The Impact of Unconventional Monetary Policy on Real Estate Markets*

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Abstract

This paper examines the heterogeneous effects of unconventional monetary policy on housing default and foreclosure across subprime and prime regions. Using both daily and monthly data and various identification schemes, we find that expansionary unconventional monetary policy shocks reduce foreclosures and have out-sized impacts in subprime regions. An examination of the underlying economic mechanisms shows that employment increases play a pivotal role in monetary policy induced foreclosure reductions, in line with theory. Overall, findings document how Fed policy reached hard-hit areas during the housing crisis.

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1 Introduction

During the 2000s meltdown of housing and the global economy, the Federal Reserve employed unconventional policy tools under exigent financial circumstances to stem the crisis, calm markets, and sustain economic activity. Those tools included large-scale Federal Reserve purchases of GSE securities (Fannie Mae and Freddie Mac) in a direct targeting of the ailing housing sector. In response to the crisis, Fed holdings of GSE mortgage-backed securities (MBS) and debt increased by over 1.5 trillion dollars, representing approximately three-quarters of the growth in the Fed's balance sheet.[1] Hence, a considerable portion of the recent Federal Reserve unconventional asset purchases comprised direct housing market stimulus. Yet while unconventional policies had a large and immediate impact on other asset markets, in the wake of crisis period disarray in housing finance uncertainty abounded as to the housing benefits of the Fed's policy innovations.[2]

This paper further considers the impact of unconventional monetary policy by analyzing its effects on arguably the most important sector for Fed crisis management: Housing and real estate.[3] Real estate assets constitute the largest portion of aggregate wealth (Tracy and Schneider, 2001) and Fed officials listed "depressed" or "weak" local housing markets as a key debilitating growth factor during the crisis.[4] Hence, the evaluation of the linkages between unconventional monetary policy and housing is crucial to understanding the efficacy of monetary policy, monetary policy heterogeneity, and the policy transmission mechanism.

Typically, researchers focus on the impact of the Fed's unconventional policies on housing markets through the so-called "refinancing channel," where a decline in bond

[1] Estimates from November 2008, when the Fed first began its unconventional monetary stimulus, to December 2013. Federal Reserve Bank of St. Louis FRED series ID numbers MBST, FEDDT, and WALCL.

[2] As late as August 2012, nearly four years after the Fed first initiated its unconventional monetary policy stimulus, Fed officials labeled the housing market as "depressed" and suggested that it was a major factor limiting economic growth. FOMC minutes, July 31 - August 1, 2012. For other studies that consider the effects of unconventional monetary policy in equity and bond markets, see Rogers et al. (2014) and Gilchrist and Zakrajšek (2013). For other studies of the effects of unconventional monetary policy on housing markets, see Hancock and Passmore (2011), Hedlund et al. (2016), and Beraja et al. (2017).

[3] See, for example, Ed Leamer, "Housing Is the Business Cycle." September 1, 2007. *Jackson Hole*. Leamer contends that housing is the key leading indicator of economic activity

[4] FOMC minutes: `http://www.federalreserve.gov/monetarypolicy/fomccalendars.htm`.

yields lowers mortgage rates and subsequently encourages household refinance.[5] Yet the hardest-hit areas during the Great Recession were subprime regions, areas where borrowers with non-standard mortgages experienced large house price declines (Mian and Sufi, 2009, 2014). Thus by the time that the Fed implemented its unconventional monetary stimulus in November 2008, most borrowers in subprime areas were underwater (had negative home equity) and cutoff from typical refinancing markets. These factors left the refinancing channel impotent in the exact areas in the most need of economic stimulus. Indeed, figure 1 plots the number of refinances per 10,000 homes from the Fannie Mae Loan Performance Dataset across subprime (blue-solid line) and prime (red-dashed line) counties.[6] Before the crisis, refinancing rates were nearly identical across prime and subprime counties. This is seen in the differences in refinances between subprime and prime counties, the green line, which hovers around zero until 2008.[7] Then once the crisis hit and the Fed implemented its unconventional monetary stimulus, refinances spiked in prime counties spiked, indicating that many borrowers in prime counties successfully refinanced to lower interest rates. In contrast, refinances in subprime counties moved comparatively little as households in subprime counties had limited access to refinancing markets. Moreover, subprime regions accounted for the vast majority employment losses during the Great Recession due to house price declines and foreclosure. These losses were concentrated in non-tradable industries (Mian and Sufi, 2014), limiting refinancing channel spillover possibilities from non-subprime regions. Hence in order for the Fed to aid distressed housing markets, the transmission of its policies needed to extend beyond the typical refinancing channel. In this paper we consider an alternative avenue for policy efficacy: housing default and foreclosure.

To measure the effects of unconventional monetary policy on housing defaults, we

[5] Lower interest rates can also aid buyers. For examples of research on the refinancing channel, see Maggio et al. (2016); Beraja et al. (2017).

[6] We define subprime counties as those in the top quintile of subprime issuance in 2005. Prime counties are in the bottom quintile of subprime issuance in 2005. We discuss the data used to make this plot below in section 3.

[7] Note that the Fannie Mae data does not include non-conforming refinances and therefore is not indicitive of total refinancing volume during the pre-crisis period. Yet during the crisis, the private market for non-standard refinances largely dried up, making the Fannie data representative of refinancing volume during the crisis period.

employ various vector autoregression models using both high frequency daily data and monthly data. First, we combine daily financial and housing data with a structural factor-augmented vector autoregression (FAVAR) model to analyze the impact of the Fed's recent actions on housing. The use of the FAVAR framework allows us to consider a large number of daily time series; this yields a more accurate measurement of monetary policy shocks and reduces the potential for omitted variable bias often found in standard VARs. We identify unconventional policy shocks by assuming that the variance of structural monetary shocks is heteroskedastic across monetary policy event and non-event days.[8] Intuitively, this assumption asserts that news regarding monetary policy surfaces in a lumpy manner.

We first find that expansionary unconventional monetary policy shocks are associated with reductions in a key housing market interest rate, Fannie Mae MBS yields. This evidence is congruent with the aforementioned refinancing channel. Yet more importantly, our results also show that a surprise unconventional monetary easing lowers the costs of credit default swaps on subprime mortgage-backed securities as measured by the ABX index, a key proxy for subprime housing default during the crisis.[9] Intuitively, a surprise unconventional monetary easing lowers financial market participants' expectations of subsequent housing default and foreclosure for subprime borrowers. This finding has important implications for the efficacy of Fed policy. As the effects of the refinancing channel were limited in the most crisis ridden areas, a key avenue for Fed policies to buttress ailing subprime markets was through a reduction in foreclosures. This is what we find in our structural VAR model, implying that the Fed's unconventional actions limited foreclosures in the areas suffering from the largest house price declines and substantial unemployment. Indeed, the underlying mortgages that constitute the ABX indices were largely issued in highly concentrated subprime regions and thus highlight the potential for unconventional monetary policy to reach areas important for crisis recovery.

Next, we examine the mechanisms through which unconventional monetary policy

[8] See Rigobon (2003), Rigobon and Sack (2003, 2004, 2005), and Wright (2012). For other applications, see Rogers et al. (2014) and Gilchrist and Zakrajšek (2013).

[9] *The Wall Street Journal*. June 21, 2007. "Index With Odd Name Has Wall Street Glued; Morning ABX.HE Dose."

can reduce housing defaults in subprime regions. Our exploration is guided by previous theoretical and empirical research. In particular, Foote et al. (2008) provide a theory of mortgage default whereby a household only defaults if faced with the "double trigger" of both negative equity *and* an adverse employment shock.[10] If a homeowner with positive equity faces an adverse shock, he can simply sell the home are reap any profits. Thus a homeowner is only in danger of default if home equity is negative. Further theory and empirical evidence suggests that households *do not* typically default if they are underwater and do not face a negative income shock.[11] Together, this line of research provides an avenue through which unconventional monetary policy may mitigate defaults in subprime areas: Through (1) an increase in house prices or (2) employment gains. A cursory exploration of house price data suggests which of these avenues are more likely. Figure 2 shows the house price indices for Las Vegas, Phoenix, and Riverside-San Bernardino, areas at the epicenter of the subprime boom in California and the Southwest from 2002Q1 to 2016Q4. The black-dashed vertical line in the plot signifies the Fed's announcement of QE1 in 2008Q4. Clearly, with house prices in these areas plunging over 40 percent from their peak to 2008Q4, and noting that the a substantial portion of mortgages in these areas were issued at the height of the boom, Fed policies would have to contribute to an increase in house prices of approximately 66 percent for buyers at the peak of the boom to no longer face negative equity.[12] Obviously, this is an unlikely possibility especially within a short time frame following the crisis. On the other hand, Gyourko and Tracy (2014) find that even small aggregate employment changes can have large effects on individual probabilities of default.[13] Thus, even small employment increases due to Fed policies would lead to a reduction in housing defaults in subprime areas. This is what we

[10]Obviously, other shocks to the household, such as divorce or health shocks, can also trigger default if the household faces negative equity.

[11]There are a number of papers that examine the household strategic mortgage default for purposes of gaining access to mortgage modifications. See for example Mayer et al. (2014). However, The announcement and implementation of these programs is exogenous from the household's perspective and does not affect our results here.

[12]Specifically for the case of Riverside, the value of the house price index at the peak of the boom in 2006Q4 was 227.70 and fell to 131.17 by 2008Q4, a reduction of 42.4 percent. Thus, for the Riverside house price index to get back to its peak value of 227.70 house prices would have had to increase by 74.0 percent. For further analyses on the causes and lead up to the crisis see Mayer et al. (2009) and Chauvet et al. (2016).

[13]See also Kelly and McCann (2016).

find in our empirical work: Expansionary unconventional monetary policy shocks lead to out-sized employment increases in subprime counties.

Specifically, to assess the effects of unconventional monetary policy in the context of the double trigger, we turn to monthly data and estimate unconventional monetary shocks using high-frequency, intra-day data, similar to the approached used by Bernanke and Kuttner (2005) during conventional times. We then combine these high-frequency intra-day shocks with the local projections approach of Jordà et al. (2005) all within a panel data framework.

First, we confirm our subprime credit default swap findings from daily FAVAR model: Results using real-estate owned foreclosures (REO; lender home repossession after a default) at the monthly frequency show that expansionary unconventional monetary policy shocks lowered foreclosures in subprime counties, but had a limited effect on foreclosures in prime counties. The vast majority of this foreclosure reduction occurred due to QE1. This latter result matches ex ante expectations as the flow of homes into foreclosure was highest during QE1, yielding a mechanism through which Fed policies could aid distressed housing markets.

Next, within our panel framework we study the effects of employment across subprime and prime counties. In line with previous research, we find that expansionary unconventional monetary policy shocks led to broad-based increases in employment (Wu and Xia, 2016). Yet our results also show that these employments were largest in subprime counties in QE1. In the context of the double trigger theory of mortgage default, these results imply that the unconventional monetary policy induced employment increases in subprime counties are important for the housing monetary policy transmission mechanism.

Finally, we examine the other side of the double trigger theory of mortgage default, house prices and housing returns. Our results show that surprise unconventional monetary shocks had little impact on housing returns during QE1. We do find a strong effect on housing returns during QE2. However, as documented below, the magnitude of the monetary policy shocks during QE2 were small compared to QE1, muting any beneficial effects. In total, the weak response of housing returns to unconventional monetary policy shocks supports the strong role of employment gains in monetary policy transmission to housing markets during times of crisis.

2 Unconventional Monetary Policy Events

In the wake of conventional easing resulting in a zero fed funds rate in 2008, the Federal Reserve employed unconventional tools in an effort to achieve its dual policy goals of full employment and stable prices. Specifically, major actions by the FOMC have included the purchase of long-term government and mortgage-backed securities as well as new guidance regarding the future direction of monetary policy. Our time period extends form the beginning of zero-lower-bound (ZLB) period in November 2008 to 2014. This time period includes QE1, QE2, QE3, and the recent Taper period. In our identification of unconventional monetary policy shocks, we use 48 policy events which include all FOMC meetings and major speeches by the Fed Chair. These dates are extended from Wright (2012) and Glick and Leduc (2015) and are listed in table B1 of appendix B.

Our structural daily VAR is parsimonious and only uses the event days listed in table B1. Yet to estimate the effects of unconventional monetary policy on data available at the monthly periodicity, we combine a high frequency identification strategy via an event study with lower frequency economic data within a VAR framework that employs local projections. These VAR methodologies are described in more detail below. Here we first outline our measurement of monetary policy shocks via an event study that will subsequently be used within our monthly VAR. Our approach extends Wright (2012) and Glick and Leduc (2015) and mirrors that used by Bernanke and Kuttner (2005) during conventional times.[14] Specially, our proxy for unconventional monetary shocks is the first principal component of the difference in the front-month futures for the two-, ten-, and thirty-year Treasuries measured from 15 minutes before to 105 minutes after each monetary policy event listed in table B1 of appendix B. Using a tight window around these future contracts isolates the impact of unconventional monetary policy news on Treasury yields. We then standardize the data to have variance equal to one and so that positive values indicate monetary easing. We summarize the unconventional monetary

[14]Event dates and times are updated from Glick and Leduc (2015).

policy event shocks across QE1, QE2, QE3, and the Taper period in table 1. In particular, we list the total number of events in each QE round and the subsequent Taper period, the number of event days with a positive or negative shock, the maximum shock, the minimum shock, as well as the sum and average of all shocks. Most of the event days were in QE1 and QE2, where slightly less than half of all event days were associated with a positive shock. The shocks, both positive and negative, were largest in QE1, around when the Fed first announced its unconventional monetary stimulus and financial markets were facing extreme turmoil, but much more subdued in QE2 and QE3. This latter result implies that market expectations more closely matched Fed actions during the QE2 and QE3 periods. Similarly, the sum and the mean of the shocks within each QE period (recall that shocks are standardized so that positive values are associated with a monetary easing) was positive in QE1, but negative in QE2 and QE3. Hence, relative to expectations, exogenous unconventional monetary easings were largely concentrated in QE1. In total, table 1 highlights the unexpected nature of QE1, while QE2 and QE3 were much better anticipated by, and perhaps underwhelmed, financial market participants.

3 Data

Our dataset spans numerous housing, financial market, and economic proxies at both monthly and daily periodicities over the period of unconventional monetary policy. The following sections describe the daily and monthly data used in this paper in more detail.

3.1 Daily Data

Within a high-frequency structural VAR where we identify structural unconventional monetary policy shocks by exploiting heteroskedasticity across monetary policy event and non-event days (described in more detail below). Our key variable of interest is the ABX Aaa index that tracks the cost mortgage default risk for subprime mortgages. We also consider a number of daily macro and financial variables as controls. The following sections discuss these variables turn.

3.1.1 ABX Index

The ABX indices reflect the price of credit default swaps on subprime mortgage-backed securities. These indices are tabulated by Markit and were closely watched on Wall Street during the crisis and its aftermath.[15] Each ABX index tracks the cost to insure an equally-weighted basket of 20 subprime mortgage-backed securities. More broadly, the ABX indices can be interpreted as a measure of default risk for subprime borrowers. The ABX series are identified by time of issuance and credit tranche. For this paper, we consider the "on the roll" ABX indices based on most recently issued mortgage-backed securities with ratings of Aaa, henceforth the ABX Aaa index. The last wave of MBS issuance tracked by the ABX was issued in the second half of 2007. We focus only on the higher quality Aaa index as the underlying securities that comprise this index are frequently traded. Further, the vast majority of subprime mortgage-backed securities were rated Aaa. Indeed, Hull (2010) contends that 90 dollars of Aaa rated securities were created from each 100 dollars of subprime mortgages.

The ABX indices are pegged at 100 on the day of issuance and then fall as mortgage and housing investors become more pessimistic about housing and mortgage market performance. For our daily VAR models, we consider the log of the ABX indices. We describe the ABX indices in more detail in appendix C as well as how the values of the ABX indices correspond to the insurance costs for subprime mortgage-backed debt.

3.1.2 Other Housing, Macro, and Financial Daily Data

In addition to the ABX Aaa index, the dataset also includes a number of other financial market indicators tabulated from various equity and debt markets. First, we consider the yields on Fannie Mae 30-year current coupon mortgage backed securities (MBS). The Fannie MBS rates represent the yields on mortgage backed securities packaged and sold by Fannie Mae.

Our data also include as controls nominal and inflation-indexed government securities, corporate bond yields and spreads, exchange rate measures, stock returns, and a proxy for

[15] *The Wall Street Journal*. June 21, 2007. "Index With Odd Name Has Wall Street Glued; Morning ABX.HE Dose."

expected stock market volatility. With regard to interest rates, as in Wright (2012), we consider the yields on the nominal 2- and 10-year zero coupon US Treasuries, Moody's Aaa and Baa rated seasoned corporate bond yields, the five-year and the five-to-ten-year forward TIPS breakeven rates.[16] Furthermore, we also include the returns on the S&P500, the log of the VIX index, the US-Euro, US-Pound, and US-Yen exchange rates, the Baa-Aaa corporate bond spread, and the ten-to-two year and the thirty-to-two year US Treasury spreads. The stock returns signal equity market performance, the VIX index measures expected risk and uncertainty in the stock and financial markets, the exchange rates capture the dynamics of the US Dollar, the Baa-Aaa spread represents corporate default risk, and the Treasury spreads signal the slope of the yield curve. Altogether, our large dataset includes a number of important financial market indicators and is likely to span the information sets used by policymakers or financial market practitioners.

3.2 Monthly Data

One aim of this paper is to measure the geographic disaggregated housing market effects of US unconventional monetary stimulus. To do this, we classify counties into subprime and prime categories as subprime and prime counties differed markedly in their economic performance both in the lead up to and after the crisis (Mian and Sufi, 2009). Specifically for each county, we compute the portion subprime mortgages originated relative to all mortgage loans in 2005, the height of the housing boom, using HMDA records and the HUD subprime lender list.[17] Then we rank counties by the percentage of subprime loans issued relative to all lending. Those in the upper quintile (counties with highest subprime issuance relative to all loans) are subprime counties, while those in the bottom quintile are prime counties. The housing and economic variables of interest at the county-level include Zillow Real Estate Owned (REO) foreclosures per 10,000 homes; the employment-population ratio from the Bureau of Labor Statistics; and Zillow housing returns.[18]

[16] See Wright (2012) and the references therein for more details.

[17] See Mayer and Pence (2008) and Gerardi et al. (2007) for descriptions of subprime data identified using HMDA and HUD. HMDA data: `https://www.ffiec.gov/hmda/hmdaproducts.htm`. HUD subprime lender list: `https://www.huduser.gov/portal/datasets/manu.html`.

[18] Zillow data from `https://www.zillow.com/research/data/` and Bureau of Labor Statistics employment data are from `https://www.bls.gov/lau/`. Population data for the employment-population ratio are from the American Community Survey.

As will be discussed below, our monthly VAR models also include the growth in industrial production and the difference in the log of the VIX index as controls. Industrial production accounts for aggregate changes in the economy, while the VIX index proxies financial market risk and uncertainty. These series were downloaded from the FRED database.[19]

4 Structural Daily VAR and the ABX Index

We begin with a structural framework and daily data where we aim to estimate the causal impact of unconventional monetary policy shocks. The key variable of interest is the ABX Aaa index that tracks the cost of mortgage default insurance on subprime mortgage backed securities rated Aaa. Our approach is to estimate a factor-augmented vector autoregression (FAVAR) model (Bernanke et al. (2005) (BBE) and Boivin et al. (2009) (BGM)) with structural identification of monetary shocks through the assumption of heteroskedasticity across event and non-event days as in Rigobon (2003), Rigobon and Sack (2003, 2004, 2005), and Wright (2012).

A key benefit of the FAVAR model is that it allows us to consider a broad set of daily time series that extend to equity, government and corporate debt, and housing markets all within a single comprehensive econometric framework. Thus, our expansive dataset is likely to span the information sets used by both central bankers and private sector practitioners. This approach allows us to more accurately measure the effects of unconventional monetary policy shocks on the variables of interest.[20] Furthermore, through the FAVAR methodology we can identify structural unconventional monetary policy shocks via heteroskedasticity in the variance of structural monetary shocks across policy announcement and non-announcement days.

With regard to the estimation of the FAVAR model, we assume that financial markets are affected by a basket of key interest rates, the observed factors, and a set of latent factors. Mirroring the data used by Wright (2012) in a standard VAR, we let the the key

[19] FRED series IDs INDPRO and VIXCLS.

[20] As noted by BBE and BGM, our large dataset and the FAVAR framework also allows us circumvent the potential omitted variable bias issues commonly found in standard VARs (e.g. the "price puzzle" of Sims (1992)).

interest rate series that constitute the observed factors be 2-year Treasury, the 10-year Treasury, the five-year TIPS breakeven, the forward-five-to-ten-year TIPS breakeven, and the Moody's AAA and BAA seasoned corporate bond yields, and the yields on Fannie Mae 30-year current coupon mortgage backed securities (MBS). In our setup, the set of observed factors also includes the ABX Aaa index to ensure that the response of the ABX to unconventional monetary policy shocks does not depend on the factor structure. Placing the ABX Aaa index in the set of informational time series (and subsequently letting its dynamics be captured by the latent factors within the FAVAR model) does not affect our results. All other daily time series discussed above in section 3 are relegated to the set of informational time series. In total, eight time series comprise the observed factors and eight separate time series make up the set of informational time series. Together, the latent and observed factors are assumed capture dynamics of financial markets over the sample period. In general, this approach mirrors that used by BBE and BGM during conventional times.

Our reduced form VAR of interest is given by

$$C_t = \Phi(L)C_{t-1} + v_t \tag{1}$$

where C_t is a $(K + 8)$ common component comprising the observed and latent factors, $\Phi(L)$ is a conformable polynomial lag of finite order and v_t is a vector of reduced-form errors.

C_t is derived from the following observation equation using principal components:

$$X_t = \Lambda C_t + e_t \tag{2}$$

where X_t is the set of informational time series (all time series not included in the observed factors) Λ is an $N \times (K+8)$ matrix of factor loadings and e_t is an $N \times 1$ vector representing the idiosyncratic component to each time series. Note that we follow BGM and impose the constraint that the observed factors are elements of C_t.[21]

Further, let $\eta_{i,t}$ be the ith structural shock at time t and assume that the structural

[21] As in BGM, we impose this constraint using the following algorithm, where F_t and S_t are the vectors of latent and observed factors, respectively: (1) extract the first K principal components from X_t, denoted $F_t^{(0)}$; (2) regress X_t on $F_t^{(0)}$ and S_t to obtain $\tilde{\lambda}_S^{(0)}$, the regression coefficient on S_t; (3) define $\tilde{X}_t^{(0)} = X_t - \tilde{\lambda}_S^{(0)} S_t$; (4) calculate the first K principal components of $\tilde{X}_t^{(0)}$ to get $F_t^{(1)}$; (5) Repeat steps (2) to (4) multiple times.

shocks are independent over both i and t.[22] Then, as in Wright (2012), we let the reduced-form errors be a linear combination of structural shocks, $\eta_{i,t}$:

$$v_t = \sum_{i=1}^{K+8} R_i \eta_{i,t} \tag{3}$$

where R_i is a $(K+8)\times 1$ vector to be estimated. Finally, as is standard in the literature, we assume that the parameters Λ, $\Phi(L)$, and $\{R_i\}_{i=1}^{K+8}$ are all constant over time.

To identify the structural monetary shock in equation 3, we assume that the variance of the monetary shock differs across event and non-event days where the events are monetary policy announcements (e.g. FOMC meetings or major policy speeches). Intuitively, this identification strategy relies upon assumption that monetary announcements are exogenous and occur by accident of the calendar, so that news about monetary policy events surfaces in a "lumpy manner" Wright (2012). More concretely, let the structural monetary policy shock be ordered first (for convenience only; VAR ordering does not determine impulse response behavior when identification is through heteroskedasticity) and have mean zero with variance σ_1^2 on event days and variance σ_0^2 on non-event days. The key assumption for identification is that $\sigma_0^2 \neq \sigma_1^2$; that the variance of the structural monetary shock is heteroskedastic across event and non-event days. Finally, assume that all other structural shocks are identically distributed with mean zero and variance 1 on all days. This latter assumption also follows directly from the notion that monetary events occur by accident of the calendar, so that the variance of all other structural shocks should be identical across event and non-event days.

In order to facilitate identification, we need to determine R_1, the parameter vector in equation 3 that relates the reduced-form errors to the structural shocks. First, let Σ_1 and Σ_0 be the variance-covariance matrices of the reduced-form forecast errors on event and non-event days, respectively. Then, following from equation 3, we see that

$$\Sigma_1 - \Sigma_0 = R_1 R_1' \sigma_1^2 - R_1 R_1' \sigma_0^2 = R_1 R_1' (\sigma_1^2 - \sigma_0^2) \tag{4}$$

As $R_1 R_1'$ and $(\sigma_1^2 - \sigma_0^2)$ are not separately identified, we follow Wright (2012) and normalize $(\sigma_1^2 - \sigma_0^2)$ to be equal to 1. Then, to estimate R_1 within our econometric framework, we

[22] This allows for other independent shocks to occur on monetary policy event days. See Wright (2012) for more details.

solve the corresponding minimum distance problem:

$$\hat{R}_1 = \underset{R_1}{\text{argmin}}[vech(\hat{\Sigma}_1 - \hat{\Sigma}_0) - vech(R_1 R_1')]'[\hat{V}_0 + \hat{V}_1]^{-1}[vech(\hat{\Sigma}_1 - \hat{\Sigma}_0) - vech(R_1 R_1')] \quad (5)$$

where the $vech(\cdot)$ operator stacks the lower triangular matrix of a square matrix into a vector, $\hat{\Sigma}_0$ and $\hat{\Sigma}_1$ are sample estimates of the variance-covariance matrices for the reduced-form residuals on non-event and event days, and $\hat{V}_0$ and $\hat{V}_1$ are the estimates of the variance-covariance matrices of $vech(\hat{\Sigma}_0)$ and $vech(\hat{\Sigma}_1)$. Essentially, equation 5 is similar to a weighted least-squares problem with unknown parameter vector R_1. Lastly, as we are not attempting to identify the other structural shocks, $(\eta_2, \ldots, \eta_p)$, no further model assumptions are required.

With $\hat{R}_1$ in hand, we can then compute the dynamic responses following an unconventional monetary policy shock. As the variable of interest, the ABX Aaa index, is a part of the set of observed factors we can compute its impulse response function in the usual way.[23]

Confidence intervals for the IRFs are computed using the two-step bootstrapping algorithm of Kilian (1998). To preserve any potential residual autocorrelation, we follow Wright (2012) and use the stationary block bootstrap of Politis and Romano (1994) and set the block length to 10 days. Note further that we also apply the Kilian bias correction to the point estimates. Altogether, this approach will allow us to then assess the impact of a monetary policy shock on key proxies of housing market performance.[24]

4.1 Results

To reiterate, the observed factors in the FAVAR model include 2-year Treasury, the 10-year Treasury, the five-year and forward-five-to-ten-year TIPS breakeven rates, and Moody's AAA and BAA corporate bond yields, the yields on Fannie Mae 30-year MBS, and the ABX Aaa index. The set of informational time series constitutes eight other time

[23] As in BBE and BGM, one could obtain the impulse response functions for all the variables in the set of informational time series, by simply multiplying the aforementioned IRFs by the factor loadings obtained from the observation equation.

[24] We also implement statistical tests to ensure that the variance-covariance matrices are different across event and non-event days and that there is a single monetary policy shock. Both of these tests pass. For more details on these tests, see Wright (2012)

series that aim to capture the dynamics of financial markets over the sample period.[25]

We allow for two latent factors in the VAR as two latent factors sufficiently captures the dynamics of the informational time series. Using larger or fewer factors does not affect our results nor does varying the variables in the sets of observed factors or informational time series.

A plot of the ABX Aaa index and the causal dynamic responses FAVAR model are in figure 3. First, panel 1A shows the plot of the ABX Aaa index over the sample period. The ABX Aaa index is pegged at 100 on the day of issuance and then falls the cost of default insurance on subprime MBS rises. The ABX Aaa index weakens in the second half of 2007 before plummeting in 2008. Recall that the Lehman Brothers crisis was in September 2008 and that the Federal Reserve first instituted its unconventional monetary stimulus in November 2008. By this point, the ABX had depreciated dramatically. Later in the sample period and during the period of Quantitative easing, the ABX partially recovers.

Plots 2A through 3B show the causal dynamic responses for selected variables following an unconventional monetary policy shock. As the size of the unconventional monetary policy is not identified in the above model, we normalize to immediately lower the 10-year Treasury by 25 basis points. Gray bands are 90 percent bootstrapped confidence intervals as described above. Panels 2A through 2B plot the dynamics for the 2- and 10-year Treasuries. The path of these IRFs is congruent with previous research (e.g. Wright (2012)): Following a surprise monetary easing that lowers the 10-year Treasury by 25 basis points, the 2-year Treasury also falls by over 20 basis points. From there, effects of the shock die out quickly and nearly completely dissipate after 200 days. Panel 3A shows the path of the dynamic response for Fannie Mae MBS yields. Similar to the Treasury yield responses, the Fannie MBS yields fall by nearly 30 basis points in response to an unexpected unconventional monetary easing. Plot 3A hence summarizes monetary policy efficacy on housing through the so-called "refinancing channel" (Maggio et al.,

[25] These series include the 30-year Treasury minus the 2-year Treasury and the 10-year Treasury minus the 2-year Treasury; log of VIX index; the corporate default spread (Baa − Aaa corporate bond yields); S&P500 returns; and the US-Euro, US-Pound, and US-Yen exchange rates.

2016; Beraja et al., 2017): As the Fed lowers long term interest rates, mortgage rates fall, households refinance obtaining lower monthly mortgage payments, and subsequently households increase consumption. This channel is obviously only efficacious for households with positive equity on fixed rate mortgages or for homeowners with adjustable rate mortgages also benefit this from "automatic refinancing." Buyers also benefit from lower mortgage rates and hence lower Fannie MBS yields will aid investors and households that purchase new homes. In the wake of the financial crisis, these buyers included both households and institutional investors.[26]

Next, panel 3B shows the IRF for the log of the ABX Aaa index. A surprise unconventional monetary easing that lowers the 10-year Treasury by 25 basis points increases the log of the ABX index by 15 basis points. Recall that the ABX increases as it becomes less expensive to insure subprime-mortgage backed debt (e.g. as investors' expectations of subprime mortgage default decrease). The results thus indicate that this monetary shock lowers the cost to insure $10m of subprime mortgage backed debt by $116,000. Hence, expansionary unconventional monetary shocks lead to substantial reductions in the default risk for the vast majority of lower qualied borrowers, meaning that recent unconventional monetary policy actions were successful in stimulating the subprime housing market system. Note that a substantial portion of subprime borrowing was concentrated geographically, in areas such as California's Inland Empire (San Bernardino and Riverside) and Las Vegas, where refinancing was not possible through standard channels due to large house price declines (Mian and Sufi, 2009; Mian et al., 2013). Therefore, the ABX result in panel 3B suggests that the Fed's unconventional monetary stimulus reached households in the most crisis-ridden regions where refinance was unlikely due to house price declines. We discuss these transmission mechanisms further below.

5 Monthly VAR and Local Projections

Next, we examine the relationship between unconventional monetary policy and key housing and employment variables of interest at the monthly frequency across prime and

[26]For an overview of buying behavior by institutional investors following the crisis, see "Investors Who Bought Foreclosed Homes in Bulk Look to Sell." *New York Times*. June 27, 2014.

subprime counties. To do this we combine the local projection method (Jordà et al., 2005) with unconventional monetary policy shocks identified using high frequency intra-day data. Specifically, we employ a panel model to estimate an impulse response for a given subprime quintile q and a variable y, j periods ahead, following an unconventional monetary policy shock:

$$\begin{aligned} y_{i,t+j} = \alpha_i + \gamma_q \cdot y_t \cdot subprime_q + \beta_q \cdot unconven\_shock \cdot subprime_q + \\ \sum_{k=1}^{p} (\delta_{k,q} y_{i,t-k} + \eta_{k,q} unconven\_shock_{t-k}) \cdot subprime_q + \\ \xi_q \cdot \mathbf{x}_t \cdot subprime_q + \varepsilon_{it} \end{aligned} \tag{6}$$

y is the outcome variable of interest such as foreclosures or employment, α_i signifies county fixed effects, *unconven_shock* is our proxy for unconventional monetary policy shocks (to be described below), $subprime_q$ represents the subprime quintile for county i, and $\mathbf{x}$ is a vector of controls. The model in equation 6 amounts to separately estimating the effects of unconventional monetary policy shocks for the set of counties in each subprime quintile (noting that the county fixed effects subsume the subprime fixed effects). The advantage of the panel setup is that it allows us to estimate the model across subprime quintiles while retaining power for our statistical tests. We therefore can estimate equation 6 separately for QE1, QE2, and QE3 and measure effects of unconventional monetary policy across the Fed's three major stimulus programs.

The coefficient of interest, β_q, captures the causal change in y, j periods ahead, due to the unconventional monetary policy shock for subprime quintile q and is the j-period local projection impulse response. We estimate equation 6 for $j = 1, \ldots, 18$, building an 18-month impulse response function. The lag-length, p, is chosen using the AIC separately for each j, and $\mathbf{x}$ includes macro financial market controls including the growth in industrial production and the change in the log of the VIX index. Heteroskedasticity-robust standard errors are clustered at the state level.

We employ high frequency data to measure unconventional monetary policy shocks. This approach builds on the work of Bernanke and Kuttner (2005) during conventional times and the measurement of unconventional monetary policy shocks within an event study framework by Wright (2012) and Glick and Leduc (2015). As noted above, we take the first principal component of the difference in front-month treasury market futures for the two-, ten-, and thirty-years Treasuries from 15 minutes before to 105 minutes after each monetary policy event.[27] This tight event window limits endogeneity concerns related to other economic announcements. With these shocks in hand, we aggregate the event study data to the monthly frequency by simply summing the shocks within each month. Monetary shocks are assumed to be zero in months with no event days. In total, this approach yields an exogenous time series representing unconventional monetary policy shocks that can be employed directly into equation 6 to build impulse response functions for key economic variables at the monthly periodicitiy.

5.1 Results – REO Foreclosures across Subprime and Prime Counties

Panel 1A of figure 4 shows the path of Zillow REO foreclosures per 10,000 homes from 2005 to 2015 for "subprime counties" (solid blue line; counties in the top quintile of subprime issuance in 2005) relative to "prime counties" (dashed red line; counties in the bottom quintile of subprime issuance). The dash-dot green line is the difference between subprime and prime counties.

Not surprisingly, REO foreclosures are persistently higher in subprime counties over the entire sample period. The path of these variables aptly summarizes the carnage that consumed US housing markets during the late 2000s: REO foreclosures were low in 2005, began to rise in 2006, and spiked in 2008 at the height of the housing crisis. The green line represents the spread between foreclosures in subprime and prime counties. The subprime-prime REO foreclosure spread more than doubles from 2005 to 2008, highlighting the out-sized adverse effects of the Great Recession in subprime counties. But in 2009, as the crisis began to abate and as the Fed's unconventional monetary policy stimulus took hold, REO foreclosures in both subprime and prime counties fell. The subprime-prime REO foreclosure spread simultaneously began to tighten due to a larger reduction in monthly REO foreclosure in subprime counties. The dramatic drop in foreclosures across both subprime and prime counties continued through 2012. Into 2013 and 2014, foreclosures fell slightly, but the rate of decline slowed compared to earlier periods.

[27]The monetary policy events are listed in table B1 of appendix B.

Clearly, the majority of the drop in monthly REO foreclosures occurred between 2009 and 2013.

Panels 2A through 2C in figure 4 show the cumulative impulse response functions computed using local projections via equation 6. Note that we estimate 6 separately for QE1, QE2, and QE3. The gray bands around the IRFs are heteroskedasticity robust ± 1 standard error bars clustered at the state-level. As before, the subprime counties are the solid-blue lines and the dashed-red lines represent prime counties. First, panel 2A presents the cumulative dynamic responses for REO foreclosures in QE1. The vertical axis can be interpreted as the total reduction in REO foreclosure per 10,000 homes after j months due a surprise unconventional monetary easing equivalent to 1 standard deviation. The results are telling: After 18 months, an unexpected QE easing equivalent to 1 standard deviation prevents 1 foreclosure for every 10K homes in subprime counties. This result is large in magnitude and economically meaningful. As the shocks associated QE1 totaled 6.6 standard deviations (see table 1), these results imply that QE1 shocks saved 6.6 homes per 10,000 from REO foreclosures in subprime counties.[28] In contrast, QE1 had a relatively muted effect on REO foreclosures in prime counties, leading to nearly no change in REO foreclosures in prime counties after 16 months.

Panel 2B shows the cumulative IRFs for REO foreclosures across prime and subprime counties in QE2. The results indicate that there was a large reduction in REO foreclosures following a surprise unconventional monetary easing in both subprime and prime counties, with a larger decline in prime counties. Yet note that magnitude of the shocks were muted in QE2, especially compared to QE1 (table 1 columns (1) and (2)). Hence while the effects associated with unconventional monetary shocks were in fact large, the overall effect of QE2 shocks on foreclosures was likely small. Panel 2C shows that following a surprise unconventional monetary easing in QE3 that REO foreclosures increased. Yet after 12 months this effect began to reverse and was trending toward zero after 18 months. Recall from panel 1A that by QE3, REO foreclosures in both subprime and prime counties reached the lower end of their range. The shocks during QE3 were also

[28] $1 * 6.606 \approx 6.6$.

relatively muted. These facts together imply that QE3 shocks likely had a minimal effect on REO foreclosures. Altogether, results from this section imply that unconventional monetary shocks had a large impact on REO foreclosures in subprime counties, matching our above daily FAVAR results, but also show that the beneficial effects were largely concentrated in QE1.

5.2 Results – Employment-Population across Subprime and Prime Counties

Figure 5 plots the path and cumulative dynamic responses for the employment-population ratio across prime and subprime counties. The employment-population ratio is a key variable of interest for housing and real estate markets due to its role in mortgage default and foreclosure. Theory and empirics find that households only default when faced with *both* the double trigger of negative equity and a loss of employment (Foote et al., 2008; Bhutta et al., 2010).[29] Employment changes thus represent an important mechanism in default behavior, providing a key channel through which unconventional monetary can affect foreclosures and thus real estate markets. Indeed, as underwater households are blocked from typical refinancing markets, the Fed can only aid distressed households and thus limit foreclosures through employment gains.

The setup of figure 5 mimics figure 4. First, panel 1A of figure 5 outlines the path of employment relative to population in subprime and prime counties. As expected, prime counties are associated with substantially higher employment before the recession and over the entire sample period. This is congruent with elevated credit ratings and lower default risk in prime counties.[30] Yet in both subprime and prime counties, employment falls beginning in 2006, plunges with the onset of the Great Recession in 2008, and recovers anemically in the aftermath of the crisis. The flat path of employment after 2009 highlights the challenge faced by policymakers following the recession.

Panels 2A through 2C of figure 5 show the cumulative IRFs for the employment-population ratio in QE1, QE2, and QE3 across subprime and prime counties. The vertical axis represents the total change in employment population ratio following an

[29] Instead of a loss of employment, a household facing negative may default due to a divorce, an adverse health shock, etc.

[30] See, for example, Mian and Sufi (2009).

unconventional monetary policy shock equivalent to 1 standard deviation after j months. In general, the results show that expansionary unconventional monetary policy shocks lead to positive employment growth in line with existing research (see e.g. Wu and Xia (2016)). Yet the impact of the monetary shocks differs across the various rounds of Quantitative Easing and prime and subprime counties. In QE1, an expansionary unconventional monetary shock equivalent to 1 standard deviation leads to an increase in the employment-population ratio in subprime counties of approximately 0.0125. This effect is large in magnitude and implies that a QE1 shock increased the employment-population ratio in subprime counties by 1.25 percentage points after 18 months. Expansionary unconventional monetary shocks also had a beneficial effect on prime counties in QE1, but the total effect after 18 months was approximately 20 percent lower than that for subprime counties.

The effects of expansionary monetary surprises on employment were large in QE2 (panel 2B of figure 5) with the prime employment-population ratio increasing nearly 2.5 percent after 18 months following an expansionary unconventional monetary shock equivalent to 1 standard deviation. Yet as noted above, the total magnitude of the shocks during QE2 were muted, relative to QE1, limiting the overall effects of QE2 shocks on employment. Finally, panel 2C shows the cumulative dynamic responses in QE3. Again, we find positive employment growth following an expansionary monetary shock, where the beneficial QE impacts are much larger for subprime counties. Indeed, after 18 months, an expansionary monetary policy shock in QE3 equivalent to 1 standard raises the subprime employment-population ratio by 1.5 percentage points after 18 months. In comparison, that same monetary shock increases the prime employment-population ratio by less than 1 percentage point.

Overall, QE shocks are associated with an increase in employment in both subprime and prime counties. In QE1 specifically, when monetary shocks notably reduced REO foreclosures in subprime counties, employment growth was comparatively large in subprime counties and thus indicating that employment gains represent a key channel through which the Fed's unconventional stimulus can aid distressed and underwater households.

5.3 Results – Housing Returns across Subprime and Prime Counties

Opposite employment in the double trigger theory of mortgage default are house prices and housing returns. Indeed, a household with positive equity that suffers an adverse shock that may result in default can simply sell the home and reap any profits (Foote et al., 2008). Yet for all households, an increase in housing returns also increases homeowner net worth, especially for highly leveraged households, potentially leading to increased refinancing opportunities, higher consumption and real economic gains (Mian et al., 2013). Thus, elevated house prices provide several channels through which monetary policy can affect housing and real estate markets. As noted in the introduction, however, house prices declined substantially between the peak of the housing market in 2006 and the start of QE1 in November 2008. Thus, in order for the Fed to mitigate foreclosures via house prices or increase refinancing opportunities in hard-hit subprime regions, the response of house prices to unconventional monetary stimulus needed to be extremely large.

Figure 6 shows monthly Zillow housing returns and cumulative IRFs across prime and subprime counties. The layout mirrors figures 4 and 5. As seen in panel 1A, monthly housing returns were large and positive prior to crisis and exceeded 1 percent *per month*. But after the US housing market peaked in 2005, housing returns began to fall before barreling downward from 2006 to 2008. Housing returns then bottomed out in 2008 and 2009 but did not reach sustained positive levels until 2012. The slow recovery of the housing market, particularly for those in subprime counties facing extreme housing leverage, was likely a key contributor to the slow economic recovery following the Great Recession (Mian et al., 2013; Gabriel et al., 2017).

The cumulative IRFs in panels 2A through 2C represent house price growth following a surprise expansionary unconventional monetary easing equivalent to 1 standard deviation. The results show that QE did not have a notable positive impact on house prices in QE1 and QE3. During QE2, however, the effects were large and positive and coincide with a large increase in other asset prices, such as those for equities: An unexpected monetary easing equivalent to 1 standard deviation increased subprime house prices by nearly 4 percent and prime house prices by over 3 percent. Yet as noted above and in table 1, shocks in QE2 were smaller than those in QE1, likely muting the impact of unconventional monetary policy on housing returns. In QE3, house prices initially increased following an expansionary unconventional monetary shock but then retreated after approximately 6 months.

Overall, the IRFs for house prices in figure 6 are small in magnitude, suggesting that the impact of unconventional monetary stimulus on foreclosures via housing returns is limited.

6 Conclusion

Overall for the Fed to achieve its mandate of full employment following a downturn, its policies must be efficacious in the local areas suffering from employment losses. Further mitigating the effects of economic factors weighing on the economy can speed recovery. In this paper we thus examine the effects of unconventional monetary policy on mortgage default and foreclosure, variables that caused the Great Recession and slowed the subsequent recovery (Mian and Sufi, 2009, 2014). Our findings show that expansionary unconventional monetary policy shocks lowered foreclosures in the hard-hit subprime regions. This effect was large in magnitude especially compared to foreclosure reductions in prime regions. We arrive at these results using both high and low frequency data in VAR models with different estimation schemes. Breaking out the effects across the various rounds of Quantitative Easing shows that the reduction in foreclosures due to unconventional monetary policy shocks was concentrated in QE1 during the height of the crisis. The effects of unconventional monetary policy shocks in QE2 and QE3 were comparatively muted: In QE2, the size of the monetary shocks was small, limiting potential effects; and by QE3 foreclosures stabilized in both subprime and prime housing markets, closing off foreclosure reduction as a monetary policy transmission mechanism.

We then explore the economic underpinnings of the relationship between unconventional monetary policy and housing defaults. Our approached is guided by the double trigger theory of mortgage default (Foote et al., 2008) and we thus investigate the effects of the Fed's recent policies on employment and housing returns. In line with the double trigger theory and beneficial effects of Fed crisis policy in hard-hit areas, we find an out-sized impact of unconventional monetary policy shocks on employment in subprime regions. This result highlights how Fed policies reached the most dire local economies at the height of the crisis.

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A Tables & Figures

Table 1: Summary of Shocks Across QE1, QE2, QE3, and the Taper Period

	QE1 (1)	QE2 (2)	QE3 (3)	Taper (4)	Total (5)
Event Days	15	21	6	6	48
Event Days with a Positive Shock	7	10	1	3	21
Event Days with a Negative Shock	8	11	5	3	27
Maximum Shock	4.287	1.139	0.413	2.045	4.287
Minimum Shock	-1.299	-1.261	-0.913	-0.811	-1.299
Sum of Shocks	6.606	-1.255	-1.666	0.933	4.618
Mean of Shocks	0.440	-0.060	-0.278	0.156	0.096

Notes: Summary statistics for unconventional monetary policy shocks over event days across QE1, QE2, QE3, and the Taper Period. Unconventional monetary policy shocks are calculated from the first principal component in the two-, ten-, and thirty-year front-month Treasury market futures from 15 before to 105 minutes after the monetary policy event. The shocks are standardized to have unit variance and so that positive shocks are associated with monetary easing.

Figure 1: Refinances per 10,000 Households Across Subprime and Prime Counties - Monthly Fannie Mae Refinances per 10,000 households. The blue line represents subprime counties, the red line signifies prime counties, and the green line is the difference between subprime and prime counties.

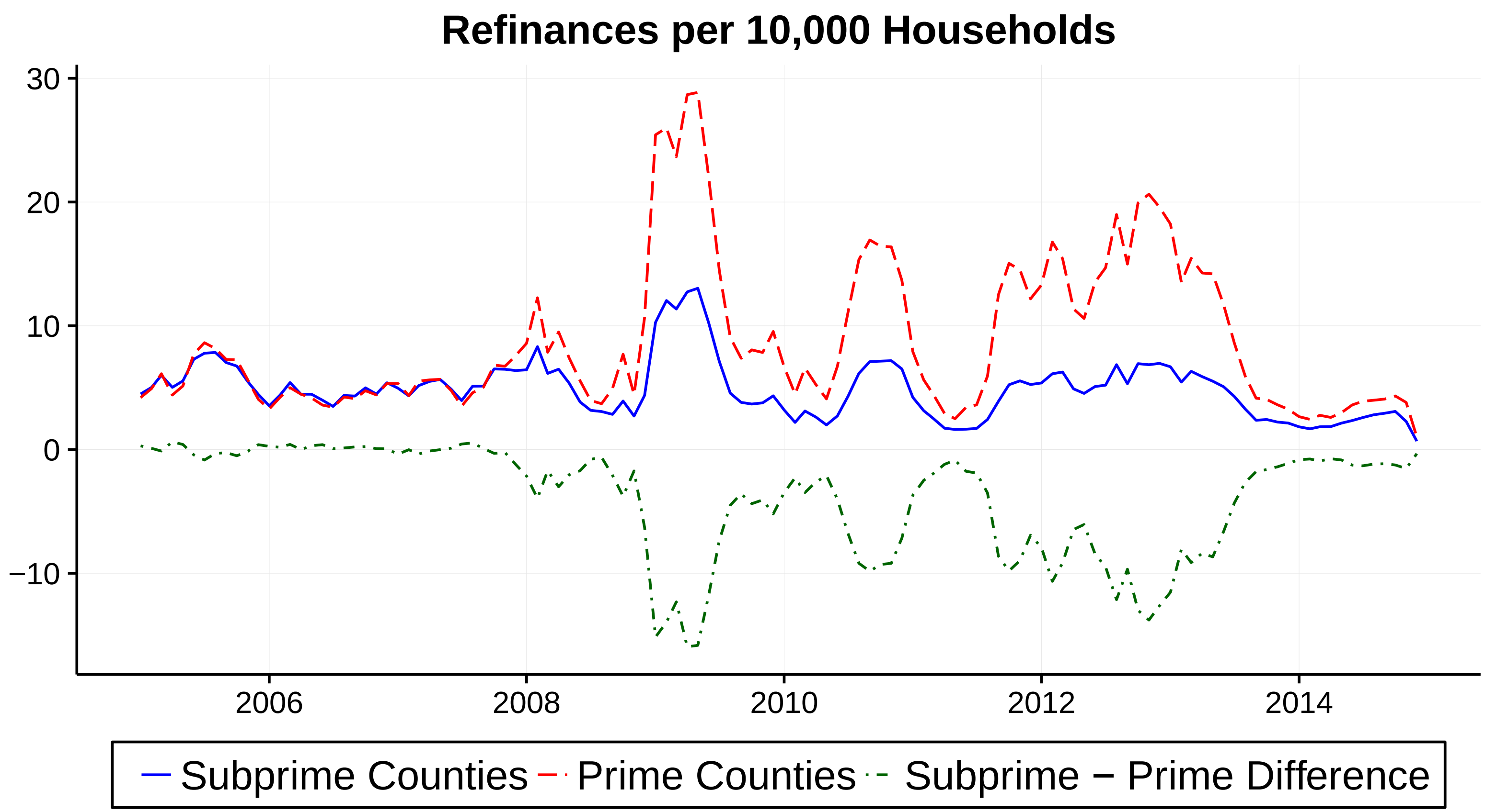


Figure 2: House Prices in Subprime Regions - FHFA quarterly all-transaction house price indices from 2002Q1 to 2016Q4. All series equal 100 in 2002Q1. The black-dashed vertical line is the is the start of QE1 in 2008Q4. The FRED series IDs for the house price indices for Las Vegas, Phoenix, and Riverside-San Bernardino are ATNHPIUS29820Q, ATNHPIUS38060Q, ATNHPIUS40140Q.

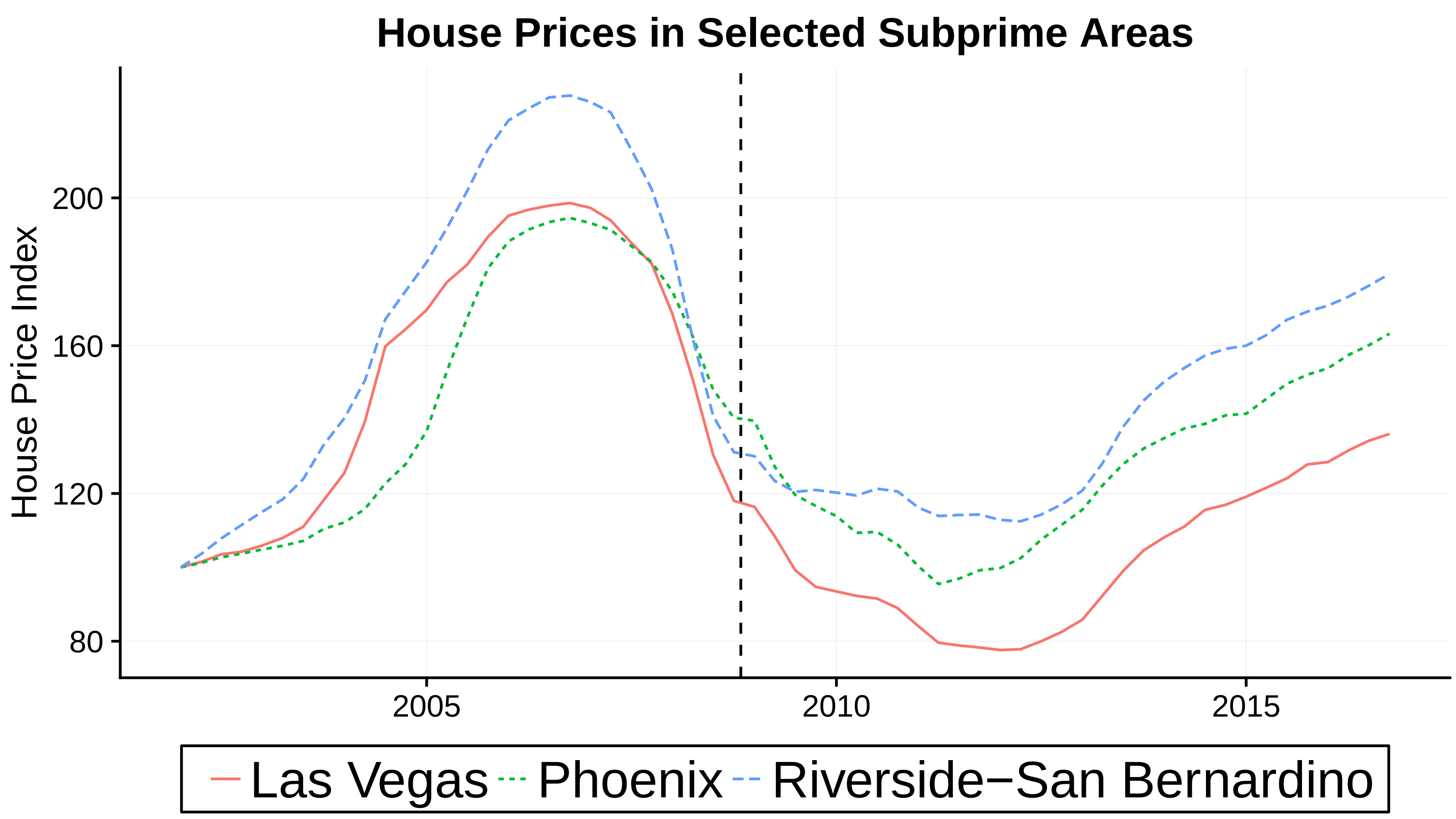


Figure 3: Daily ABX Aaa Subprime Credit Default Swaps - The ABX Aaa index measures the cost to insure subprime Aaa mortgage debt. Panel 1A plots the daily ABX Aaa index from 2006 to 2014. Panels 2A through 3B plot structural dynamic responses during the zero lower bound period. The vector autoregression is identified by assuming that unconventional monetary shocks are heteroskedastic across monetary policy event and non-event days. Impulse responses are normalized so that the 10-year Treasury falls immediately by 25 basis points. Gray bands are 90 percent confidence intervals computed using the two-step stationary bootstrap procedure of Kilian (1998) and Politis and Romano (1994).

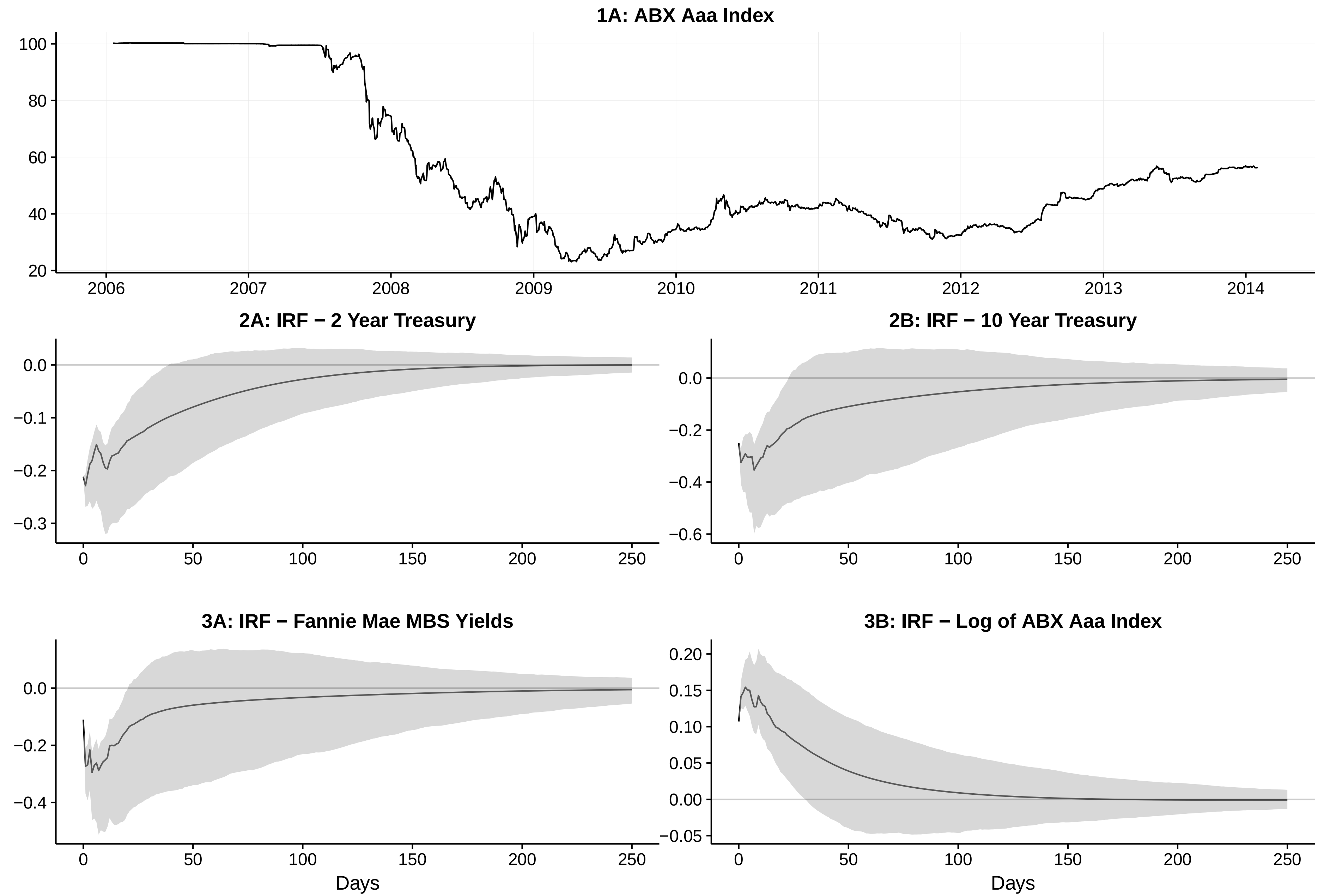


Figure 4: Foreclosures Across Subprime and Prime Counties - Monthly Zillow Real Estate Owned (REO) Foreclosures per 10,000 homes across subprime and prime counties. The blue-solid lines represent subprime counties, the red-dashed lines are prime counties, and green line is the difference between subprime and prime counties. Panel 1 plots Zillow REO Foreclosures per 10,000 homes from 2005 to 2015. Panels 2A, 2B, 2C show cumulative reduced-form dynamic responses following a surprise unconventional monetary easing equivalent to 1 standard deviation for QE1, QE2, or QE3, respectively. The IRFs are estimated using local projections. The gray bands are ±1 heteroskedasticity-robust standard errors clustered at the state-level.

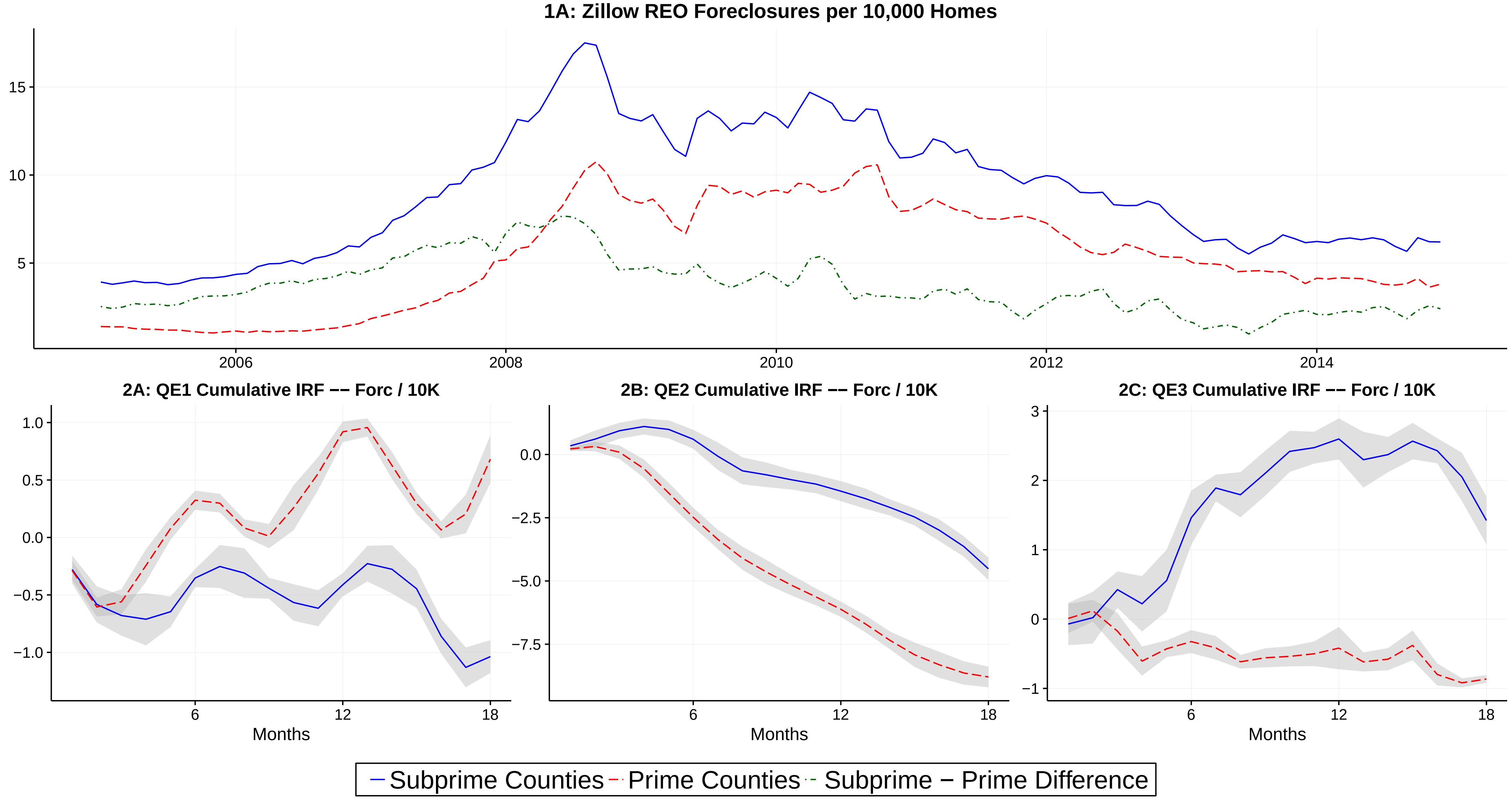


Figure 5: Employment-Population Across Subprime and Prime Counties - The monthly employment-population ratio across subprime and prime counties. The blue-solid lines represent subprime counties, and the red-dashed lines are prime counties. Panel 1 plots employment-population ratio from 2005 to 2015. Panels 2A, 2B, 2C show cumulative dynamic responses following a surprise unconventional monetary easing equivalent to 1 standard deviation for QE1, QE2, or QE3, respectively. The IRFs are estimated using local projections. The gray bands are ±1 heteroskedasticity-robust standard errors clustered at the state-level.

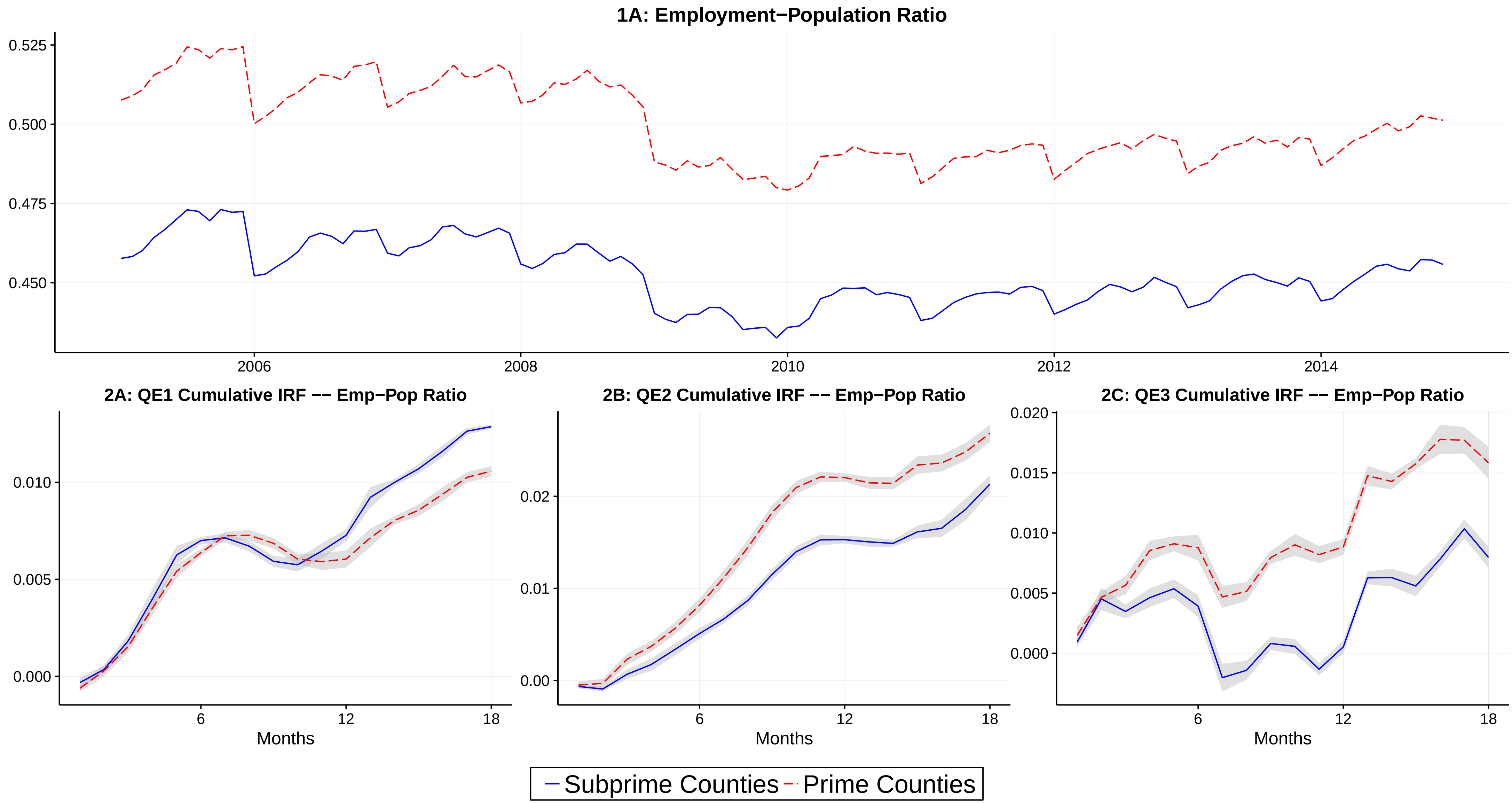
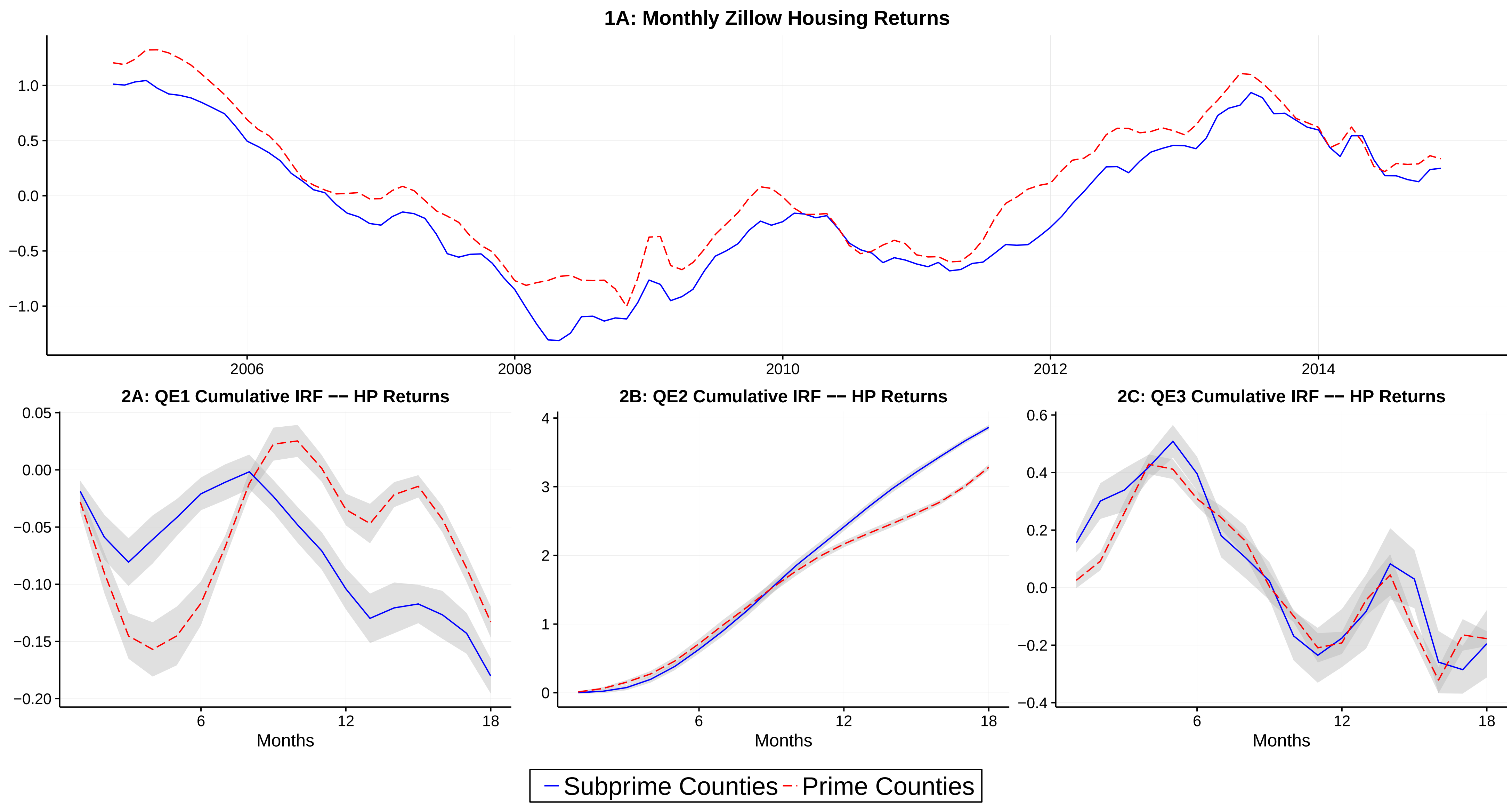


Figure 6: House Price Returns Across Subprime and Prime Counties - Monthly Zillow house price returns across subprime and prime counties. The blue-solid lines represent subprime counties, and the red-dashed lines are prime counties. Panel 1 plots house price returns from 2005 to 2015. Panels 2A, 2B, 2C show cumulative dynamic responses (house price growth) following a surprise unconventional monetary easing equivalent to 1 standard deviation for QE1, QE2, or QE3, respectively. The IRFs are estimated using local projections. The gray bands are ±1 heteroskedasticity-robust standard errors clustered at the state-level.



B Appendix: Tables

Table B1: Unconventional Monetary Policy Events

Event	Date	QE	Type	Event	Date	QE	Type
1	2008-11-25	1	FOMC Press Release	25	2011-06-22	2	FOMC Meeting
2	2008-12-01	1	Fed Chair Speech	26	2011-08-09	2	FOMC Meeting
3	2008-12-16	1	FOMC Meeting	27	2011-08-26	2	Fed Chair Speech
4	2009-01-28	1	FOMC Meeting	28	2011-09-21	2	FOMC Meeting
5	2009-03-18	1	FOMC Meeting	29	2011-11-02	2	FOMC Meeting
6	2009-04-29	1	FOMC Meeting	30	2011-12-13	2	FOMC Meeting
7	2009-06-24	1	FOMC Meeting	31	2012-01-25	2	FOMC Meeting
8	2009-08-12	1	FOMC Meeting	32	2012-03-13	2	FOMC Meeting
9	2009-09-23	1	FOMC Meeting	33	2012-04-25	2	FOMC Meeting
10	2009-11-04	1	FOMC Meeting	34	2012-06-20	2	FOMC Meeting
11	2009-12-16	1	FOMC Meeting	35	2012-08-01	2	FOMC Meeting
12	2010-01-27	1	FOMC Meeting	36	2012-08-31	3	Fed Chair Speech
13	2010-03-16	1	FOMC Meeting	37	2012-09-13	3	FOMC Meeting
14	2010-04-28	1	FOMC Meeting	38	2012-10-24	3	FOMC Meeting
15	2010-06-23	1	FOMC Meeting	39	2012-12-12	3	FOMC Meeting
16	2010-08-10	2	FOMC Meeting	40	2013-01-30	3	FOMC Meeting
17	2010-08-27	2	Fed Chair Speech	41	2013-03-20	3	FOMC Meeting
18	2010-09-21	2	FOMC Meeting	42	2013-05-01	3	FOMC Meeting
19	2010-10-15	2	FOMC Meeting	43	2013-05-22	Taper	Congressional Testimony
20	2010-11-03	2	FOMC Meeting	44	2013-06-19	Taper	FOMC Meeting
21	2010-12-14	2	FOMC Meeting	45	2013-07-31	Taper	FOMC Meeting
22	2011-01-26	2	FOMC Meeting	46	2013-09-18	Taper	FOMC Meeting
23	2011-03-15	2	FOMC Meeting	47	2013-10-30	Taper	FOMC Meeting
24	2011-04-27	2	FOMC Meeting	48	2013-12-18	Taper	FOMC Meeting

C Appendix: The ABX Index

In this appendix, we briefly describe the ABX indices. Each ABX index tracks the cost to insure a basket of 20 subprime mortgage backed securities, equally weighted.

The ABX indices are split up based on investment quality and time of issuance. The ratings are synonymous to those in the bond industry: Aaa is the highest and Bbb- is the lowest. The 2007-02 set of ABX indices, for example, is comprised of loans made in the second half of 2007. We can interpret $(100 - ABX)$ as the upfront payment above the coupon required to insure certain mortgage loans.

To exactly understand how the ABX relates to the cost for insurance we first define the following variables:

- The value for the ABX index (ABX). The ABX is always 100 on the day of issuance.
- The $Loan$: The amount of mortgage backed securities to be insured.
- The $Coupon$: The annual fixed payment for the insurance, reported in basis points.
- The $Factor$: The proportion of the principal currently outstanding. This equals one on the day of issuance.

Using the above variables we can calculate the cost to insure a given amount of mortgage backed securities:

$$\begin{aligned} \text{Insurance Cost} &= (100 - ABX) \cdot Loan \cdot Factor + Loan \cdot Factor \cdot Coupon \\ &= (100 - ABX + Coupon) \cdot Loan \cdot Factor \end{aligned} \tag{7}$$

The derivative of equation 7 with respect to ABX is negative. Hence, it becomes more costly to insure mortgage backed securities as ABX falls. In other words, the ABX indices fall as investors become more pessimistic about mortgage backed securities. Finally, we can calculate the change in the up-front cost to insure debt by simply multiplying $Loan$ by the change in the ABX index represented as a percent.[31]

[31] See, for example, "Subprime Mortgage Bond Derivatives Fall After NovaStar's Loss." *Bloomberg News*, February 21, 2007. Also, "Goldman Pushes Subprime ABX Index as Housing Rebounds: Mortgages." *Bloomberg News*, November 30, 2012.