THE INTEREST RATE ELASTICITY OF HOUSE PRICES: EVIDENCE FROM SURPRISE MACROECONOMIC NEWS

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Abstract. This paper examines the relationship between house prices and interest rates. I use surprise changes in interest rates occurring within macroeconomic news windows to identify the sensitivity of house prices to interest rates. I estimate these eleasticities at the national, state, metro and micro area, county, and ZIP levels. I then explore the relationship between the interest rate elasticity of house prices to other related measures from the housing supply literature: land unavailability, land-use regulation, and housing supply elasticities. I find that house prices are more sensitive to changes in interest rates in areas with less land available for development, in areas with more land-use regulation, and in areas with more inelastic housing supply. (*JEL* E52, G14, G21, R31)

1. Introduction

Housing is the main store of wealth for many U.S. households. According to the Federal Reserve's Survey of Consumer Finances (Bricker, et al., 2017), among households owning their homes median net housing wealth rose 5.5 percent during the 2013–2016 period, to $185,000. Moreover, net housing wealth accounted for over 30 percent of household assets (Dettling, et al., 2017). As house prices fluctuate, so to does the value of this main store of wealth. This can affect consumption, employment, and mortgage default.[1] The magnitudes of these effects can vary widely from region to region, based largely on the elasticity of housing supply. That is, a shift in housing demand will tend to have larger effects on house

Date: This Version: December 27, 2020.

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I thank Scott Frame, Geng Li, and participants at numerous seminars for helpful comments and suggestions. The views expressed herein are those of the author and do not necessarily reflect the views of the Federal Open Market Committee, its principles, of the Board of Governors of the Federal Reserve System.

[1]Campbell and Cocco (2007) show that rising house prices tend to be associated with increased consumption. Mian, Rao, and Sufi (2013) find that households in ZIP codes that experienced large house price declines experienced larger drops in consumption during the 2006-2009 period, while Mian and Sufi (2014) conclude that households in counties with large house price declines suffered larger employment losses during the 2007-2009 period. Mian and Sufi (2011) show that homeowners' extraction of nearly $1.25 trillion in housing equity during the 2002-2008 period greatly increased households' overall mortgage debt and contributed to subsequent mortgage default activity.

prices in areas where housing supply is more inelastic than in areas where housing supply is more elastic.

Over the past 40 years, interest rates have tended to move lower while house prices have tended to move higher. On simple inspection, this simple correlation might lead one to believe that house prices and interest rates are negatively correlated, consistent with economic theory. One difficulty in studying the relationship between interest rates and house prices, however, is that both interest rates and house prices rely on current and expected economic conditions. That is, one might observe house prices and interest rates moving together over certain periods of time, driven by economic conditions. That is, when economic conditions improve, interest rates and house prices might tend to move higher. In contrast, when economic conditions deteriorate, interest rates and house prices might tend to move lower. In both cases, house prices and interest rates would then be positively correlated.

To address the challenge arising because house prices and interest rates are correlated with and potentially driven by underlying economic conditions, this paper uses a high-frequency event-study design to decompose changes in interest rates into various components. In particular, our identification strategy isolates changes in interest rates that are uncorrelated with contemporaneous changes in macroeconomic conditions. We focus our attention on small time windows around macroeconomic news releases to identify those changes in interest rates. We then aggregate these changes in interest rates over each month and explore the response of house prices to these changes in interest rates. We perform our analysis at the national, state, metro and micro area, county, and ZIP levels.

We then compare our elasticity estimates to several related housing supply measures from the literature. In particular, we consider two land unavailability measures (Saiz, 2010; Lutz and Sand, 2017), the Wharton Residential Land Use Regulation Index (Gyourko, Hartley, and Krimmel, 2019), and two sets of housing supply elasticity estimates (Saiz, 2010; Howard and Liebersohn, 2018). We find statistically significant relationships between our interest rate elasticities and these housing supply measures: House prices are more sensitive to interest rates in areas with less land available for development, in areas with more land-use regulation, and in areas with more inelastic housing supply.

This paper is one of many to explore the determinants of house prices. Many papers start with a standard user cost model. Gallin (2006) and Gallin (2008) find tight links between house prices and income, and house prices and rents, respectively. Davis and Heathcote (2007) show that land is the primary determinant of house price movements (as construction costs are fairly constant). Glaeser, Gottlieb, and Gyourko (2013) find that loan-to-value ratios, loan approval rates, and low interest rates during the 1996–2006 period can explain only a portion of the large increase in house prices during that time period.

Similarly, Kuttner (2013) shows that low interest rates cannot explain the tremendous run up in house prices observed during the 1998–2007 period.

Some of the literature has also examined the effects of underwriting standards and mortgage products on house prices. Mayer, Pence, and Sherlund (2009) show that subprime and alt-A mortgage lending grew rapidly and had notoriously loose underwriting standards, likely putting upward pressure on house prices. Nadauld and Sherlund (2013) show that private-label securitization likely applied upward pressure on house prices in already high house-price appreciation areas. Johnson (2019) finds that tightened underwriting standards led to lower house prices.

Other papers have explored the effects of monetary policy on house prices. Dokko et al. (2009) show that monetary policy alone (low interest rates) cannot explain the tremendous run up in house prices observed during the 1998–2007 period. Fratantoni and Schuh (2003) show that monetary policy can have different effects in different regional housing markets. Del Negro and Otrok (2007) show that although house prices were driven by local components during the 1986–2000 period, they were driven by a strong national component during the 2001–2005 period. In contrast, Buchinsky and Sherlund (2020) find both strong national (interest rate) and local (unemployment and inflation) components to house prices, especially during the housing boom and bust.

This paper is more closely related to other papers in the literature. Adelino, Schoar, and Severino (2012) use the conforming loan limit to find an elasticity of house prices to interest rates of 1.2 to 9.1 percent (depending on how large the jumbo-conforming spread is estimated to be). DeFusco and Paciorek (2017) use a discontinuity in interest rates at the conforming loan limit to estimate the interest rate elasticity of mortgage demand. They find that a one percentage point increase in mortgage rates decreases mortgage demand by 2–3 percent. Bhutta and Ringo (2017) use an unexpected price reduction in FHA's annual mortgage insurance premium to examine the effect of interest rates on home buying. While they find a statistically significant positive effect on home buying, they find a statistically insignificant, albeit positive, effect on house prices.

This paper uses high-frequency event-study analysis to study the effect of exogenous changes in interest rates on house prices. A similar methodology has been used by Gurkaynak, Sack, and Swanson (2005a) to show that asset prices tend to change quickly around macroeconomic and monetary policy news. Similarly, Gurkaynak, Sack, and Swanson (2005b) use a similar methodology to show how monetary policy news affects asset prices. Moulton and Wentland (2017) and Fischer, Huber, Pfarrhofer, and Staufer-Steinnocher (2019) use monetary policy announcement dates to examine the regional effects of monetary policy on house prices. Similar to our results, they report larger sensitivities in areas with more inelastic housing supply.

As in Adelino, Schoar, and Severino (2012) and Glaeser, Gottlieb, and Gyourko (2013), we are interested in identifying the effect of interest rates on house prices. We focus on high-frequency macroeconomic news surprises to isolate particular changes in interest rates (similar to the methodology of Gurkaynak, Sack, and Swanson, 2005a) that might shift housing demand. In particular, we are interested in isolating changes in interest rates occurring shortly after macroeconomic news releases. Moulton and Wentland (2017) and Fischer, Huber, Pfarrhofer, and Staufer-Steinnocher (2019) examine the effects of monetary policy surprises on house prices. This paper focuses on the effects of macroeconomic news surprises on house prices, while controlling for high-frequency monetary policy news and expectations in the analysis. It is important to note that the high-frequency event-study design used here obviates the need for specifying a set of instrumental variables.

We then compare our elasticity estimates to several related housing supply measures. In particular, Gyourko, Saiz, and Summers (2008) build the Wharton Residential Land Use Regulation Index for municipalities (cities and towns) based on a survey administered in 2006. Gyourko, Hartley, and Krimmel (2019) update the Wharton Residential Land Use Regulation Index based on a follow up survey administered in 2018. Both of these studies focus on the measuring land-use regulations at the local level. Saiz (2010) estimates land unavailability and housing supply elasticities for metro areas. Lutz and Sand (2017) construct land unavailability measures for states, metro areas, counties, and ZIP codes. Howard and Liebersohn generate a parametric representation of housing supply elasticities that depend on the Wharton Residential Land Use Regulation Index, population density, and proximity to a coastline. We show that our elasticity estimates are correlated with each of these related housing supply measures: House prices are more sensitive to interest rates in areas with less land available for development, in areas with more land-use regulation, and in areas with more inelastic housing supply.

The remainder of this paper is organized as follows. Section 2 introduces our model of house prices and the model's predictions. Section 3 sets up the empirical model. Section 4 discusses the data used in the empirical analysis. Section 5 overviews the empirical results at the national, state, metro and micro, county, and ZIP levels, then compares these estimates to the related measures from the existing literature. Section 6 concludes.

2. Model of House Prices

As in Gallin (2006), the demand for owner-occupied housing depends on income, Y, population, N, wealth, W, the user cost of housing, and other demand shifters, θ_d, such as underwriting standards and expectations. The user cost of housing, in turn, depends on the price of housing, P, mortgage rates, r, income taxes and property taxes, τ_y and τ_p, maintenance and depreciation, δ, and expected capital gains, g. The demand for housing can therefore be written as

$$Q_d \equiv Q_d(P, Y, N, W, r, \tau_y, \tau_p, \delta, g; \theta_d). \tag{1}$$

The supply of housing depends on the price of housing, P, the cost of new construction, C, and other supply shifters, θ_s. It can be written as

$$Q_s \equiv Q_s(P, C; \theta_s). \tag{2}$$

The price of housing can then be written as

$$P = f(Y, N, W, C, r, \tau_y, \tau_p, \delta, g; \theta_d, \theta_s). \tag{3}$$

Upon simple inspection, Equation 3 suggests that estimating the elasticity of house prices with respect to interest rates would be relatively straightforward. However, interest rates reflect current and expected economic conditions such as those captured in θ_d. That is, interest rates (and house prices) tend to move with economic conditions (current and expected). So when economic conditions improve, interest rates and house prices tend to move higher. Similarly, when economic conditions deteriorate, interest rates and house prices tend to move lower. Thus, some changes in interest rates are driven by changes in economic conditions and therefore do not have a clear negative relationship with house prices. Thus, the empirical challenge is to isolate changes in r that are unrelated to contemporaneous changes in economic conditions from those that are related to contemporaneous changes in economic conditions.

We therefore augment the simple model above with a two-period design. In month t, households receive aggregate income Y_t. The financial market cannot observe Y_t directly, but forms expectations about Y_t in setting asset prices (including r_t). Let Y_t^e be the portion of Y_t that the financial market prices into interest rates. (Assume that $dr/dY^e > 0$). In this case, interest rates and economic conditions move together, so $\partial P/\partial Y > 0$ and $\partial P/\partial r < 0$ conflict and the total effect on house prices is unclear. If economic conditions improve more than interest rates rise then house prices could increase, whereas if interest rates rise faster than economic conditions improve then house prices might decrease. When expectations about future economic conditions improve, house prices can increase or decrease depending upon how much interest rates rise relative to improvements in income.

In month $t+1$, the financial market observes $Y_t \equiv Y_t^e + Y_t^s$, where Y_t^s is the "surprise" component of the macroeconomic news release. The financial market then revises asset prices to account for Y_t^s, thus affecting r_{t+1}. (Assume that $dr/dY^s > 0$). Here, the direct effect of $\partial P/\partial Y > 0$ occurred in month t, so the only effect in month $t+1$ comes from $\partial P/\partial r < 0$. It is this latter effect that I use to isolate and identify the effect of interest rates on house prices. Here, if interest rates go up then house prices go down, and if interest rates go down then house prices go up.

As an example of how economic conditions and interest rates evolve over the course of a month, consider the nonfarm payrolls component of the August employment report released on September 7, 2007 at 8:30 a.m. The market had priced in a median expectation of 113,000 jobs added. That is, interest rates, stock market prices, and expectations about monetary policy had already priced in a median expectation of 113,000 jobs added that morning for the entire month of August. But the employment report instead revealed 4,000 jobs lost, a forecast error of -117,000 (-1.14 standard deviations). Figure 2 shows how asset prices evolved during the day. In particular, within minutes of the employment report's release, 10-year Treasury yields declined about 5 basis points, S&P 500 futures prices declined 0.6 percent, and year-ahead monetary policy expectations declined over 15 basis points. Note that the aggregate demand for housing had already shifted based on how the economy evolved in August (as well as on how interest rates evolved based on expectations about how the overall economy evolved in August). Once markets repriced the morning of the release, households observed the new set of asset prices which affected housing demand. This is a pure shock to the aggregate demand for housing working solely through the interest rate channel.[2] When added up over the course of the month, these small perturbations in housing demand allow one to identify the interest rate elasticity of house prices.

3. Empirical Model

We start with a simple setup for our empirical model, in which we relate log house prices p to interest rates r, unemployment rates u, income y, and mortgage credit conditions c.[3] In particular,

$$p_t = \alpha_0 + \alpha_1 r_{t-1} + \alpha_2 u_{t-1} + \alpha_3 y_{t-1} + \alpha_4 c_{t-1} + \varepsilon_t. \tag{4}$$

This model is similar to studies that find a negative relationship between house prices and interest rates over long periods of time.

Taking first differences, the change in log house prices Δp is related to the change in interest rates Δr, the change in unemployment rates Δu, the change in income Δy, and the change in mortgage credit conditions Δc. In particular,

$$\Delta p_t = \alpha_0 + \alpha_1 \Delta r_{t-1} + \alpha_2 \Delta u_{t-1} + \alpha_3 \Delta y_{t-1} + \alpha_4 \Delta c_{t-1} + v_t. \tag{5}$$

In theory, $\alpha_1 < 0$. But as we showed above, estimates of α_1 might be contaminated by interest rate movements induced by macroeconomic news. This might bias the estimate of α_1 toward zero, especially if $dr/dy > 0$ (essentially averaging through positive responses

[2]In the results to follow, I control for similar changes in equity prices and monetary policy expectations to control for effects coming through wealth and monetary policy channels.

[3]We include monthly indicator variables in each of our regressions to capture seasonal factors.

and negative responses). We therefore decompose the change in interest rates observed over the course of a month into several components: those occurring within macroeconomic news release windows, those occurring within monetary policy news windows, and the remainder occurring outside macroeconomic or monetary policy news windows. In other words,

$$\Delta r_t = \Delta r_t^w + \Delta r_t^m + \Delta r_t^o, \tag{6}$$

where Δr_t is the total change in interest rates during month t, Δr_t^w is the total change in interest rates occurring during macroeconomic news windows during month t, Δr_t^m is the total change in interest rates occurring during monetary policy news windows during month t, and Δr_t^o is the total change in interest rates occurring outside macroeconomic and monetary policy news release windows during month t.

In our main set of empirical results, we augment Equation 6 to include additional financial variables. We include changes in equity prices and monetary policy expectations inside and outside of macroeconomic news windows to control for the wealth and monetary policy expectations channels, the slope of the yield curve to further capture expectations, and changes in agency mortgage-backed securities (MBS) and primary-secondary spreads to capture any pricing differences between Treasury and mortgage markets. We include measures of the Federal Reserve's quantitative easing programs during the 2009–2014 period.

4. The Data

The primary data we use cover the January 1998 to December 2019 period. House price indexes (p_t) come from CoreLogic, Zillow, and the Federal Housing Finance Agency (FHFA). 2-year and 10-year Treasury yields (r_t), S&P 500 futures prices (s_t), and year-ahead Eurodollar futures prices (m_t) come from Bloomberg. Mortgage rates come from the Freddie Mac Primary Mortgage Market Survey and agency MBS yield data come from Barclays. These are used to calculate the primary-secondary market spread (z_t^p) and the MBS spread (z_t^m). Unemployment rate (u_t) data come the Bureau of Labor Statistics. The Housing Credit Availability Index (c_t) comes from the Urban Institute. The Federal Reserve's agency MBS and Treasury security holdings (q_t^m and q_t^τ) come from the Federal Reserve Bank of New York. Figure 1 shows each of these series for the nation during the 1998-2019 period.

To define the changes in interest rates, equity prices, and monetary policy expectations during macroeconomic news windows, we take the change in 10-year Treasury yields, S&P 500 futures prices, and year-ahead Eurodollar futures prices observed from 5 minutes before to 25 minutes after each macroeconomic news release. We track 35 macroeconomic news releases to specify our macroeconomic news windows. These news releases are listed in Table 2 along with their frequencies and sources. Similarly, to define the changes in interest rates during monetary policy news windows, we take the change in 10-year Treasury yields observed from 15 minutes before to 60 minutes after each monetary policy news event. Monetary policy news events include FOMC statements, FOMC minutes, and Congressional testimony. Each set of window definitions is consistent with Gurkaynak, Sack, and Swanson (2005a) and Gurkaynak, Sack, and Swanson (2005b). Table 1 shows descriptive statistics for the variables used in our regression analysis.

5. Empirical Results

To begin, we follow the simplest form of Equation 4 and regress (the log of) national house prices p on interest rates r. This simple construct suggests that house prices increase 9.7 percent for every one-percentage-point decline in 10-year Treasury yields (Column 1 of Table 3). Once one conditions on unemployment rates u, income y, and mortgage credit conditions c, however, the relationship between house prices and interest rates becomes small and statistically insignificant (Column 2 of Table 3).

We next examine the relationship between the monthly change in log house prices on the monthly change in interest rates, unemployment rates, income, and mortgage credit conditions. As shown in the first column of Table 4, the relationship between the change in house prices and the change in interest rates is small and statistically insignificant. Changes in mortgage credit conditions and unemployment rates, however, have strong relationships with changes in house prices.

We then separate the changes in interest rates occurring within macroeconomic and monetary policy news windows ($\Delta r_t^w + \Delta r_t^m$) from those occurring outside these news windows (Δr_t^o) as proposed in Equation 6. The second column of Table 4 shows these results. Though still statistically indistinguishable from zero, the effect of changes in interest rates occurring within macroeconomic and monetary policy news windows is at least of the correct (negative) sign. Moreover, a strong positive relationship between house prices and changes in interest rates occurring outside macroeconomic and monetary policy news windows emerges, consistent with the hypothesis set forth above (that house prices and interest rates tend to move together with changes in underlying economic conditions). Changes in mortgage credit conditions and unemployment rates retain their statistically significant relationships with changes in house prices.

We next separate the changes in interest rates occurring within macroeconomic and monetary policy news windows into their separate macroeconomic news and monetary policy news components (Δr_t^w and Δr_t^m). The third column of Table 4 shows these results. Changes in interest rates occurring within macroeconomic news windows have a strong, statistically significant negative relationship with changes in house prices, implying an interest rate elasticity of house prices of -0.9. The effect coming from interest rate changes outside news windows retains its strong positive relationship with house prices, reinforcing the view that a third factor (e.g., economic conditions) might be driving both interest rates and house prices. Interestingly, the effect coming from monetary policy news is not statistically significant, perhaps because monetary policy actions are often communicated well in advance of monetary policy news windows. Changes in mortgage credit conditions and unemployment rates retain their statistically significant relationships with changes in house prices.

We next add in other financial variables: changes in equity prices and monetary policy expectations inside and outside macroeconomic news windows, the slope of the yield curve, and changes in MBS and primary-secondary spreads. Equity prices are included to capture any wealth effects occurring within macroeconomic news windows that might be correlated with house prices. Monetary policy expectations are included to capture any expected actions of the Federal Reserve as a reaction to macroeconomic news. The slope of the yield curve is included as a forward-looking measure of inflation and economic conditions. MBS and primary-secondary spreads are included to account for differences that might arise between 10-year Treasury yields and mortgage rates. The fourth column of Table 4 shows these results. Changes in interest rates occurring within macroeconomic news windows retain their strong, statistically significant negative relationship with changes in house prices, suggesting an interest rate elasticity of house prices of -2.7. Changes in interest rates coming from monetary policy news or occurring outside macroeconomic news windows come in statistically insignificant. Changes in mortgage credit conditions and unemployment rates retain their statistically significant relationships with changes in house prices. Changes in equity prices outside macroeconomic news windows and monetary policy expectations inside macroeconomic news windows have statistically significant positive effects on changes in house prices.

The fifth column of Table 4 includes the level of unemployment rates and mortgage credit conditions as the overall stance of economic and mortgage credit conditions are likely to have effects on changes in house prices that are independent of those coming from changes in economic and mortgage credit conditions. The sixth column also includes a measure of the Federal Reserve's quantitative easing programs during the 2009–2014 period. Similar to our prior results, changes in interest rates occurring within macroeconomic news windows retain their strong, statistically significant negative relationship with changes in house prices, implying interest rate elasticities of house prices of -3.2 to -3.3. Changes in interest rates coming from monetary policy news or occurring outside macroeconomic news windows come in statistically insignificant. The levels and changes in mortgage credit conditions and unemployment rates have statistically significant relationships with changes in house prices. Changes in equity prices outside macroeconomic news windows and monetary policy expectations inside macroeconomic news windows have statistically significant positive effects on changes in house prices. MBS spreads, the slope of the yield curve, and the Federal Reserve's MBS purchase programs are also positively correlated with changes in house prices.

We next consider different house price indexes. The first house price index we consider covers jumbo mortgages (those with loan amounts above the conforming loan limit) and comes from CoreLogic. The second house price index covers conforming mortgages (those with loan amounts at or below the conforming loan limit) and comes from CoreLogic. The third house price index is constructed from Zillow. The final house price index covers conforming mortgages and comes from the Federal Housing Finance Agency (FHFA). Each index is national is scope. Table 5 shows the estimation results for these alternative house price indexes. In each case, changes in interest rates occurring within macroeconomic news windows continue to have a strong, statistically significant negative relationship with changes in house prices, implying interest rate elasticities of house prices of -1.7 (FHFA) to -3.1 (CoreLogic conforming). The levels and changes in mortgage credit conditions and unemployment rates have statistically significant relationships with changes in house prices. Changes in equity prices inside and outside macroeconomic news windows and monetary policy expectations inside macroeconomic news windows have varying statistically significant positive effects on changes in the various house price measures. The slope of the yield curve and the Federal Reserve's MBS and Treasury security purchase programs also tend to be positively correlated with changes in house prices.

5.1. **Geographic Results.** We next take the model estimated in the final column of Table 4 and apply it for individual geographic levels for which we observe house price indices. The geographic levels we are able to consider include individual states, individual metro and micro areas, counties, and ZIP codes.[4] Unemployment rates are measured at the state, metro and micro area, and county levels.[5] All financial variables are measured at the national level.

As examples, Table 6 shows the estimation results for California, Florida, Arizona, Nevada, and Michigan. In each case, changes in interest rates occurring within macroeconomic news windows have a strong, statistically significant negative relationship with changes in house prices. Changes in interest rates coming from monetary policy news windows have a statistically significant positive relationship with changes in house prices in California, Arizona, Nevada, and Michigan. Changes in interest rates outside macroeconomic news windows come in statistically insignificant for each of these states. For these states, a one-percentage-point surprise increase in interest rates tends to decrease house

[4]House price data are the limiting factor. We observe house price indices for all 51 states (including the District of Columbia); all 933 metro and micro areas; 1,401 counties; and 8,153 ZIP codes.

[5]For our ZIP-level regressions, we use county-level unemployment rates.

prices by 3.1 to 4.7 percent. The levels and changes in mortgage credit conditions and unemployment rates have statistically significant relationships with changes in house prices. Changes in equity prices inside and outside macroeconomic news windows and monetary policy expectations inside macroeconomic news windows have statistically significant positive effects on changes in house prices. MBS spreads, the slope of the yield curve, and the Federal Reserve's MBS and Treasury security purchase programs tend to be positively correlated with changes in house prices.

Figure 3 shows the estimated interest rate elasticities of house prices across states in the United States. The most inelastic states include Arizona (-4.3), California (-4.2), Florida (-4.0), and Nevada (-4.7); these are statistically different from zero at at least the 99-percent confidence level. The most elastic states include Iowa (-0.4), Louisiana (-0.3), Nebraska (-0.4), and South Dakota (+0.1), but none of these elasticity estimates is statistically different from zero. The average elasticity estimate across all 51 states is -2.2; 35 of the 51 estimated elasticities are negative and statistically significant at the 90-percent confidence level (50 are negative).[6] Two caveats of using state-level house price indexes are that they mask a lot of local variation and being transaction-based tend to rely more heavily on urban areas.

Figure 4 shows the estimated interest rate elasticities of house prices across metro and micro areas in the United States. The most inelastic areas include Madera CA (-6.7), Merced CA (-6.4), Pahrump NV (-7.8), and Stockton-Lodi CA (-6.5); these are statistically different from zero at at least the 99-percent confidence level. The most elastic areas include Brenham TX (+3.1), Decatur IL (+3.3), Marion OH (+4.3), and Moberly MO (+2.3); only the first three are statistically different from zero at the 95-percent confidence level. The average elasticity estimate across metro and micro areas is -2.1; 421 of the 933 estimated elasticities are negative and statistically significant at the 90-percent confidence level (819 are negative).[7] Among metro areas only, the average estimated elasticity is -2.2; 186 of the 384 estimated elasticities are negative and statistically significant at the 90-percent confidence level (344 are negative).

Figure 5 shows the estimated interest rate elasticities of house prices across counties in the United States. The most inelastic counties include Amador CA (-7.0), Calaveras CA (-6.9), Nye NV (-7.8), and Washington NY (-7.8); these are statistically different from zero at at least the 99-percent confidence level. The most elastic counties include Burnet TX (+4.1), Fulton OH (+3.4), Lackawanna PA (+3.7), and Marion OH (+4.3); two other counties (Macon IL (+3.3) and Clinton IL (+2.7)) have positive estimates that are statistically different from zero at the 95-percent confidence level. The average elasticity estimate across counties is -2.2; 498 of the 1,401 estimated elasticities are negative and statistically

[6] Average is weighted by state population.

[7] Average is weighted by metro and micro area population.

significant at the 90-percent confidence level (1,168 are negative).[8] Among counties in metro areas only, the average estimated elasticity is -2.2; 356 of the 899 estimated elasticities are negative and statistically significant at the 90-percent confidence level (759 are negative).

We also calculated elasticities at the ZIP level. Figure 6 shows the estimated interest rate elasticities of house prices across ZIPs in the United States. The most inelastic ZIPs are located in Brooksville FL (-9.6), Delhi CA (-9.3), Madera CA (-9.5), and Miami FL (-10.0); these are statistically different from zero at at least the 99-percent confidence level. The most elastic ZIPs are located in Groton CT (+4.0), Jackson TN (+5.8), Moberly MO (+4.1), and New Braunsfels TX (+4.5); 14 other ZIPs have positive estimates that are statistically different from zero at the 95-percent confidence level. The average elasticity estimate across ZIPs is -2.3; 3,396 of the 8,153 estimated elasticities are negative and statistically significant at the 90-percent confidence level (7,064 are negative).[9]

5.2. **Comparison to Land Unavailability, Housing Supply Elasticities, and Land-Use Regulation.** If the elasticity estimates of this paper are indeed identified off perturbations in housing demand, they should be correlated with some of the housing supply measures from the existing literature. In this section, we examine the relationships between our house price elasticities and the land availability measures of Saiz (2010) and Lutz and Sand (2017), the housing supply elasticities of Saiz (2010) and Howard and Liebersohn (2018), and the land-use regulation measure of Gyourko, Hartley, and Kimmel (2019). We do so at the state, metro- and micro-area, county, and ZIP levels.[10] The Lutz and Sand land unavailablility measures are available at the state, metro-area, county, and ZIP levels. We also aggregate the county-level data up to cover micro areas. The WRLURI is available at the municipality level. We aggregate these up to form state, metro- and micro-area, county, and ZIP levels. The Saiz land availability and housing supply elasticities are available only for metropolitan areas. We follow Howard and Liebersohn and parameterize the housing supply elasticity at the county level.[11] We then aggregate the county-level housing supply elasticities to form state, metro- and micro-area. We also calculate the Howard and Liebersohn housing supply elasticities for individual ZIP Codes, classifying any ZIP Code in a coastal county as coastal.

Figure 7 shows the state-level relationships between our house price elasticity estimates and land unavailability, housing supply elasticities, and the WRLURI. The area of each bubble is proportional to each state's population. The relationships are all downward sloping, indicating that in states with less land available for development, more inelastic

[8]Average is weighted by county population.

[9]Average is weighted by ZIP population.

[10]In results not reported here, we also aggregate each of these measures to the commuting zone and ZIP3 levels. Our results are qualitatively unchanged.

[11]$exp(3.409 - .362\text{WRLURI} + .358\text{WRLURImissing} - .446\log(\text{Density}) - .522\text{Coastal})$

housing supply, or more land-use regulation, house prices are more sensitive to interest rates.

Similarly, Figure 8 shows the metro-area relationships between our house price elasticity estimates and land unavailability, housing supply elasticities, and the WRLURI. Figure 9 shows the micro-area relationships between our house price elasticity estimates and land unavailability, housing supply elasticities, and the WRLURI. The area of each bubble is proportional to each metro-area's population. The relationships are all downward sloping, indicating that in metro and micro areas with less land available for development, more inelastic housing supply, or more land-use regulation, house prices are more sensitive to interest rates.

Figure 10 shows the county-level relationships between our house price elasticity estimates and land unavailability, housing supply elasticities, and the WRLURI. The area of each bubble is proportional to each county's population. The relationships are all downward sloping, indicating that in counties with less land available for development, more inelastic housing supply, or more land-use regulation, house prices are more sensitive to interest rates. Figure 11 shows the ZIP-level relationships between our house price elasticity estimates and land unavailability and the WRLURI. The area of each bubble is proportional to each ZIP's population. The relationships are all downward sloping, indicating that in ZIPs with less land available for development or with more land-use regulation, house prices are more sensitive to interest rates.

Finally, we consider these relationships jointly. For each geographic level for which each measure is available, we examine the relationship between our elasticity estimates and the land unavailability measures of Lutz and Sand and Saiz, the land-use regulation measure of Gyourko, Hartley, and Krimmel, and the housing supply elasticity estimates of Saiz and Howard and Liebersohn. Table 7 shows the results of these regressions. Land unavailability enters negative and statistically significant at all levels but ZIP. Housing supply elasticities only enter negative and statistically significant for CBSA (metro only) and county. WRLURI enters negative and statistically significant for all levels of geography. At the ZIP level, only the land-use regulation measure is highly correlated with the interest rate elasticity of house prices. Table 8 splits the Lutz and Sand land unavailability measure into its slope unavailability, water unavailability, and wetland unavailability components. The slope and wetland unavailability measures enter negative and statistically significant; water unavailability does not enter to a statistically significant degree. Housing supply elasticities still only enter negative and statistically significant for counties. WRLURI still enters negative and statistically significant for all levels of geography. In total, house price are more sensitive to interest rates in areas with less land available for development, in areas with more land-use regulation, and in areas with more inelastic housing supply.

What is reassuring is that our elasticity measures are correlated with these other measures related to housing supply. Differences could arise because of different sample time frames, changes in land availability or lang-use regulation, or shifts in the supply curve over periods of time. Despite this, we feel that our elasticity measures do reflect the average response of house prices to a change in interest rates, holding the housing supply curve fixed over short periods of time. Moreover, our elasticity estimates are generally contained within the range estimated by Adelino, Schoar, and Severino (2012).

5.3. **Comparison to House Price Appreciation During Periods of Time.** We next look at the house price experiences of ZIP Codes during several periods of time: 1998–2002, 2003–2006, 2007–2011, 2012–2015, and 2016–2019. Figure 8 shows the relationship between our house price elasticity and changes in house prices during these times. The relationships are all strong and of the correct direction. Not surprisingly, house prices increased the most during the 2003-2006 period in ZIPs that were more inelastic. Similarly, house prices decreased the most during the 2007–2011 period in ZIPs that were more elastic. That is, house prices increase (and decrease) the fastest in ZIPs where house prices are more sensitive to changes in interest rates. Table 9 corroborates these simple correlations by including the other housing supply measures available at the ZIP level. Here, house prices increase (and decrease) the fastest in ZIPs where house prices are more sensitive to changes in interest rates, in ZIPs with more land-use regulation, and generally in ZIPs with less land available for development.

5.4. **Other Housing Market Results.** Table 10 examines the relationships between our surprise interest rate measure and home sales and housing starts. In each regression, the dependent variable is log sales or log housing starts.[12] In each case, changes in interest rates occurring within macroeconomic news windows have a strong, statistically significant negative relationship with various measures of home sales and housing starts. Our estimates suggest that for every one-percentage-point increase in interest rates: total home sales decline 0.5 percent, existing home sales decline 0.4 percent, new home sales decline 0.7 percent, and housing starts decline 0.7 percent. The levels and changes in mortgage credit conditions and unemployment rates have statistically significant relationships with home sales and housing starts. Changes in equity prices inside and outside macroeconomic news windows and monetary policy expectations inside macroeconomic news windows have statistically significant positive effects on home sales and housing starts. The slope of the yield curve and the Federal Reserve's Treasury security purchase programs are also positively correlated with home sales and housing starts.

[12]We lead each home sales measure by four months and housing starts by two months based on the Akaike information criterion.

6. Conclusion

This paper examines the relationship between house prices and interest rates using a high-frequency event-study design. One difficulty in studying the relationship between interest rates and house prices is that both rely heavily on current and expected economic conditions. So when economic conditions are good, both interest rates and house prices tend to move higher. When economic conditions worsen, interest rates and house prices might move lower. This spurious correlation might contaminate estimates of the response of house prices to movements in interest rates, which are usually assumed to be negative.

To address the challenge that changes in interest rates are correlated with underlying economic conditions, we decompose changes in interest rates into various components. Our identification strategy depends on changes in interest rates that are uncorrelated with contemporaneous changes in economic conditions. Using data on changes in interest rates around macroeconomic news releases, we focus our attention on small windows around macroeconomic news releases to identify "surprise" changes in interest rates. We then aggregate these surprise changes in interest rates over the course of the month and explore the sensitivity of house prices to these surprise changes. We perform our analysis at the national, state, metro and micro area, county, and ZIP levels.

We then compare our elasticity estimates to several related housing supply measures from the literature. In particular, we consider two land unavailability measures (Saiz, 2010; Lutz and Sand, 2017), the Wharton Residential Land Use Regulation Index (Gyourko, Hartley, and Krimmel, 2019), and two sets of housing supply elasticity estimates (Saiz, 2010; Howard and Liebersohn, 2018). We find statistically significant relationships between our interest rate elasticities and these housing supply measures: House prices are more sensitive to interest rates in areas with less land available for development, in areas with more land-use regulation, and in areas with more inelastic housing supply.

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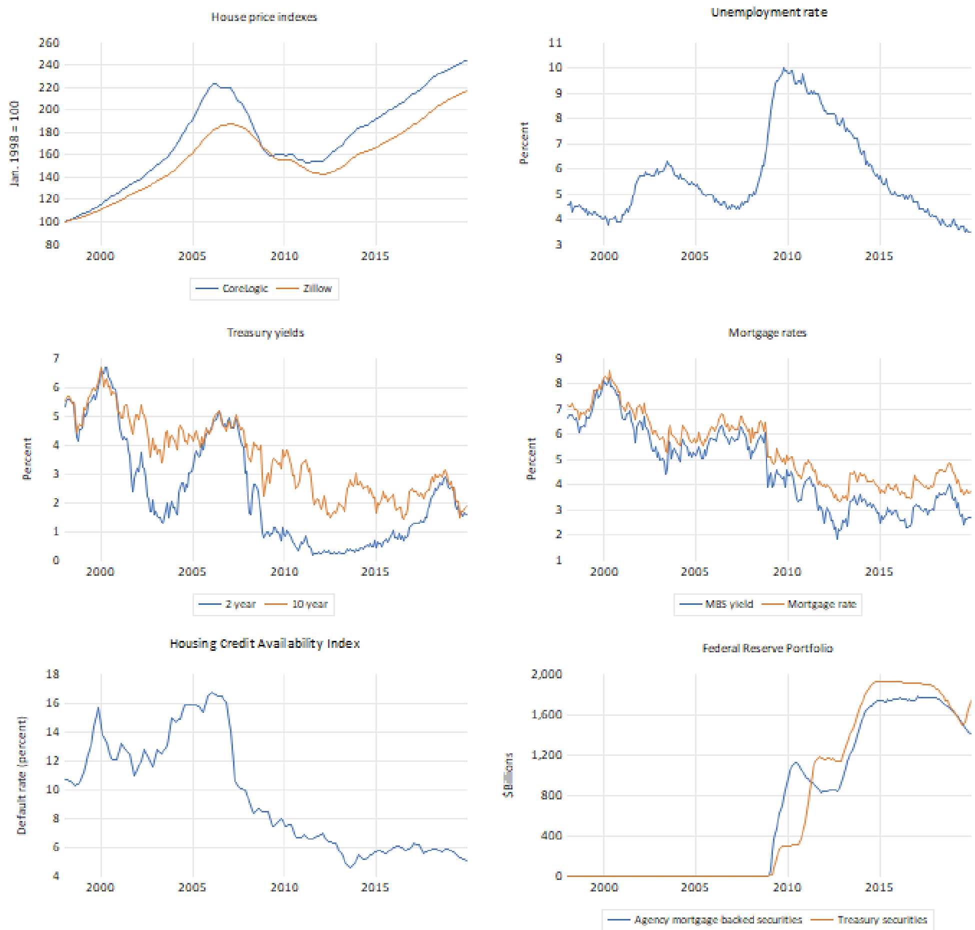

FIGURE 1. National Time Series

Sources: For house prices, CoreLogic; for unemployment rates, Bureau of Labor Statistics, for interest rates, Federal Reserve; for agency MBS yields, Barclays; for 30-year fixed-rate mortgages rates, Freddie Mac; for Mortgage Credit Availability Index, Urban Institute; for Federal Reserve portfolio, Federal Reserve Bank of New York.

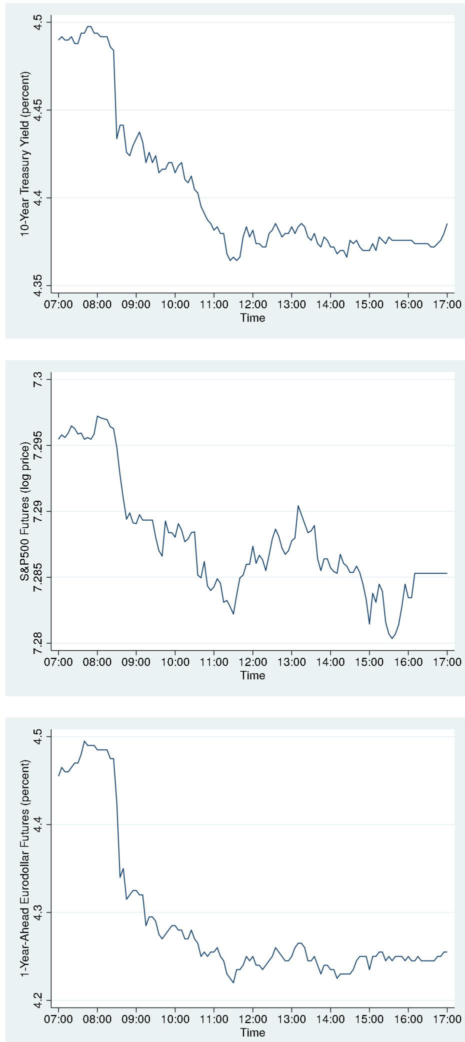

Figure 2. Macroeconomic News Surprises

Notes: This figure shows the evolution of 10-year Treasury yields, S&P 500 futures prices, and year-ahead Eurodollar futures during September 7, 2007, the date of the August 2007 Employment Situation release (release occurred at 8:30 a.m.).

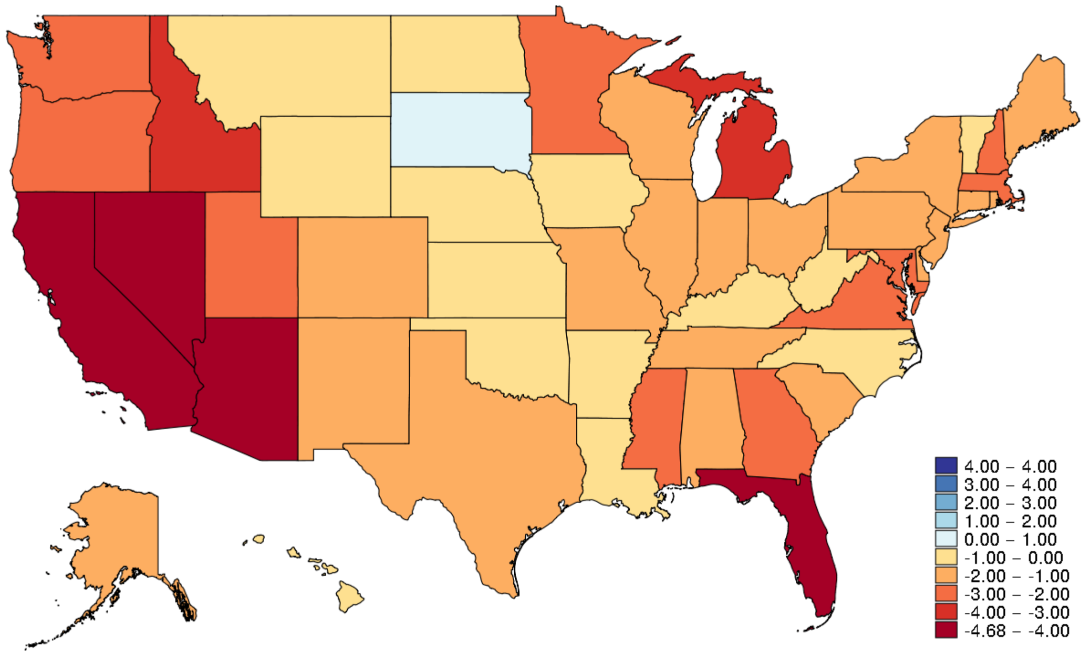

FIGURE 3. State-Level Elasticity Estimates

Notes: This figure shows estimated interest rate elasticities of house prices for each state.

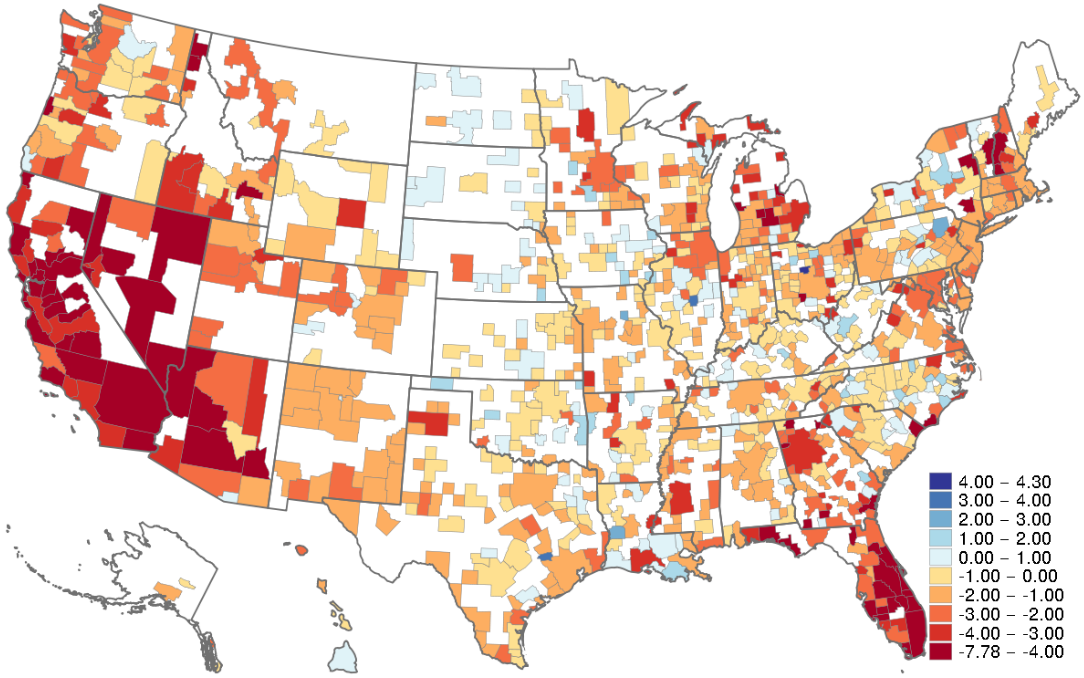

FIGURE 4. Metro and Micro Area Elasticity Estimates

Notes: This figure shows estimated interest rate elasticities of house prices for each metro and micro area.

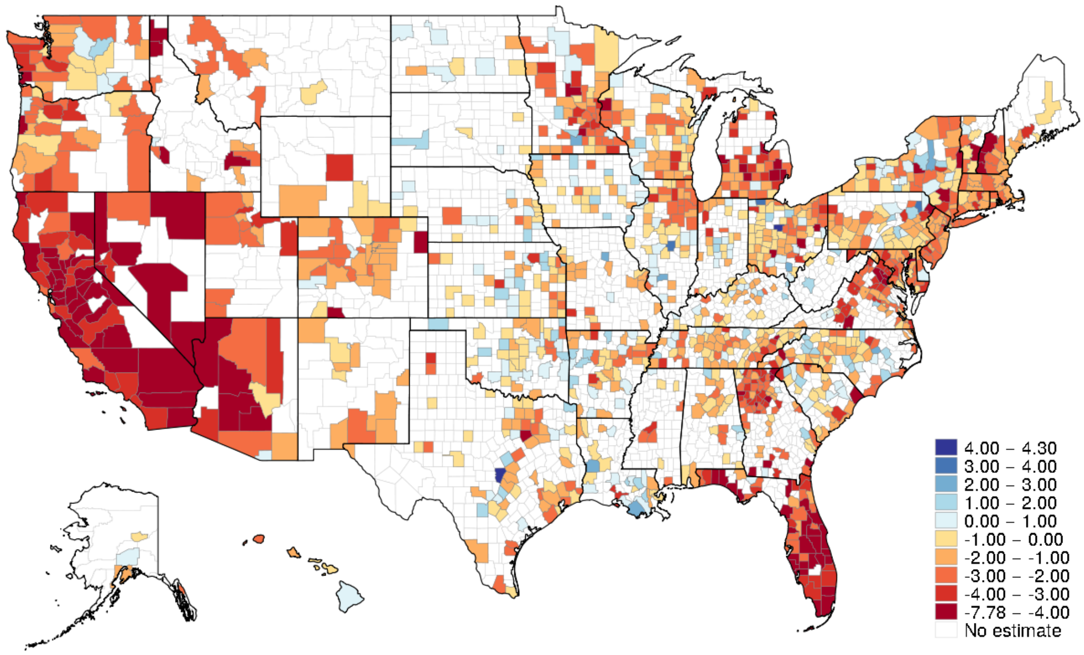

Figure 5. County-Level Elasticity Estimates

Notes: This figure shows estimated interest rate elasticities of house prices for each county.

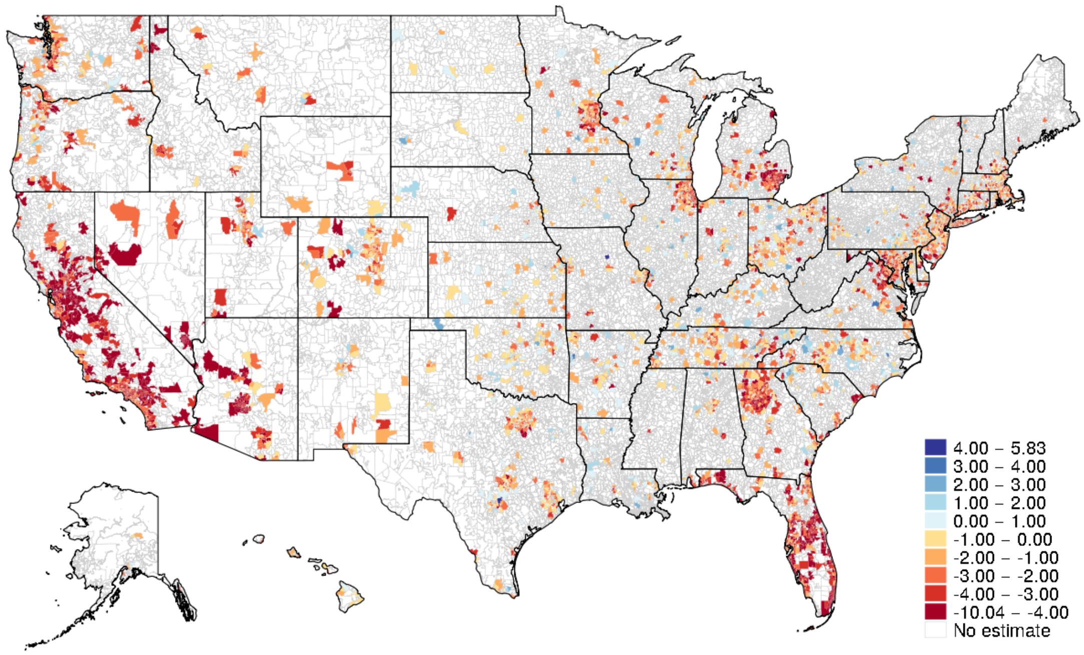

FIGURE 6. ZIP-Level

Notes: This figure shows estimated interest rate elasticities of house prices for each ZIP.

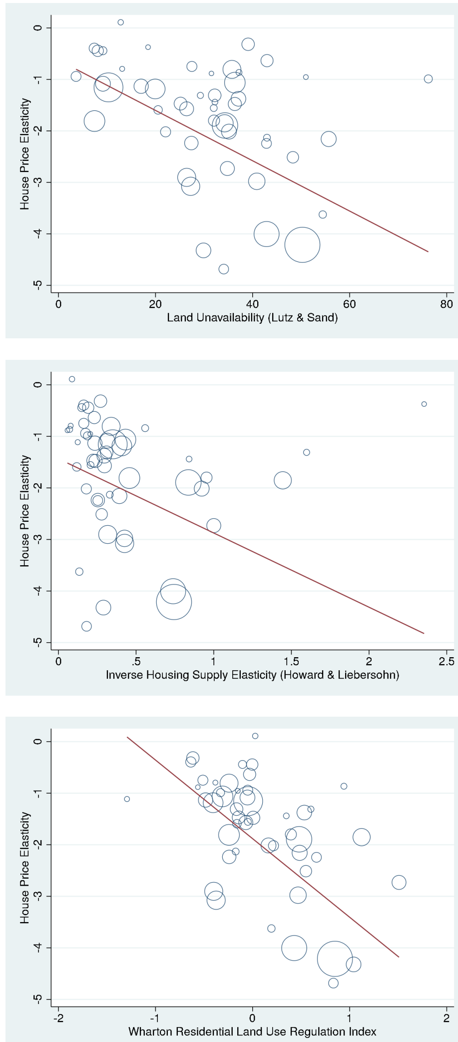

Figure 7. Comparisons Across States

Notes: The top panel shows the relationship between Lutz and Sand's (2017) land unavailability measures and estimates of the interest rate elasticity of house prices (R-squared value is 0.316). The middle panel shows the relationship between Howard and Liebersohn's (2018) inverse housing supply elasticity and estimates of the interest rate elasticity of house prices (R-squared value is 0.126). The bottom panel shows the relationships between Gyourko, Hartley, and Krimmel's (2019) Wharton Residential Land Use Regulation Index and estimates of the interest rate elasticity of house prices (R-squared value is 0.404). The area of each bubble is proportional to each state's population.

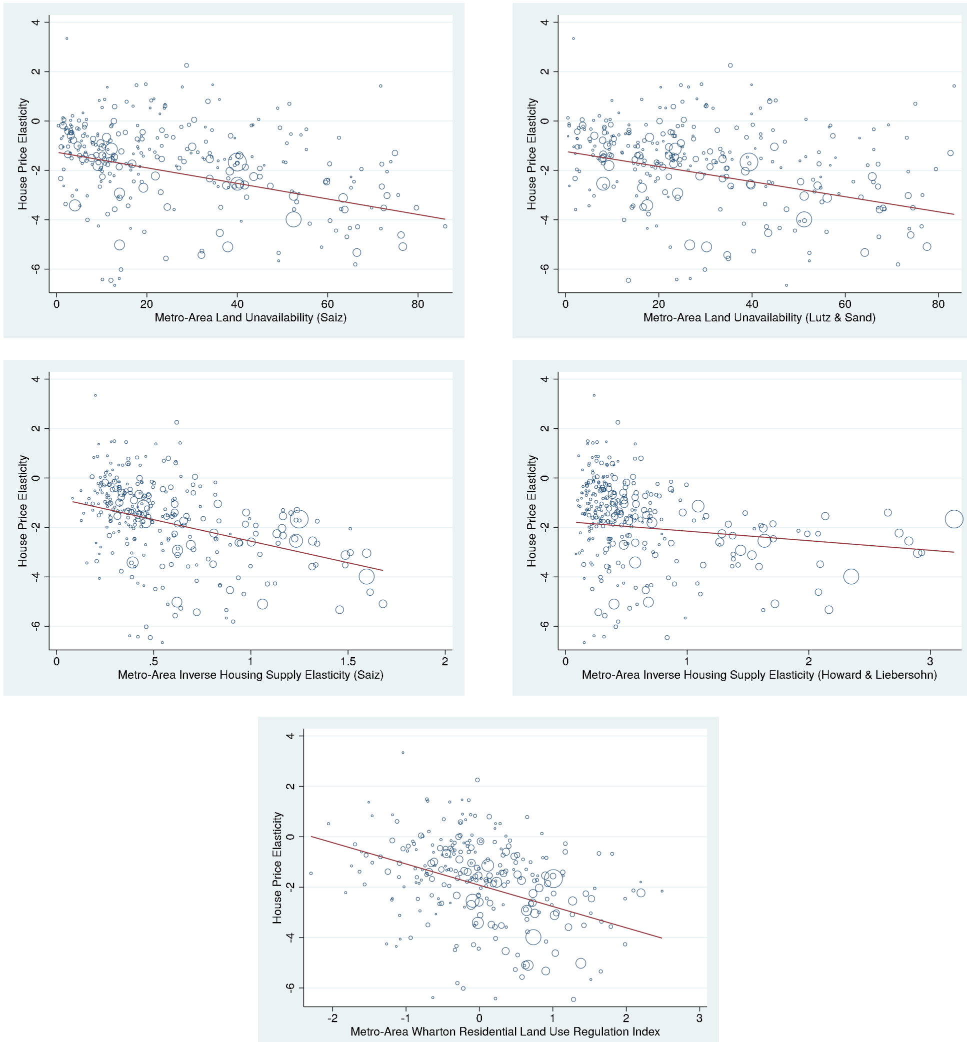

Figure 8. Comparisons Across Metropolitan Areas

Notes: The top two panels show the relationships between land unavailability measures (Saiz, 2010, on the left; Lutz and Sand, 2017, on the right) and estimates of the interest rate elasticity of house prices (R-squared values are 0.192 and 0.156, respectively). The middle two panels show the relationships between housing supply elasticities (Saiz, 2010, on the left; Howard and Liebersohn, 2018, on the right) and estimates of the interest rate elasticity of house prices (R-squared values are 0.235 and 0.052, respectively). The bottom panel shows the relationship between the WRLURI (Gyourko, Hartley, and Krimmel, 2019) and estimates of the interest rate elasticity of house prices (R-squared value is 0.165). The area of each bubble is proportional to each metro-area's population.

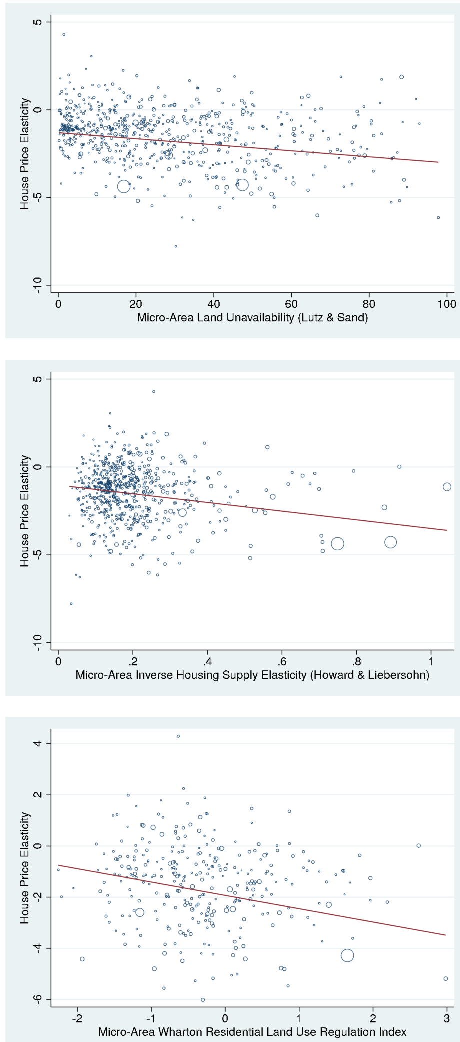

FIGURE 9. Comparisons Across Micropolitan Areas

Notes: The top panel shows the relationship between land unavailability measures (Saiz, 2010) and estimates of the interest rate elasticity of house prices (R-squared value is 0.046). The middle panel shows the relationship between housing supply elasticities (Howard and Liebersohn, 2018) and estimates of the interest rate elasticity of house prices (R-squared value is 0.127). The bottom panel shows the relationship between the WRLURI (Gyourko, Hartley, and Krimmel, 2019) and estimates of the interest rate elasticity of house prices (R-squared value is 0.091). The area of each bubble is proportional to each micro-area's population.

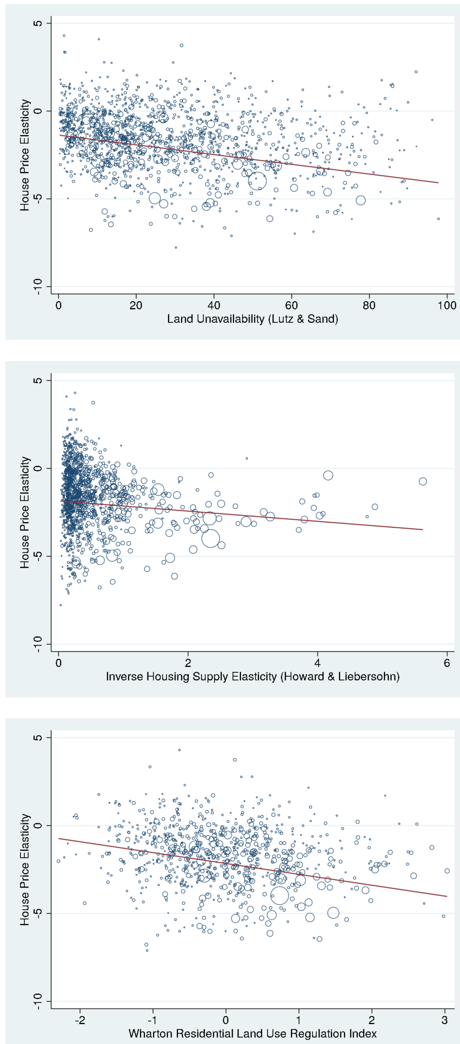

Figure 10. Comparisons Across Counties

Notes: The top panel shows the relationship between Lutz and Sand's (2017) land unavailability measures and estimates of the interest rate elasticity of house prices (R-squared value is 0.111). The middle panel shows the relationship between Howard and Liebersohn's (2018) inverse housing supply elasticity and estimates of the interest rate elasticity of house prices (R-squared value is 0.032). The bottom panel shows the relationships between Gyourko, Hartley, and Krimmel's (2019) Wharton Residential Land Use Regulation Index and estimates of the interest rate elasticity of house prices (R-squared value is 0.101). The area of each bubble is proportional to each county's population.

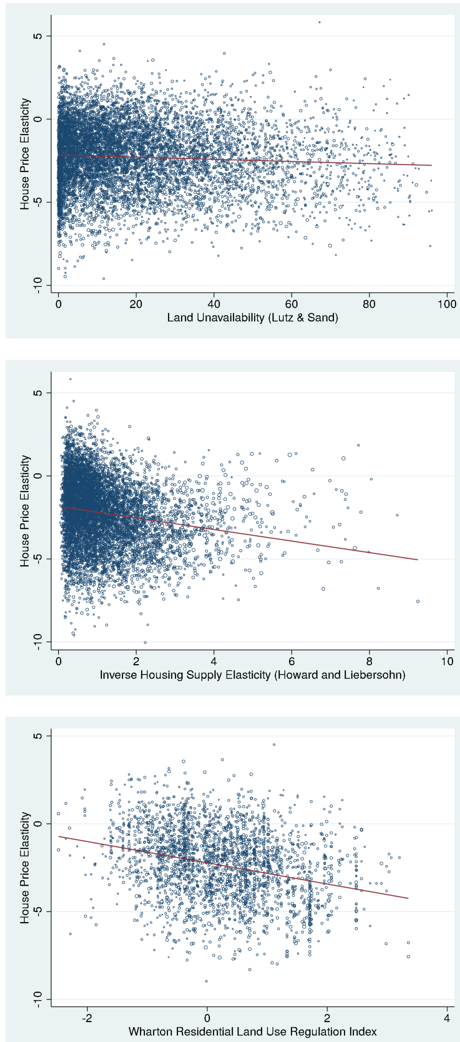

Figure 11. Comparisons Across ZIP

Notes: The top panel shows the relationship between Lutz and Sand's (2017) land unavailability measures and estimates of the interest rate elasticity of house prices (R-squared value is 0.003). The middle panel shows the relationship between Howard and Liebersohn's (2018) inverse housing supply elasticity and estimates of the interest rate elasticity of house prices (R-squared value is 0.039). The bottom panel shows the relationships between Gyourko, Hartley, and Krimmel's (2019) Wharton Residential Land Use Regulation Index and estimates of the interest rate elasticity of house prices (R-squared value is 0.081). The area of each bubble is proportional to each ZIP Code's population.

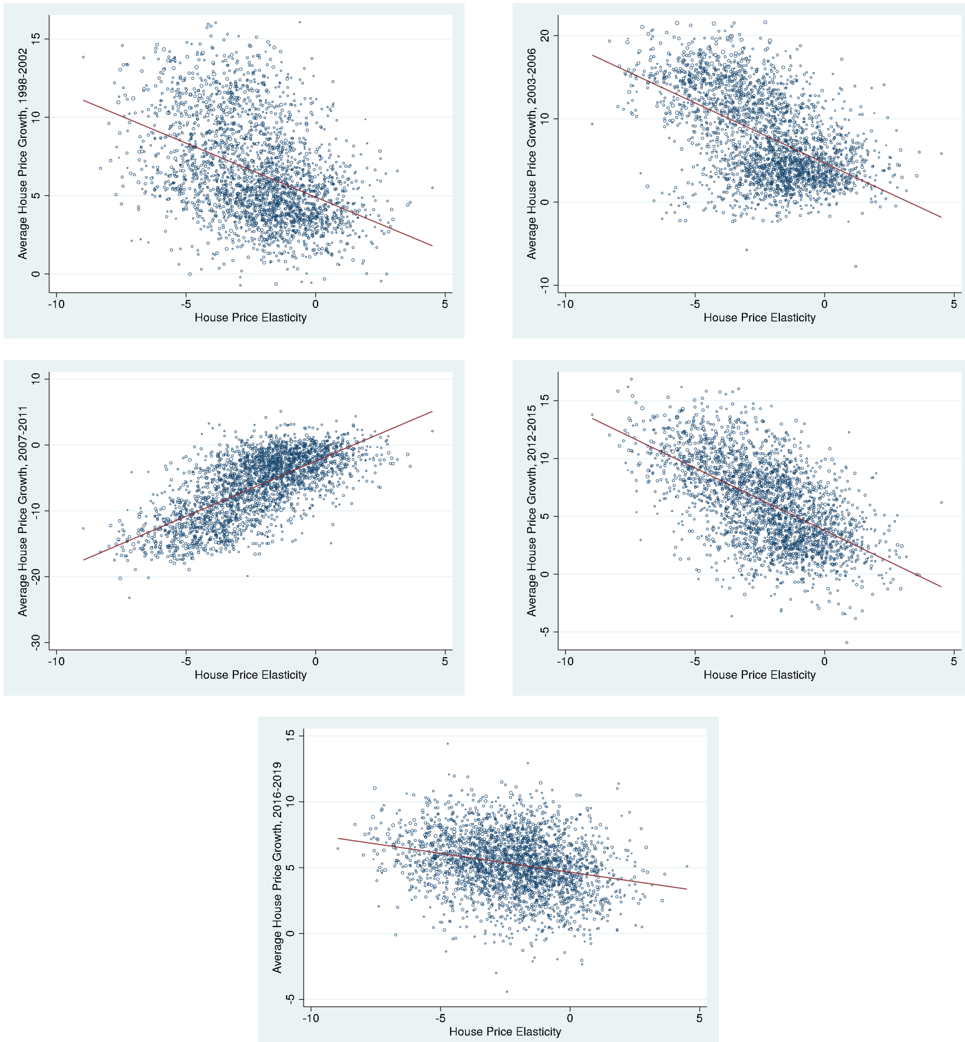

Figure 12. House Price Growth Over Time by ZIP

Notes: The top two panels show the relationships between estimates of the interest rate elasticity of house prices and average house price growth during the 1998–2002 and 2003–2006 periods (R-squared values are 0.184 and 0.350, respectively). The top two panels show the relationships between estimates of the interest rate elasticity of house prices and average house price growth during the 2007-2011 and 2012–2015 periods (R-squared values are 0.484 and 0.354, respectively). The bottom panel shows the relationship between estimates of the interest rate elasticity of house prices and average house price growth during the 2016–2019 period (R-squared value is 0.070). The area of each bubble is proportional to each ZIP Code's population.

Table 1. Descriptive Statistics

Variable	Unit	Mean	Std. Dev.	Minimum	Maximum
Δp_t	pct.	0.340	0.800	-2.466	1.972
Δr_t	pps.	-0.014	0.252	-1.045	0.885
Δr_t^w	pps.	-0.001	0.094	-0.319	0.430
Δr_t^m	pps.	-0.005	0.068	-0.512	0.198
Δr_t^o	pps.	-0.008	0.219	-1.046	0.701
u_t	pct.	5.749	1.806	3.310	10.557
Δu_t	pps.	-0.007	0.353	-0.907	1.353
c_t	pct.	9.491	3.847	4.567	16.773
Δc_t	pps.	-0.021	0.253	-1.145	0.644
Δy_t	pct.	0.362	0.734	-5.745	5.129
Δs_t^w	pps.	-0.082	1.347	-5.715	3.832
Δs_t^o	pps.	0.535	4.262	-15.367	10.400
Δm_t^w	pps.	-0.006	0.112	-0.435	0.475
Δm_t^o	pps.	-0.008	0.266	-1.604	2.046
Δz_t^m	pps.	-0.001	0.114	-0.518	0.351
Δz_t^p	pps.	0.002	0.154	-0.473	0.716
$(r_t^{10} - r_t^2)$	pps.	1.201	0.926	-0.474	2.813
Δq_t^m	\$bn.	5.356	23.349	-45.662	167.411
Δq_t^τ	\$bn.	6.577	22.757	-41.980	114.481

Sources for author's calculations: for house prices, CoreLogic; for interest rates, Bloomberg; for agency MBS yields, Barclays; for 30-year fixed-rate mortgages rates, Freddie Mac; for Mortgage Credit Availability Index, Urban Institute; for unemployment rates, Bureau of Labor Statistics.

Table 2. Macroeconomic News Releases

Release	Frequency	Source
Business inventories	Monthly	Census Bureau
Capacity utilization	Monthly	Federal Reserve Board
Chicago PMI	Monthly	ISM-Chicago
Construction spending	Monthly	Census Bureau
Consumer confidence	Monthly	The Conference Board
Consumer credit	Monthly	Federal Reserve Board
Consumer price index	Monthly	Bureau of Labor Statistics
Consumer price index (exc. F&E)	Monthly	Bureau of Labor Statistics
Durable goods orders	Monthly	Census Bureau
Employment cost index	Quarterly	Bureau of Labor Statistics
Existing home sales	Monthly	National Association of Realtors
Factory orders	Monthly	Census Bureau
Hourly earnings	Monthly	Bureau of Labor Statistics
Housing starts	Monthly	Census Bureau
Industrial production	Monthly	Federal Reserve Board
Initial jobless claims	Weekly	Department of Labor
ISM manufacturing PMI	Monthly	Institute for Supply Management
ISM nonmanufacturing NMI	Monthly	Institute for Supply Management
Leading economic indicators	Monthly	The Conference Board
Manufacturing payrolls	Monthly	Bureau of Labor Statistics
Michigan consumer sentiment (final)	Monthly	University of Michigan
Michigan consumer sentiment (prelim)	Monthly	University of Michigan
Net exports of goods and services	Monthly	Bureau of Economic Analysis
New home sales	Monthly	Census Bureau
Nonfarm payrolls	Monthly	Bureau of Labor Statistics
Personal consumption expenditure	Monthly	Bureau of Economic Analysis
Personal income	Monthly	Bureau of Economic Analysis
Philadelphia Fed business outlook	Monthly	Federal Reserve Bank of Philadelphia
Producer price index	Monthly	Bureau of Labor Statistics
Producer price index (exc. F&E)	Monthly	Bureau of Labor Statistics
Real GDP advance	Quarterly	Bureau of Economic Analysis
Retail sales	Monthly	Census Bureau
Retail sales (exc. autos)	Monthly	Census Bureau
Treasury budget	Monthly	Department of Treasury
Unemployment rate	Monthly	Bureau of Labor Statistics

TABLE 3. House Price Levels

Variable	(1)	(2)
r_t	-9.746***	-0.028
	(0.909)	(0.687)
u_t		-1.239***
		(0.241)
c_t		4.653***
		(0.169)
y_t		1.229***
		(0.032)
Constant	534.265***	-678.215***
	(5.327)	(31.998)
R-squared	0.318	0.937

Notes: Dependent variable is log house prices. Regressions include monthly indicator variables to capture seasonal variation. Standard errors in parentheses. ***, **, * denotes significance at the 1-, 5-, and 10-percent levels.

Table 4. Estimation Results

Variable	(1)	(2)	(3)	(4)	(5)	(6)
Δr_t	0.180					
	(0.177)					
$\Delta(r_t^w + r_t^m)$		-0.313				
		(0.364)				
Δr_t^w			-0.939**	-2.672***	-3.180***	-3.247***
			(0.469)	(0.842)	(0.818)	(0.807)
Δr_t^m			0.776	0.807	0.562	0.810
			(0.635)	(0.652)	(0.628)	(0.635)
Δr_t^o		0.334*	0.344*	0.245	0.233	0.154
		(0.202)	(0.201)	(0.261)	(0.251)	(0.249)
u_t					-0.106***	-0.141***
					(0.037)	(0.040)
Δu_t	-1.037***	-1.008***	-0.904***	-0.765***	-0.793***	-0.845***
	(0.261)	(0.261)	(0.264)	(0.267)	(0.258)	(0.255)
c_t					0.039***	0.040***
					(0.011)	(0.011)
Δc_t	0.813***	0.813***	0.829***	0.937***	0.801***	0.835***
	(0.173)	(0.173)	(0.172)	(0.177)	(0.173)	(0.170)
Δy_t	0.070	0.071	0.068	0.063	0.042	0.047
	(0.060)	(0.060)	(0.060)	(0.059)	(0.057)	(0.056)
Δs_t^w				0.047	0.055*	0.053
				(0.035)	(0.033)	(0.033)
Δs_t^o				0.019*	0.024**	0.021**
				(0.011)	(0.011)	(0.011)
Δm_t^w				1.411**	1.742***	1.846***
				(0.672)	(0.649)	(0.640)
Δm_t^o				0.108	0.119	0.146
				(0.181)	(0.175)	(0.173)
Δz_t^m				0.753*	0.833*	0.851**
				(0.454)	(0.436)	(0.431)
Δz_t^p				-0.272	-0.347	-0.373
				(0.349)	(0.335)	(0.330)
$(r_t^{10} - r_t^2)$				-0.046	0.169**	0.159**
				(0.046)	(0.073)	(0.072)
Δq_t^m						0.006***
						(0.002)
Δq_t^τ						0.001
						(0.002)
Constant	-0.120	-0.140	-0.133	-0.032	-0.067	0.108
	(0.157)	(0.157)	(0.156)	(0.165)	(0.251)	(0.256)
R-squared	0.306	0.312	0.324	0.362	0.417	0.440

Notes: Dependent variable is the change in log house prices (percent). Regressions include monthly indicator variables to capture seasonal variation. Standard errors in parentheses. ***, **, * denotes significance at the 1-, 5-, and 10-percent levels.

TABLE 5. Alternative House Prices

Variable	Jumbo	Conforming	Zillow	FHFA
Δr_t^w	-2.244***	-3.047***	-1.720***	-1.706***
	(0.526)	(0.795)	(0.451)	(0.622)
Δr_t^m	0.864**	0.743	0.552	-0.263
	(0.414)	(0.626)	(0.355)	(0.489)
Δr_t^o	0.153	0.098	0.175	-0.121
	(0.162)	(0.245)	(0.139)	(0.192)
u_t	-0.114***	-0.141***	-0.161***	-0.140***
	(0.026)	(0.039)	(0.022)	(0.031)
Δu_t	-0.830***	-0.831***	-0.625***	-0.436**
	(0.166)	(0.251)	(0.143)	(0.197)
c_t	0.050***	0.034***	0.025***	0.017**
	(0.007)	(0.011)	(0.006)	(0.009)
Δc_t	0.484***	0.817***	0.363***	0.334**
	(0.111)	(0.168)	(0.095)	(0.131)
Δy_t	0.036	0.048	0.003	0.005
	(0.037)	(0.055)	(0.031)	(0.043)
Δs_t^w	0.025	0.054	0.039**	0.016
	(0.021)	(0.032)	(0.018)	(0.025)
Δs_t^o	0.007	0.022**	0.009	0.022***
	(0.007)	(0.011)	(0.006)	(0.008)
Δm_t^w	1.327***	1.786***	1.148***	0.894*
	(0.417)	(0.630)	(0.357)	(0.492)
Δm_t^o	0.051	0.138	0.103	0.032
	(0.113)	(0.170)	(0.096)	(0.133)
Δz_t^m	0.720**	0.750*	0.432*	0.112
	(0.281)	(0.425)	(0.241)	(0.332)
Δz_t^p	-0.153	-0.355	-0.099	-0.558**
	(0.215)	(0.325)	(0.185)	(0.254)
$(r_t^{10} - r_t^2)$	0.113**	0.139**	0.138**	0.118**
	(0.047)	(0.071)	(0.040)	(0.055)
Δq_t^m	0.003**	0.006**	0.003***	0.002
	(0.001)	(0.002)	(0.001)	(0.002)
Δq_t^τ	0.001	0.001	-0.003**	-0.001
	(0.001)	(0.002)	(0.001)	(0.002)
Constant	0.434**	0.237	0.825***	0.452**
	(0.167)	(0.252)	(0.143)	(0.197)
R-squared	0.527	0.409	0.469	0.532

Notes: Dependent variable is the change in log house prices (percent). Regressions include monthly indicator variables to capture seasonal variation. Standard errors in parentheses. ***, **, * denotes significance at the 1-, 5-, and 10-percent levels.

TABLE 6. Selected State Results

Variable	California	Florida	Arizona	Nevada	Michigan
Δr_t^w	-4.213***	-4.004***	-4.321***	-4.685***	-3.077***
	(1.089)	(1.040)	(1.223)	(1.277)	(0.885)
Δr_t^m	1.499*	0.884	1.685*	2.365**	1.682**
	(0.855)	(0.820)	(0.954)	(0.990)	(0.699)
Δr_t^o	0.208	0.290	0.285	0.334	0.233
	(0.336)	(0.322)	(0.378)	(0.389)	(0.275)
u_t	-0.099***	-0.182***	-0.022	-0.123***	-0.178***
	(0.036)	(0.038)	(0.056)	(0.034)	(0.026)
Δu_t	-1.641***	-1.762***	-1.786***	-3.537***	-0.073
	(0.302)	(0.285)	(0.351)	(0.415)	(0.143)
c_t	0.054***	0.053***	0.047***	0.031	-0.036***
	(0.015)	(0.015)	(0.018)	(0.019)	(0.012)
Δc_t	0.995***	0.956***	1.086***	0.651**	0.829***
	(0.231)	(0.222)	(0.254)	(0.272)	(0.192)
Δy_t	0.046	0.024	0.031	-0.126	0.031
	(0.076)	(0.073)	(0.085)	(0.089)	(0.062)
Δs_t^w	0.077*	0.105**	0.076	0.082	0.045
	(0.044)	(0.043)	(0.050)	(0.052)	(0.036)
Δs_t^o	0.028*	0.020	0.038**	0.036**	0.021*
	(0.014)	(0.014)	(0.016)	(0.017)	(0.012)
Δm_t^w	2.284***	2.336***	3.023***	3.147***	1.684**
	(0.861)	(0.825)	(0.964)	(1.008)	(0.704)
Δm_t^o	0.193	0.188	0.316	0.227	0.129
	(0.232)	(0.224)	(0.260)	(0.270)	(0.191)
Δz_t^m	0.902	1.016*	0.868	0.830	1.039**
	(0.581)	(0.557)	(0.652)	(0.682)	(0.478)
Δz_t^p	-0.537	-0.365	-0.314	-0.330	-0.163
	(0.445)	(0.426)	(0.498)	(0.515)	(0.364)
$(r_t^{10} - r_t^2)$	0.263***	0.336***	-0.044	0.505***	0.192***
	(0.091)	(0.090)	(0.106)	(0.101)	(0.074)
Δq_t^m	0.009***	0.003	0.002	0.004	0.008***
	(0.003)	(0.003)	(0.003)	(0.003)	(0.002)
Δq_t^τ	-0.002	0.001	-0.003	-0.011***	0.006***
	(0.003)	(0.003)	(0.003)	(0.003)	(0.002)
Constant	-0.318	-0.154	-0.328	0.302	0.742**
	(0.332)	(0.318)	(0.418)	(0.382)	(0.239)
R-squared	0.431	0.445	0.338	0.477	0.546

Notes: Dependent variable is the change in log house prices (percent). Regressions include monthly indicator variables to capture seasonal variation. Standard errors in parentheses. ***, **, * denotes significance at the 1-, 5-, and 10-percent levels.

TABLE 7. Comparison Across Housing Supply Measures

Variable	State	Metro	Metro	Micro	County	ZIP
Land unavailability						
Lutz-Sand	-0.027 **	-0.021 ***		-0.020 ***	-0.023 ***	-0.005 **
	(0.011)	(0.005)		(0.004)	(0.003)	(0.002)
Saiz			-0.006			
			(0.007)			
Housing supply elasticity						
Inverse Howard-Liebersohn	0.183	0.052		-1.846 ***	-0.219 ***	-0.426 ***
	(0.600)	(0.114)		(0.561)	(0.071)	(0.037)
Inverse Saiz			-1.096 ***			
			(0.378)			
Land-use regulation						
WRLURI	-1.208 ***	-0.636 ***	-0.460 ***	-0.091	-0.308 ***	-0.270 ***
	(0.383)	(0.145)	(0.126)	(0.132)	(0.077)	(0.049)
Constant	-1.208 ***	-1.393 ***	-0.974 ***	-0.625 ***	-1.299 ***	-1.580 ***
	(0.434)	(0.177)	(0.179)	(0.245)	(0.117)	(0.075)
R-squared	0.475	0.224	0.283	0.186	0.184	0.126
No. observations	48	259	259	308	782	2,618

Notes: Dependent variable is the estimated elasticity (percent). Standard errors in parentheses. ***, **, * denotes significance at the 1-, 5-, and 10-percent levels.

Table 8. Comparison Across Housing Supply Measures

Variable	State	Metro	Micro	County	ZIP
Land unavailability					
Lutz-Sand Slope	-0.025 **	-0.022 ***	-0.020 ***	-0.024 ***	-0.003
	(0.011)	(0.005)	(0.005)	(0.003)	(0.002)
Lutz-Sand Water	0.165	0.015	-0.034	0.003	0.004
	(0.094)	(0.016)	(0.025)	(0.009)	(0.006)
Lutz-Sand Wetland	-0.089 ***	-0.038 ***	-0.007	-0.035 ***	-0.025 ***
	(0.026)	(0.008)	(0.011)	(0.005)	(0.005)
Housing supply elasticity					
Inverse Howard-Liebersohn	-0.151	-0.102	-1.977 ***	-0.299 ***	-0.438 ***
	(0.725)	(0.132)	(0.623)	(0.078)	(0.037)
Land-use regulation					
WRLURI	-1.464 ***	-0.621 ***	-0.052	-0.300 ***	-0.270 ***
	(0.388)	(0.147)	(0.142)	(0.078)	(0.049)
Constant	-1.251 ***	-1.332 ***	-0.606 ***	-1.268 ***	-1.530 ***
	(0.413)	(0.177)	(0.249)	(0.117)	(0.076)
R-squared	0.550	0.246	0.191	0.195	0.132
No. observations	48	259	308	782	2,618

Notes: Dependent variable is the estimated elasticity (percent). Standard errors in parentheses. ***, **, * denotes significance at the 1-, 5-, and 10-percent levels.

Table 9. House Price Growth Over Time by ZIP

Variable	1998–2002	2003–2006	2007–2011	2012–2015	2016–2019
House Price Elasticity	-0.611 ***	-1.291 ***	1.614 ***	-0.986 ***	-0.264 ***
	(0.029)	(0.044)	(0.035)	(0.029)	(0.021)
Land unavailability	0.018 ***	0.044 ***	-0.004	-0.005	-0.007 ***
	(0.003)	(0.005)	(0.004)	(0.003)	(0.002)
WRLURI	0.560 ***	1.082 ***	-0.459 ***	0.718 ***	0.173 ***
	(0.062)	(0.094)	(0.075)	(0.062)	(0.045)
Constant	4.632 ***	4.022 ***	-2.395 ***	3.881 ***	4.784 **
	(0.101)	(0.154)	(0.123)	(0.102)	(0.075)
R-squared	0.221	0.350	0.492	0.386	0.077
No. observations	2,618	2,618	2,618	2,618	2,618

Notes: Dependent variable is the annualized change in log house prices (percent). Standard errors in parentheses. ***, **, * denotes significance at the 1-, 5-, and 10-percent levels.

TABLE 10. Extended Housing Market Results

Variable	Home sales	Existing home sales	New home sales	Housing starts
Δr_t^w	-0.485***	-0.454***	-0.707***	-0.732***
	(0.139)	(0.134)	(0.218)	(0.222)
Δr_t^m	0.066	0.050	0.166	0.263
	(0.109)	(0.106)	(0.171)	(0.175)
Δr_t^o	0.041	0.039	0.061	0.137**
	(0.043)	(0.041)	(0.067)	(0.069)
u_t	-0.062***	-0.050***	-0.166***	-0.161***
	(0.007)	(0.007)	(0.011)	(0.011)
Δu_t	-0.090**	0.090**	-0.071	-0.156**
	(0.044)	(0.043)	(0.069)	(0.071)
c_t	0.026***	0.019***	0.074***	0.074***
	(0.002)	(0.002)	(0.003)	(0.003)
Δc_t	0.094***	0.085***	0.143***	0.124***
	(0.029)	(0.028)	(0.046)	(0.047)
Δy_t	-0.005	-0.004	-0.012	0.006
	(0.010)	(0.009)	(0.015)	(0.015)
Δs_t^w	0.015**	0.013**	0.023***	0.027***
	(0.006)	(0.005)	(0.009)	(0.009)
Δs_t^o	0.003*	0.003	0.007**	0.010***
	(0.002)	(0.002)	(0.003)	(0.003)
Δm_t^w	0.317***	0.312***	0.361**	0.404**
	(0.110)	(0.106)	(0.172)	(0.176)
Δm_t^o	0.037	0.043	-0.001	-0.004
	(0.030)	(0.029)	(0.047)	(0.048)
Δz_t^m	0.075	0.078	0.049	0.304**
	(0.074)	(0.072)	(0.116)	(0.119)
Δz_t^p	-0.050	-0.043	-0.094	-0.011
	(0.057)	(0.055)	(0.090)	(0.092)
$(r_t^{10} - r_t^2)$	0.078***	0.069***	0.145***	0.127***
	(0.012)	(0.012)	(0.019)	(0.020)
Δq_t^m	0.001	0.001	0.001	0.001
	(0.001)	(0.001)	(0.001)	(0.001)
Δq_t^τ	-0.001**	-0.001**	-0.002***	-0.002***
	(0.001)	(0.001)	(0.001)	(0.001)
Constant	15.503***	15.381***	13.417***	13.719***
	(0.045)	(0.044)	(0.071)	(0.072)
R-squared	0.664	0.552	0.867	0.863

Notes: Dependent variable is the log of home sales or the log of housing starts. Regressions include monthly indicator variables to capture seasonal variation. Standard errors in parentheses. ***, **, * denotes significance at the 1-, 5-, and 10-percent levels.

Appendix A. Decomposing Surprise Changes in Interest Rates

Not all of the change in interest rates observed within the macroeconomic news window is necessarily a pure surprise (perhaps households can anticipate future changes in interest rates because they more directly observe contemporaneous economic conditions). We therefore decompose changes in interest rates occurring within macroeconomic news windows into pure "surprise" and "expected" components. Consider again the nonfarm payrolls component of the August employment report released on September 7, 2007 at 8:30 a.m. The market had priced in a median expectation of 113,000 jobs added. But the employment report revealed 4,000 jobs lost, a forecast error of 117,000 (-1.14 standard deviations). Recall that within minutes of the employment report's release, 10-year Treasury yields declined about 5 basis points, S&P 500 futures prices declined 0.6 percent, and year-ahead monetary policy expectations declined over 15 basis points (Figure 2). Some of the change in asset prices might be forecastable: If one could anticipate the a forecast error (or even the direction of the forecast error), one could form an expectation on the expected change in interest rates. Any change in interest rates beyond that expected is a pure surprise to both the market and households. Keep in mind that even though the market observed a large negative surprise, housing demand already reflected the actual jobs data.

We take the realized forecast errors for 35 macroeconomic news releases listed in Table 2 for the October 1991 through December 2019 period and standardize them to have zero mean and unit variance. We then regress the change in interest rates observed during macroeconomic news windows on these standardized forecast errors.[13] Table A1 shows the estimation results.[14] Not all macroeconomic news surprises are treated equal. Some, such as the change in nonfarm payrolls and ISM Manufacturing, have larger effects on asset prices than others; some do not seem to move markets at all. We use these estimates to calculate what changes in interest rates were justified given the forecast errors observed for all 35 macroeconomic news releases we track. That is, we compute the "expected" change in interest rates conditional on the forecast error (Δr_t^e), and the residual which forms the basis for the pure "surprise" change in interest rates (Δr_t^s). This pure surprise component should not be forecastable by households, so this is a pure surprise change in interest rates and should have an effect on housing demand and therefore house prices.

Figure A1 shows the relationship between surprises in nonfarm payrolls and changes in interest rates occurring during macroeconomic news windows. As shown, negative surprises tend to reduce interest rates (as they convey negative news), while positive surprises tend to increase interest rates (they convey positive news). 40 percent of the changes in interest rate are forecastable given the forecast error in nonfarm payrolls. In April 1994, the market observed a $+2\sigma$ surprise to the nonfarm payrolls release and interest rates rose 17 basis points. This increase in interest rates was larger than expected given the $+2\sigma$ surprise, resulting in a pure surprise increase in interest rates of about 6 basis points. In August 2004, the market observed a 2σ surprise to the nonfarm payrolls release and interest rates fell 21 basis points. This decline in interest rates was also larger than expected, resulting in a pure surprise decline in interest rates of about 12 basis points. We also show the September 2007 even for reference, in which the market observed a $-\sigma$ surprise to the nonfarm payrolls release and interest rates declined about 5 basis points. This latter decline in interest rates was close to what was expected, resulting in little pure surprise change in interest rates.

[13]We aggregate up to macroeconomic news release times in order to test the joint effects of overlapping news releases.

[14]In the main regression, we use all data from 1991–2019. We also report results using 3-year rolling regressions for each macroeconomic release (imposes a three-year look-back period).

After calculating the pure surprise component of interest rate changes occurring during each macroeconomic news window, we aggregate these up to the monthly level. Table A3 shows what macroeconomic news was released during September 2007, median expectations for those news releases, the standardized forecast error, and the expected and actual changes in 10-year Treasury yields from 5 minutes before the release to 25 minutes after each release. Macroeconomic news tended to be fairly negative during the month, but interest rates did not fall as much as the market might have expected, leading to a large and positive pure surprise component to the interest rate changes observed during the month.

Figure A2 shows how the various interest rate components vary over time. At times, the pure surprise component can be very large, while at other times the monetary policy or expected components tend to be more dominant. Early on in the financial crisis, the pure surprise component tended to be large and positive, possibly creating an extra drag on housing demand and putting downward pressure on house prices. Table A2 provides descriptive statistics for the various interest rate components during the 1998–2019 period.

Table A4 shows the estimation results of the change in log house prices on the set of variables used throughout our analysis, but separating the interest rate changes observed during macroeconomic news windows into their pure surprise and expected components. Pure surprise changes and expected changes in interest rates occurring within macroeconomic news windows both have strong, statistically significant negative relationships with changes in house prices. What is interesting is that separating out the two effects has little effect on our elasticity estimates. This could be viewed as evidence that households anticipate neither the pure surprise nor the "expected" components of interest rate changes—both tend to affect changes in house prices equally. A simple F-test cannot reject the null hypothesis that the coefficients on Δr_t^s and Δr_t^e are equal (and equal to that from Δr_t^w). Thus, households do not anticipate future changes in interest rates, as the coefficients on the expected and surprise components are equal. That is, interest rate changes observed during macroeconomic news release windows seem to be exogenous to households.

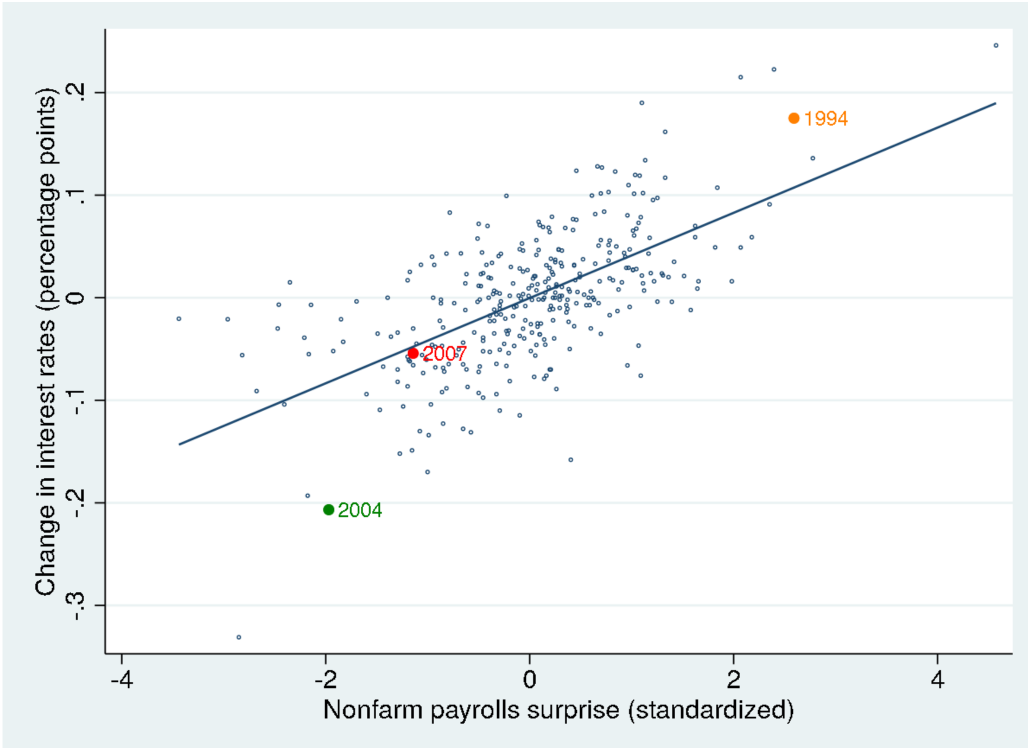

Figure A1. Macroeconomic News Surprises and Interest Rate Changes

Notes: This figure shows the relationship between surprises (normalized forecast errors) from the nonfarm payrolls release and changes in interest rates occurring during the macroeconomic news windows (5 minutes before the release to 25 minutes after each release). Highlighted data points correspond to April 1994, August 2004, and September 2007.

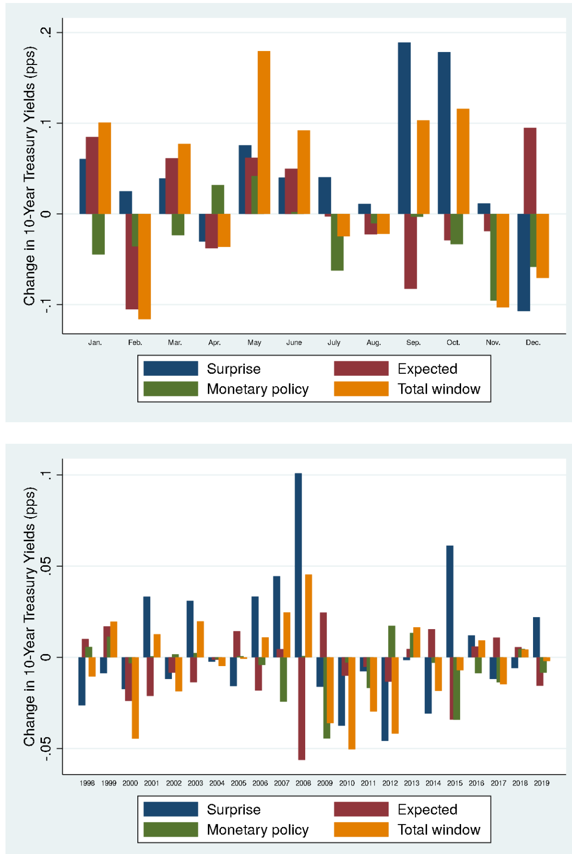

FIGURE A2. Macroeconomic News Surprises and Interest Rate Changes

Notes: Top panel shows the components of monthly interest rate changes during 2007. Bottom panel shows the components of annual interest rates changes during the 1998–2019 period.

TABLE A1. Macroeconomic News Releases and Treasury Yields

Variable	Estimate	Variable	Estimate
Business inventories	0.087	Leading economic indicators	0.190 *
	(0.113)		(0.113)
Capacity utilization	0.441 ***	Manufacturing payrolls	0.081
	(0.175)		(0.121)
Chicago PMI	0.982 ***	Michigan consumer sentiment (final)	0.053
	(0.125)		(0.113)
Construction spending	0.037	Michigan consumer sentiment (prelim)	0.245
	(0.113)		(0.227)
Consumer confidence	0.970 ***	Net exports of goods & services	0.242 **
	(0.113)		(0.113)
Consumer credit	0.052	New home sales	0.742 ***
	(0.113)		(0.113)
Consumer price index	0.165	Nonfarm payrolls	4.204 ***
	(0.135)		(0.118)
Consumer price index (xFE)	1.226 ***	Personal consumption expenditure	0.164
	(0.135)		(0.113)
Durable good orders	0.662 ***	Personal income	0.029
	(0.113)		(0.113)
Employment cost index	0.955 ***	Philly Fed business outlook	0.410 ***
	(0.203)		(0.126)
Existing home sales	0.432 ***	Producer price index	0.350 **
	(0.151)		(0.128)
Factory orders	0.195 *	Producer price index (xFE)	0.843 ***
	(0.113)		(0.127)
Hourly earnings	1.533 ***	Real GDP advance	1.129 ***
	(0.117)		(0.197)
Housing starts	0.320 ***	Retail sales	0.507 ***
	(0.113)		(0.160)
Industrial production	0.017	Retail sales exc. autos	0.923 ***
	(0.175)		(0.161)
Initial jobless claims	-0.565 ***	Treasury budget	-0.015
	(0.054)		(0.113)
ISM manufacturing	2.028 ***	Unemployment rate	-0.955 ***
	(0.113)		(0.114)
ISM nonmanufacturing	0.710 ***	Constant	-0.018
	(0.151)		(0.024)
		R-squared	0.274

Notes: Dependent variable is the change in 10-year Treasury rates (basis points). Changes measured from 5 minutes before to 25 minutes after macroeconomic news release. Independent variables are normalized surprise macroeconomic news: actual macroeconomic release less expected macroeconomic release. Standard errors in parentheses. ***, **, * denotes significance at the 1-, 5-, and 10-percent levels.

TABLE A2. Descriptive Statistics

Variable	Unit	Mean	Std. Dev.	Minimum	Maximum
Δr_t	pps.	-0.014	0.252	-1.045	0.885
Δr_t^w	pps.	-0.001	0.094	-0.319	0.430
Δr_t^m	pps.	-0.005	0.068	-0.512	0.198
Δr_t^o	pps.	-0.008	0.219	-1.046	0.701
Δr_t^s	pps.	0.005	0.092	-0.216	0.341
Δr_t^e	pps.	-0.005	0.064	-0.208	0.214

Table A3. Macroeconomic News Effects on 10-Year Treasury Yields

			Macroeconomic News Release			10-year Treasury Yields	
Date	Time	Macroeconomic News	Median Expectation	Actual Value	Surprise (σ)	Predicted Change	Actual Change
Sep. 4	10:00	Construction	0.00	-0.36	-0.30	-0.16	1.36
		ISM manufacturing	53.0	52.9	-0.06		
Sept. 6	8:30	Initial jobless claims	327	318	-0.51	0.27	-0.58
	10:00	ISM nonmanufacturing	55.8	55.8	0.01	-0.01	0.00
Sep. 7	8:30	Unemployment rate	4.60	4.64	0.53	-5.37	-5.42
		Nonfarm payrolls	113	-4	-1.14		
		Manufacturing payrolls	-10	-46	-1.58		
		Hourly earnings	0.30	0.29	0.05		
Sep. 10	15:00	Consumer credit	8.30	8.89	-0.31	-0.03	1.34
Sep. 11	8:30	Net exports	-59.00	-59.25	0.02	-0.01	1.34
Sep. 13	8:30	Initial jobless claims	325	319	-0.34	0.17	1.74
	14:00	Treasury budget	-70	-102	-3.10	0.03	-0.97
Sep. 14	8:30	Retail sales	0.50	0.28	-0.37	-1.36	-3.30
		Retail sales (exc. autos)	0.20	-0.36	-1.25		
	9:15	Capacity utilization	82.00	82.22	0.69	0.28	-0.97
		Industrial production	0.30	0.22	-0.17		
	10:00	Business inventories	0.30	0.41	0.41	0.02	3.30
Sep. 18	8:30	Producer price index	0.30	-1.37	-2.44	-0.50	1.56
		Producer price index (xF&E)	0.10	0.19	0.44		
	14:15	FOMC Statement		-0.50			-1.95
Sep. 19	8:30	Consumer price index	0.00	-0.14	-1.02	-0.76	1.75
		Consumer price index (xF&E)	0.20	0.15	-0.42		
		Housing starts	1.35	1.33	-0.21		
Sep. 20	8:30	Initial jobless claims	322	311	-0.62	0.34	2.36
	10:00	Leading economic indicators	-0.40	-0.65	-1.45	0.08	0.39
		Philly Fed business outlook	3.0	10.9	0.91		
Sep. 25	10:00	Consumer confidence	104.8	99.8	-1.03	-1.02	1.97
		Existing home sales	5.5	5.5	-0.02		
Sep. 26	8:30	Durable goods orders	-3.00	-4.86	-0.71	-0.49	3.17
Sep. 27	8:30	Initial jobless claims	316	298	-1.02	0.56	3.56
	10:00	New home sales	828	795	-0.67	-0.52	-1.38
Sep. 28	8:30	Personal consumption expenditure	0.40	0.56	0.85	0.11	0.00
		Personal income	0.40	0.34	-0.33		
	9:45	Chicago PMI	53.1	54.2	0.15	0.13	0.59
	10:00	Construction	-0.20	0.19	0.47	-0.02	-1.17
		Michigan survey	84.0	83.4	-0.31		
		Total monthly change					4.75
		Macroeconomic news					10.64
		Monetary policy news					-1.95
		Residual change					-3.94
		Macroeconomic news (expected)					-8.26
		Macroeconomic news (surprise)					18.90

Notes: Median expectations from Action Economics. Change in 10-year Treasury yields measured in basis points.

TABLE A4. Results

Variable	Baseline Model ($\Delta r_t^s + \Delta r_t^e$)	Full Model (Δr_t^s, Δr_t^e)
Δr_t^w	-3.247***	
	(0.807)	
Δr_t^s		-3.249***
		(0.809)
Δr_t^e		-3.032***
		(1.113)
Δr_t^m	0.810	0.810
	(0.635)	(0.637)
Δr_t^o	0.154	0.143
	(0.249)	(0.252)
u_t	-0.141***	-0.142***
	(0.040)	(0.040)
Δu_t	-0.845***	-0.838***
	(0.255)	(0.257)
c_t	0.040***	0.040***
	(0.011)	(0.011)
Δc_t	0.835***	0.828***
	(0.170)	(0.172)
Δy_t	0.047	0.046
	(0.056)	(0.057)
Δs_t^w	0.053	0.052
	(0.033)	(0.033)
Δs_t^o	0.021**	0.021**
	(0.011)	(0.011)
Δm_t^w	1.836***	1.783***
	(0.640)	(0.668)
Δm_t^o	0.146	0.139
	(0.173)	(0.175)
Δz_t^m	0.851**	0.823*
	(0.431)	(0.443)
Δz_t^p	-0.373	-0.370
	(0.330)	(0.331)
$(r_t^{10} - r_t^2)$	0.159**	0.160**
	(0.072)	(0.072)
Δq_t^m	0.006***	0.006***
	(0.002)	(0.002)
Δq_t^τ	0.001	0.001
	(0.002)	(0.002)
Constant	0.108	0.107
	(0.256)	(0.257)
R-squared	0.440	0.440

Notes: Dependent variable is the change in log house prices (percent). Regressions include monthly indicator variables to capture seasonal variation. Standard errors in parentheses. ***, **, * denotes significance at the 1-, 5-, and 10-percent levels.

Appendix B. Variable Definitions

Table A5. Key to Variable Names

Variable	Description
Δp_t	Total change in (log) house prices
Δr_t	Total change in interest rate
Δr_t^w	Change in interest rate during macroeconomic news window
Δr_t^s	Pure surprise component of change in interest rate during macroeconomic news window
Δr_t^e	Expected change in interest rate, conditional on data surprise, during macroeconomic news window
Δr_t^m	Change in interest rate during monetary policy news window
Δr_t^o	Change in interest rate outside macroeconomic or monetary policy news windows
u_t	Unemployment rate
Δu_t	Change in unemployment rate
c_t	Mortgage credit availability
Δc_t	Change in mortgage credit availability
Δy_t	Change in (log) income
Δs_t^w	Change in S&P 500 during macroeconomic news window
Δs_t^o	Change in S&P 500 outside macroeconomic news window
Δm_t^w	Change in year-ahead Eurodollar futures during macroeconomic news window
Δm_t^o	Change in year-ahead Eurodollar futures outside macroeconomic news window
Δz_t^m	Change in MBS to Treasury spread
Δz_t^p	Change in mortgage rate to MBS spread
$(r_t^{10} - r_t^2)$	Slope of yield curve (10-year less 2-year)
Δq_t^m	Fed purchases of agency MBS
Δq_t^τ	Fed purchases of Treasury securities