Monetary Policy and the Housing Market: Evidence from National Microdata

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Abstract

When the Federal Open Market Committee (FOMC) makes monetary policy announcements, liquid markets tend to react immediately to both the direct change (or holding steady) of short term rates and expectations about the future path of monetary policy. In this paper, we examine the extent to which a much less liquid market, residential housing, responds to monetary policy announcements using a novel micro dataset that covers millions of individual property transactions nationally. Rather than using monthly or quarterly aggregated data, we use the underlying microdata obtained from Zillow ("ZTRAW" data set) that includes rich information on individual transactions as well as corresponding home characteristics for each property. Methodologically, transactions-intra-monthly data better exploits the timing of the announcements for cleaner identification, providing new insights into how monetary policy shocks affect a market that makes up a substantial portion of the economy, where interest rates are thought to play a key role. Empirically, we compare the effect of "surprise" announcements to "expected" announcements on home prices using a regression discontinuity design (RDD), finding that monetary policy surprises generally have a more potent, immediate impact on home prices. Further, we explore the effects of quantitative easing on this market, as well as geographical variation in home price response to monetary policy more generally.

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1. Introduction

The housing market plays a critical role in the U.S. economy and the business cycle more generally. Some have gone so far as to claim that "housing really is the business cycle," as Edward Leamer (2014) provocatively titled his recent article in the *Journal of Money, Credit, and Banking*. The U.S. experience during the Great Recession certainly conformed to this notion, as much of the fallout in the financial crisis stemmed directly from the housing sector and the corresponding bust near the end of the last decade. In response to these events, the Federal Reserve lowered its target rate (eventually to near zero) and pulled a variety of policy levers (e.g. quantitative easing, expansion of its term auction facility, etc.) in an attempt to limit the damage and aid in the economy's recovery. Hence, the purpose of this paper is to investigate the following: when the Fed has made these decisions, are key sectors like the housing market noticeably affected immediately, or are the effects felt with 'long and variable' lags?

There is ample evidence from financial markets that Federal Reserve policy announcements can have an immediate impact. Since 1994 the Federal Open Market Committee (FOMC) has systematically announced its policy decisions after scheduled meetings (usually at 2:15 p.m. ET), communicating their stance on monetary policy via their federal funds rate target and rationale/outlook. Financial markets react to these announcements quickly,[1] as evidenced by trading data from debt and equity markets where prices incorporate the stated policy target and whatever new information that has been communicated about the future path of monetary policy,

[1] On how market interest rates respond to the Fed, see, for example, Cook and Hahn (1989), Romer and Romer (2000), Kuttner (2001), Piazzesi (2002), as well as more recent work on how quantitative easing (QE) impacted rates, like Hancock and Passmore (2011), Swanson (2011), Wright (2012), Hamilton and Wu (2012), Christensen and Rudebusch (2012).

often within seconds or minutes of the release.[2] The financial economics literature has studied this extensively, leveraging high quality data from financial markets to investigate the Fed's impact, using announcements as "events" or shocks to the market.[3]

Unlike financial data, key housing data like the number of housing starts or national price indices generally come to policy-makers in monthly or quarterly aggregates and are released on regular schedules, with much of the intra-month variation concealed by the topline numbers. Because this data and other non-financial data are often only available to researchers at these coarse time intervals, an identical very short-term event study approach cannot be implemented effectively, and vector autoregression (VAR) analysis or other empirical approaches are often used to study monetary policy shocks on the real economy over longer periods of time. Milton Friedman and Anna Schwartz (1963) provide an example of an early, seminal case of empirically evaluating the effects of monetary policy on the economy using a long history of Federal Reserve policy actions. Based on their empirical work (which was complete by not yet in print at that point), Friedman (1961) famously concluded in a *Journal of Political Economy* piece that, "monetary actions affect economic conditions only after a lag that is both long and variable" (p. 447).

While a deep literature has reevaluated Friedman's claim since the 1960s,[4] it raises a relevant empirical question that, thanks to better data, we can explore in new ways: is there evidence that monetary policy can cause an *immediate* impact on key sectors of the real economy

[2] For examples on how Fed policy changes affect asset and equity markets, see Bernanke and Kuttner (2005), or more recently Kontonikas MacDonald, and Saggu (2013), Nakamura and Steinsson (2013), Lucca and Moench (2015), Johnson and Paye (2016), and Mueller, Tahbaz-Salehi, and Vedolion (2017).
[3] In addition to Fed announcements, there is also a large literature showing how financial markets respond quickly to macroeconomic news and other events, for example Barber and Odean (2007), Brenner, Pasquariello, and Subrahmanyam (2009), Lee (2011), and Bernile, Hu, and Tang (2016).
[4] See Ramey's (2016) survey of the empirical work since Friedman and Schwartz (1963), "Macroeconomic Shocks and their Propagation," in the *Handbook of Macroeconomics*.

like housing? Given that the housing market is generally not as liquid as other markets, especially financial markets, it is not obvious that the Fed's actions can be felt in this market very quickly; and, if there is any market that may be subject to "long and variable' lags it would be this one. Our goal is to evaluate this claim empirically using national (transaction-level) microdata, exploiting rich intra-month variation in home prices to determine whether policy decisions do in fact 'affect economic conditions only after a lag that is both long and variable.'

We employ a new data set initially compiled by Zillow ("ZTRAX" data set), which contains detailed information about hundreds of millions of real estate transactions spanning more than two decades across the United States. A key advantage of this kind of data is that we have a national sample of housing transactions that occur at a daily-level, which we can use to examine periods just before and just after a monetary policy announcement in the spirit of an event study framework. Indeed, announcements occur at various times throughout a given month (and sometimes within the same month), so strictly monthly-level data will likely suffer from substantial measurement error (where a late-month announcement may have a different impact on the following month(s) than an early month announcement). This measurement error could explain, at least in part, why researchers like Friedman and Schwartz (among numerous others since) may find limited evidence of an immediate impact on the real economy, supporting the 'long and variable' claim in a number of contexts. Methodologically, the coarseness of monthly and quarterly data also conceal important variation that is key for researchers to identify a given monetary shock; and, our aim is to exploit the intra-month variation in home prices that our data allows, more appropriately identifying the timing of the monetary policy shock.

We find that monetary policy decisions, in fact, can have an immediate impact on the national housing market, particularly when the rate changes are a surprise or, in the case of

quantitative easing, when the policy is oriented toward putting direct pressure on long-term rates. Specifically, we find that an unexpected rate cut resulted in a roughly 2 percent increase in home prices in the run up to the recession, and a larger effect during the housing bust and the beginning of the recession (2007 to 2008) at 2 to 5 percent. These effects were larger in the so-called "sand states" (Arizona, California, Florida, Nevada) that experienced a pronounced bubble prior to the recession, but experienced smaller effects during the recession and recovery. We find that expected rate changes may have affected home prices, but consistent with theory, the effect is generally much smaller and not statistically significant in all specifications. The more recent data suggests that the quantitative easing operations that were more concretely directed toward expanding the Fed's long-term securities portfolio, and Operation Twist more dramatically, were able to provide accommodative support to home prices during the recovery following the Great Recession. However, the evidence suggests that the Fed was most successful in stimulating the housing sector in the *non-sand* states, which were not nearly as adversely affected by the recession and housing bust. In particular, we find that home prices rose by roughly 1.5 percent in sand states following expansionary changes to quantitative easing, compared to 2.2 to 5.3 percent in non-sand states.

This study makes several contributions. First, the results suggest that home prices, despite being a less liquid market, can respond immediately to monetary policy shocks, both to traditional interest rate changes and to less conventional QE policies that targeted longer-term assets. This is consistent with recent literature that has shown that QE policies immediately moved real estate-related financial markets like mortgage backed securities (Hancock and Passmore, 2015), mortgage rates (Wang, 2016), and real estate investment trusts or REIT markets (Gabriel and Lutz, 2017)). At first the fact that the real sector is mirroring its financial

counterparts may appear banal; but, we note that financial markets often immediately capitalize expectations of 'long and variable' lags in sales for other markets (most notably in tech, where stock valuations often move well ahead of real sales on the ground). Hence, the immediate response from financial markets may not necessarily be indicative of a quick reaction from the corresponding real sector, which motivates much of our analysis here.

Second, using micro data, we apply methods from the applied microeconomics literature to answer this ostensibly macro question. As we alluded to above, much of the macro literature to this point has used monthly or quarterly aggregates to examine the effect of monetary policy on housing markets. The dominant empirical methodology is to use a VAR or some variation of this (e.g. factor-augmented VAR or FAVAR) that exploits aggregate variation over time. In some cases the studies focus on monetary policy's effect on the domestic housing market (e.g. Del Negro and Otrok [2007], Vargas-Silva [2008a], Vargas-Silva [2008b], Gupta and Kabundi [2010], McDonald and Stokes [2013], and Rahal [2016]), while others exploit international cross-sectional evidence using a similar methodology (e.g. Ahearne, Ammer, Doyle, Kole, and Martin [2005], Goodhart and Hofman [2008], Iacoviello and Minetti [2008], Bjørnland and Jacobsen [2010], Calza, Monacelli, and Stracca [2013], Eickmeier and Hofmann [2013], and Gambacorta, Hofmann, and Peersman [2014]). More specifically, we employ a simple regression discontinuity (RD) design where time is the running variable and the FOMC announcement is the "event" or day that identifies the discontinuity, where we measure the jump (or fall) in home prices and potential trend changes that directly correspond with the timing of a given monetary policy change.

Third, we further explore the role monetary policy played in the bubble, bust, and recovery by investigating whether decisions had different impacts among more bubbly, so-called

"sand states" as compared to the rest of the country. The data allows us to control for a rich set of property characteristics for each home, as well as location, which we also utilize to explore the extent to which monetary policy has heterogeneous effects across geography. If monetary policy alone was responsible for the bubble and bust in the U.S. housing market, then we might observe a consistently more dramatic impact of monetary policy on the sand states than elsewhere. In fact, the data shows that prior to the recession there was a slightly higher effect size for surprise rate cuts, however other types of monetary policy changes were relatively larger in non-sand states.

Finally, while the housing sector is a critical sector in its own right, there is a large literature that explores how housing wealth spills into economic activity of other sectors. For example, a change in housing wealth is often cited as a mechanism through which monetary policy can affect consumer spending and other aspects of the individual's balance sheet (e.g. Campbell and Cocco [2007], Attanasio, Blow, Hamilton, and Leicester [2009], Carroll, Otsuka, and Slacalek, [2011], Mian, Rao, K. and Sufi [2013]), Browning, Gørtz, and Leth-Petersen [2013]). A better understanding of house price dynamics in response to monetary policy, particularly in the short run, has broader implications the economy more generally.

2. Data

We use residential real estate microdata from ZTRAX, a dataset compiled by Zillow that contains transaction data as well as rich individual property characteristics for sales recorded from local tax assessment data. The coverage of this data is representative of the United States' national housing market, initially containing 374 million detailed records of transactions across

more than 2,750 counties,[5] which includes information on each home's sale price, closing date, mortgage information, foreclosure status, and other information commonly disclosed by a local tax assessor's office. We link this data with each home's property characteristics that Zillow also obtains from the local assessor's office, which typically includes the size of the home (in square feet), number of bedrooms and bathrooms, year built, and a variety of other characteristics of the home.[6] Because each locality may report certain data differently, it was a heroic effort on Zillow's part to compile and organize this massive amount of data, which we received in a somewhat raw form, requiring additional cleaning for research purposes.

We gave careful consideration to missing data and extreme values as part of our data cleaning and culling of outliers. The raw data contains sales of empty plots of land, some commercial property transactions, agricultural sales, and a host of types of properties that are not relevant for our analysis of the residential housing market. Therefore, we confine the sample to single family homes, townhouses, apartments, condos, and properties that are typical associated with the residential market. We cull the top five percent of the lot size distribution (cutting many large farms) and outlier homes that are on the upper tail of the distribution (i.e. they either have more than six bedrooms, more than five bathrooms, or have a garage that holds more than five cars).[7] After dropping homes that sold for one dollar, the bulk of which are not arms-length transactions, we cull the top and bottom five percent of the price distribution, calculated separately for each state year. We cull homes that were built prior to 1865 or report a negative

[5] We note that some states do not require mandatory disclosure of the sale price, so we have limited data for the following states currently: Idaho, Indiana, Kansas, Mississippi, Missouri, Montana, New Mexico, North Dakota, South Dakota, Texas, Utah, and Wyoming.
[6] Zillow's Ztrax data contains separate transaction and assessment files by state, where all transactions need to be linked to corresponding assessment records. With guidance from Zillow, we were able to merge the bulk of the data, but not without some data loss (which figures into the size of our final sample).
[7] We also create indicator variables equal to one if the property reported a lot size of zero or there are missing bedrooms or bathrooms.

age of home (i.e. sale year – year built). While the Zillow data set contains a vast number of property characteristics, in our initial analysis we primarily rely on the variables above that have the most coverage nationally so we limit how much data we would effectively have to throw away.[8]

Our final sample consists of approximately 54 million home sales that took place from 1996 through 2014. Since we are interested exclusively in transactions that took place in windows around monetary policy changes (which we discuss in more detail in the next section), our final sample is substantially smaller than our initial data set, even after culling for outliers. To ensure the quality of the final sample, we compared our Zillow sample to the U.S. Census American Community Survey (ACS) to ensure that this administrative data aligned with carefully collected (albeit more limited) survey data provided by the Census. Generally, we found that the limited set of characteristics of homes that were in both the ZTRAX data and the ACS are quite similar in terms of their summary statistics. In untabulated results, we find that the shared characteristics across data sets (number of rooms, bedrooms, year built, acreage, and tax amount) had variable median and mean values that fell within a few percentage points of one another.

In Table 1, we show summary statistics across relevant cuts of the data. First, we separate the sample by time periods, the 1996 to 2008 period where interest rates (IR) were the primary monetary policy tool, and the 2008 to 2014 period where quantitative easing (QE) was the primary policy tool. Second, we provide statistics for the full sample and what the housing literature (e.g. Davidoff [2013], Coulson and Greico [2013], Frame [2010]) has commonly referred to as "sand states" (Arizona, California, Florida, and Nevada) and "non-sand states,"

[8] In later draft, we plan conduct a sensitivity analysis that employs more property characteristics to determine whether the results are sensitive to omitted variables for which we can control.

where the former group of states were outliers in numerous respects. The sand states had most pronounced housing bubble and burst, with high rates of defaults and distressed sales. Because these states were somewhat unique in the magnitudes of their housing sector dynamics over the past two decades when compared to much of the rest of the country, we evaluate whether these states also responded to monetary policy much differently.

There are roughly 35 million observations in the IR sample and 19 million in the QE sample. The sales price in nominal dollars is slightly higher in the IR sample compared to the QE sample and higher in sand states in comparison to non-sand states. The average home in the dataset is roughly 1,750 square feet, sits on a quarter of an acre, has 2.35 bedrooms, and 1.66 bathrooms.

3. Methodology – Baseline RD Approach

We investigate the impact of monetary policy announcements on home prices following a research design that is similar to that used by Moulton, Waller, and Wentland (2017). The design consists of the combination of a hedonic sale price model and a standard linear spline RD model using the sale day as the running variable,[9] as seen in equation (1). More generally, hedonic regression analysis has been a commonly used methodology in the housing literature since Rosen (1974); but, more recently the approach has been increasingly coupled with a quasi-experimental framework (for a review, see Parmeter and Pope, 2013.).

$$ln(SalePrice_h) = \alpha + \beta_1(SaleDay_h - C) + \beta_2 \mathbf{1}(SaleDay_h \geq C)(SaleDay_h - C) + \beta_3 \mathbf{1}(SaleDay_h \geq C) + \beta' X_h + \varepsilon_h \quad (1)$$

[9] As our running variable is time, we acknowledge that it may be more precise to refer to this as interrupted time series (ITS). It is not uncommon to use time as a running variable, where the discontinuity is a point in time. See Hausman and Rapson (2017) who discuss RD using a time running variable generally.

Specifically, we use the logged sale price of house *h* as the outcome. We re-center the sale day trend around the appropriate cutoff (C) at the announcement day. The coefficient β_1 captures the sale price time trend prior to the cutoff. We also include this same re-centered trend interacted with an indicator variable equal to one when the sale day was at or past the announcement day cutoff. The coefficient β_2 represents the change in the post-cutoff price time trend, which can be used to determine if any price change following the announcement dissipates or grows over the post-cutoff window. The β_3 coefficient that is associated with an indicator variable equal to one when the sale day is after the announcement, estimates the difference in the pre- and post-cutoff trends' intercepts at the cutoff. This estimated intercept difference is interpreted as the treatment effect of the announcement, which is the key coefficient of interest and is labeled "Discontinuity" in the proceeding tables. X_h represents the following controls common to hedonic price regressions that account for observable characteristics of heterogeneous properties: square footage, number of bedrooms and bathrooms, size of garage (number of cars), logged acreage, whether the home is a single story ranch, has a pool, has a basement, sale day of the week fixed effects, indicators for no acreage, missing bedrooms or bathrooms, and FIPS county fixed effects.

Methodologically, the controls serve a number of purposes. We are comparing cross-sections of homes over time, and these homes are heterogeneous along a number of important dimensions. While aggregation across a large national data set may allay compositional concerns, controlling for arguably the most important determinants of a home's price (size, bedrooms, bathrooms, location, etc.) allows for a more straightforward apples-to-apples comparison of homes. Second, by controlling for these factors, the hedonic framework runs more congruently to the financial economics literature, which often examines the "excess return" of an

asset or group of assets within an event study framework. Hence, the estimated monetary policy announcement effect comes from the variation in price not explained by these factors.

Sales in the housing market can take a while. The time from initial offer to final sale is not immediate and may take weeks. However, negotiation takes place throughout the process due to home inspections and appraisals, where it is not unheard of for parties to make concessions right up through the 11th hour. As a result, for each home in our sample, we use the closing date as the date a given home transaction is finalized. However, we acknowledge that norms and stickiness of the negotiation process may mean that transactions just after a monetary policy announcement were likely set prior to the announcement. Our analysis addresses this aspect of the housing market through the usage of donut RD, where we drop the observations that are most likely to be highly influenced by the previous policy regime, creating a hole or "donut" in our regression discontinuity design near the discontinuity itself. Thus, we omit the first week of observations just after the announcement, as these are the most likely to fall into this category.[10]

In another variation of donut RD, we also omit the week prior to the announcement in an additional specification. One concern about a standard RD design is that the announcement is more likely to be anticipated by the market the closer it gets to the announcement date. This is particularly relevant for policy changes that are expected by the market, whereas an anticipated increase, for example, may start to be reflected by housing prices just prior to the increase actually occurring. So, we proceed by estimating three different RD specifications for each set of analysis for sensitivity and to address these concerns.

[10] In additional tests, we cut the second week, but the results tend not to be dramatically different. In later drafts, we intend to explore both optimal bandwidth and donut length.

To discern between expected and surprise announcements, we follow Kuttner (2001), Weber and Gorodnichenko (2016), and numerous other studies in the literature that use the extent to which the Federal Funds Rate (FFR) futures market anticipates (or is surprised by) the actual change in the FFR on the announcement date. We define the different types of shocks we examine below and Table 2 provides the Federal Reserve announcement dates for each of these classifications:

- *Surprise Cut*: Rate changes where more than 10 basis points of the rate cut was unexpected, although in many cases it was higher than this. Note that some of these changes also resulted in rate reductions greater than 25 basis points.
    - Prediction: Home prices should **rise** on this news, but it remains an empirical question whether it will take substantial time for the price to reflect this news since it was a surprise.
- *Expected Cut*: Rate cuts where 10 or less basis points of the change was unexpected.
    - Prediction: Rate cuts will lead prices to **rise**; however, it may not be discontinuous since rates may fall prior to the actual announcement, thus the estimated effect should be **more muted** than a surprise.
- *Large Expected Cut*: An expected rate cut, but one where the rate was reduced by more than 25 basis points (usually 50 bp).
    - Prediction: Home prices will **rise** by even more than the *Expected Decrease* classification, but given that these were often expected, the same muted effect is possible.
- *Surprise No Change*: These are instances where investors expected a rate hike, but the Federal Reserve made no change to the targeted rate.
    - Prediction: While seemingly passive, this policy may be quite accommodative. We expect that home prices will **rise** and this may follow a similar pattern to *Surprise Decrease*, given that this is effectively a surprise in a loose direction.
- *Expected Hike:* All target rate hikes were actually expected by investors, so all hikes are classified as expected.

    - Prediction: Home prices will **fall** as a result of these changes, however the price change may not be discontinuous as the change was expected, where the measured effect may be muted as a result.
- *QE – Long-Run Expansionary*: A quantitative easing announcement focused on explicitly and actionably increasing purchases of longer-term securities, from which we quote and classify in Table 3.
- *QE – Other*: A quantitative easing announcement that did not actionably increase the Fed's purchases of longer-term securities, or an announcement that may have simply continued/reduced prior policy. The classifications are shown in Table 3.

While the predictions above are for the target rate change alone, recall that the Fed's statement is more than just a single number release to the public. A monetary policy announcement typically consists of two portions: 1) the announcement of the target rate change (if any) and 2) rationale for the FOMC's decision, which often consists of general statements about the Fed's outlook on the current and future economy. With the latter, the Fed may also reveal information that gives the markets a sense of the path of future interest rates and policy actions in the coming months or year. Therefore, both β_2 and β_3 may capture some aspect of either of these policy mechanisms, depending on whether the impact on the housing market is a discrete jump (β_3) or a change in the trajectory of home prices over time (β_2). As a result, while we initially expect there to be a muted effect of an expected change, if the expected change is accompanied with a sense of the future path of policy, then we may observe a significant change in home prices (even when the announced target is fully anticipated). Because our primary research question concerns the immediate timing of monetary policy announcements, much of the proceeding analysis focuses on the coefficient estimates of the discontinuities.

Finally, at the end of 2008, when the FFR reached zero, the Fed explored other policy options. On November 25, 2008, the Federal Reserve announced that it would purchase "up to

$100 billion in GSE direction obligations, and up to $500 billion in mortgage backed securities (MBS)," a policy that came to be known as quantitative easing (or, in its first instance, QE1). While its policy target to this point had focused on the federal funds rate, which is a rate on very short-term debt obligations, the Fed turned to putting additional accommodative stimulus on still positive long term rates. Indeed, it is long-term rates that are most directly linked to the housing market, which was clearly the market in most distress to that point. Thus, we expect its announcements about expanding QE that specifically targeted the longer-term securities to have the most impact on the housing market.

In Table 3, we reproduce a table from Hancock and Passmore (2015) that cataloged all major QE announcements and communications from the Federal Reserve, and we identified the announcements that explicitly took action on expanding purchases of longer-term securities, classifying them as long term easing QE. We contrast this with other announcements, which were either less oriented toward action taken to reduce long-term rates or announced a tapering of the existing policy.

4. Results

4.1. Interest Rate Policy Changes – U.S. Housing Boom Period (1996 – 2006)

We begin by examining the results of the full sample over the period most closely associated with the housing boom in the United States, comparing the five changes across three different RD specifications (with the latter two being donut RD specifications discussed in the previous section). Table 4 summarizes the results, omitting the hedonic property characteristic controls for brevity. Overall, the results broadly align with our predictions; and, where some results deviate from initial expectations, they logically follow from methodological issues that

are addressed by the donut specifications. Our first result in Table 4, for example, shows that on average home prices seemed to fall immediately by 0.46% on the *surprise* announcement of a cut in the target FFR. Yet, it is clear from Figure 1A that the homes that closed during the week following the announcement naturally followed the pre-announcement trend. However, there is a clear jump in prices after the first week, as reflected by the donut RD results in regression (6) in Table 4, and is visible in Figure 1A. This amounts to approximately a 2% increase in home prices as a result of a surprise cut in rates, which is also consistent when we expand the size of the donut in regression (11) in Table 4 to exclude the observations a week prior to the announcement.

While there were only a couple instances of this in our sample, the housing market reacted strongly to accommodative indecision on the part of the FOMC, whereas on average home prices rose by about 2.35% in response to a *surprise* no change in interest rates when the market expected a rate hike, as shown by both regressions (4) and (14) in Table 4. When only the first week after the announcement is omitted, the effect is somewhat smaller, but still highly significant. Moreover, these surprises were generally accompanied by a substantial positive change in the post-trend. In both a surprise cut and a surprise no change, it is clear that housing markets respond quickly and the jump in prices is economically significant, suggesting these policy changes had immediate potency over this time period.

Table 2 and Figure 3 also show that *expected* cuts and hikes had generally small measurable effects, which were somewhat mixed across specifications. Because they were expected changes, where anticipatory effects were more binding, we suspect that panel C (which removes the observations for both the week before and week after the announcement) is likely the more credible specification for that reason. It shows that expected decreases had no

statistically significant effect on home prices, while expected increases had a small (0.66%) positive effect on prices. Large decreases in the market, while expected, had a 1-2% positive effect on home prices within the donut specifications. Although, for the full sample the evidence from the "eyeball test" reveals much weaker visual evidence for all types of announcements where the interest rate changes were expected, particularly when compared to the surprises where the jump is more visible.

4.2 Sand States vs. the Rest of the U.S. during the Boom (1996-2006)

The so-called sand states (Arizona, California, Florida, and Nevada) had primarily responded to surprise decreases by the FOMC, and there is little evidence that any of the other changes had a consistent impact on housing markets in these states during the boom period. In particular, Table 5 shows that the average surprise rate cut corresponded to a 1.4-3.29% immediate increase in home prices in the sand states during this period. If anything, some of the expected rate cut changes had an adverse effect on these markets according to the donut specifications, although the visual evidence from the panels in Figure 2 are all weak (whereas the surprise cut in Figure 2A appears to show a clear discontinuity in home prices).

The donut specifications in Table 6 show that monetary policy announcements had an immediate impact on non-sand states. Specifically, the both surprises (i.e. cut and no change) and the large expected decreases showed significant positive jumps in home prices, whereas specifications for the other announcements appear more mixed (as the visual evidence confirms in the panels from Figure 5). The most striking comparison to the sand states is the large and significant surprise no change effect, which ranged from 2.8% to 3.72% depending on the specification. Overall, the higher sensitivity to monetary policy in non-sand states suggests that monetary policy alone was unlikely to be the sole factor in driving the real estate bubble. For it

to be, we would expect to see the sand states be more highly more elastic in their response to rate changes during the boom, while, if anything, other than the effect for surprise cuts the evidence suggests that it may in fact be the other way around.

4.3 The Real Estate Bust and the onset of the Great Recession (2007-2008)

In a series of announcements within a short period of time beginning in 2007, the FOMC lowered the FFR from 5.25% to a new low near 0.00% by December 2008. Because this series of announcements was specifically responding to distress in the housing sector and related markets, we examine these separately to assess the potency of open market operations during the abrupt slide in this sector. We report our regression discontinuity results in Tables 7, 8 and 9 (and Figures 4, 5 and 6) for the full sample, sand states, and non-sand states respectively.

The results from the full sample show that, on average, surprise cuts and large expected cuts in the FFR had large immediate impacts on the housing market during this period. A surprise rate cut during this period was associated with a 2.23-5.28% increase in home prices; however, the steep trend prior to these announcements was unambiguously negative, functioning as a strong headwind to these policy changes. Ultimately, the end result of a large national home price dip (with a great deal of regional variation) is well known. It turns out that large expected rate cuts had similar potency as the surprise cuts during this period, perhaps signaling an aggressive rate cutting path going forward in a way that more modest expected cuts did not. In fact, modest expected cuts during this period show virtually no simulative effects.

More strikingly, when comparing the rate cuts between the sand states and the rest of the U.S. in 2007-08, it is clear that monetary policy had much stronger effects on non-sand states, where the housing market was generally more stable anyway. As the sand states began to

experience spiking defaults and distressed sales, monetary policy provided relatively little measurable impact there, at best showing a 1.73% increase in home prices on average for the surprise cut dual donut specification (with a much smaller effect in the other specifications and little noticeable effect from the visual evidence from the figures). This may reflect some of the structural, supply-side factors specific to the housing markets in the sand states, but we leave this line of inquiry for future research. On the other side of the spectrum, some of the largest market effects we observe in this paper come from the rate cuts in the non-sand state markets during 2007-2008. Table 9 shows that surprise cuts and large cuts exhibited about a 3-7% and a 3-5% increase in home prices for each respective cut (depending on the specification), while more modest expected cuts little if any positive impact during this period.

4.4 Quantitative Easing Results

We report the results of QE and other operations during the recovery period in Table 10 and Figures 7, 8, and 9. The results show that the announcements that were more oriented toward putting downward pressure on long-term rates increased home prices by about 1.5-3% on average for the full sample, with a somewhat more modest effect for the other announcements. In untabulated results, the announcement of Operation Twist on September 21, 2011, which was specifically oriented toward 'twisting' or flattening the yield curve, had one of the clearest discontinuous positive effects on the housing market, as long term rates subsequently lowered throughout much of 2012. Table 10 also shows that QE had more pronounced positive effects on the housing market in non-sand states (1.63-3.21%) on average during the recovery period, with more modest (1.19-2.31%) positive effects in the sand states. Overall, the results are consistent with some of the macroeconomics literature that has shown QE effects on the broader

economy,[11] and should also flow directly from the literature (e.g. Hancock and Passmore [2011]) that found that QE did, in fact, lower long-term rates (including mortgages).

5. Conclusion

Economists in the popular press and other commentators during the Great Recession and recovery periods often worried that the Fed's rate cuts may be "pushing on a string," which carried a number of implications. There were widespread doubts that the Fed's policies were not able to do much to about falling home prices. Using a regression discontinuity design and a nationally representative housing microdata, our results indicate that monetary policy (both interest rate changes and quantitative easing) can affect home prices almost immediately after the announcement. In particular, using daily-level data, we show that unanticipated target rate changes and expansionary quantitative easing generally increase home prices within about seven days of the announcement.

Despite homes being a relatively long run asset, which are often characterized as being relatively less liquid than other investments such as stocks and bonds, home prices appear to adjust to new information very rapidly. This result also runs counter to seminal work by Friedman and Schwartz (1963) and empirical macroeconomics literature that claims that the economy changes in response to monetary policy only after 'long and variable' lags. In fact, the evidence suggests that prices, even in notoriously slow moving sectors like housing, may actually respond quickly to monetary shocks.

Like the housing bubble and bust, monetary policy effects were not uniform across all states in the U.S.. We find that the impact of monetary policy was larger for sand states in the run

[11] For example, see Gagnon, Raskin, Remache, and Sack, (2011), Kapetanios, Mumtaz, Stevens, and Theodoridis, (2012), Chen, Cúrdia, and Ferrero, (2012), and Weale and Wieladek (2016).

up to the Great Recession, while it was larger for non-sand states during the first part of the Great Recession and during the recovery. Quantitative easing was also relatively more effective in non-sand states. This may be evidence that other, possibly more structural or supply-side factors had a strong role in the housing boom and bust, which is a topic we leave for future research.

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Figures and Tables

Figure 1A: Full Sample Surprise Cut MPA – 1996 to 2006

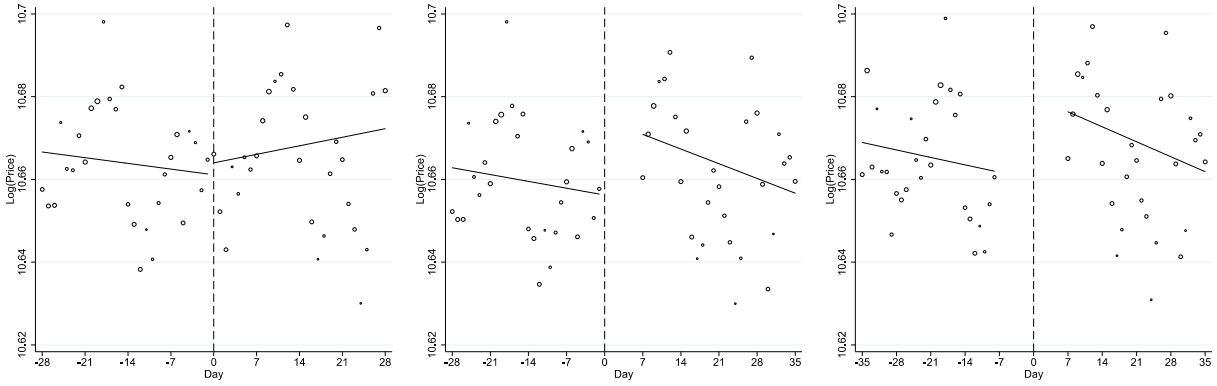


Figure 1B: Full Sample Expected Cut MPA – 1996 to 2006

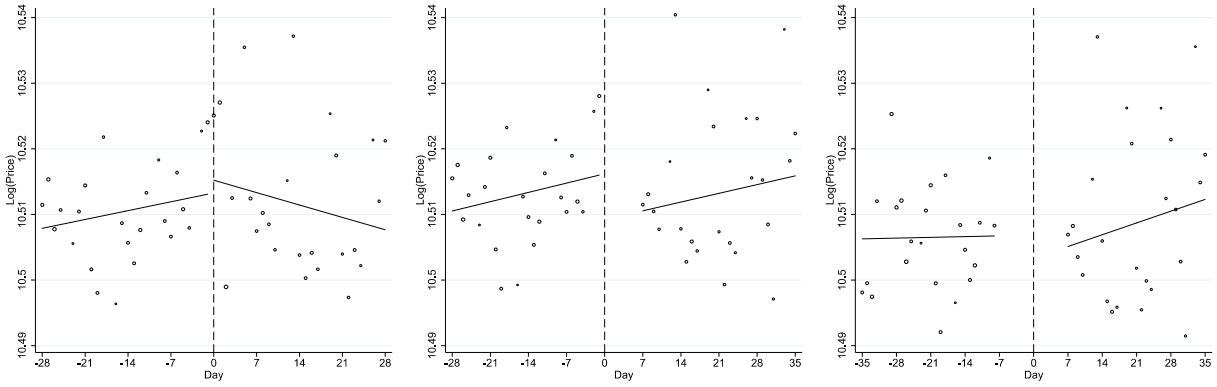


Figure 1C: Full Sample Large Expected Cut MPA – 1996 to 2006

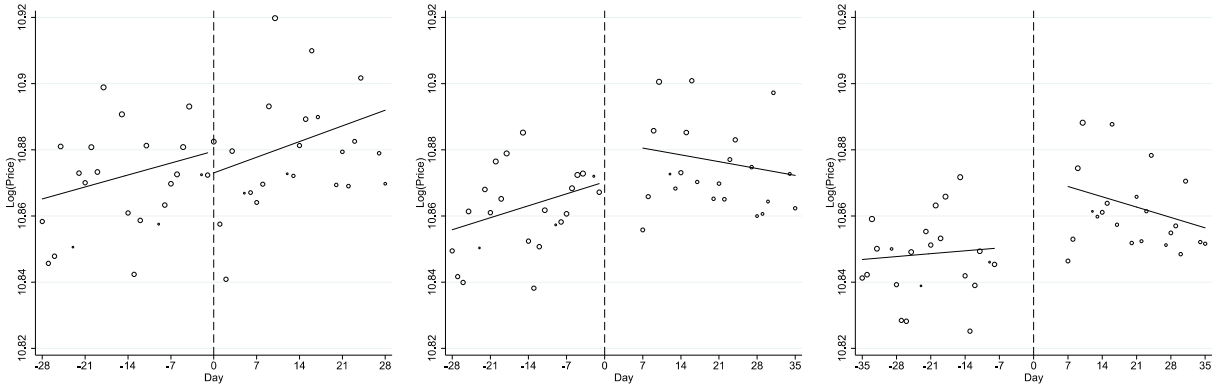


Figure 1D: Full Sample Surprise – No Change MPA – 1996 to 2006

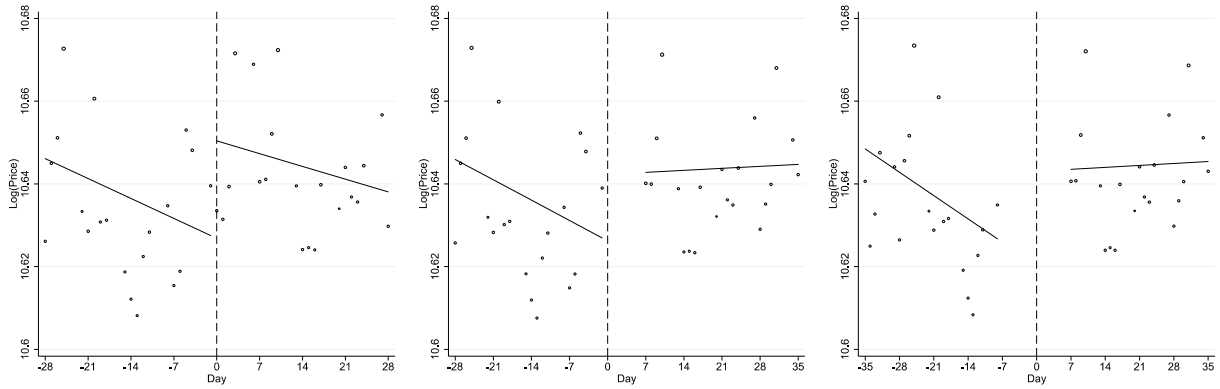
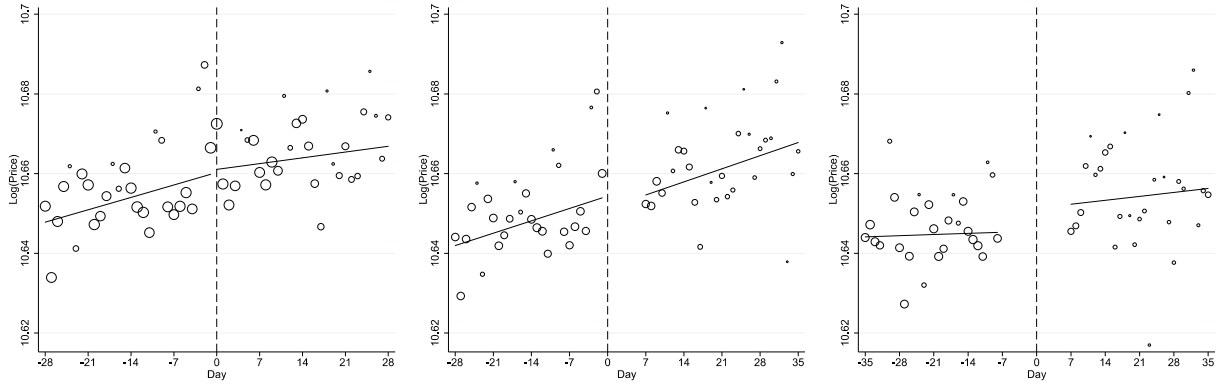


Figure 1E: Full Sample Expected Hike MPA – 1996 to 2006



Source: Zillow's ZTRAX

Notes: Figures are depictions of the estimates in Table 4. Figures include a scatterplot of daily conditional average home prices (controlling for all the covariates in our hedonic RD) and linear splines through these averages. The left panel is the default RD, the middle panel is a donut RD that omits the 7 days following the MPA, and the right panel is a donut RD that omits the 7 days before and after the MPA.

Figure 2A: Sand State Surprise Cut MPA – 1996 to 2006

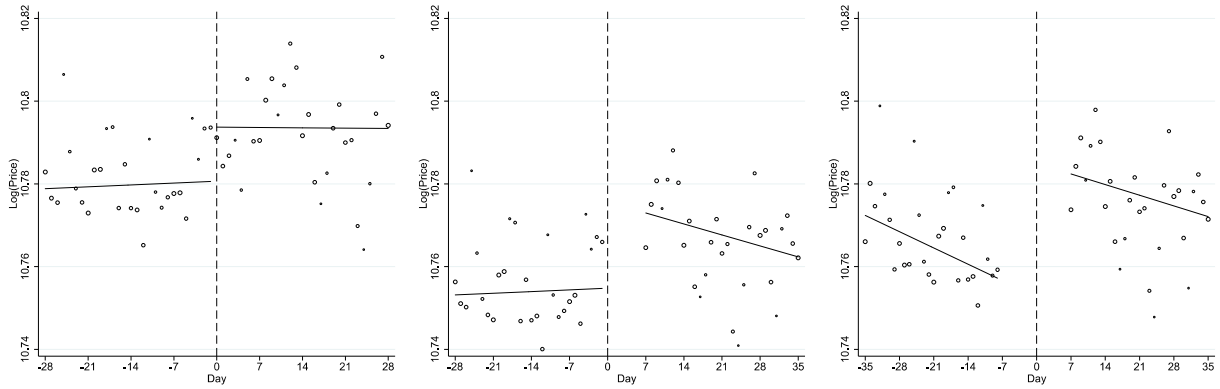


Figure 2B: Sand State Expected Cut MPA – 1996 to 2006

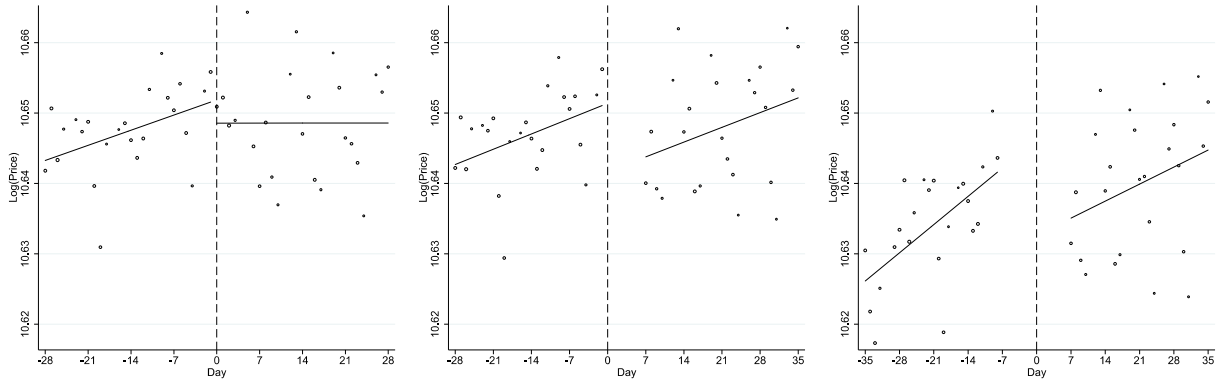


Figure 2C: Sand State Large Expected Cut MPA – 1996 to 2006

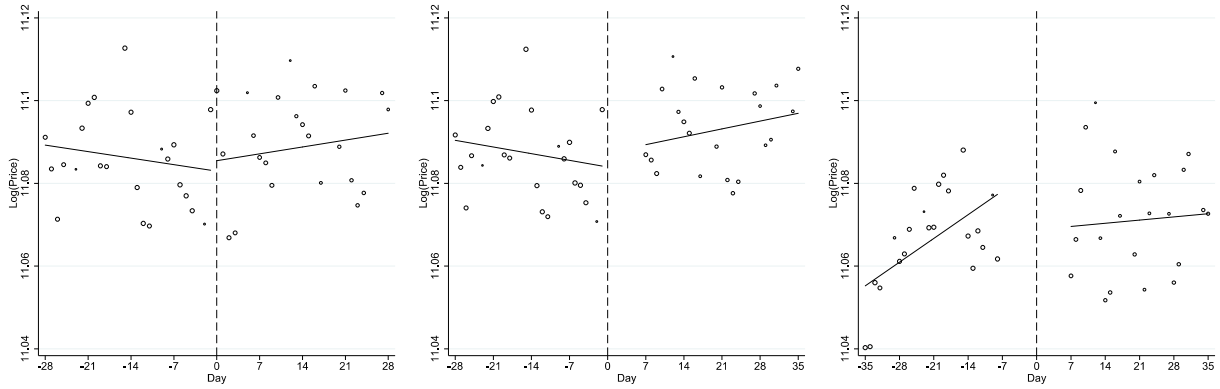


Figure 2D: Sand State Surprise – No Change MPA – 1996 to 2006

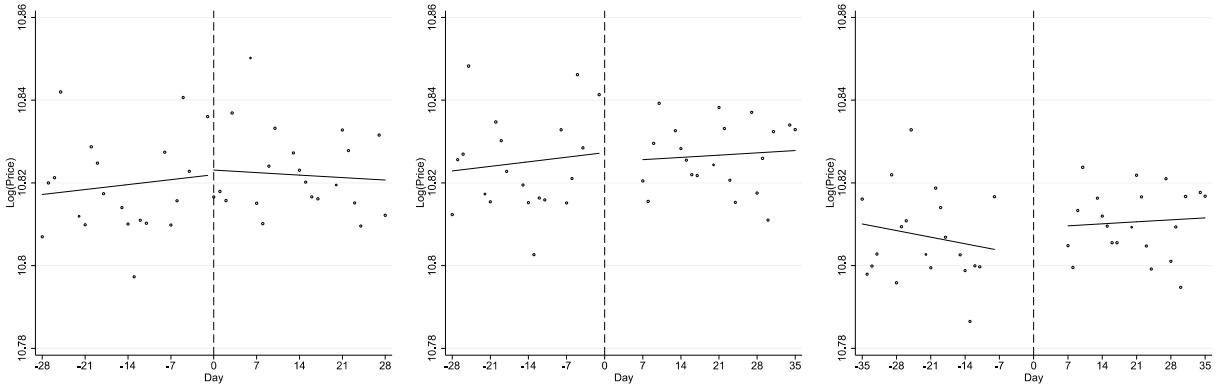
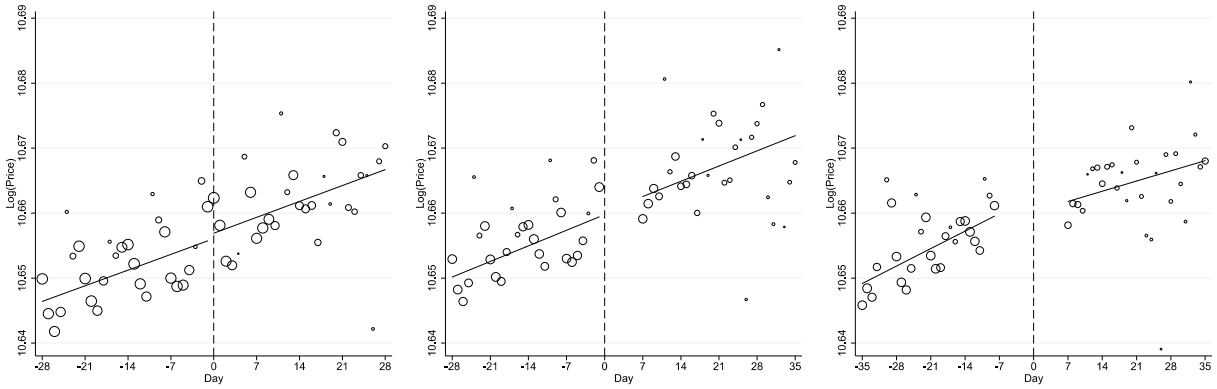


Figure 2E: Sand State Expected Hike MPA – 1996 to 2006



Source: Zillow's ZTRAX

Notes: Figures are depictions of the estimates in Table 5. Figures include a scatterplot of daily conditional average home prices (controlling for all the covariates in our hedonic RD) and linear splines through these averages. The left panel is the default RD, the middle panel is a donut RD that omits the 7 days following the MPA, and the right panel is a donut RD that omits the 7 days before and after the MPA.

Figure 3A: Non-Sand State Surprise Cut MPA – 1996 to 2006

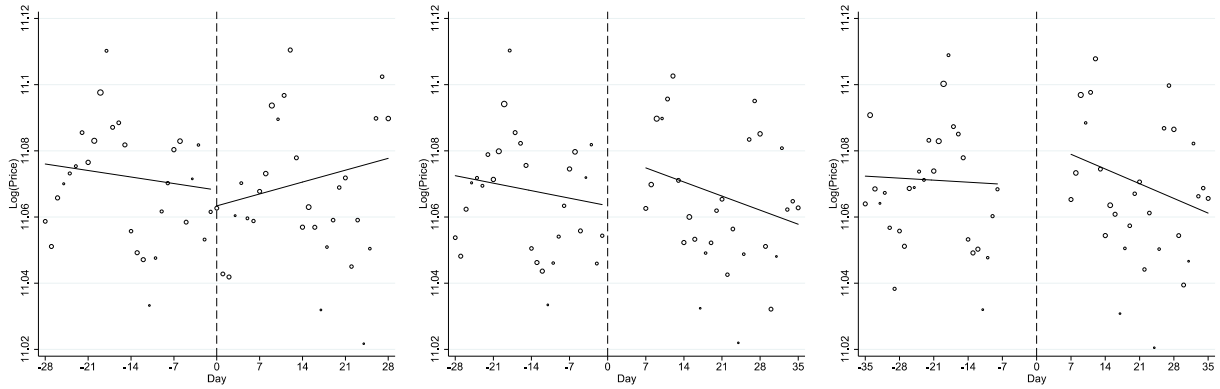


Figure 3B: Non-Sand State Expected Cut MPA – 1996 to 2006

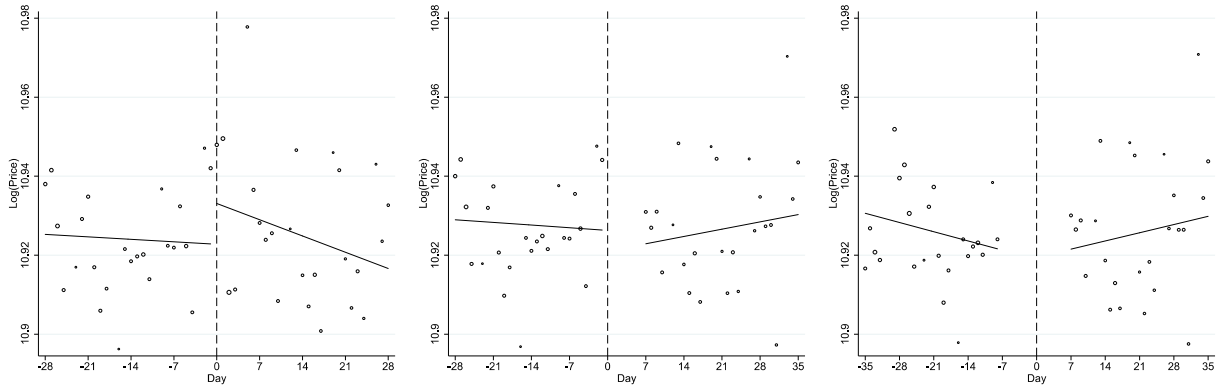


Figure 3C: Non-Sand State Large Expected Cut MPA – 1996 to 2006

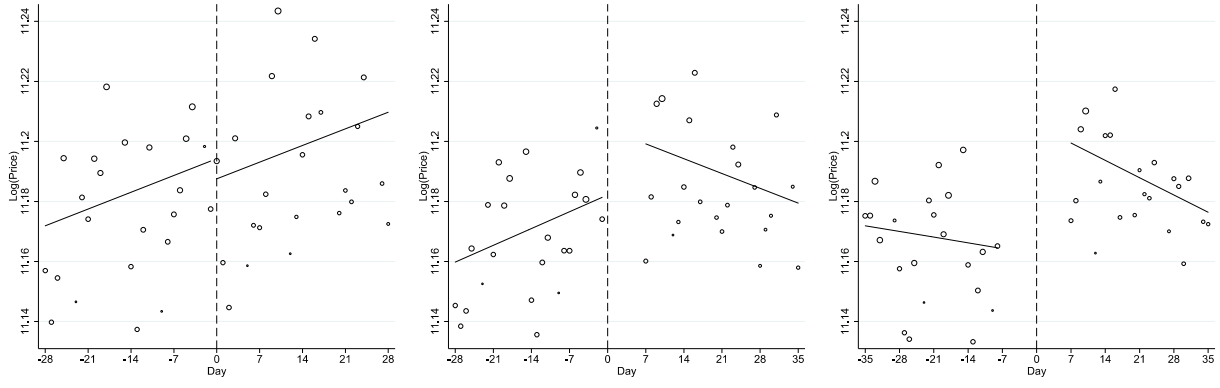


Figure 3D: Non-Sand State Surprise – No Change MPA – 1996 to 2006

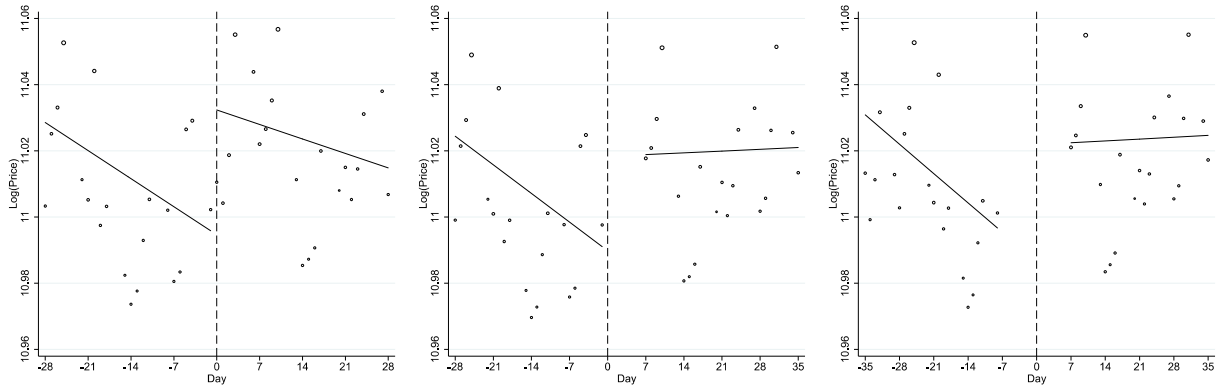
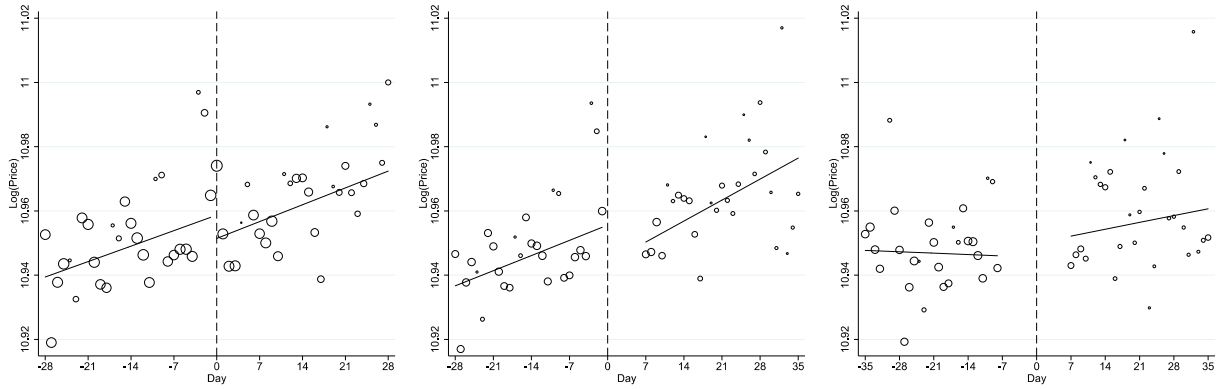


Figure 3E: Non-Sand State Expected Hike MPA – 1996 to 2006



Source: Zillow's ZTRAX
Notes: Figures are depictions of the estimates in Table 6. Figures include a scatterplot of daily conditional average home prices (controlling for all the covariates in our hedonic RD) and linear splines through these averages. The left panel is the default RD, the middle panel is a donut RD that omits the 7 days following the MPA, and the right panel is a donut RD that omits the 7 days before and after the MPA.

Figure 4A: Full Sample Surprise Cut MPA – 2007 to 2008

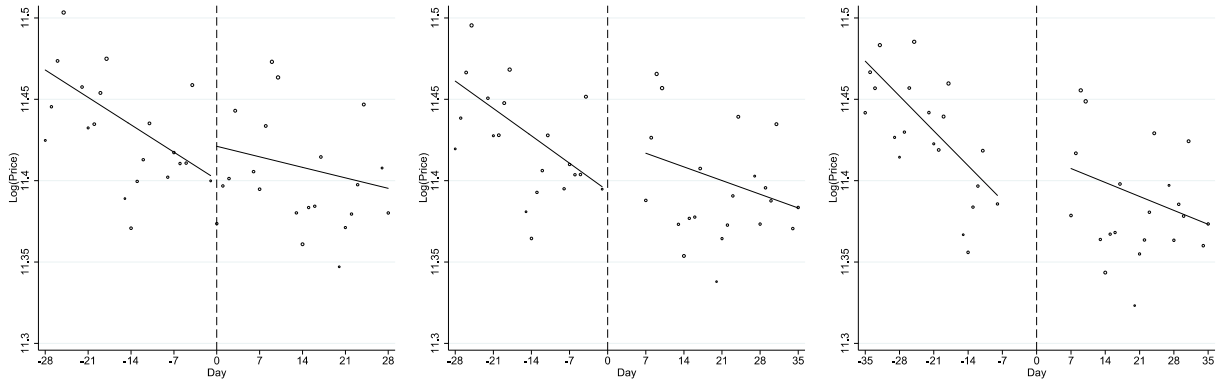


Figure 4B: Full Sample Expected Cut MPA – 2007 to 2008

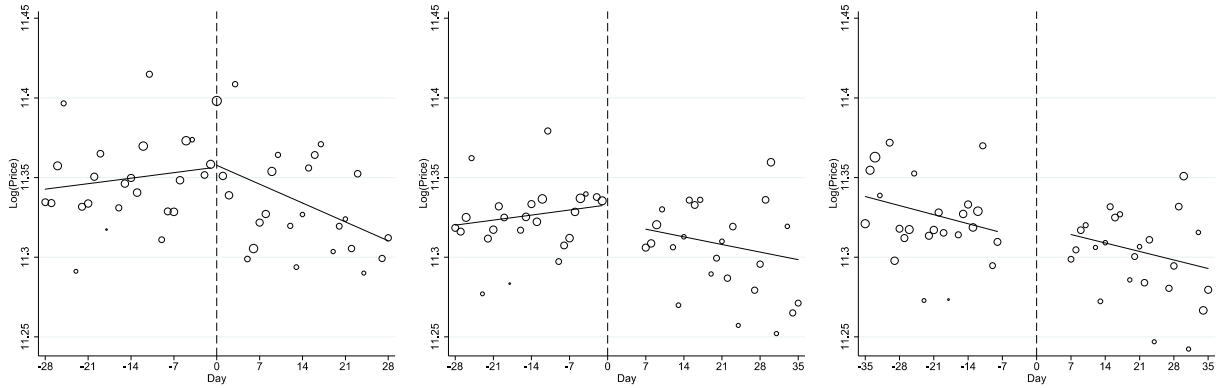
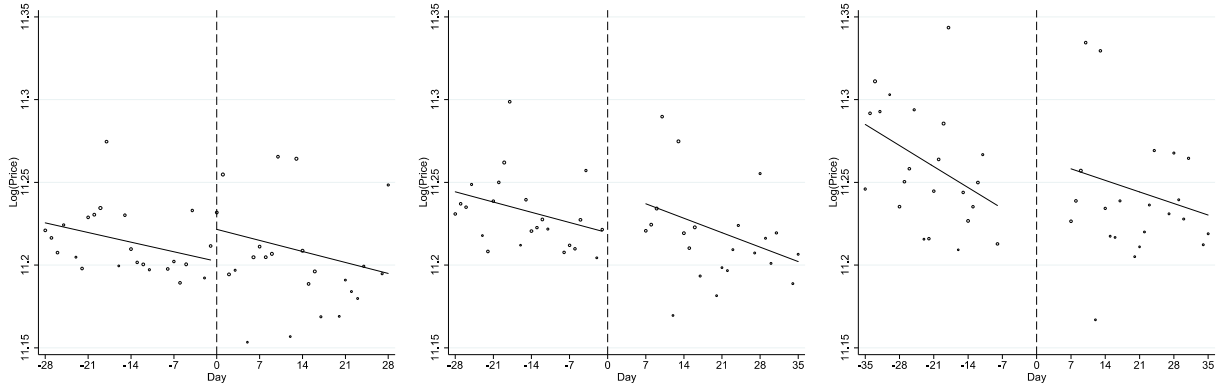


Figure 4C: Full Sample Large Expected Cut MPA – 2007 to 2008



Source: Zillow's ZTRAX

Notes: Figures are depictions of the estimates in Table 7. Figures include a scatterplot of daily conditional average home prices (controlling for all the covariates in our hedonic RD) and linear splines through these averages. The left panel is the default RD, the middle panel is a donut RD that omits the 7 days following the MPA, and the right panel is a donut RD that omits the 7 days before and after the MPA.

Figure 5A: Sand State Surprise Cut MPA – 2007 to 2008

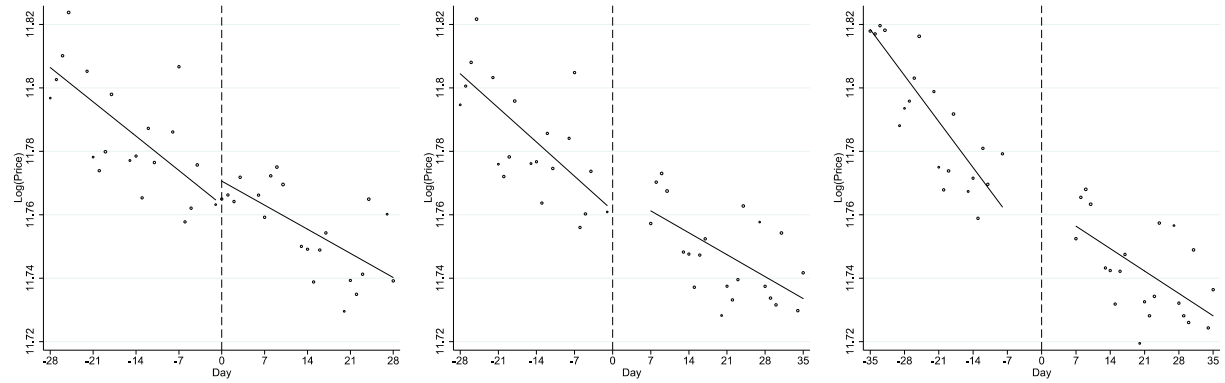


Figure 5B: Sand State Expected Cut MPA – 2007 to 2008

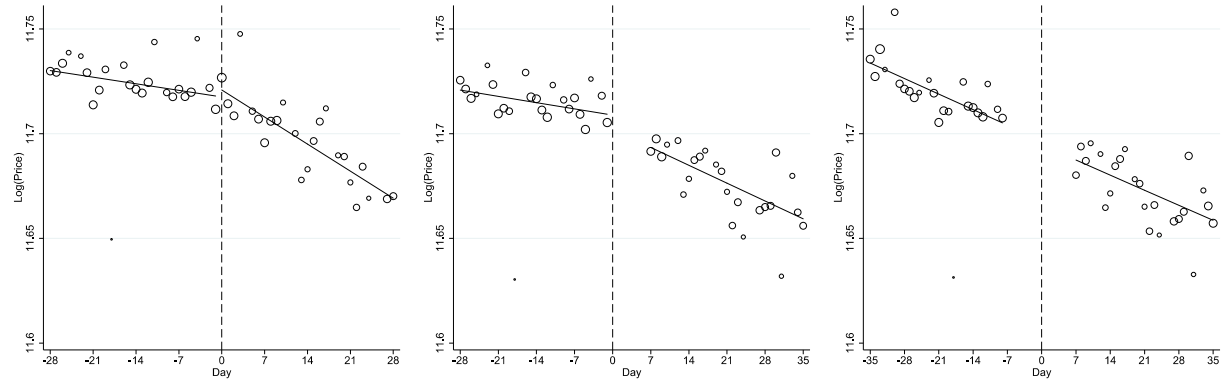
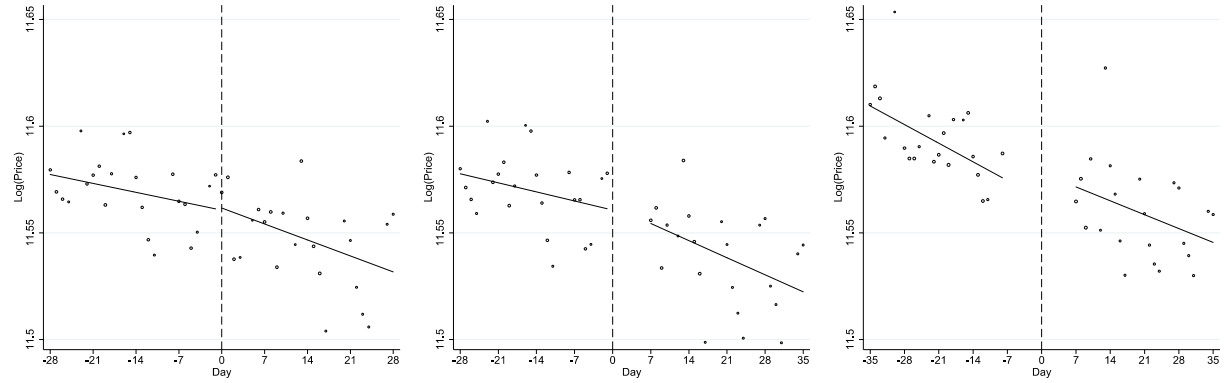


Figure 5C: Sand State Large Expected Cut MPA – 2007 to 2008



Source: Zillow's ZTRAX

Notes: Figures are depictions of the estimates in Table 8. Figures include a scatterplot of daily conditional average home prices (controlling for all the covariates in our hedonic RD) and linear splines through these averages. The left panel is the default RD, the middle panel is a donut RD that omits the 7 days following the MPA, and the right panel is a donut RD that omits the 7 days before and after the MPA.

Figure 6A: Non-Sand State Surprise Cut MPA – 2007 to 2008

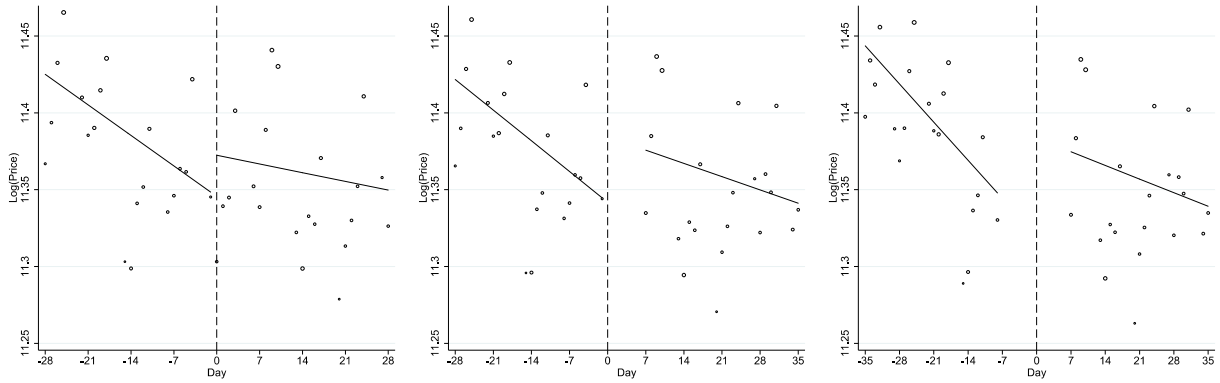


Figure 6B: Non-Sand State Expected Cut MPA – 2007 to 2008

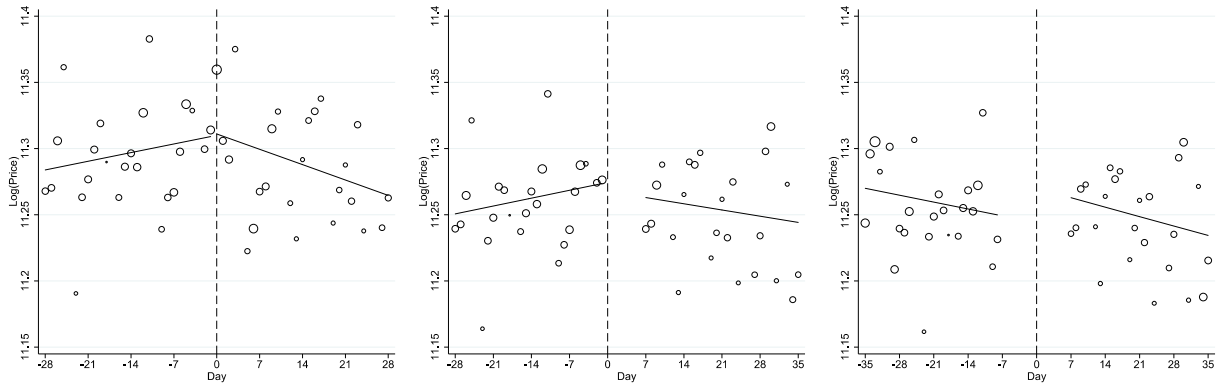
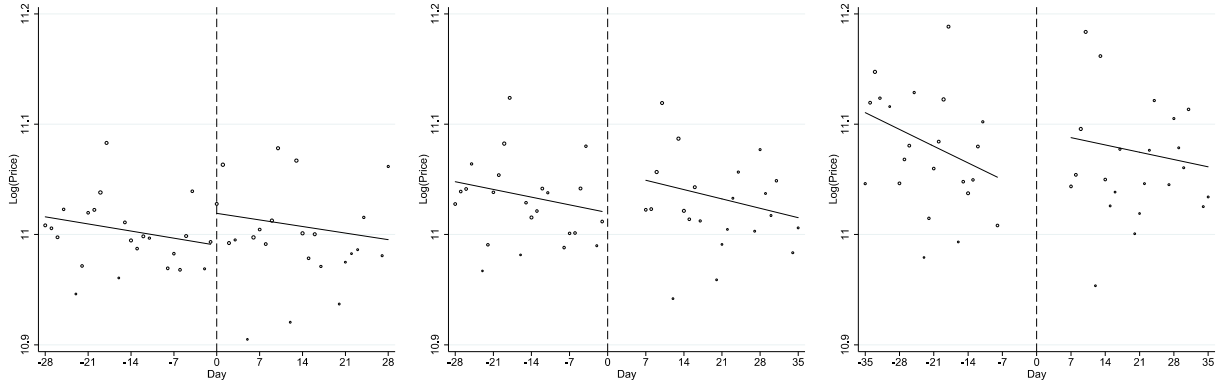


Figure 6C: Non-Sand State Large Expected Cut MPA – 2007 to 2008



Source: Zillow's ZTRAX

Notes: Figures are depictions of the estimates in Table 9. Figures include a scatterplot of daily conditional average home prices (controlling for all the covariates in our hedonic RD) and linear splines through these averages. The left panel is the default RD, the middle panel is a donut RD that omits the 7 days following the MPA, and the right panel is a donut RD that omits the 7 days before and after the MPA.

Figure 7A: Full Sample Easing QE – 2008 to 2013

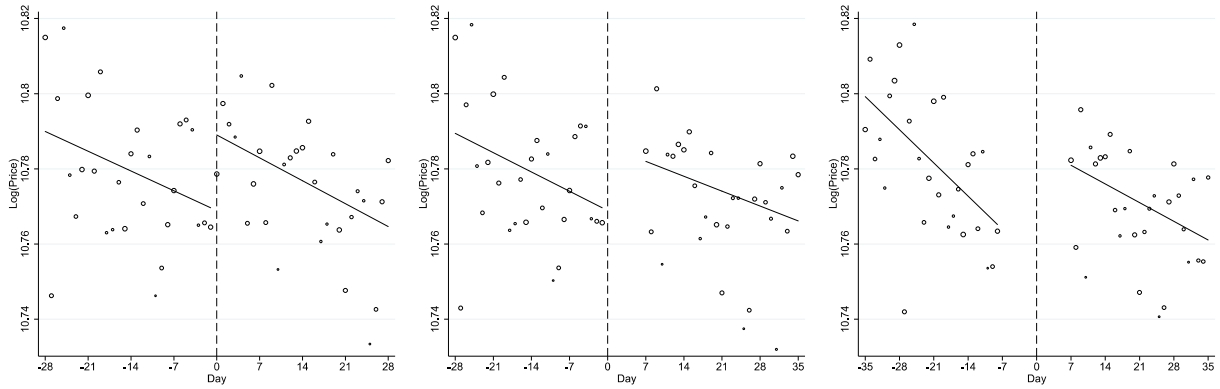
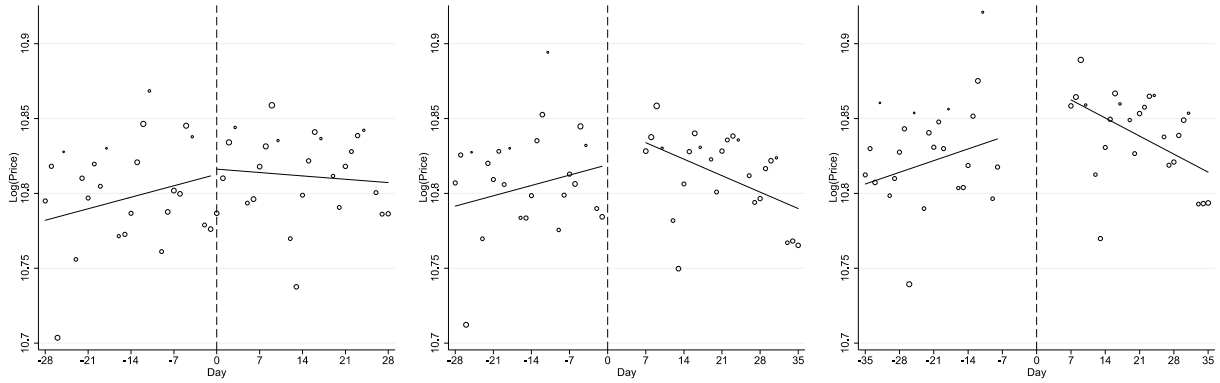


Figure 7B: Full Sample Other QE – 2008 to 2013



Source: Zillow's ZTRAX

Notes: Figures are depictions of the estimates in Table 10, Panel A. Figures include a scatterplot of daily conditional average home prices (controlling for all the covariates in our hedonic RD) and linear splines through these averages. The left panel is the default RD, the middle panel is a donut RD that omits the 7 days following the QE announcement, and the right panel is a donut RD that omits the 7 days before and after the QE announcement.

Figure 8A: Sand State LR Easing QE – 2008 to 2013

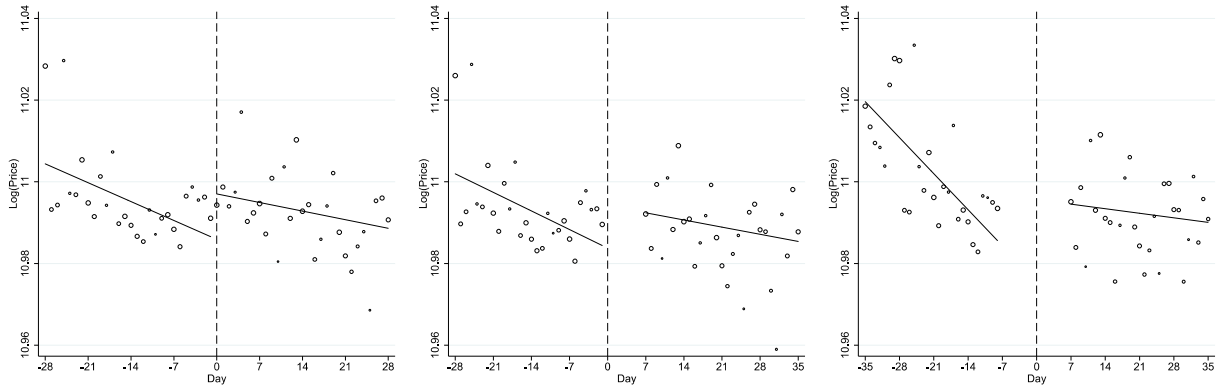
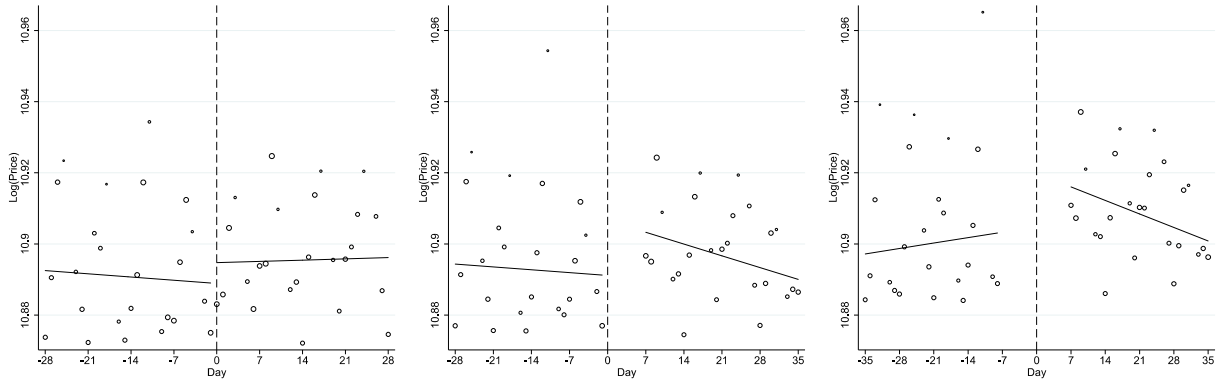


Figure 8B: Sand State Other QE – 2008 to 2013



Source: Zillow's ZTRAX

Notes: Figures are depictions of the estimates in Table 10, Panel B. Figures include a scatterplot of daily conditional average home prices (controlling for all the covariates in our hedonic RD) and linear splines through these averages. The left panel is the default RD, the middle panel is a donut RD that omits the 7 days following the QE announcement, and the right panel is a donut RD that omits the 7 days before and after the QE announcement.

Figure 9A: Non-Sand State LR Easing QE – 2008 to 2013

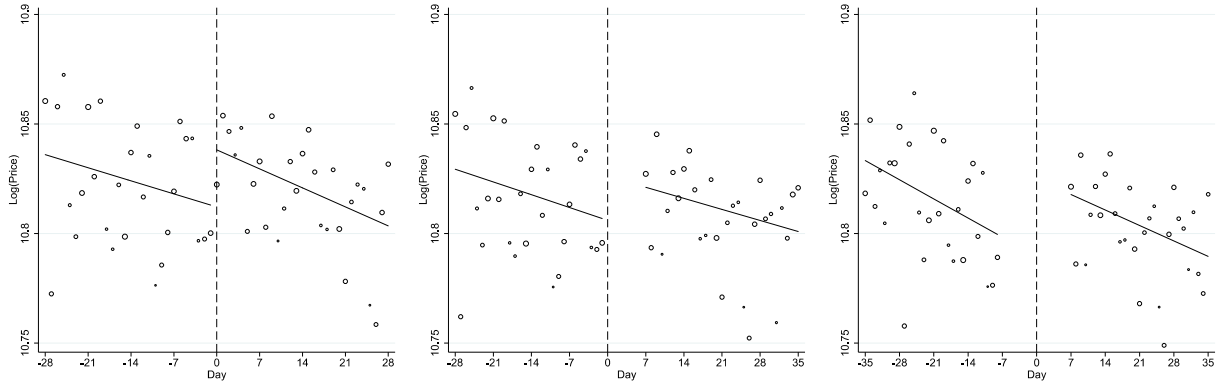
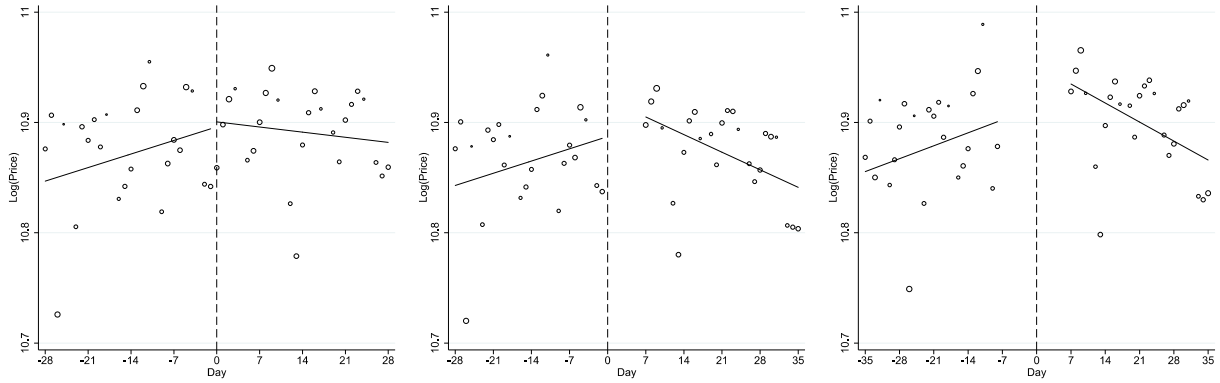


Figure 9B: Non-Sand State Other QE – 2008 to 2013



Source: Zillow's ZTRAX

Notes: Figures are depictions of the estimates in Table 10, Panel C. Figures include a scatterplot of daily conditional average home prices (controlling for all the covariates in our hedonic RD) and linear splines through these averages. The left panel is the default RD, the middle panel is a donut RD that omits the 7 days following the QE announcement, and the right panel is a donut RD that omits the 7 days before and after the QE announcement.

Table 1: Summary Statistics

	1996 to 2008			2008 to 2014		
	Full	Sand States	Non-Sand States	Full	Sand States	Non-Sand States
	(1)	(2)	(3)	(4)	(5)	(6)
Sales Price (Mean)	203,155	248,657	175,386	193,714	227,538	172,120
	(151,152)	(184,202)	(118,525)	(149,395)	(166,083)	(133,271)
Sales Price (Median)	165,000	202,000	148,500	157,491	182,750	143,100
Square Footage	1,747	1,746	1,747	1,747	1,790	1,748
	(752)	(724)	(768)	(768)	(761)	(778)
Acreage	0.24	0.22	0.26	0.26	0.21	0.29
	(0.34)	(0.31)	(0.36)	(0.37)	(0.31)	(0.40)
No Acreage	0.15	0.12	0.18	0.16	0.13	0.18
	(0.36)	(0.32)	(0.38)	(0.37)	(0.34)	(0.39)
Bedrooms	2.35	2.41	2.32	2.30	2.39	2.24
	(1.50)	(1.47)	(1.52)	(1.53)	(1.49)	(1.55)
Bathrooms	1.66	1.81	1.56	1.69	1.79	1.63
	(1.00)	(0.94)	(1.02)	(0.99)	(0.97)	(1.00)
Missing Bathrooms/Bedrooms	0.27	0.23	0.29	0.29	0.25	0.32
	(0.44)	(0.42)	(0.45)	(0.46)	(0.43)	(0.47)
Ranch	0.46	0.57	0.39	0.47	0.58	0.40
	(0.50)	(0.49)	(0.49)	(0.50)	(0.49)	(0.49)
Basement	0.16	0.03	0.25	0.17	0.02	0.26
	(0.37)	(0.16)	(0.43)	(0.37)	(0.15)	(0.44)
Garage (# of Cars)	1.14	1.27	1.05	1.15	1.30	1.06
	(1.02)	(1.00)	(1.03)	(1.04)	(1.00)	(1.05)
Pool	0.17	0.17	0.03	0.08	0.16	0.03
	(0.27)	(0.37)	(0.16)	(0.27)	(0.36)	(0.16)
N	34,968,335	13,252,680	21,715,655	19,166,244	7,468,301	11,697,943

Source: Zillow's ZTRAX
Notes: Summary statistics are provided separately for the Monetary Policy Announcement regime from 1996 to 2008 and the quantitative easing regime from 2008 to 2014. The statistics are also stratified by whether the property is located in a "sand state": Arizona, California, Nevada, or Florida.

Table 2: Announcement Classification

	1996 to 2006	2007 to 2008	2008 to 2014
MPA Surprise Cut	*15oct1998 03jan2001 18apr2001 17sep2001 06nov2002*	*18sep2007 22jan2008*	
MPA Expected Cut	*31jan1996 29sep1998 17nov1998 27jun2001 21aug2001 11dec2001 25jun2003*	*31oct2007 11dec2007 30apr2008*	
MPA Large Expected Cut	*31jan2001 20mar2001 15may2001 02oct2001 06nov2001*	*30jan2008 18mar2008*	
MPA Surprise - No Change	*24sep1996 20may1997*		
MPA Expected Hike	*25mar1997 30jun1999 24aug1999 16nov1999 02feb2000 21mar2000 16may2000 30jun2004 10aug2004 21sep2004 10nov2004 14dec2004 02feb2005 22mar2005 03may2005 30jun2005 09aug2005 20sep2005 01nov2005 13dec2005 31jan2006 28mar2006 10may2006 29jun2006*		
QE Easing			*25nov2008 28jan2009 18mar2009 27aug2010 03nov2010 21sep2011 13sep2012*
QE Other			*01dec2008 16dec2008 12aug2009 23sep2009 04nov2009 10aug2010 21sep2010 12dec2012 20jun2012 22may2013*

Notes: Table provides the Federal Reserve announcements dates that are grouped into our announcement type classifications.

Table 3: QE Announcements

Date	Announcement Summary	Type
25nov2008	The Federal Reserve will purchase "up to $100 billion in GSE direct obligations, and up to $500 billion in MBS."	*Expansionary*
01dec2008	In a speech, Chairman Bernanke states that the Federal Reserve "could purchase longer-term Treasury or agency securities . . . in substantial quantities."	*Other*
16dec2008	The FOMC "anticipates . . . exceptionally low levels of the federal funds rate for some time." It also "stands ready to expand its purchases of agency debt and mortgage-backed securities . . . [and] is also evaluating the potential benefits of purchasing longer-term Treasury securities."	*Other*
28jan2006	The FOMC "is prepared to purchase longer-term Treasury securities."	*Expansionary*
18mar2009	The FOMC "anticipates . . . exceptionally low levels of the federal funds rate for an extended period." It will also purchase "up to an additional $750 billion of agency mortgage-backed securities, up to $100 billion" in agency debt, and "up to $300 billion of longer-term Treasury securities over the next six months."	*Expansionary*
12aug2009	The FOMC "decided to gradually slow the pace" of Treasury purchases ("up to" language with reference to Treasury purchases is also removed).	*Other*
23sep2009	The FOMC "will gradually slow the pace" of agency MBS purchases ("up to" language with reference to agency MBS purchases is also removed).	*Other*
04nov2009	The FOMC "will purchase . . . about $175 billion of agency debt" ("up to" language with reference to agency debt is also removed).	*Other*
10aug2010	The FOMC will reinvest "principal payments from agency debt and agency mortgage-backed securities in longer-term Treasury securities."	*Other*
27aug2010	In a speech, Chairman Bernanke announces that "additional purchases of longer-term securities . . . would be effective in further easing financial conditions."	*Expansionary*
21sep2010	The FOMC "is prepared to provide additional accommodation if needed."	*Other*
03nov2010	The FOMC "intends to purchase a further $600 billion of longer term Treasury securities by the end of the second quarter of 2011, at a pace of about $75 billion per month."	*Expansionary*
21sep2011	The FOMC "intends to purchase, by the end of June 2012, $400 billion of Treasury securities with remaining maturities of six years to 30 years and to sell an equal amount of Treasury securities with remaining maturities of three years or less. To help support conditions in mortgage markets, the Committee will now reinvest principal payments from its holdings of agency debt and agency mortgage-backed securities in agency mortgage-backed securities."	*Expansionary*
20jun2012	The FOMC "decided to, continue through the end of the year its program to extend the average maturity of, its holdings of securities." An accompanying statement by the Federal Reserve Bank of New York clarifies that this continuation will "result in the purchase, as well as the sale and redemption, of about $267 billion in Treasury securities by the end of 2012."	*Other*
13sep2012	The FOMC "will increase the Committee's holdings of longer-term securities by about $85 billion each month through the end of the year, including purchasing additional agency mortgage-backed securities at a pace of $40 billion per month."	*Expansionary*
12dec2012	The FOMC will continue purchasing "at least as long as the unemployment rate remains above 6–1/2%, inflation between one and two years ahead is projected to be no more than a half percentage point above the Committee's 2% longer-run goal, and longer-term inflation expectations continue to be well anchored."	*Other*
22may2013	In a speech to Congress, Ben Bernanke states that "If we see continued improvement, and we have confidence that it is going to be sustained, in the next few meetings we could take a step down in our pace of purchases."	*Other*

Source: Announcement summaries from Hancock and Passmore (2015).

Table 4: Full Sample - Monetary Policy Announcements (1996 to 2006)

	Surprise Cut	Expected Cut	Large Expected Cut	Surprise - No Change	Expected Hike
	Log(Price)	Log(Price)	Log(Price)	Log(Price)	Log(Price)
	(1)	(2)	(3)	(4)	(5)
	Panel A: Default				
Discontinuity	-0.41***	0.26**	-0.64***	2.35***	0.16***
	(0.14)	(0.10)	(0.14)	(0.23)	(0.05)
Trend	-0.02***	0.02***	0.05***	-0.07***	0.04***
	(0.01)	(0.00)	(0.01)	(0.01)	(0.00)
Post-Trend	0.05***	-0.05***	0.01	0.04***	-0.02***
	(0.01)	(0.01)	(0.01)	(0.01)	(0.00)
N	1,833,994	2,520,574	1,635,863	531,534	10,713,896
	(6)	(7)	(8)	(9)	(10)
	Panel B: + 7 Donut				
Discontinuity	1.93***	-0.55***	1.18***	1.62***	-0.19***
	(0.15)	(0.13)	(0.17)	(0.26)	(0.07)
Trend	-0.03***	0.02***	0.05***	-0.07***	0.04***
	(0.01)	(0.00)	(0.01)	(0.01)	(0.00)
Post-Trend	0.03***	-0.00	-0.08***	0.08***	0.00
	(0.01)	(0.01)	(0.01)	(0.01)	(0.00)
N	1,847,349	2,365,714	1,532,854	528,354	9,476,216
	(11)	(12)	(13)	(14)	(15)
	Panel C: +/- 7 Donut				
Discontinuity	2.12***	-0.14	1.96***	2.35***	0.66***
	(0.18)	(0.16)	(0.20)	(0.32)	(0.09)
Trend	-0.03***	-0.00	0.01**	-0.08***	0.00
	(0.01)	(0.00)	(0.01)	(0.01)	(0.00)
Post-Trend	-0.03***	0.02***	-0.05***	0.09***	0.01*
	(0.01)	(0.01)	(0.01)	(0.01)	(0.00)
N	1,867,872	2,257,980	1,466,292	528,781	8,367,479

Source: Zillow's ZTRAX

Notes: Estimates are from a hedonic RD with the date of the MPA serving as the cutoff. Results are provided for each of the different MPA types described in the Methods section. Untabulated results include the controls described in the Data section. Panel B omits sales that closed in the 7 days following the MPA and Panel C omits sales that closed within 7 days of the MPA on both sides of the cutoff. Heteroskedastic-robust standard errors are included in parenthesis. * 10%, ** 5%, *** 1%.

Table 5: Sand State - Monetary Policy Announcements (1996 to 2006)

	Surprise Cut	Expected Cut	Large Expected Cut	Surprise - No Change	Expected Hike
	Log(Price)	Log(Price)	Log(Price)	Log(Price)	Log(Price)
	(1)	(2)	(3)	(4)	(5)
	Panel A: Default				
Discontinuity	1.40***	-0.27	0.25	0.20	0.15**
	(0.22)	(0.17)	(0.22)	(0.34)	(0.07)
Trend	0.00	0.03***	-0.02**	0.01	0.03***
	(0.01)	(0.01)	(0.01)	(0.01)	(0.00)
Post-Trend	-0.01	-0.03***	0.05***	-0.02	0.00
	(0.01)	(0.01)	(0.01)	(0.02)	(0.00)
N	671,470	954,988	618,153	211,661	4,110,389
	(6)	(7)	(8)	(9)	(10)
	Panel B: + 7 Donut				
Discontinuity	2.16***	-0.83***	0.39	-0.15	0.13
	(0.25)	(0.21)	(0.29)	(0.39)	(0.09)
Trend	0.00	0.03***	-0.02**	0.00	0.03***
	(0.01)	(0.01)	(0.01)	(0.01)	(0.00)
Post-Trend	-0.04***	-0.00	-0.05***	-0.00	-0.00
	(0.01)	(0.01)	(0.02)	(0.02)	(0.01)
N	679,186	914,492	577,031	213,665	3,629,154
	(11)	(12)	(13)	(14)	(15)
	Panel C: +/- 7 Donut				
Discontinuity	3.29***	-1.15***	-1.64***	0.81*	-0.16
	(0.29)	(0.25)	(0.33)	(0.47)	(0.12)
Trend	-0.06***	0.05***	0.08***	-0.03*	0.03***
	(0.01)	(0.01)	(0.01)	(0.02)	(0.00)
Post-Trend	0.02	-0.02**	-0.07***	0.03	-0.02***
	(0.01)	(0.01)	(0.01)	(0.02)	(0.01)
N	687,777	867,340	546,535	214,462	3,212,030

Source: Zillow's ZTRAX

Notes: Estimates are from a hedonic RD with the date of the MPA serving as the cutoff. Results are provided for each of the different MPA types described in the Methods section. Untabulated results include the controls described in the Data section. Panel B omits sales that closed in the 7 days following the MPA and Panel C omits sales that closed within 7 days of the MPA on both sides of the cutoff. Heteroskedastic-robust standard errors are included in parenthesis. * 10%, ** 5%, *** 1%.

Table 6: Non-Sand State Monetary Policy Announcements – 1996 to 2006

	Surprise Cut Log(Price)	Expected Cut Log(Price)	Large Expected Cut Log(Price)	Surprise - No Change Log(Price)	Expected Hike Log(Price)
	(1)	(2)	(3)	(4)	(5)
	Panel A: Default				
Discontinuity	-0.43**	1.11***	-0.68***	3.72***	-0.58***
	(0.17)	(0.13)	(0.17)	(0.23)	(0.01)
Trend	-0.03***	-0.01**	0.08***	-0.13***	0.06***
	(0.01)	(0.01)	(0.01)	(0.01)	(0.00)
Post-Trend	0.08***	-0.05***	-0.01	0.07***	0.01
	(0.01)	(0.01)	(0.02)	(0.02)	(0.01)
N	1,162,524	1,565,586	1,017,710	319,873	6,603,507
	(6)	(7)	(8)	(9)	(10)
	Panel B: + 7 Donut				
Discontinuity	1.59***	-0.34**	2.00***	2.80***	-1.03***
	(0.19)	(0.17)	(0.22)	(0.35)	(0.10)
Trend	-0.03***	-0.01**	0.01***	-0.13***	0.06***
	(0.01)	(0.01)	(0.01)	(0.01)	(0.00)
Post-Trend	-0.03***	0.03***	-0.14***	0.14***	0.02***
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
N	1,168,163	1,451,222	955,823	314,689	5,847,062
	(11)	(12)	(13)	(14)	(15)
	Panel C: +/- 7 Donut				
Discontinuity	1.47***	0.25	4.27***	3.51***	0.61***
	(0.22)	(0.20)	(0.25)	(0.44)	(0.12)
Trend	-0.01	-0.04***	-0.03***	-0.13***	-0.01***
	(0.01)	(0.01)	(0.01)	(0.01)	(0.00)
Post-Trend	-0.05*	0.06***	-0.05	0.14***	0.03***
	(0.01)	(0.01)	(0.01)	(0.02)	(0.01)
N	1,180,095	1,390,640	919,757	314,319	5,155,449

Source: Zillow's ZTRAX

Notes: Estimates are from a hedonic RD with the date of the MPA serving as the cutoff. Results are provided for each of the different MPA types described in the Methods section. Untabulated results include the controls described in the Data section. Panel B omits sales that closed in the 7 days following the MPA and Panel C omits sales that closed within 7 days of the MPA on both sides of the cutoff. Heteroskedastic-robust standard errors are included in parenthesis. * 10%, ** 5%, *** 1%.

Table 7: Full Sample - Monetary Policy Announcements (2007 to 2008)

	Surprise Cut Log(Price)	Expected Cut Log(Price)	Large Expected Cut Log(Price)
	(1)	(2)	(3)
	Panel A: Default		
Discontinuity	2.23***	-0.08	2.17***
	(0.27)	(0.01)	(0.29)
Trend	-0.24***	0.06***	-0.09***
	(0.01)	(0.01)	(0.01)
Post-Trend	0.15***	-0.24***	-0.03*
	(0.02)	(0.01)	(0.02)
N	752,027	1,083,387	698,974
	(4)	(5)	(6)
	Panel B: + 7 Donut		
Discontinuity	3.24***	-1.77***	2.75***
	(0.31)	(0.26)	(0.34)
Trend	-0.24***	0.06***	-0.09***
	(0.01)	(0.01)	(0.01)
Post-Trend	0.13***	-0.11***	-0.06***
	(0.02)	(0.01)	(0.02)
N	753,678	1,025,538	649,439
	(7)	(8)	(9)
	Panel C: +/- 7 Donut		
Discontinuity	5.28***	0.01	3.87***
	(0.35)	(0.31)	(0.41)
Trend	-0.31***	-0.07***	-0.17***
	(0.01)	(0.01)	(0.01)
Post-Trend	0.20***	0.03*	0.05***
	(0.02)	(0.01)	(0.02)
N	772,464	1,029,487	597,055

Source: Zillow's ZTRAX
Notes: Estimates are from a hedonic RD with the date of the MPA serving as the cutoff. Results are provided for each of the different MPA types described in the Methods section. Untabulated results include the controls described in the Data section. Panel B omits sales that closed in the 7 days following the MPA and Panel C omits sales that closed within 7 days of the MPA on both sides of the cutoff. Heteroskedastic-robust standard errors are included in parenthesis. * 10%, ** 5%, *** 1%.

Table 8: Sand State - Monetary Policy Announcements (2007 to 2008)

	Surprise Cut Log(Price)	Expected Cut Log(Price)	Large Expected Cut Log(Price)
	(1)	(2)	(3)
	Panel A: Default		
Discontinuity	0.77***	0.26	0.17
	(0.30)	(0.22)	(0.29)
Trend	-0.15***	-0.04***	-0.06***
	(0.01)	(0.01)	(0.01)
Post-Trend	0.04**	-0.14***	-0.04**
	(0.02)	(0.01)	(0.02)
N	232,770	364,281	246,072
	(4)	(5)	(6)
	Panel B: + 7 Donut		
Discontinuity	0.65*	-0.65**	0.31
	(0.34)	(0.28)	(0.35)
Trend	-0.15***	-0.04***	-0.07***
	(0.01)	(0.01)	(0.01)
Post-Trend	0.06***	-0.08***	-0.05**
	(0.02)	(0.01)	(0.02)
N	235,260	349,790	231,619
	(7)	(8)	(9)
	Panel C: +/- 7 Donut		
Discontinuity	1.73***	-0.26	1.40***
	(0.40)	(0.34)	(0.42)
Trend	-0.21***	-0.10***	-0.13***
	(0.01)	(0.01)	(0.01)
Post-Trend	0.11***	0.11	0.03*
	(0.02)	(0.01)	(0.02)
N	238,009	343,648	211,845

Source: Zillow's ZTRAX
Notes: Estimates are from a hedonic RD with the date of the MPA serving as the cutoff. Results are provided for each of the different MPA types described in the Methods section. Untabulated results include the controls described in the Data section. Panel B omits sales that closed in the 7 days following the MPA and Panel C omits sales that closed within 7 days of the MPA on both sides of the cutoff. Heteroskedastic-robust standard errors are included in parenthesis. * 10%, ** 5%, *** 1%.

Table 9: Non-Sand State - Monetary Policy Announcements (2007 to 2008)

	Surprise Cut Log(Price)	Expected Cut Log(Price)	Large Expected Cut Log(Price)
	(1)	(2)	(3)
	Panel A: Default		
Discontinuity	2.95***	-0.13	3.27***
	(0.37)	(0.27)	(0.42)
Trend	-0.28***	0.12***	-0.09***
	(0.02)	(0.01)	(0.02)
Post-Trend	0.21***	-0.30***	-0.03
	(0.02)	(0.02)	(0.03)
N	519,257	719,106	452,902
	(4)	(5)	(6)
	Panel B: + 7 Donut		
Discontinuity	4.51***	-2.08***	3.82***
	(0.41)	(0.37)	(0.50)
Trend	-0.28***	0.11***	-0.10***
	(0.02)	(0.01)	(0.02)
Post-Trend	0.17***	-0.15***	-0.06**
	(0.02)	(0.02)	(0.03)
N	518,418	675,748	417,820
	(7)	(8)	(9)
	Panel C: +/- 7 Donut		
Discontinuity	6.92***	0.82*	5.10***
	(0.47)	(0.44)	(0.59)
Trend	-0.37***	-0.06***	-0.19***
	(0.02)	(0.01)	(0.02)
Post-Trend	0.25***	0.02	0.08***
	(0.02)	(0.02)	(0.03)
N	534,455	685,839	385,210

Source: Zillow's ZTRAX
Notes: Estimates are from a hedonic RD with the date of the MPA serving as the cutoff. Results are provided for each of the different MPA types described in the Methods section. Untabulated results include the controls described in the Data section. Panel B omits sales that closed in the 7 days following the MPA and Panel C omits sales that closed within 7 days of the MPA on both sides of the cutoff. Heteroskedastic-robust standard errors are included in parenthesis. * 10%, ** 5%, *** 1%.

Table 10: Quantitative Easing – 2008 to 2013

	Long-Run Expansionary			Other		
	Default Log(Price)	+ 7 Donut Log(Price)	+/- Donut Log(Price)	Default Log(Price)	+ 7 Donut Log(Price)	+/- Donut Log(Price)
	(1)	(2)	(3)	(4)	(5)	(6)
	Panel A: Full Sample					
Discontinuity	1.85***	1.52***	3.01***	-0.44***	1.70***	1.73***
	(0.17)	(0.20)	(0.24)	(0.15)	(0.18)	(0.23)
Trend	-0.07***	-0.07***	-0.12***	0.13***	0.12***	0.13***
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
Post-Trend	-0.01	0.02**	0.06***	-0.12***	-0.24***	-0.27***
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
N	2,618,302	2,572,997	2,462,704	3,258,502	3,080,102	2,930,491
	(7)	(8)	(9)	(10)	(11)	(12)
	Panel B: Sand States					
Discontinuity	1.20***	1.19***	2.31***	0.14	1.00***	0.72***
	(0.18)	(0.21)	(0.25)	(0.16)	(0.20)	(0.25)
Trend	-0.07***	-0.07***	-0.13***	-0.00	-0.00	0.03***
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
Post-Trend	0.04***	0.04***	0.11***	0.03***	-0.02**	-0.07***
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
N	1,083,669	1,065,737	1,014,349	1,252,336	1,179,614	1,126,161
	(13)	(14)	(15)	(16)	(17)	(18)
	Panel C: Non-Sand States					
Discontinuity	2.30***	1.63***	3.21***	-0.61***	2.19***	2.19***
	(0.25)	(0.30)	(0.36)	(0.22)	(0.26)	(0.34)
Trend	-0.07***	-0.07***	-0.12***	0.20***	0.18***	0.20***
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
Post-Trend	-0.04**	0.02	0.03*	-0.21***	-0.36***	-0.40***
	(0.02)	(0.02)	(0.02)	(0.01)	(0.01)	(0.01)
N	1,534,633	1,507,260	1,448,355	2,006,166	1,900,488	1,804,330

Source: Zillow's ZTRAX
Notes: Estimates are from a hedonic RD with the date of the QE serving as the cutoff. Results are provided for each of the different QE types described in the Methods section. Untabulated results include the controls described in the Data section. The donut RDs are provided in different columns, rather than panels as in prior tables. Panel A provides results for the full sample, Panel B for sand states, and Panel C for non-sand states. Heteroskedastic-robust standard errors are included in parenthesis. * 10%, ** 5%, *** 1%.