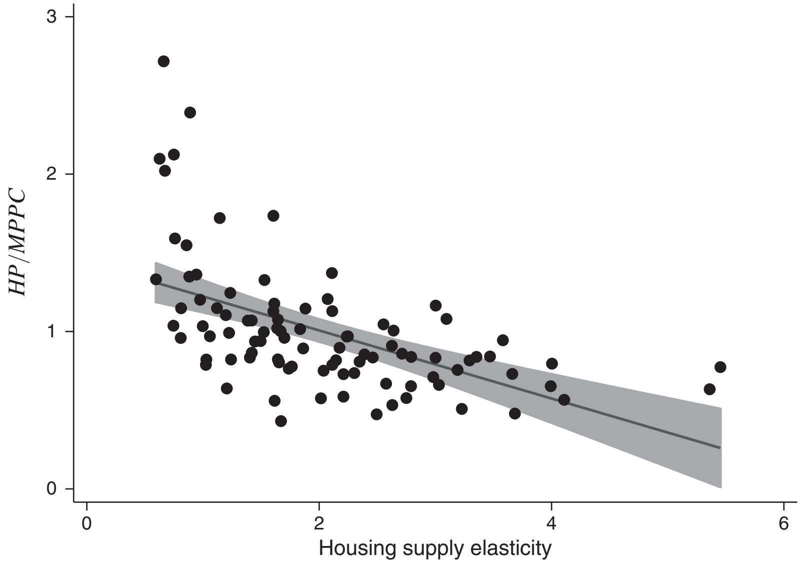


Figure 3. Average Ratios of House Prices to MPCC versus Housing Supply Elasticities

*Notes:* The figure shows a scatterplot between average house prices relative to minimum-profitable production costs (average over the 1985–2007 period), as calculated in Glaeser and Gyourko (2018b), and the housing supply elasticities from Saiz (2010). The fans are 95 percent confidence intervals.

The maps are constructed so that the color spectrum in the two panels have the same range in absolute value, with a darker color indicating a greater response in housing starts. Results are consistent with our finding regarding the asymmetric effects of monetary policy on house prices. First, housing supply responds more strongly to price increases in areas in which housing is supplied elastically. Second, house price falls lead to similar supply-side adjustments across areas with different housing supply elasticities. This supports the notion that regulatory and topographic constraints are most relevant as bottlenecks for increasing construction activity. Third, supply responds more to a price increase than a price reduction in areas with high housing supply elasticity. This is consistent with our finding that contractionary shocks have a greater impact on house prices in these areas. Fourth, supply responds less to price increases than to price decreases in areas in which supply is inelastic. This is consistent with our finding that these areas respond more strongly to expansionary monetary policy shocks than contractionary ones.

### B. *Other Possible Explanations of the Asymmetric Effects*

*Competition in the Banking Sector*.—Using county-level data, Scharfstein and Sunderam (2016) find that the pass-through from the Fed funds rate to mortgage rates are lower in markets with little competition in the banking sector. Thus, the degree of concentration in the banking sector may be one factor that contributes to explain differential house price responses to monetary shocks across regional markets. Moreover, the pass-through of expansionary shocks and contractionary shocks

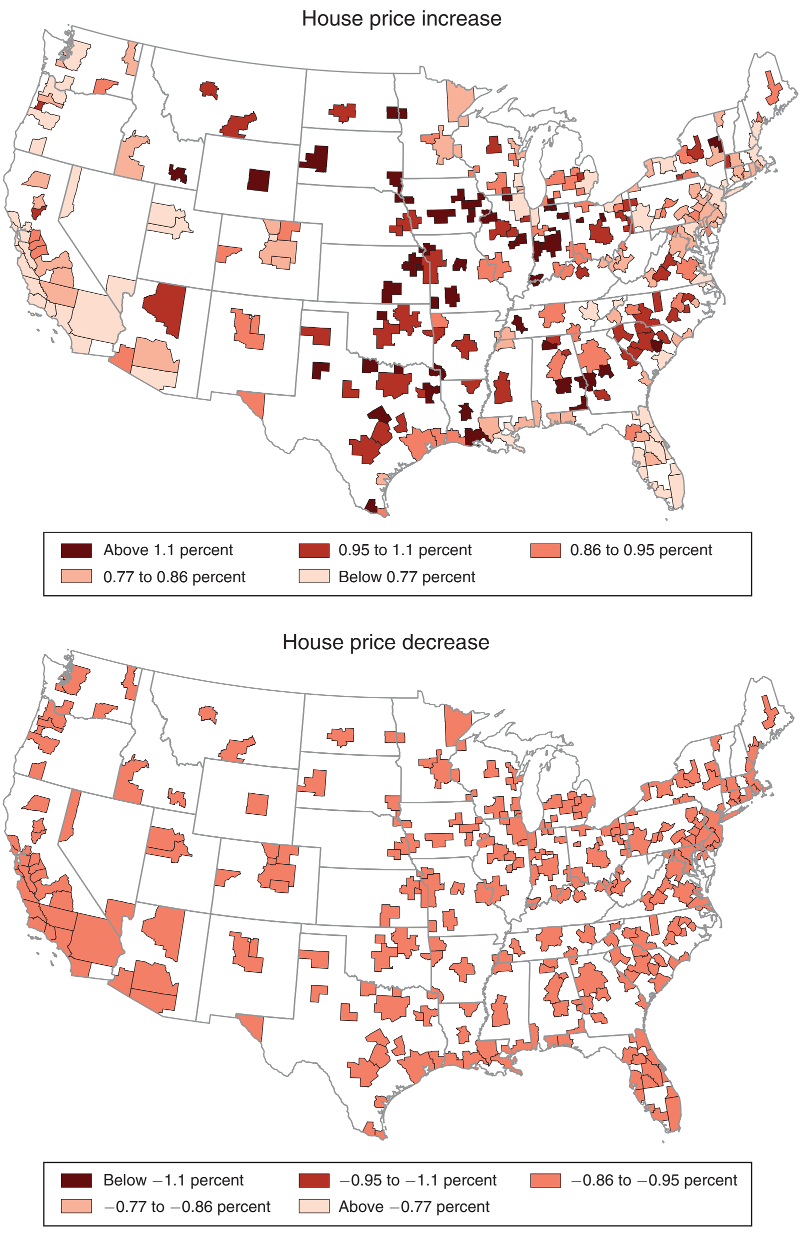


Figure 4. Regional Variation in the Effect of House Price Changes on Housing Starts Relative to the Existing Housing Stock

*Notes:* The effect of a house price increase (upper panel) and a house price decrease (lower panel) on housing starts relative to the existing housing stock—the housing investment rate—for MSAs with different housing supply elasticities. To draw the geographical boundaries of MSAs and US states, we use the *maptile* code written by Meru Bhanot and Michael Stepner. We use 2019 GIS data for CBSAs and US states, downloaded from the NHGIS; see Manson et al. (2020a, b). While our dataset mostly contain MSAs, it also includes a few MDs. In order to include these MDs in the map, we need to match them with their corresponding CBSA code. We do this by using delineation files for CBSAs, MDs, and CSAs from the US Census Bureau.

may also vary with banking competition. In particular, the pass-through from expansionary shocks may be lower in more concentrated markets, since banks may exploit low competition to increase their margins. In contrast, contractionary shocks may be more quickly passed through to mortgage rates. To explore this as a potential explanation of the finding that house prices respond asymmetrically to expansionary and contractionary shocks, we have accessed data on the MSA-level HHI in Acolin, An, and Wachter (2018a).[24] They use the Home Mortgage Disclosure Act data to identify the share of loans originated by different lenders in each MSA over the years 1990–2007. Based on this, they calculate the HHI of lender shares.

To explore the importance of banking sector competition for the transmission of monetary shocks to house prices, we augment our baseline specification with HHI, HHI interacted with the housing supply elasticity, HHI interacted with the monetary shocks, and the triple interaction between HHI, the monetary policy shocks, and the housing supply elasticity. The other controls are similar to those in the baseline specification. Detailed estimation results are summarized in Table A.3 in the online Appendix. The interaction terms are significant for the expansionary shocks, but not for the contractionary shocks. Our results therefore suggest that it is mostly the pass-through of expansionary shocks that has been affected by changing levels of banking competition.

To ease interpretation and understand how the level of banking competition affects the transmission of expansionary and contractionary monetary policy shocks to the housing market, we consider the effects of expansionary and contractionary shocks on house prices after eight quarters when keeping HHI at its 1990 median (relatively low levels of banking competition) and its 2007 median (relatively high levels of banking competition). Further, we distinguish between a low-elasticity area (twenty-fifth percentile) and a high-elasticity area (seventy-fifth percentile). Results are summarized in Table 4.

We find that expansionary shocks have a greater impact on house prices when there is more banking competition. This holds true for both supply-elastic and supply-inelastic areas. Our results also show a somewhat smaller effect of contractionary shocks on house prices when competition in the banking sector increases. These findings are consistent with the results in Scharfstein and Sunderam (2016), suggesting that the level of banking concentration matters for the transmission of monetary policy shocks to local area mortgage rates.

For supply-inelastic areas, we find that expansionary shocks have a greater impact on house prices than contractionary shocks do. This holds true for both high (HHI at 1990 median) and low (HHI at 2007 median) levels of banking competition. The asymmetry gets more pronounced as competition in the banking sector increases. For supply-elastic areas, we find that contractionary shocks have a greater impact on house prices when competition in the banking sector is low. When it increases, the asymmetry is reversed. These results suggest that time-varying and cross-sectional variations in banking concentration matter for the magnitude of the asymmetric effects of monetary policy on house prices.

[24] The data were provided to us by Arthur Acolin.

Table 4—Banking Competition and Asymmetric and Heterogeneous Effects of Monetary Policy Shocks on House Prices

| Expansionary shocks | | Contractionary shocks | |
|---|---|---|---|
| Low el. | High el. | Low el. | High el. |
| *HHI at 1990 median* | | | |
| 4.28 | 2.24 | −3.60 | −2.90 |
| (0.86) | (0.53) | (1.03) | (0.62) |
| *HHI at 2007 median* | | | |
| 6.22 | 2.97 | −2.90 | −1.89 |
| (0.91) | (0.62) | (1.10) | (0.70) |

*Notes:* The table shows how expansionary and contractionary shocks affect house prices after two years when the level of banking concentration, as measured through the HHI in Acolin, An, and Wachter (2018b), is kept at its 1990 median (high concentration) and its 2007 median (low concentration). Effects are evaluated for a low-supply-elasticity area (twenty-fifth percentile) and a high-supply-elasticity area (seventy-fifth percentile). We use Conley (1999, 2008) standard errors that are robust to both spatial correlation and autocorrelation, by employing the code developed by Hsiang (2010). We use the QGIS software to calculate latitudes and longitudes of MSA centroids and set the cutoff distance for the spatial correlation at 100 miles. The kernel that is used to weigh the spatial correlations decays linearly with distance in all directions. The standard errors are reported in absolute value in parentheses below the point estimates. Detailed estimation results are summarized in Table A.3 in the online Appendix. To calculate MSA centroids, we use 2019 TIGER/Line files for US CBSAs from https://www.census.gov/cgi-bin/geo/shapefiles/index.php.

*Asymmetric Momentum Effects.*—Following the seminal article by Case and Shiller (1989), numerous studies have documented that aggregate house price changes are autocorrelated (see, e.g., Cutler, Poterba, and Summers 1991; Røed Larsen and Weum 2008; and Head, Lloyd-Ellis, and Sun 2014). 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 reasons 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, Lloyd-Ellis, and Sun 2014), information frictions (Anenberg 2016), extrapolative expectation formation (Case and Shiller 1987; Glaeser, Gyourko, and Saiz 2008; Gelain and Lansing 2014; Glaeser and Nathanson 2017; Armona, Fuster, and Zafar 2019), heterogeneous beliefs and the existence of momentum traders (Piazzesi and Schneider 2009; Burnside, Eichenbaum, and Rebelo 2016), and strategic complementarities (Guren 2018).

We are agnostic about the exact source of the momentum effect, but the presence of momentum effects may be another factor explaining why expansionary monetary policy shocks can lead to a larger response in house prices than contractionary monetary policy shocks can. In particular, if the momentum effect is more pronounced when house prices are increasing, positive demand shocks are amplified relatively more than negative demand shocks. This would contribute to strengthen the effect of expansionary monetary policy shocks, especially so in supply-inelastic areas.

To investigate whether there is evidence of an asymmetric momentum effect, we consider an AR(2) model, an AR(4) model, and an AR(8) model for house price

Table 5—Asymmetric Momentum Effects

| | AR(2): | | AR(4): | | AR(8): | |
|---|---|---|---|---|---|---|
| Momentum | 0.37 | 0.14 | 0.57 | 0.31 | 0.62 | 0.38 |
| | (0.02) | (0.04) | (0.02) | (0.04) | (0.02) | (0.04) |
| Additional momentum | | 0.39 | | 0.41 | | 0.38 |
| when $\Delta ph_{i,t-1} > 0$ | | (0.06) | | (0.05) | | (0.05) |
| Adjusted $R^2$ | 0.14 | 0.15 | 0.23 | 0.24 | 0.29 | 0.30 |
| Observations | 23,739 | | 23,212 | | 22,160 | |
| MSAs | 263 | | 263 | | 263 | |

*Notes:* The table reports the sum of coefficients on lagged house price appreciation based on estimating an AR(2) model, an AR(4) model, and an AR(8)-model for house price growth. We control for MSA fixed effects, and the dataset covers a panel of 263 US MSAs over the period 1983:I–2007:IV. The first, third, and fifth columns show the case of symmetric coefficients, whereas the second, fourth, and sixth columns show coefficients when we allow for an additional momentum effect when house prices in the previous period were increasing. We use Conley (1999, 2008) standard errors that are robust to both spatial correlation and autocorrelation, by employing the code developed by Hsiang (2010). We use the QGIS software to calculate latitudes and longitudes of MSA centroids and set the cutoff distance for the spatial correlation at 100 miles. The kernel that is used to weigh the spatial correlations decays linearly with distance in all directions. The standard errors are reported in absolute value in parentheses below the point estimates. To calculate MSA centroids, we use 2019 TIGER/Line files for US CBSAs from https://www.census.gov/cgi-bin/geo/shapefiles/index.php.

growth, allowing the coefficients on lagged house price appreciation to have an additional effect whenever house prices in the previous period were increasing. All models include MSA fixed effects. Table 5 reports the sum of the AR coefficients for both the case in which we do not distinguish between periods of increasing and decreasing house prices and the case in which we allow the momentum effect to differ when house prices in the previous period were increasing. These results support the notion of a momentum effect that is more pronounced when house prices are increasing, which contributes to reinforce the relative effect of expansionary monetary policy shocks.[25,26]

*Loss Aversion and Down Payment Constraints*.—Santoro et al. (2014) embed prospect theory into a DSGE model to rationalize why monetary policy could exercise asymmetric effects on output over the course of the business cycle. A similar approach also may be relevant in the context of the housing market, especially in terms of explaining potential asymmetric effects during a housing boom-bust cycle. Genesove and Mayer (2001) have shown that sellers in the housing market are loss averse, which leads to downward rigidity in ask prices in housing downturns. They

[25] In a previous version of this paper, we looked at the particular case of asymmetric house price expectations. We used data from Case, Shiller, and Thompson (2012), who measure house price expectations based on a series of surveys of home buyers in four metropolitan areas over the period 2003–2012. Our results suggested that the extrapolation of current house price growth is more pronounced in periods of increasing house prices.

[26] We have also explored whether the momentum effect depends on 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 a booming market for each MSA. We then regressed these variables on supply elasticity. The result of an additional momentum effect in a booming market is maintained in this case. Further, the additional momentum effect is, if anything, somewhat stronger in markets with low supply elasticity.

document that sellers facing a prospective loss will increase their ask price and keep their units on the market for a longer time to avoid selling below their reservation price. To the extent that contractionary monetary policy shocks bring expected house prices below sellers' reservation prices, the rigidity in ask prices could be an additional explanation of why house prices respond asymmetrically to monetary policy shocks.

Further, sellers typically use the equity extracted from their current home to make a down payment on their next home (Stein 1995; Genesove and Mayer 1997). If the equity on their current home falls following a contractionary monetary policy shock, households will have less equity for their next purchase and may decide to postpone the sale of their current home, which could also generate an asymmetry in the response to monetary policy shocks. When contractionary monetary policy shocks are followed by severe drops in house prices, households may be prevented from moving because they are underwater (Brown and Matsa 2020).

## V. Robustness and Sensitivity Checks

*Alternative Monetary Policy Shocks*.—As documented in Ramey (2016), the estimated dynamic responses to monetary policy shocks can be sensitive to the choice of monetary policy shock. An alternative to the Romer and Romer (2004) shocks is to identify monetary policy shocks using high-frequency surprises around policy announcements (see, for instance, Gürkaynak, Sack, and Swanson 2005; Gertler and Karadi 2015a; Nakamura and Steinsson 2018). We check whether our baseline results are robust to high-frequency identification of monetary policy shocks.

We follow Gertler and Karadi (2015a) and identify the monetary policy shock using changes in 3-month-ahead contracts on Fed funds futures in a 30-minute window around FOMC announcement dates.[27] As argued by, among others, Kuttner (2001), this measure is plausibly uncorrelated with other shocks because they are changes across a short announcement window. We follow custom and use high-frequency monetary surprises as an instrument for the underlying shock in a local projection instrumental variable framework (Ramey 2016; Stock and Watson 2018). Gertler and Karadi (2015a) use the one-year Treasury bill yield as the relevant monetary policy indicator. Since we are focusing on the housing market, we instead use the 30-year fixed mortgage rate as the relevant interest rate.[28]

[27] The monthly monetary policy shock series was downloaded in August 2016 from the replication files of Gertler and Karadi (2015b) (https://www.openicpsr.org/openicpsr/project/114082/version/V1/view). We construct quarterly observations of the shock by taking the average of the monthly observations within each quarter.

[28] As discussed in Stock and Watson (2018), the monetary surprise alone is an invalid instrument in the LP-IV regression without controls. We therefore follow Ramey (2016) and Stock and Watson (2018) and include 4 lags of CPI inflation, 4 lags of the Congressional Budget Office (CBO) output gap, and 4 lags of the Gilchrist and Zakrajšek (2012) excess bond premium (EBP) providing a measure of financial stress, in addition to 4 lags of the change in 30-year mortgage rate and 4 lags of the monetary surprise in the first-stage regression. In the second-stage regression, we include the same controls as in our baseline specification. The data for CPI (series: CPIAUCSL), the CBO ouput gap (calculated as the percentage deviation between real GDP (series: GDPC1) and real potential GDP (series: GDPPOT)) and the Freddie Mac 30-year mortgage rate (series: MORTGAGE30US) were downloaded in April 2020 from FRED Federal Reserve Bank of St. Louis (https://fred.stlouisfed.org). The EBP series was downloaded in August 2016 from the replication files of Gertler and Karadi (2015b) (https://www.openicpsr.org/openicpsr/project/114082/version/V1/view).

We summarize results from using this alternative shock in Table A.4 in the online Appendix. Our finding that expansionary shocks have a greater impact in supply-inelastic areas is maintained. We also find that expansionary shocks have a greater impact on house prices than contractionary shocks in many MSAs. The effect of contractionary shocks are, however, smaller and less precisely estimated than what we find when using the Romer and Romer (2004) shocks.

*Alternative Measure of Supply Elasticity*.—Recent work have highlighted two potential shortcomings with the Saiz (2010b) elasticity (Davidoff 2016; Guren et al. 2021a). Davidoff (2016) shows that it is correlated with other city characteristics, including productivity proxies such as historical education levels, immigration, and national employment growth in locally prevalent industries. This raises the concern that cities with lower housing supply elasticities, as measured by Saiz (2010a), might be generally more cyclical due to differences in other characteristics. A second weakness of the Saiz (2010b) elasticity is that it loses power before 2000. Guren et al. (2021a) propose a new proxy for (the inverse of) housing supply elasticities that overcomes these two challenges. Their new proxy of housing supply elasticities is based on earlier work of Palmer (2015) by exploiting the fact that house prices in some cities are systematically more sensitive to regional house-price cycles than are house prices in other cities. They refer to their new measure as a sensitivity instrument.

We check whether our baseline results are robust to using the sensitivity measure by Guren et al. (2021b) as an alternative proxy for city-specific housing supply elasticities.[29] Results are summarized in Table A.5 in the online Appendix. In interpreting these results, it is important to remember that the sensitivity measure is a proxy for the inverse of the housing supply elasticity. Our finding that expansionary shocks have a greater impact in supply-inelastic areas (higher sensitivity) is maintained. We also find that expansionary shocks have a greater impact on house prices than contractionary shocks in supply-inelastic areas.

*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 dummies for all nine census divisions for all quarters spanned by our sample.[30,31]

Results are reported in Table A.6 in the online Appendix. Our results are robust to controlling for census division–by–quarter fixed effects. In particular, the interaction

[29] The data were downloaded in October 2020 from the webpage of Emi Nakamura (https://eml.berkeley.edu/~enakamura/papers.html).

[30] We have also done this exercise using common time fixed effects. Results are robust to this as well.

[31] We cannot include the noninteracted variables for expansionary and contractionary monetary policy shocks in this case. This is because a linear combination 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 draw any conclusion regarding the absolute response to expansionary and contractionary shocks.

term between expansionary shocks and elasticity is highly significant at all horizons, except contemporaneously. This suggests that expansionary shocks have a greater impact on house prices the lower that the elasticity of supply is. On the contrary, there is little evidence that the effect of contractionary shocks depends on housing supply elasticity.

*Differential Demographics*.—If more supply-inelastic areas have a larger fraction of young people, our finding that expansionary shocks have a greater impact in supply-inelastic areas may reflect different purchase patterns and propensities to refinance among young people when interest rates are lowered. To explore this, we construct a measure of the fraction of young people in each MSA over the sample period, where the fraction of young people is defined as the fraction of people in the age group 20–34 relative to the number of people aged above 20 years.[32] We then augment our baseline specification with the fraction of young people, the interaction between the fraction of young people and the monetary policy shocks, the interaction between the fraction of young people and the supply elasticity, and the triple interaction between the fraction of young people, the supply elasticity, and the monetary policy shocks.[33] Our results show that none of the interaction variables are significant, and all our main results are robust to this extension. Detailed results are shown in Table A.7 in the online Appendix.

*News Effects of Monetary Policy*.—Nakamura and Steinsson (2018) argue that actions taken by the Fed affect beliefs about both monetary policy and economic fundamentals. Expansionary monetary policy shocks may therefore have two opposing effects on house prices: (i) a lower interest rate boosts housing demand and leads to higher house prices, and (ii) a lower interest rate can signal expectations about lower economic activity in the future. This will lower housing demand and lead to lower house prices. To the extent that the second channel is more important in supply-elastic areas, this provides an alternative explanation of why expansionary shocks have less impact on house prices in these areas. Moreover, if the expectations channel of contractionary shocks is more similar across areas, house price responses may also be more similar. Thus, the news channel of monetary policy may affect the relative effects of expansionary and contractionary shocks. To investigate this, we augment our baseline specification with Greenbook forecasts as controls. We add the nowcast and the one-quarter- and two-quarters-ahead forecasts for GDP, inflation, and unemployment rates.[34] None of our results are materially affected by this. Table A.8 in the Online Appendix gives detailed estimation results.

*Other Nonlinearities*.—We follow Tenreyro and Thwaites (2016) and add the third power of the monetary policy shock as well as its interaction with the supply elasticity. Our results are maintained in this case, suggesting that results are not

[32] Younger age groups are excluded, since they are unlikely to be home buyers.

[33] We also include double and triple interactions between the fraction of young people and the control variables.

[34] The Greenbook forecast data for real GDP [gRGDP], inflation [gPGDP] and the unemployment rate [UNEMP] were downloaded in October 2017 from the Philadelphia Fed (https://www.philadelphiafed.org/surveys-and-data/real-time-data-research/philadelphia-data-set).

driven by a few extreme outliers. Results are tabulated in Table A.9 in the online Appendix.

*MSA-by-MSA Analysis*.—In our baseline model, we account for heterogeneity through the intercept term (MSA fixed effects) and the interactions with the supply elasticity. While a panel approach has several 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, Pesaran, and Shin (2003); Pesaran, Shin, and Smith (1999); and Phillips and Moon (2000), the pooling assumption of equal slope coefficients may often be disputed. To investigate whether our results are sensitive to this assumption, we have estimated separate models for each MSA. 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). None of our conclusions are materially affected by this alternative econometric approach, and results are summarized in Table A.10 in the online Appendix.

*Balanced Panel*.—In our baseline results, reported in 3, 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 (1983:I–2007:IV), covering 147 MSAs. Our results are not affected by this; see Table A.11 in the online Appendix.

## VI. Conclusion

We have analyzed the effects of contractionary and expansionary monetary policy shocks in regional housing markets. We find that expansionary shocks have a substantially greater impact on house prices in markets with an inelastic housing supply. We also find that 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 can be explained by differential supply-side dynamics in supply-elastic and supply-inelastic areas. We also find that time-varying and cross-sectional differences in the level of banking competition, as well as a momentum effect that is more important when house prices are increasing than when they are falling, are complementary mechanisms that could explain or reinforce the asymmetry.

These 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. As documented in Tenreyro and Thwaites (2016); Barnichon and Matthes (2018); and Angrist, Òscar Jordà, and Kuersteiner (2018), a reduction in the interest rate is less effective in stimulating the real economy than an interest rate increase is in dampening economic activity. In contrast, our results suggest that an interest rate reduction contributes to amplifying the volatility of house prices—particularly so in supply-inelastic areas. At the same time, an increase in the interest rate does not affect house prices to the same extent as an expansionary monetary policy shock in many large US metro areas.

Finally, as pointed out by Nakamura and Steinsson (2018), estimates based on cross-sectional identification are powerful in order to discriminate between alternative theoretical views. Our findings call for theoretical models that incorporate differential housing supply dynamics, an asymmetric transmission of monetary policy shocks to mortgage rates, and state-dependent momentum effects in the housing market.

## Appendix. Data Description for MSA-Level Data from Moody's Analytics

**Housing Starts:** Number of housing units in which construction work has started. The start of construction is when excavation begins for the footings or foundation of a building. Source: Census Bureau and Moody's Analytics (Moodys' Mnemonic: RHSTM.IUSA_XXXX).[35]

**Housing Stock:** A house, apartment, mobile home or trailer, group of rooms, or single room that is occupied or available for occupancy. Source: Census Bureau and Moody's Analytics (Moodys' Mnemonic: RHSTKQ.IUSA_XXXX).

**FHFA House Price Index:** Weighted, repeat-sales index, measuring average price changes in repeat sales or refinancings on the same single-family properties whose mortgages have been purchased or securitized by Fannie Mae or Freddie Mac. The mortgages measured by the house price index are both conforming and conventional. Source: FHFA, Moody's Analytics (Moodys' Mnemonic: HOFHOPIQ.IUSA_XXXX).

**Population:** Total resident population in each MSA. Source: Census Bureau and Moody's Analytics (Moodys' Mnemonic: RFPOPQ.IUSA_XXXX).

**Net Migration:** The movement of people within an MSA, computed as the difference between immigration and outmigration as a fraction of total population. Source: Census Bureau and Moody's Analytics (Moodys' Mnemonic: RFNMQ.IUSA_XXXX).

**CPI:** Consumer price index for all urban consumers in each MSA. Source: BEA, BLS, and Moody's Analytics (Moodys' Mnemonic: RCPIUM.IUSA_XXXX).

**Real Disposable Personal Income per Capita:** The nominal income available to persons for spending or saving. It is equal to personal income less personal current taxes. Nominal disposable income (Moodys' Mnemonic: RYPDPIQ.IUSA_XXXX)

[35] _XXXX refers to short MSA-name in Moody's Analytics database.

is then divided by the MSA's CPI and population to obtain real disposable income per capita. Source: BEA and Moody's Analytics.

**Fraction Young:** The fraction of people in the age group 20–34 relative to the number of people aged above 20 years. Source: Census Bureau and Moody's Analytics.

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