Unconventional Monetary Policy and the Allocation of Credit*

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Abstract

Despite massive large-scale asset purchases (LSAPs) by central banks around the world since the global financial crisis, there is a lack of empirical evidence on whether and how the composition of purchased assets matters for the effectiveness of unconventional monetary policy. Using uniquely rich mortgage-market data, we document that there is a "flypaper effect" of LSAPs, where the transmission of unconventional monetary policy to interest rates and (more importantly) origination volumes depends crucially on the nature of the assets purchased. For example, QE1, which involved significant purchases of GSE-guaranteed mortgages, increased GSE-guaranteed mortgage originations significantly more than the origination of non-GSE mortgages. In contrast, QE2's focus on purchasing Treasuries did not have such differential effects. This *de facto* allocation of credit across mortgage market segments, combined with sharp bunching around GSE eligibility cutoffs, establishes an important complementarity between mortgage-market policy and the effectiveness of Fed MBS purchases. In particular, more relaxed GSE eligibility requirements would have resulted in more refinancing from economically distressed regions and fewer households deleveraging overall. Overall, our results are consistent with the capital constraints channel of unconventional monetary policy.

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1 Introduction

In recent years, many central banks have undertaken unconventional monetary policy to stimulate their economies, mainly through long-duration large-scale asset purchase programs (LSAPs). A common feature of these programs is their significant size; the Federal Reserve increased the size of its balance sheet more than fivefold (Figure 1). However, LSAPs have varied significantly in the type of assets purchased by central banks, e.g., from Treasuries and Agency debt in the U.S. to ETFs and corporate bonds in Japan. Despite the newfound popularity of LSAPs worldwide, their effectiveness and the channels through which they affect the aggregate economy have been at the center of a vigorous policy and academic debate. We contribute to this debate by investigating the channels through which LSAPs impact the real economy and ask whether the composition of assets purchased (in addition to their duration) matters.

There is no clear consensus on whether LSAPs do benefit an economy and on potential transmission mechanisms. Non-standard open market operations are irrelevant in a frictionless world, as shown by Wallace (1981) and Eggertsson and Woodford (2003). Moving away from a frictionless world, the literature on unconventional monetary policy has suggested multiple explanations for why LSAPs may have real effects. First, under the portfolio-balancing channel, the central bank affects the return of different assets by affecting their relative supply.[1] Second, the segmentation channel posits that LSAPs are effective when capital-constrained intermediaries are unable to arbitrage in the short run across different market segments (e.g., Vayanos and Vila, 2009 and Greenwood et al., 2015).[2] Third, the capital-constraints channel highlights how LSAPs can offset the decline in private lending from disruptions in financial intermediation (see Gertler and Karadi, 2011 and Curdia and Woodford, 2011).

Under the portfolio-balancing and duration-segmentation channels, only the duration (or riskiness) of assets purchased drives their effectiveness because investors will reallocate their resources to other similar assets not purchased by the central bank. However, if investors specialize in trading a specific asset class, or if the financial intermediation sector is constrained, there will be only limited

[1] LSAPs could have real effects by taking safe assets out of the market and therefore inducing cautious investors to take more risk. For related arguments, see Gurley et al. (1960), Tobin and Brainard (1963), Tobin (1969), and Brunner et al. (1973).

[2] We refer to this channel as the duration-segmentation channel if the inhibiting segmentation is along asset duration.

spillovers of central-bank purchases to other asset classes, and the effectiveness and allocative effects of LSAPs will depend on not only the duration but also the specific type of assets purchased.[3] In other words, to the extent that portfolio rebalancing or duration-segmentation is driving the effectiveness of LSAPs, we should observe spillovers from central-bank purchases to other assets with similar duration. An absence of such spillovers would support the view that LSAPs stimulate real activity through the capital constraints channel or a narrow-segmentation channel. This paper empirically investigates this hypothesis.

Identifying the effects of aggregate policies is particularly challenging given that such policies explicitly respond to current and anticipated aggregate shocks. For traction, most of the literature has used event studies of short-run asset-price changes immediately surrounding central bank policy announcements. We supplement such before/after comparisons with an identification strategy that exploits the segmentation of the U.S. mortgage market and the legal restriction that the Fed can only purchase mortgages guaranteed by the Government Sponsored Enterprises (GSEs). The outstanding balance on GSE-guaranteed mortgages must be less than the so-called conforming loan limits and must have loan-to-value ratios at or below 80 percent.[4] This allows us to estimate the effects of quantitative easing by contrasting how each LSAP campaign affected refinancing activities in the conforming and non-conforming segments. Specifically, finding *spillovers* between these two segments supports the portfolio-rebalancing channel or duration-segmentation channels of unconventional monetary policy, while rejecting spillovers would be more consistent with the capital-constraints or narrow segmentation channels.

We start our analysis by considering the changes in mortgage interest rates. Consistent with existing work, we find that interest rates decreased by more than 100 basis points on average in response to the beginning of QE1. However, we show that interest rates on jumbo loans decreased significantly less, increasing the jumbo-conforming spread by 40-50 basis points, nearly as much as this spread increased from the collapse in private securitization in late 2007. By contrast, QE2, the Maturity Extension Program ("Operation Twist") enacted in September 2011, and QE3 led to overall mortgage rate reductions of 20-40 basis points without detectable differential effects across conforming and non-conforming segments. We also investigate the effects of the Fed's tapering its

[3] Agency-mortgage REITs are one example of such an investor, investing mainly in a single asset class.

[4] An important exception to the 80% LTV cutoff was made possible by the Home Affordable Refinancing Program (HARP), a policy we show had visible effects on the effectiveness of Fed MBS purchases.

MBS purchases starting in June 2013, finding that rates increased in response by about 25 basis points more for the conforming segment than the non-conforming segment.

We then turn to examining the main question of the paper, how unconventional monetary policy affected the volume of new mortgages issued. We find that financial institutions more than tripled their monthly origination of mortgages that were eligible for purchase by the Fed around the announcement of QE1, while the origination of loans above the conforming loan limits increased much less dramatically. Next, we verify that this heterogeneity in the mortgage market response to QE1 was a function of the type of debt the central bank purchased, by contrasting the effect of various QE episodes. As shown in Figure 3 and discussed in detail in Section 3, QE1 and QE3 involved MBS and Treasury purchases, while QE2 purchases consisted exclusively of Treasuries. We show that MBS purchases had a relatively immediate and economically significant effect on refinancing activity. QE1 in particular, which occurred at a time when the banking sector was much less healthy than in QE3, had a much stronger impact on the origination of mortgages that were eligible to be bundled into the type of MBS that the Fed was purchasing, with more modest effects on other types of mortgages.

Our focus on quantities has several advantages over studies that rely on high-frequency asset-price event studies. Asset prices respond immediately to central bank announcements, making it unlikely that other shocks hit market prices at the same time as QE announcements. However, market price reactions in the immediate short run might be very different from the programs' effects in the longer run.[5] Second, event-study papers investigate secondary-market yields.[6] To the extent that the pass-through of mortgage-backed securities (MBS) yields to primary-market mortgage interest rates is imperfect during this period (as documented in Fuster et al., 2013 and Scharfstein and Sunderam, 2013), these studies may overstate the real effect of LSAPs. More importantly, interest rates are observed conditional on origination, meaning that inferring the effects of unconventional monetary policy by merely looking at interest rate changes will be an overstatement by assuming perfect availability of credit.[7] These reasons motivate our focus on the detection of "real effects" of

[5]This can be either because of partial segmentation of different asset classes as in Greenwood et al. (2015) or because investors' understanding of the effectiveness of LSAPs changes over time.

[6]A notable exception is Hancock and Passmore (2011), who look for effects on primary-market mortgage rates.

[7]The preponderance of fixed-rate mortgages in the United States means that most households need to qualify for a new refinance mortgage to benefit from monetary stimulus, excluding underwater fixed-rate borrowers (and fixed-rate borrowers who cannot qualify for new refinance mortgages) from the direct benefits of QE (see Di Maggio et al., 2014 and Keys et al., 2014 for further discussion).

unconventional monetary policy, specifically of the credit easing induced by LSAPs as distinct from effects on financial variables like asset prices and interest rates.

To identify the causal impacts of LSAPs, we account for time-varying credit demand and supply shocks that might otherwise confound our results. First, our loan-level dataset combines agency and non-agency mortgages, allowing us, for example, to compare observationally similar loans above and below the conforming loan limit that are plausibly exposed to the same shocks to funding and fundamentals. Event studies support this parallel trends assumption, particularly with our specifications' tight windows around policy dates. Further steps to address demand shocks include focusing on refinancing, which is mainly driven by changes in interest rates, and controlling for regional shocks to fundamentals (income, house prices, expectations, etc.) by controlling for county $\times$ month effects. Additional measures suggest that our results are not driven by segment-specific credit supply shocks. We focus our analysis on the post-2008 period to avoid making inference off of the asset-backed securities market disruptions that differentially affected the jumbo-lending market as it transitioned away from being heavily reliant on private securitization. We also show that our results are robust to the inclusion of time-series controls proxying for segment-specific shocks to funding availability (BBB-AAA credit spreads and GSE guarantee fee changes).

Finally, we complement this mortgage-level evidence with borrower-level evidence using a novel dataset linking mortgages to borrowers and their credit bureau information to track borrowers before and after they take out a new mortgage to study how households responded to the differential improvement of the GSE-eligible segment of the mortgage market. Theoretically, refinancing can affect consumption through three different channels. First, savings from lower monthly payments result in immediately higher disposable income (Di Maggio et al., 2014 and Keys et al., 2014). Second, the present value of lower interest payments functions as a positive (albeit illiquid) wealth shock for borrowers even absent any change in monthly payments. While both these channels support increased consumption by refinancers, a third channel might amplify or mitigate the strength of such a response in aggregate. When borrowers have insufficient equity to refinance, they may cash-in refinance by bringing cash to closing to take out a smaller loan than their previous one, decreasing their stock of liquid wealth. Conversely, borrowers with sufficient equity may choose to cash-out refinance, with the opposite implication for cash-on-hand and with likely very different impacts on consumption (Kaplan and Violante, 2014 and Greenwald, 2016). This effect is indeed

very sizable; we find that over 40% of jumbo borrowers who refinanced from 2008–2013 took out a GSE-eligible loan, on average paying down their original mortgages by $81,000. A similar fraction of borrowers who refinance loans with current LTVs over 80 percent engage in cash-in refinancing, on average paying down $12,300 of mortgage principal. Importantly, we also find that the Home Affordable Refinancing Program (HARP) alleviated this deleveraging behavior significantly by allowing eligible high-LTV borrowers refinancing opportunities, highlighting the complementarity between unconventional monetary policy and other interventions in the mortgage market.

Overall, the targeted nature of the Fed's MBS purchase program coupled with its lack of spillovers during QE1 means that Fed purchases *de facto* allocated credit within the mortgage market towards GSE-eligible borrowers. An immediate implication of this lack of reallocation is that the borrowers who benefitted the most from monetary stimulus during the recession had relatively high levels of home equity or cash-on-hand and disproportionately lived in the least hard-hit areas.

The paper proceeds as follows. Section (2) reviews the relevant academic literature on monetary policy transmission. Section 3 provides further background on the Federal Reserve's Quantitative Easing program as well as institutional details about the credit markets we study in this paper. Sections 4 and 5 detail the data sources used in our analysis and our research design, respectively. Section 6 presents our results on debt origination and household behavior, and section 7 summarizes and concludes with a discussion of policy implications.

2 Related Literature

The main contribution of the paper is to provide evidence that the Fed effectively allocated credit through LSAPs and to show that these programs had very limited spillovers to other assets. It contributes to the empirical literature on LSAPs which generally finds that targeted asset purchases and/or direct extensions of credit to private borrowers by the Fed and other central banks have affected equilibrium rates of return, including Ashcraft et al. (2011), Baba et al. (2006), Gagnon et al. (2010), Hancock and Passmore (2011), Sarkar and Shrader (2010), Stroebel and Taylor (2012) and Swanson (2015).[8] In addition to providing corroborating evidence on the effects of QE on asset

[8]See also Chodorow-Reich (2014) and Di Maggio and Kacperczyk (2015), who study the impact of unconventional monetary policy on different sectors of the financial markets, such as pension funds, insurance companies, and money market funds.

returns as highlighted by these papers, we complement this strand of the literature by documenting how LSAPs shaped the refinancing activities in the aftermath of the crisis and induced households to delever to be able to refinance their debt.

Our results also inform the growing theoretical literature studying the effects of unconventional monetary policy. Until the financial crisis, the benchmark theory for many macroeconomists has always been that non-standard open market operations in private assets are irrelevant as shown first by Wallace (1981), and extended to models with nominal frictions, money in the utility function and zero nominal interest rate by Eggertsson and Woodford (2003). The idea in these papers is that once the nominal interest rate reaches its lower bound, liquidity has no further role in this class of models, or in most other standard models with various types of frictions, such as Rotemberg and Woodford (1997) or Christiano et al. (2005).

In the aftermath of the crisis, other studies have highlighted the mechanisms through which unconventional monetary policy can have a significant impact. For instance, Curdia and Woodford (2011) provide a model with heterogeneous agents and imperfections in private financial intermediation to demonstrate that quantitative easing will affect the economy provided either 1) the increase in reserves increases central-bank lending to the private sector or 2) the policy changes expectations about how future interest-rate policy will be conducted, both of which seem to be satisfied by QE1. Brunnermeier and Sannikov (2015) show that monetary policy can work against the adverse feedback loops that precipitate crises by affecting the prices of assets held by constrained agents and redistributing wealth. Drechsler et al. (2014) point out the role played by large-scale asset purchases, equity injections, and asset guarantees in supporting risky asset prices. Similarly, Gertler and Karadi (2011) show in the context of a DSGE model of unconventional monetary policy that during a crisis, the balance sheet constraints on private intermediaries tighten, raising the net benefits from central bank intermediation. These benefits may be substantial when the zero lower bound constraint binds. Greenwood et al. (2015) demonstrate that understanding market segmentation is important in designing and evaluating LSAPs.

Closer in spirit to our analysis is the work by Del Negro et al. (2011), who investigate the effects of interventions in which the government provides liquidity in exchange for illiquid private paper once the nominal interest rate reaches the zero bound. In their study, the source of the 2008 crisis is a shock to the liquidity of private paper (e.g., mortgage-backed securities) with secondary

markets for these securities freezing. They show that unconventional monetary policy can alleviate the crisis by directly targeting the source of the problem, which is the illiquidity of private paper. By swapping illiquid private paper for liquid government debt, the Fed improves the liquidity of the aggregate portfolio holdings of the private sector, and the intervention lubricates financial markets, arresting the fall in investment and consumption. We test this mechanism and show that the type of purchases made by the Fed matter for understanding the response of the financial institutions. That is, injecting liquidity by purchasing MBS has a different effect than purchasing Treasuries.

Our paper is also related to a broader strand of the literature that investigates the channels through which monetary policy impacts banks' lending decisions. In a seminal paper, Kashyap and Stein (2000) provide evidence of the bank lending channel of the transmission of (conventional) monetary policy. More recently, Jimenez et al. (2014) show that a lower overnight interest rate induces less capitalized banks to lend to riskier firms, while Jimenez et al. (2012) show that for distressed banks, tighter monetary policy and worse economic conditions substantially reduce lending. Agarwal et al. (2015) estimate banks' marginal propensity to lend out of a decrease in their cost of funds to show that banks were reluctant to lend to riskier borrowers in the aftermath of the crisis. Finally, Maddaloni and Peydro (2011) find that low short-term interest rates for an extended period eventually soften lending standards for household and corporate loans.[9] Rodnyansky and Darmouni (2015) look explicitly at the effect of QE on bank lending, whereas Beraja et al. (2015) highlights the heterogeneous regional effect of QE1 depending on the regions' economic conditions. We add to these studies by uncovering the impact of unconventional monetary policy on individual household refinancing, deleveraging, and consumption decisions. Finally, we also contribute to a strand of the literature investigating the redistributional consequences of monetary policy, e.g., Doepke and Schneider (2006), Fuster and Willen (2010), and Sterk and Tenreyro (2014).

3 Background

In this section, we provide a brief summary of the Federal Reserve's Quantitative Easing program and discuss how its MBS purchases were conducted on the secondary mortgage market. For reference, Figure 2 provides a timeline of the various Fed LSAP programs, relying where possible on the

[9] See also Bernanke and Blinder (1988), Christiano and Eichenbaum (1992), Landier et al. (2013), Stein (2012) and Williamson (2012).

dates provided by Krishnamurthy and Vissing-Jorgensen (2013). Specifically, QE1 lasted from late November 2008 until March 2010, and QE2 was first announced in mid-August 2010 and ran from November 2010 to June 2011. In September of 2011, the Fed began a program known as the Maturity Extension Program (MEP) or Operation Twist. We consider QE2 to have begun in September 2010 when the Fed signaled that it was considering a second round of monetary stimulus and June 2013 for the beginning of the Fed tapering, following Bernanke's tapering announcement on May 22, 2013.[10] Under the MEP, the Federal Reserve reduced the supply of longer-term Treasury securities in the market by selling and redeeming about $600 billion in shorter-term Treasury securities and using the proceeds to buy longer-term Treasuries.[11] QE3 was announced in September 2012.

In late November 2008, the Fed announced its mortgage-buying program with the intent to purchase about $500 billion in mortgage-backed securities, consisting of mortgages guaranteed by Fannie Mae, Freddie Mac, and to a lesser extent, Ginnie Mae. In March 2009, the Fed announced an expansion to this program, subsequently purchasing an additional $750 billion in mortgage-backed securities with 50-70% Agency originations each month ending up on the Fed's balance sheet. The first quantitative easing program ended in the first quarter of 2010, with a total of $1.25 trillion in purchases of mortgage-backed securities and $175 billion of agency debt purchases. Figure 3 depicts the gross amount of MBS purchased and sold by the Fed since beginning LSAPs. During QE1, the Fed purchased both MBS and Treasuries with a greater emphasis on MBS purchases. QE2, on the other hand, was exclusively focused on Treasuries, and QE3 was roughly equally weighted between Treasuries and MBS. As Figure 3 shows, a greater fraction of each QE campaign's MBS purchases have occurred at the beginning of each program, with purchases slowly declining over the course of each LSAP campaign.[12] Notably, the Fed was effectively able to purchase $1.85 trillion (about 40% more than the usually reported $1.25 trillion amount of net purchases) by contemporaneously reselling a substantial fraction of these securities, perhaps enhancing market liquidity without further expanding the Fed balance sheet. Figure 4 shows the relative magnitude of GSE MBS net purchases compared with the total size of the GSE-guaranteed mortgage market. During QE1, the volume of

[10] Krishnamurthy and Vissing-Jorgensen (2013) found that most of the market reaction to QE2 was when it was first signaled in September 2010. Interest rates actually increased after the official announcement in November 2010 as it failed to live up to market expectations.

[11] See Foley-Fisher, Ramcharan, and Yu (2014) for a recent paper on the effect of this program on firms' financing constraints.

[12] Note that the policy of the Fed to reinvest principal prepaid on its MBS holdings into new MBS purchases results in non-zero MBS purchases even after QE3 officially ends.

Fed purchases was similar in magnitude to the volume of new issuance of GSE-guaranteed MBS. During QE3, Fed net GSE MBS purchases were roughly half of the GSE market.

Contrary to popular perception, Fed MBS purchases did not involve buying legacy (and underperforming) MBS from banks. Instead, Fed MBS purchases were on the TBA (To-be Announced) mortgage market.[13] A key feature of the Agency MBS market is the existence of this highly liquid forward market, through which more than 90% of Agency MBS trading volume occurs and which consists predominantly of newly originated mortgages (Vickery and Wright, 2013), with trading volumes on the order of $200 billion per day and around $100 billion delivered each month. See Appendix A for additional details on the TBA market.

Nevertheless, the eligibility requirements for mortgages to be included in TBAs provide to sharp cross-sectional predictions on the effect of MBS purchases on loan originations. Because TBA delivery must be accomplished with Agency-eligible mortgages that are usually recent originations, the strict eligibility rules for GSE guarantees allow us to compare origination volumes by loan size. Specifically, GSE guarantees require loan sizes to be beneath published conforming loan limits (CLLs).[14] Mortgages with a loan size exceeding geographically and time-varying CLLs (known as jumbo mortgages) are essentially ineligible for inclusion in GSE MBS. Many of our results below will test for a deviation in mortgage origination volume for loans just below the CLL, which should be directly affected by Fed purchases because of their TBA eligibility, and loans just above the CLL, which should only be indirectly affected by Fed MBS purchases.

4 Data

The workhorse data source we use is the Equifax's Credit Risk Insight™ Servicing McDash (CRISM) dataset, which covers roughly 65 percent of the mortgage market during our sample period (2008-2013). One of the features of this dataset is that it merges McDash Analytics mortgage-servicing records (from Lender Processing Services) with credit bureau data (from Equifax). This provides us with information about the characteristics of each mortgage at origination, such as the mortgage

[13] A limited number of the TBA securities purchased by the Fed at the beginning of QE1 included MBS CUSIPs that had been originated in early 2008 instead of roughly contemporaneous with Fed purchases. Still, these were GSE-eligible mortgages originated in 2008 and not the types of legacy MBS that were troubling banks, having been filled with mortgages originated under questionable underwriting standards that were deeply underwater by 2009.

[14] See Adelino et al. (2013) and DeFusco and Paciorek (2015) for studies of the consequences of the sharp change in GSE eligibility at the conforming loan limit.

type, the size of the loan, the monthly payments, the interest rate, the borrower's FICO, as well as their behavior over time. In addition, we also observe all the other liabilities of the borrowers, such as their auto loans, HELOCs, and credit cards. Panels I and II of Table 1 report loan-level summary statistics on conforming and jumbo loans from the CRISM database. Our sample include more than seven million loans below the conforming loan limit and about 170,000 jumbo loans. On average, non-jumbo (jumbo) borrowers in our sample have a 750 (760) FICO score and an LTV of 67% (65%). The average balance of conforming and jumbo loans in our data are $211,000 and $960,000, respectively. Panel III reports summary statistics for time series controls used in robustness checks, including guarantee fees from Fuster et al. (2013) and bond yields from Federal Reserve Economic Data (FRED) at the Federal Reserve Bank of St. Louis. The guarantor fees are about 34 basis points, while the BBB-AAA bond spread is about 134 basis points over our sample period.

The unique advantage of this data is that it enables us to link multiple loans by the same borrower together, allowing us to gather more complete information about the circumstances accompanying a borrower's refinancing decision. While existing datasets follow individual mortgages over time, we can match borrowers to mortgages and observe each borrower in the credit bureau data six months before any mortgage origination and track him as the current mortgage is refinanced. This allows us to study cash-in/cash-out refinancing much more accurately. For example, by observing the outstanding amount of the old loan and the principal amount of the new loan, we can measure the dollar amount of equity that is added to the borrower's position during the refinancing process.

5 Empirical Strategy

In this section we present our main empirical strategy to identify the effects of LSAPs on both interest rates and refinancing volumes.

5.1 Quantifying the Effect of QE on Interest Rates

In the spirit of the empirical QE literature's focus on debt yields, we begin by comparing the reaction of the interest rates to LSAPs for loans above and below the conforming loan limit. To form a comparable jumbo/conforming sample, we only consider loans that are 30-year fixed-rate first-lien mortgages secured by owner-occupied single-family houses with an initial LTV of 25-80%

and without any prepayment penalty or balloon-payment or interest-only deferred amortization features. We also drop FHA mortgages, which require mortgage insurance and have more flexible lending requirements than those for conventional loans.

Changes in borrower composition over time limit the usefulness of simple time-series comparisons of interest-rates. Instead, we take into account that rates change in response to changing mortgage-borrower characteristics. For example, some of the decrease interest rates that we observe is due to stricter credit standards at the end of our sample—later mortgages feature both higher average FICO scores and lower LTVs.

To facilitate graphical comparisons of composition-adjusted interest rates over time, we estimate the following regression separately for loans above and below the conforming loan limit

$$r_{it} = \alpha_t + \beta_1(FICO_i - 720) + \beta_2(LTV_i - 0.75) + \varepsilon_{it},$$

where r_{it} is the interest rate of loan i at time t measured in basis points. We control for the difference between the FICO score and loan-to-value ratio of loan i and benchmark FICO and LTV ratios such that estimated time effects α_t capture "rate-sheet–adjusted" interest rates—interest rates for a representative borrower with a FICO score of 720 and an LTV ratio of 75%.

To quantity the differential reaction of jumbo and conforming interest rates to purchase program events, we pool jumbo and non-jumbo mortgages together and estimate the following loan-level specification around the beginning of each monetary policy event separately

$$r_{igt} = X_i'\beta + \theta_1 Program_t + \theta_2 Program_t \cdot Jumbo_i + \gamma_{gt} + \varepsilon_{igt} \tag{1}$$

where $Program$ is an indicator for month t being after the institution of a specific monetary policy program (e.g., QE1), $Jumbo_i$ is an indicator variable for whether loan i was a jumbo mortgage, and X_i is a vector of flexible loan-level controls consisting of 5-point LTV bins, 20-point FICO bins, and an indicator for missing FICO scores. We also control for county $\times$ month fixed effects γ_{gt} to purge interest rates in both segments of static and time-varying regional shocks to credit demand, including differences in house price growth. We consider the three quantitative easing programs as well as the Maturity Extension Program in September 2011 and the beginning of tapering in June

2013. We choose to cluster our standard errors at the month level to account for the correlation between contemporaneous shocks across loans and geographies.

The coefficient θ_1 reports the number of basis points by which interest rates for non-jumbo mortgages fell on average in the three (or six) months immediately following the beginning of each QE campaign relative to the period immediately prior. The coefficient θ_2 tells us how the jumbo-conforming spread changed in response to each QE campaign's commencement, in other words by how much more or less interest rates in the jumbo segment responded. We interpret θ_1 as causal only with some degree of caution because it will combine the effect of LSAPs with any contemporaneous shock to mortgage rates, even those effects not caused by the monetary policy events in question. The identifying assumption behind our causal interpretation of θ_2 is that, conditional on borrower and loan characteristics and county-month fixed effects, time-varying shocks do not affect the jumbo and conforming differently. In other words, our ability to identify the effect of unconventional monetary policy on mortgage-market segments relies on a parallel-trends assumption, which, as we discuss below, seems to be satisfied, especially over the short time horizons used to estimate equation (1).

5.2 Quantifying the Effect of QE on Mortgage Origination Volumes

As discussed above, inferring the impact of unconventional monetary policy from changes in the interest rates tends to overstate policy effectiveness by assuming perfect availability of credit. In particular, interest rates are observed conditional on origination, but not all mortgages are eligible for purchase by the Fed. Considering the volume of debt issuance in response to the LSAPs is an essential consideration in estimating the response of financial markets to new measures of monetary policy adopted after the crisis. Furthermore, we can test for the presence of spillovers from the conforming segment, directly affected by the LSAPs, to the jumbo segment.

To form a comparable jumbo/conforming sample, we drop FHA mortgages and consider first-lien refinance loans for single-family houses (note that this sample restriction is more inclusive than the interest-rate sample restrictions needed to compare interest rates on equal footing). We quantify these effects on county $g \times$ month $t \times$ mortgage-market segment $s \in \{Jumbo,\ non\text{-}Jumbo\}$

origination volumes Q_{sgt} by estimating

$$\log Q_{sgt} = \beta_1 Program_t + \beta_2 Program_t \cdot Jumbo_s + \delta_{gt} + \varepsilon_{sgt}. \tag{2}$$

For each policy event, we provide baseline results in which we control for county fixed effects and a more restrictive specification in which we allow for county $\times$ month fixed effects. We also restrict attention to counties where we observe an active jumbo market by restricting the sample to counties that have at least one jumbo refinance origination each month. Again, we conservatively cluster our standard errors at the month level.

The coefficient β_1 tells us by how many log points average county $\times$ segment origination volumes increased in the months following an LSAP event relative to the months immediately preceding that event. We focus our attention on β_2, which is an estimate of whether jumbo origination volumes responded differently from conforming origination volumes. Again, the identifying assumption required for β_2 to be an unbiased estimate of differential allocation of LSAP credit across mortgage market segments is that there were no other shocks occurring coincident with QE events that affected the jumbo market more (or less) than the conforming market. The requirement for parallel trends across conforming and non-conforming segments justifies our focus on the conforming loan limit since underwriting standards in the conforming and prime jumbo market are similar. The graphical evidence discussed below also supports this parallel-trends assumption.

6 Results

We present three main sets of results. First, we examine the response of mortgage rates to the LSAPs, we then turn to the changes in refinancing volume in the mortgage market. Finally, we turn to the household-level analysis to shed further lights on how LSAPs affected households' refinancing decisions.

6.1 The Effect of LSAPs on the Primary Mortgage Market

6.1.1 Interest Rate Results

In Figure 5, we plot the estimated interest rates for loans above and below the conforming loan limit. There is a visible change in interest rates as QE1 began, when mortgage interest rates declined markedly, from 6.5% to about 5.5% and 5% for loans just above and just below the conforming loan limit, respectively. While rates for the two types of loans follow each other quite closely, conforming-loan rates declined almost 50% more than prime jumbo mortgage rates. For context, the increase in the jumbo-conforming spread from the announcement of QE1 is on par with the spread increase observed in the second half of 2007, when the securitization market froze.

To quantify the average magnitude of these effects over each monetary policy event, Tables 2 and 3 report the estimates for the interest-rate response to the announcements of the different LSAPs within a three-month window (Table 2) and a six-month window (Table 3) around the event, both for jumbo and non-jumbo loans. We find that the most significant reaction is to the announcement of QE1 with an interest-rate reduction of more than 100 basis points. Consistent with Figure 6, jumbo-mortgage interest rates also decline after QE1, but the conforming rate falls by an additional 40 basis points. Interestingly, rates decline by 35 basis points in response to QE2, without any differential effect across segments, which is suggestive of the fact that the Fed was purchasing only Treasuries during that program. This lower reduction in interest rates might also be indicative that, while QE1 was a significant surprise, the second quantitative easing program was largely anticipated by market participants. The maturity extension program also resulted in a reduction of about 40 basis points, but we observe no differential effect for the conforming and non-conforming segments. QE3, instead, led to a reduction of about 20 basis points in the three months after the beginning of the program. Finally, the beginning of the Fed tapering led to an increase in interest rates concentrated in the conforming loan segment. The results are qualitatively similar when we consider a longer window around the announcement in Table 3, but their economic magnitude is significantly larger.

Our identification approach is particularly suited to control demand shocks affecting both segments at the same time. In each specification we control for loan characteristics, including flexibly specified loan-to-value ratios and FICO scores, to ensure that the differential response of jumbo and

conforming mortgages is not driven by time-varying borrower composition. In columns 2, 4, 6 and 10 of Tables 2 and 3, we absorb time-varying regional heterogeneity and find that our results on the jumbo-conforming spread are not driven by such shocks.

Overall, these results show two robust patterns. First, interest rates decline significantly more for the conforming market during QE1, which indicates that mortgage market segmentation crucially affected its response to Fed purchases. Second, the interest rate decline is strongest for QE1, while we detect little effect for QE2, which suggests that the type of assets purchased by the Fed (MBS vs. Treasuries) plays a key role in determining the effectiveness of these measures.

6.1.2 Mortgage Origination Results

Figure 6 plots the origination amount of refinance mortgages recorded by LPS for mortgages with loan sizes above and below the GSE conforming loan limit (CLL). The jumbo and non-jumbo segments trend very similarly in origination counts and total volume prior to the beginning of QE1, bolstering our identifying assumption of parallel trends. Right at the commencement of QE1, the amount of refinance origination increases by a factor of three (counts) or four (dollar volume). The sudden increase and subsequent fading of below-CLL refinance originations coincides quite closely with the dynamics of Fed MBS purchases, as seen in Figure 7. By contrast, refinance origination above the conforming loan limit is fairly flat until a modest increase in April 2009. In other words, while the increase in the conforming spread indicates a differential response of rates depending on GSE eligibility, loan origination suggests an even deeper relationship between the allocation of credit supply and QE1 MBS purchases.

Table 4 reports results from estimating equation (2) for a three-month window, while Table 5 shows their robustness to a six-month window. The dependent variable is the log of the total dollar amount of monthly loan origination. Columns 1-2 show that mortgage refinancing activity increased by almost 80% during QE1, with all the effect concentrated in the conforming loan segment. In contrast to QE2 whose effect on the mortgage market were significantly smaller with no differential effect across loan segment. QE3 had no effect on the refinancing activities over a three-month horizon, while generated a significant increase in mortgage origination with increase between 15 and 30 percent over a six month horizon. The MEP also had a significant effect whose magnitude is about half of that observed for QE1, but we find no differential impact on the jumbo market.

Finally, tapering significantly reduced the refinancing activities in the conforming segment, while there is no effect in the jumbo market. Table 5 shows that overall these effects might also be larger, if we consider a longer window around the announcements.

One potential concern is that these differences among loans below and above the conforming loan limit could be an artifact of the January 2008 change in the limit itself. The analysis in Appendix B addresses this threat to validity, confirming that the differential origination pattern holds even in those areas that did not see an increase in the conforming loan limit.

6.1.3 Allocation of Credit Across Regions

Given that unconventional monetary stimulus from QE1 was not distributed evenly across the mortgage market, what implications did this have for the geography of credit allocation? We investigate this by analyzing where 2009 refinancing activity was concentrated. To ensure full coverage of the mortgage market, we use Home Mortgage Disclosure Act data, which reports the universe of mortgage originations by institutions large enough to be regulated by the act. In Figure 8, we plot the state-level percentage of outstanding mortgage balance refinanced in 2009 against two lagged measures of state-level economic health: 2006-2008 home price appreciation (top panel) and 2006-2008 real GDP growth (bottom panel).

Panel I shows that even though a clear objective of QE1 was to stimulate distressed housing markets, there is a strong positive relationship between past home price appreciation and new refinancing activity, suggesting that the QE1-induced increased availability of refinancing credit may not have reached the areas that arguably needed it the most. In particular, note that the states most affected by the housing bust (the so-called "sand states" of California, Florida, Arizona and Nevada) were the states with the lowest refinancing activity.[15] Panel II of Figure 8 repeats this exercise, relating refinancing activity to state-level growth in real GDP from 2006–2008. Again, there is a clear positive relationship with contracting states benefitting less from QE1. Taken together, these figures provide evidence that time-invariant mortgage market segmentation combined with contemporaneous banking sector stress to allocate credit to the regions with the most potential GSE-eligible refinances, i.e., areas with the strongest local economies and smallest share of underwater

[15]Note that while the correlation between *purchase* mortgage credit growth could also be driven by shocks to fundamentals that simultaneously reduced demand for mortgage credit and lowered home prices, this is less of a concern for the refinancing activity measure shown here.

borrowers. While clearly less identified than the across-segment results presented in section (6.1.2), these across-region results highlight the important interplay between GSE mortgage-market policy and the effectiveness of monetary stimulus at reaching the local economies that would benefit the most.

In sum, QE1, and to a lesser extent the MEP and QE3, were effective at inducing new debt origination and cheaper monthly payments for households by supporting credit supply for the conforming segment of the market, while QE2 had no such beneficial effect. More broadly, the evidence suggests that loan origination is a more revealing indicator of *de facto* allocation of credit by Fed purchases. Moreover, the benefits of the Fed's LSAPs seem to have accrued to the least distressed areas.

6.1.4 Robustness to Allowing for Correlated Time-Varying Shocks

Our identification strategy takes advantage of the natural segmentation in the mortgage market and effectively employs a differences-in-differences approach in an event-study framework by comparing the refinancing activities in the conforming (the treated group) and non-conforming (the control group) segment in a narrow window around the policy events. This allows us to limit the role of other common shocks affecting both segments at the same time and control for changes in credit demand. However, one potential limitation of this approach is the possibility that unobserved credit supply shocks, occurring at about the same time of the policy announcements and differentially impacting the conforming and jumbo loan segments, might confound our results. For example, because funding for jumbo lending is significantly more reliant on private sources than is conforming lending, lenders might face different shocks to funding constraints in the two segments of the market.

We propose two such shocks (credit-spread shocks and guarantee fees), demonstrate that they explain a significant amount of variation in differential movements in the jumbo and conforming segments, and verify that our r results are robust to the inclusion of time-series controls measuring aggregate shocks to funding availability in these two segments. The BBB-AAA bond spread and the guarantee fee ("g-fee") originators must pay to the GSEs to accept a loan's default risk together explain 70% of the variation in the jumbo-conforming spread. Intuitively, the credit spread captures the price of risk and the g-fee reflects the price to avoid default risk, both of which might influence (and be correlated with) the relative market supply of jumbo-mortgage credit. When g-fees increase,

we expect the jumbo-conforming spread to decrease, and when credit spreads rise, we expect the jumbo spread to follow suit.

In order to have a stable and uncontaminated estimate of the contribution of these two factors to interest rates and quantities, we adopt the following abnormal-returns event-study procedure using data on bond-yield spreads from the St. Louis Fed and on g-fees from Fuster et al. (2013). First, for each QE event, we use the 2008–2013 sample period except for the three (Table 6) and six (Appendix Table 2) months surrounding the QE event in question to estimate the coefficients on the spread and g-fee in a linear regression with county $\times$ month fixed effects and a jumbo indicator. These coefficients are reported in Appendix Table 3—we note the relative stability of the coefficients across sample periods, finding that these two factors alone explain a significant portion of the overall variation in interest rates and quantities, as evidenced from the R^2 statistics in Appendix Table 3. We then partial out these two factors, by subtracting the contribution of contemporaneous credit spreads and g-fees from current interest rates and quantities to reestimate the specifications in Tables 2–5 controlling for time-varying credit spreads and g-fees.

Table 6 and Appendix Table 2 report these results for three- and six-month windows, respectively. We find that the effects highlighted in Tables 2–5 are still economically and statistically significant, but as expected the magnitude of the differential behavior between jumbo and conforming segments is reduced. For instance, the top panel shows that the jumbo mortgage rates experience a lower reduction as the jumbo-conforming spread widens by 29 basis points in the post-QE1 period conditional on credit spreads and g-fees, in contrast to the 42 basis point widening reported in Table 2. No differential effect is found for QE2, the MEP, or QE3, although the Fed tapering spread narrowing is robust to these added controls.

The bottom panel of Table 6 reports the results for the refinancing activity. The economic magnitude of the coefficients is reduced by 15 to 20 percent, which indicates that during this period there might indeed have been other factors affecting the intermediaries' willingness to lend in these two segments, but the main takeaways remain the same. Specifically, we observe a significant increase in refinancing of conforming loans right after QE1 and the maturity extension program, whereas we find that tapering reduced significantly more the refinancing activity of the conforming segment than of the jumbo one. Overall, this evidence is suggestive that our results are not entirely driven by time-series variation in credit supply.

6.2 Household-level Analysis

6.2.1 Refinancing Propensity Hazard Regressions

A complementary way to examine the impact of QE uses the individual-level panel structure of our data to test whether each QE campaign altered the likelihood that a given individual refinanced. We estimate a hazard model of the form

$$\lambda_{it} = \exp(X'_{it}\beta)\lambda_0(t - t_0(i))$$
$$X'_{it}\beta = \theta'_B W_{it}^{loan} + \theta'_B W_i^{borrower} + \sum_k \sum_{\tau=Dec2008}^{Feb2008} \beta_{k\tau} \cdot QE1_t \times S_{k,it}$$

where λ_{it} is the instantaneous probability that loan i will refinance in the calendar month corresponding to loan-age t, conditional on not yet having refinanced by month t. The nonparametrically estimated baseline hazard function $\lambda_0(\cdot)$ is a function of loan age (current month t minus loan i's origination month $t_0(i)$) and captures the standard life-cycle of mortgage prepayment, while covariates scale the baseline hazard depending on their contribution to prepayment risk. The covariates in X_{it} consist of loan- and borrower-level controls. Loan-level controls W_{it}^{loan} include current LTV, original balance, and an indicator for whether the loan size is currently above the conforming loan limit. Borrower-level controls $W_{it}^{borrower}$ include FICO bins, DTI ratio, and an indicator for whether the DTI is missing. The coefficients of interest are $\beta_{k\tau}$, which are coefficients for each of the three months following the beginning of QE1 on the QE1 indicator variable interacted with two separate indicators for whether loan i is currently GSE ineligible (whether loan i's current LTV exceeds .9 and whether its loan size exceeds the CLL). We take for our sample all loans that were outstanding as of September 2008, and use the continuous-time maximum-likelihood estimator described in Palmer (2015).

In Table 7, we report results from estimating hazard models of refinancing, as just described. Column (1) shows that each of the three months following the announcement and beginning of Fed MBS purchases saw an increase of individual refinancing likelihood. For example, the January 2009 coefficient implies that individuals holding observationally equivalent loans were 125% more likely to refinance in January 2009 than in the three months preceding December 2008. Column (2) shows that borrowers whose outstanding mortgages were GSE ineligible were significantly less

likely to prepay their mortgages. Mortgages with current loan-to-value ratios exceeding 90% were 36% less likely to prepay their mortgage in January 2009 than those borrowers with LTVs under 90%. Similarly, jumbo borrowers—borrowers of mortgages whose size exceeded the local conforming loan limit—were 17% less likely to prepay in January 2009 than borrowers with mortgages under the CLL. Column (3) demonstrates that these findings are quite similar even when focusing on observationally identical borrowers taking out mortgages with similar characteristics.

6.2.2 Households Deleveraging

Having shown the increase in origination of conforming loans and the higher likelihood of refinancing we can also exploit the granularity of our data to study the borrowers' refinancing decision in more detail. This allows us to investigate the effects of the LSAPs on real economic activity.

There are three types of refinancing: cash-in, in which borrowers use cash to lower their loan-to-value ratio; cash-out, in which borrowers extract equity from their homes; and no cash-out. In principle, different types of refinancing can have different effects on consumption as they might work through three distinct channels. First, lower monthly payments lead to higher "disposable" income, which might boost consumption to the extent that borrowers have a positive marginal propensity to consume out of this additional income. Lowering interest payments is equivalent to a positive wealth shock for borrowers, which should lead to an increase in consumption as long as borrowers are not liquidity constrained. Finally, cash-in/cash-out decisions change the borrower's stock of liquid wealth; cash-in refinancing may even have a negative multiplier on economic activity because borrowers have to draw down their liquid wealth to refinance.

We are interested in assessing to what extent the increased credit availability provided by QE MBS purchases has influenced borrower borrowing and saving behavior. Specifically, we can measure whether borrowers bunch at eighty percent LTV to qualify for the Fed purchases, e.g., borrowers' propensity to cash-in refinance. We measure cash-in refinancing by linking the new refinanced loan to the unpaid balance on borrower's prior loan. We allow for $3,000 closing costs to be rolled into the new loan without being classified as cash-in refinancing.[16] One of the main advantages of our panel data is that it allows us to observe loan amounts before refinancing and to estimate the LTV

[16] Average closing costs are reported here by state http://www.bankrate.com/finance/mortgages/closing-costs/closing-costs-by-state.aspx

prior to the refinance. Since in March 2009 the Federal Housing Finance Agency introduced the Home Affordable Refinance Program (HARP) with the objective to help underwater homeowners to refinance their mortgages, we are going to distinguish between the pre- and post-HARP period.

Panel I of Figure 9 estimates bunching from the fraction of borrowers over 80% current LTV that originate a new mortgage at or below 80% LTV: the differential availability and price of GSE eligible vs. GSE ineligible mortgages resulted in significant deleveraging. Around 40% of households who prepay from a mortgage that is initially ineligible for a GSE-guaranteed refinance deleverage, increasing their equity position via their liquid wealth. The effect is substantial: conditional on deleveraging borrowers cashed-in about $12,300 ($26,000 for jumbo-mortgage holders). The subset of refinancing borrowers who deleveraged was substantial enough to have aggregate effects: the average borrower (not conditional on deleveraging) paid down their mortgage $2,300 (in addition to closing costs) while refinancing. This means that a significant amount of resources that could have been devoted to support aggregate demand have instead been employed to refinance existing mortgages. Unconventional monetary policy might thus perversely affect the economy by inducing borrowers to delever. We can also measure the expansionary effects of LSAPs by looking at cash-out refinancing. Panel II shows a bunching rate of about 22% with the average borrower cashing out $4,000. That is, about 22% of the refinances with a LTV between 70 and 80 percent before refinancing decide to cash out from their mortgages by refinancing at 80% LTV.

The second panel of Figure 10 performs a similar exercise for the loans that refinanced through HARP. Panel I clearly shows that this program alleviated deleveraging behavior significantly, with bunching declining from 40% to 18%, while Panel II shows that cash-out refinances were not significantly affected. This result highlights that GSE eligibility was a limiting factor in the effectiveness of Fed MBS purchases and that there is scope for GSE policies such as HARP to amplify the effectiveness of MBS purchases by relaxing eligibility requirements.

We conclude this section by performing a similar analysis around the conforming loan limit (CLL). Panel I of Figure 11 estimates bunching from the fraction of borrowers with a mortgage size above the CLL that originate a new mortgage at or below the CLL. Consistently with the results on bunching to the 80% LTV, we find that about 43% of households who prepay a GSE-ineligible mortgage deleverage, with an average cash-in amount of about $27,000 (corresponding to $81,000 on average for deleveraging mortgagors). Panel II shows a significantly less bunching from the left of

the CLL, with only 10% of the borrowers using the new mortgage to cash out an average of $1,400. Overall, these findings highlight that the intersection of LSAPs and GSE policy has profound effects on the liquidity of household wealth.

7 Conclusion

Prior to the fall of 2007, the Fed had largely held Treasury securities on its balance sheet. However, in response to the financial crisis, the Fed started several new programs—liquidity facilities (under which the Fed lent directly to certain sectors of the economy) and targeted purchases of trillions of dollars of long-term Treasuries and GSE-guaranteed mortgage-backed securities. The impacts of these unconventional monetary policies have been the subject of ongoing debate.

In this paper, we focus on detecting and quantifying the pass-through of unconventional monetary policy to the mortgage market. Under the portfolio-rebalancing channel (where investors have a desired duration mix), central-bank purchases of long-duration assets will have spillover effects, easing credit to other sectors of the economy as capital is reallocated across the economy. In contrast to this view, using rich loan-level microdata, we find strong evidence of a "flypaper effect" of unconventional monetary policy during QE1, which passed through to borrowers who were able to refinance into mortgages bundled into MBS purchased by the Fed but significantly less to borrowers who couldn't qualify for a GSE-eligible mortgage. This *de facto* allocation of credit is consistent with the Capital Constraints view of unconventional monetary policy and highlights a main takeaway from our analysis: the effectiveness of unconventional monetary policy depends crucially on the composition of central-bank asset purchases.

Finally, exploiting the ability of our data to link mortgages across borrowers, we document an important complementarity between GSE policy and Fed purchases. Because banks during QE1 did not reallocate capital to non-conforming segments of the mortgage market, many households initially ineligible for a conforming mortgage (current loan-to-value ratios exceeding 80% or loan balances over the conforming loan limit) did not benefit from QE MBS purchases. Those who did benefit often delevered by bringing cash to closing ("cash-in refinancing") to take advantage of low interest rates during the height of QE1 MBS purchases. Overall, tight GSE-eligibility requirements and the lack of spillovers from LSAPs likely dampened the multiplier effects of lower interest

rates and suggests that countercyclical macroprudential policy could enhance the effectiveness of MBS purchases. In particular, relaxing LTV caps during the crisis would have disproportionately benefitted economically distressed areas by enabling more households to refinance and by reducing household deleveraging.

There are several implications of these findings for designing effective unconventional monetary policy. First, given the limited spillover of Fed purchases, Federal Reserve Act provisions that restrict Fed purchases to government-guaranteed debt have consequences in allocating credit to certain sectors (i.e., housing) and particular segments within those sectors (i.e., conforming mortgages). Even operating within the legal constraints that govern Federal Reserve purchases, it appears preferable for LSAPs to purchase MBS directly instead of Treasuries during times when banks are reluctant to lend. Another implication of the flypaper effect of unconventional monetary policy is that central-bank interventions could be more effective by providing more direct funding to banks for lending to small business and households.[17] Finally, we demonstrate a strong interaction between GSE policy and the effectiveness of MBS purchases. Programs like HARP had a role in extending credit to the households who needed it most, as did the significant expansion in FHA market share during the crisis.

[17]While U.S. programs such as TALF and CPFF ostensibly encouraged lending to businesses and households, their main focus was providing liquidity to (and preventing a further collapse of) securitization markets. The high cost of credit under those programs limited their scope as market confidence returned (Ashcraft et al., 2012). For another example of such a program, see also the Bank of England's "Lending for Funding Scheme."

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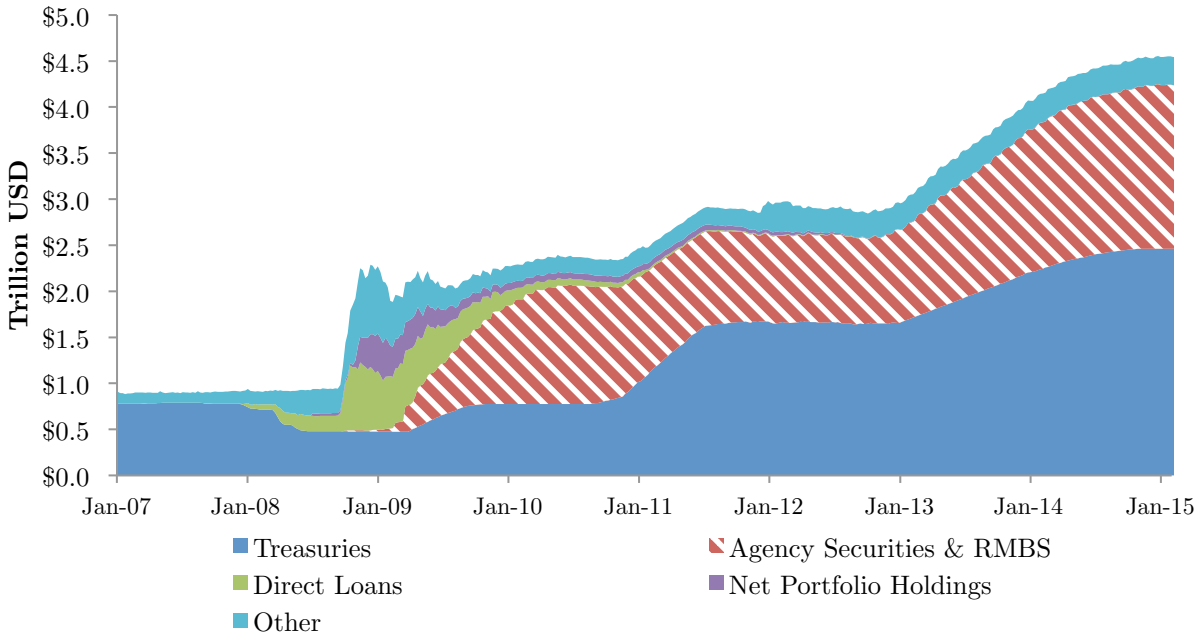
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Figure 1. Federal Reserve Balance Sheet: Assets



Notes: Graph shows the size and the composition of assets on the Fed Balance sheet from 2007-2015. Source: Fed H4.1 weekly reports.

Figure 2. Quantitative Easing Timeline

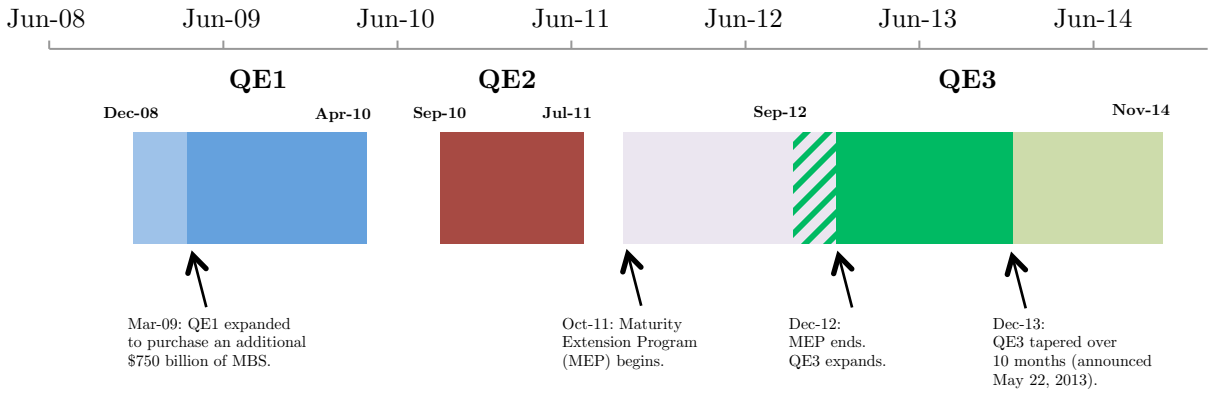
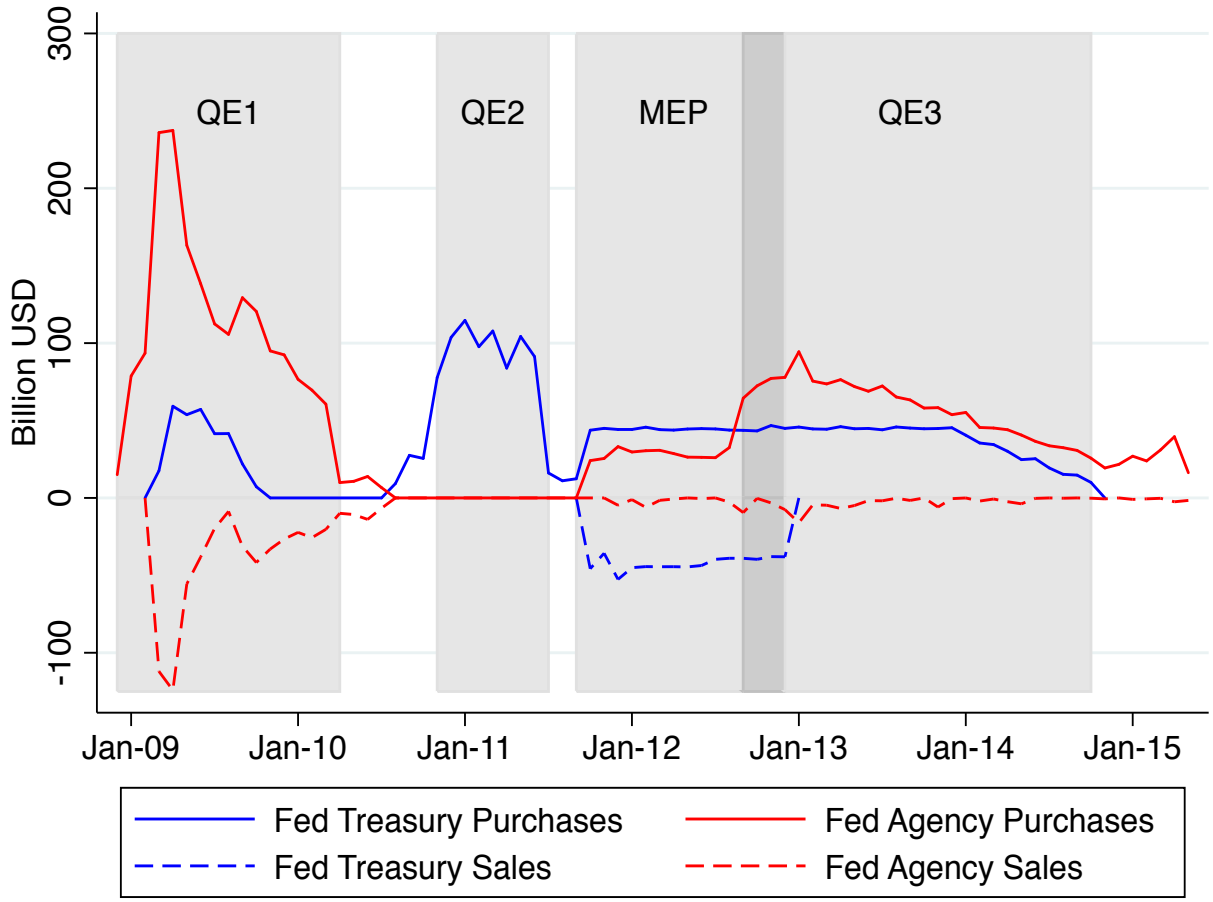
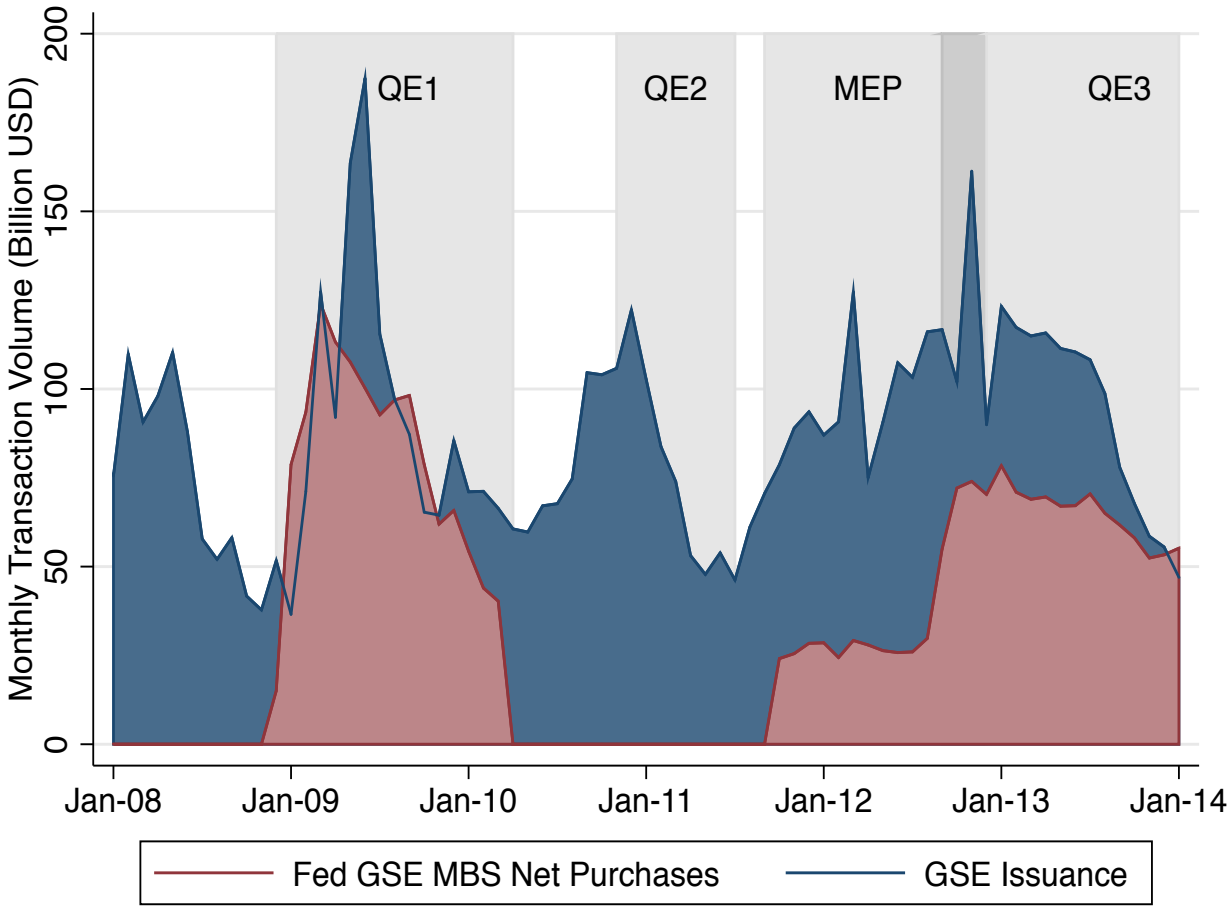


Figure 3. Federal Reserve Asset Purchases & Sales



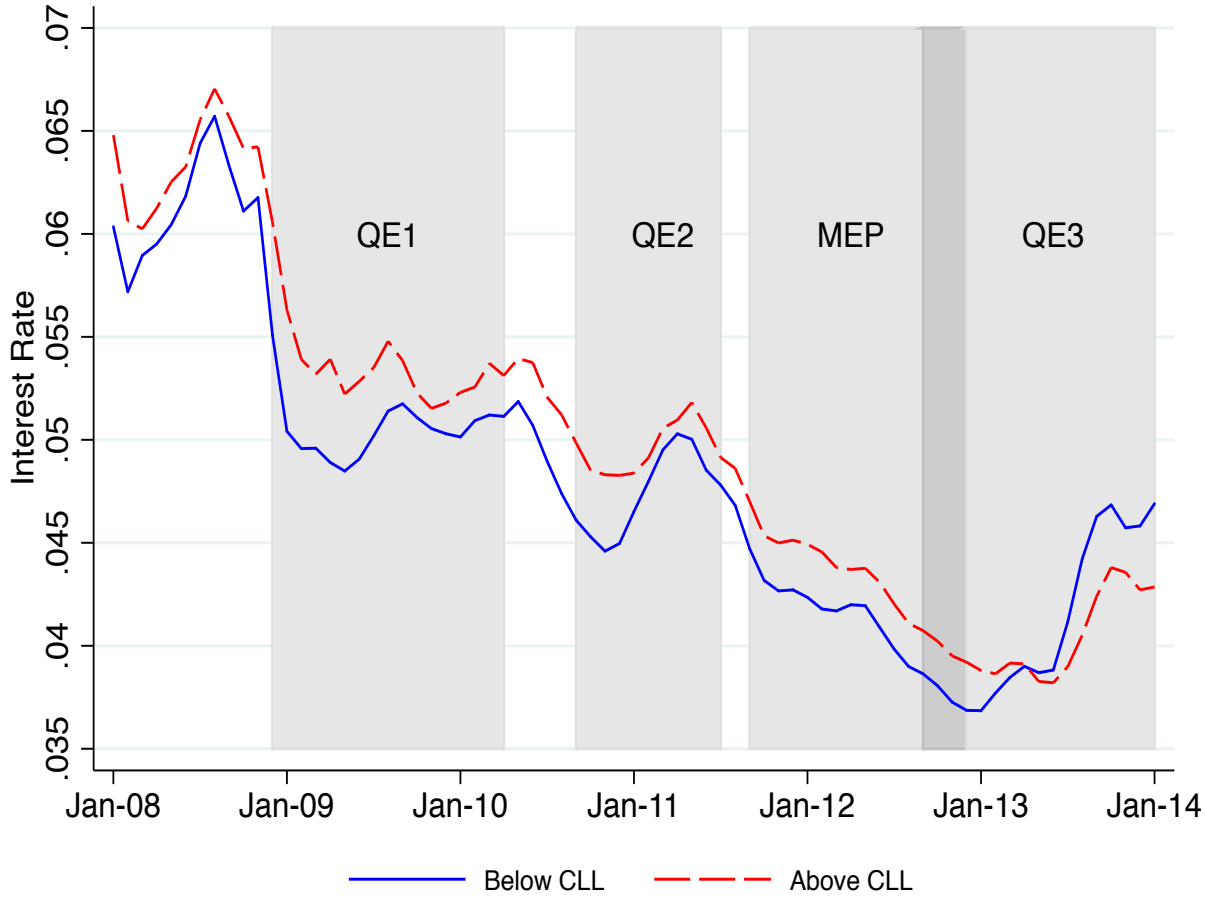
Notes: Figure plots monthly gross transaction amounts for the purchase and sale of mortgage-backed securities (in red) and Treasuries (in blue) by the Fed during the each quantitative easing operation. MEP shading represents the period of the Matury Extension Program, also known as Operation Twist, that involved the swapping of short- and long-term Treasuries. Source: NY Fed Open Market Operations Data.

Figure 4. Fed GSE MBS Net Purchases vs. Monthly GSE Issuance



Notes: Figure plots the transaction amounts for the purchase of mortgage-backed securities by the Fed and the issuance of GSE securities during the three quantitative easing operations. Source: NY Fed Open Market Operations Data, Fannie Mae, and Freddie Mac.

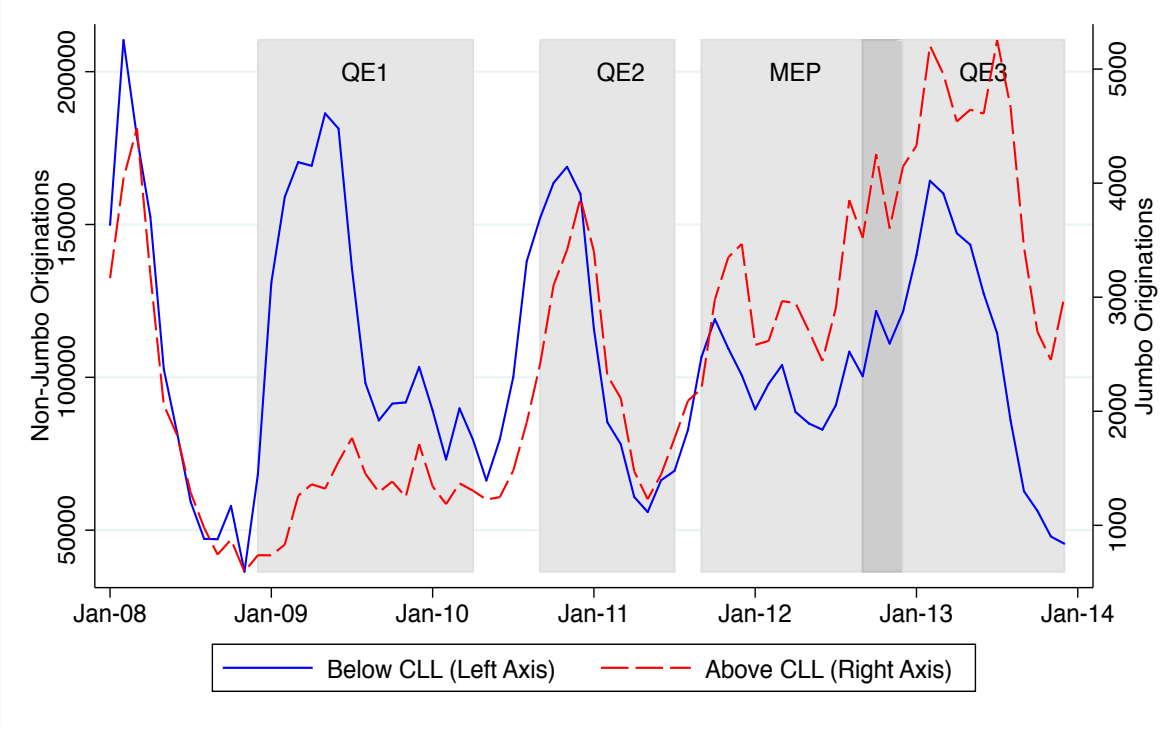
Figure 5. Interest Rates for Conforming and Jumbo Refinance Loans



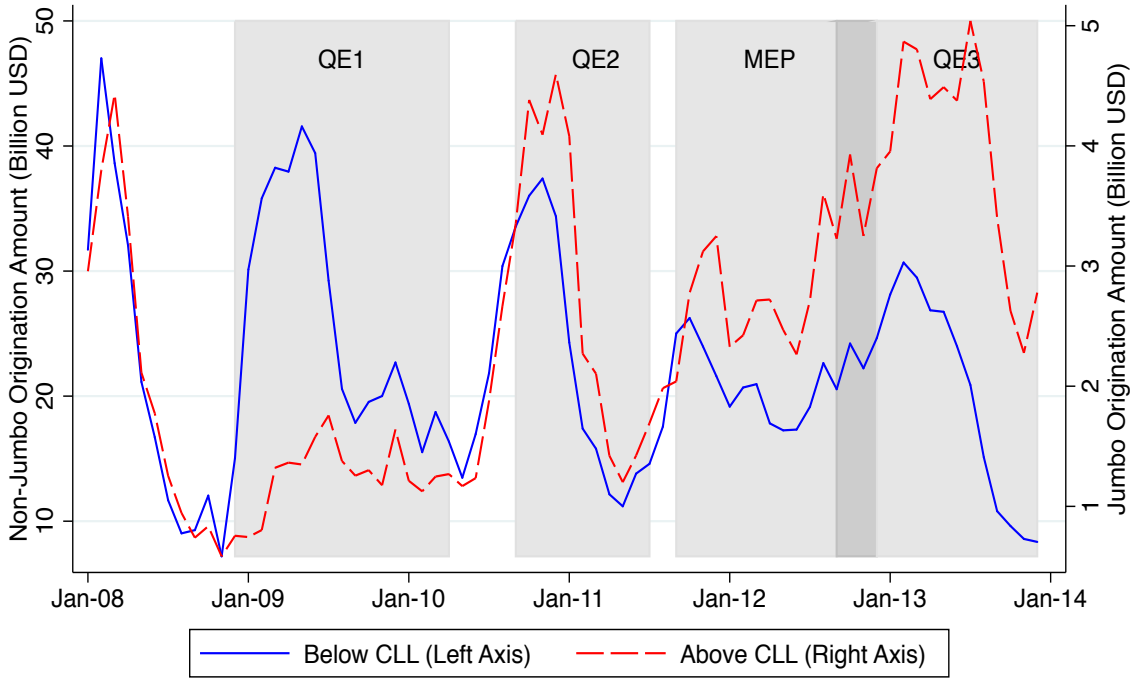
Notes: Figure plots the estimated monthly interest rates for refinance loans above and below the confoming loan limit with a loan-to-value ratio of 75% and a FICO score of 760 and 30 year fixed rate mortgage. The estimates are based on all non-FHA first-lien refinance loans in LPS with LTV less or equal to 80% and adjusted for the LTV and credit score of the borrower. See Section 5.1 for more details.

Figure 6. Refinance Origination Volume

Panel I. Number of Originations

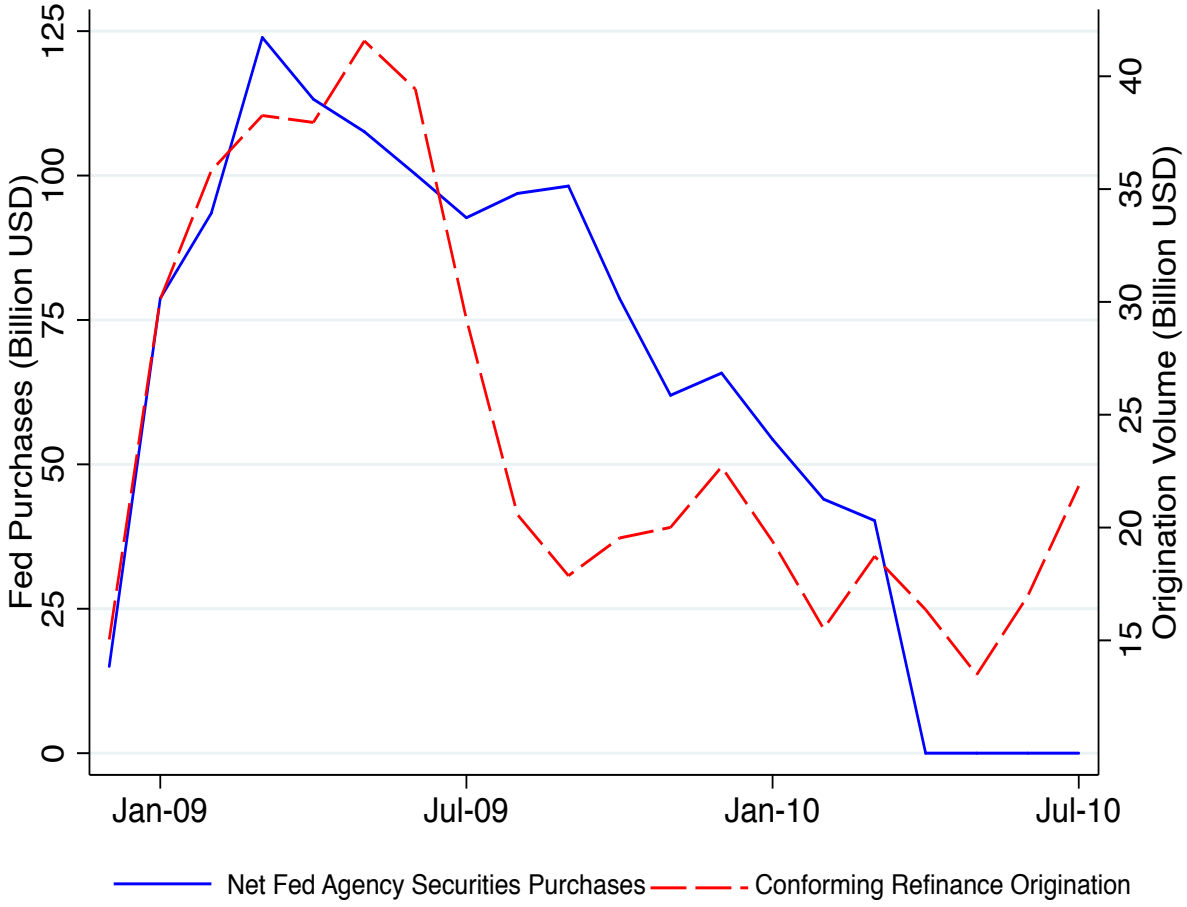


Panel II. Origination Volume



Notes: Figure plots the number of originations (top panel) and the origination volume (bottom panel) of refinance mortgages below the conforming loan limit and above the conforming loan limit as recorded by LPS. FHA loans are excluded from the data.

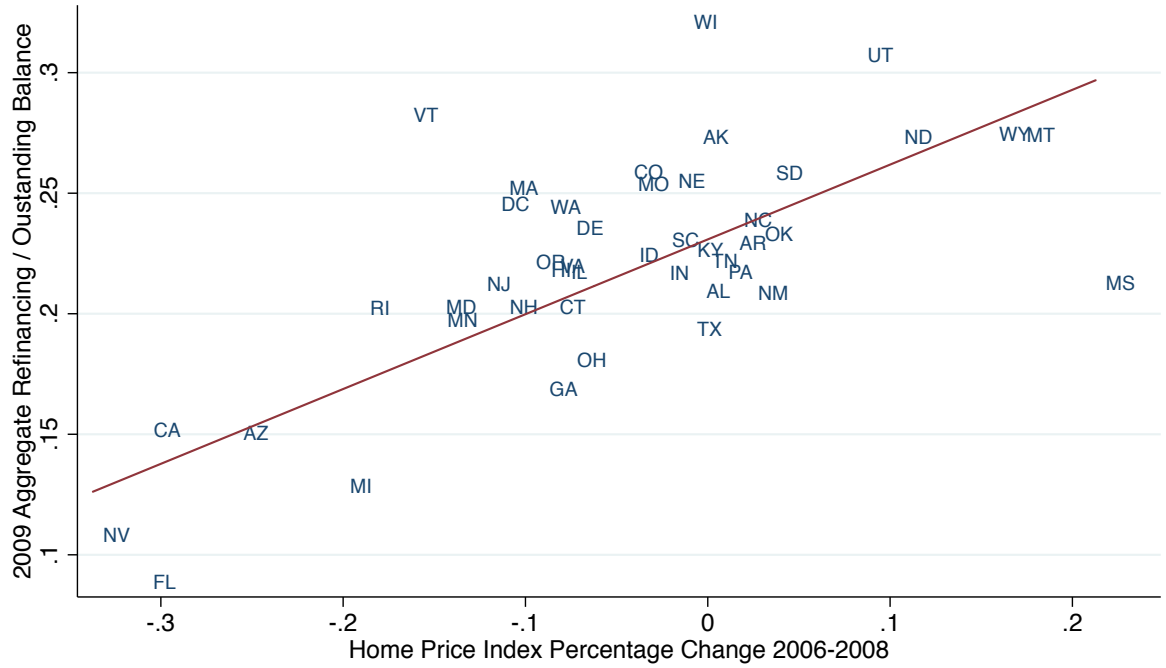
Figure 7. Fed Gross MBS Purchases vs. Conforming Origination Volume



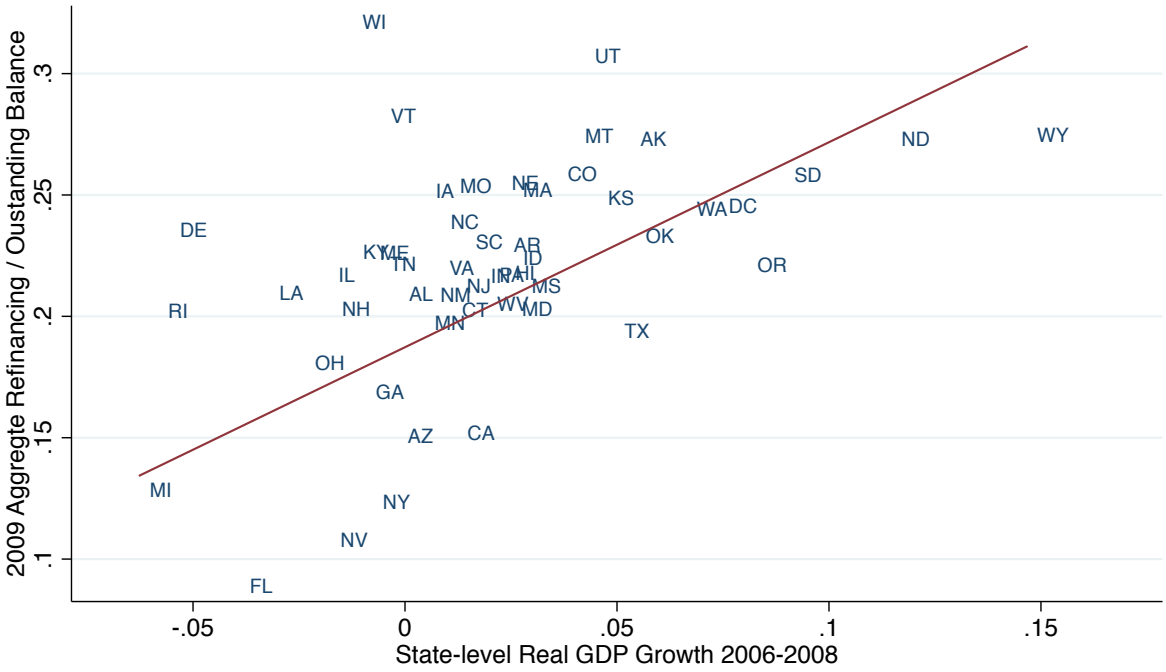
Notes: Figure plots the monthly origination amount of refinance mortgages below the conforming loan limit (right axis) recorded by LPS against the net monthly amount of Fed purchases of Agency securities observed in NY Fed Open Market Operations data (left axis).

Figure 8. State-level Refinancing Activity vs. Lagged HPI and GDP Growth

Panel I. Refinancing Activity and House-Price Growth



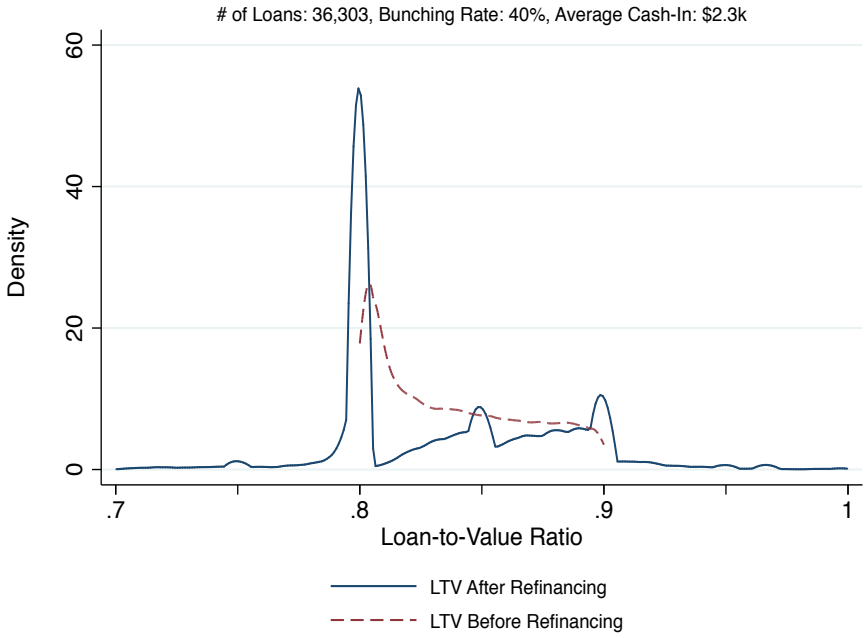
Panel II. Refinancing Activity and Real GDP Growth



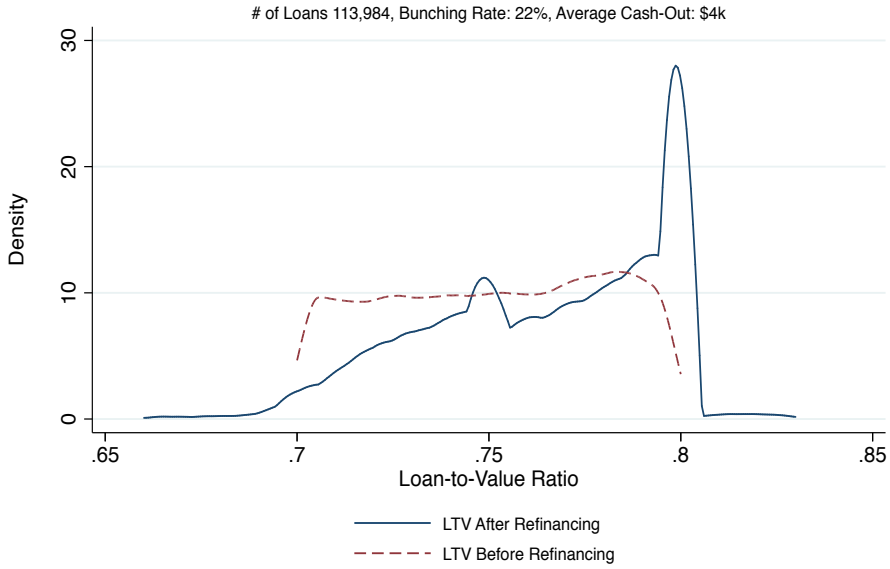
Notes: Figures plot the state-level percentage of 2009 outstanding mortgage balances that were refinanced in 2009 against state-level 2006-2008 Zillow Home Price Index percentage changes (Panel I) and 2006-2008 state-level real GDP growth (Panel II) from the BEA, along with the corresponding bivariate regression line. The robust t-stats are 4.7 for panel I and 4.2 for panel II.

Figure 9. Loan-to-Value Ratio Bunching Pre-HARP

Panel I. Distribution of LTV for Original LTVs 80-90%



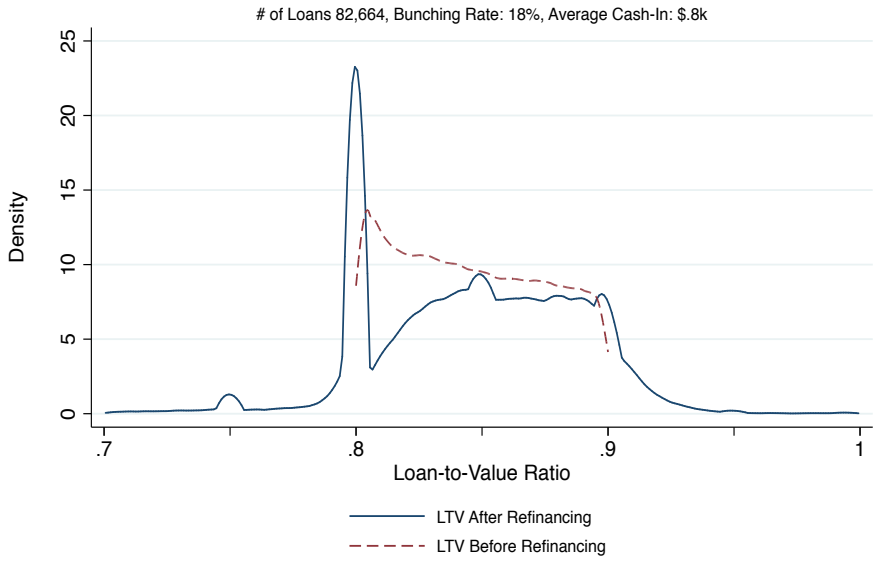
Panel II. Distribution of LTV for Original LTVs 70-80%



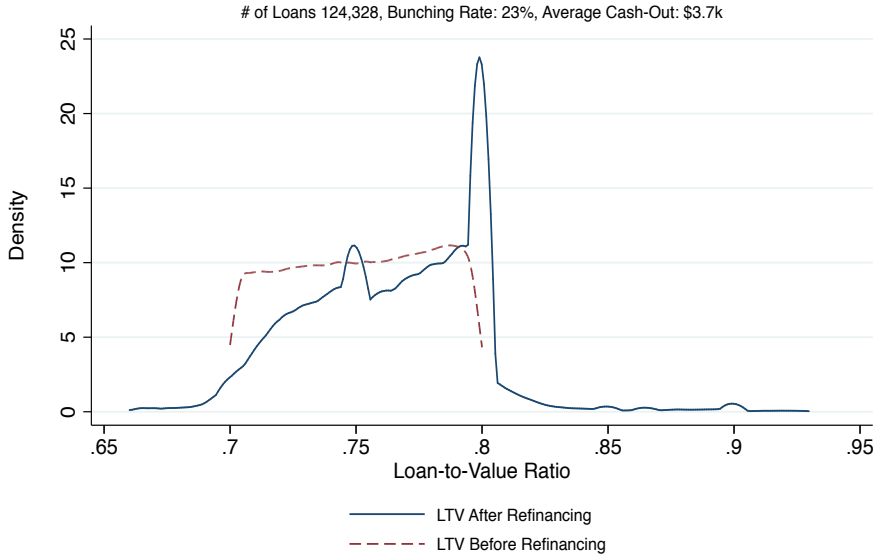
Notes: Figures report the distribution of borrower LTV ratios before and after refinancing during QE1 but before the start of the Home Affordable Refinance Program (HARP) (Dec. 2008 to May 2009). Panel I includes loans for which we observe the predecessor loan with imputed LTV 80-90%, while Panel II includes loans for which we observe the predecessor loan with imputed LTV below 70-80%. The dashed lines represent the imputed loan-to-value ratio distribution for mortgages that will be refinanced during the time period. To account for rolling closing costs into the balance of the new loan, we add average refinancing costs ($3,000) to the loan balance before the refinance. The solid blue lines report the distribution of actual LTV ratios for originated refinance mortgages. The bunching rate is the number of refinance mortgages with an 80% or lower (higher) LTV ratio at origination divided by the total number of loans with an imputed LTV ratio exceeding (below) 80% that refinance. Reported average cash-in (cash-out) is the average amount borrowers refinancing an above (below) 80%-LTV ratio mortgage provide at the closing of their new refinance mortgage. See text for average cash-in amounts conditional on deleveraging.

Figure 10. Loan-to-Value Ratio Bunching Post-HARP

Panel I. Distribution of LTV for Original LTVs 80-90%



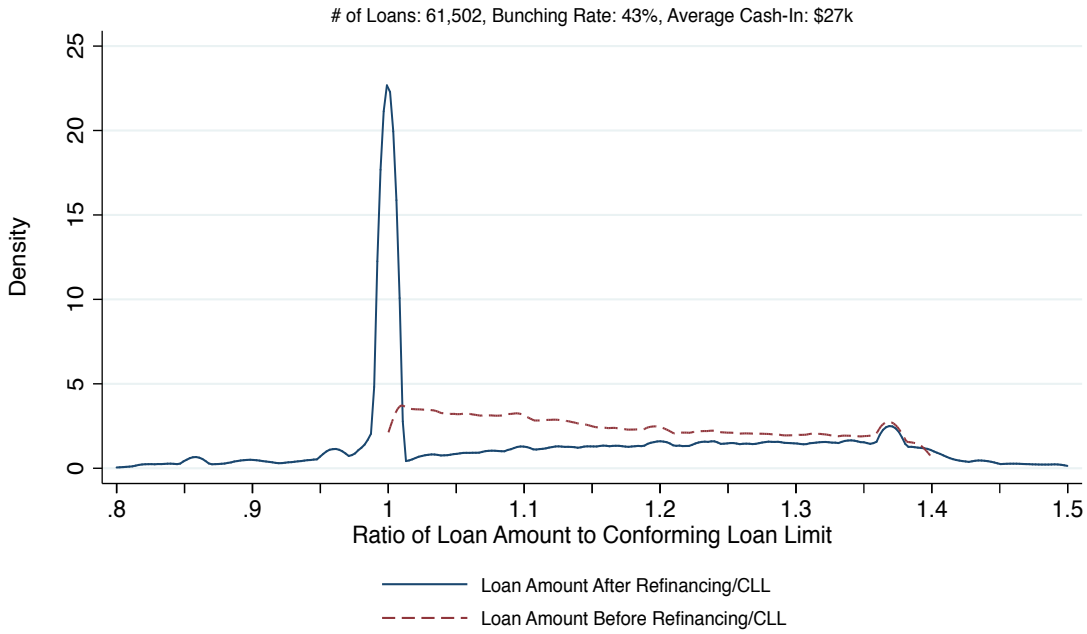
Panel II. Distribution of LTV for Original LTVs 70-80%



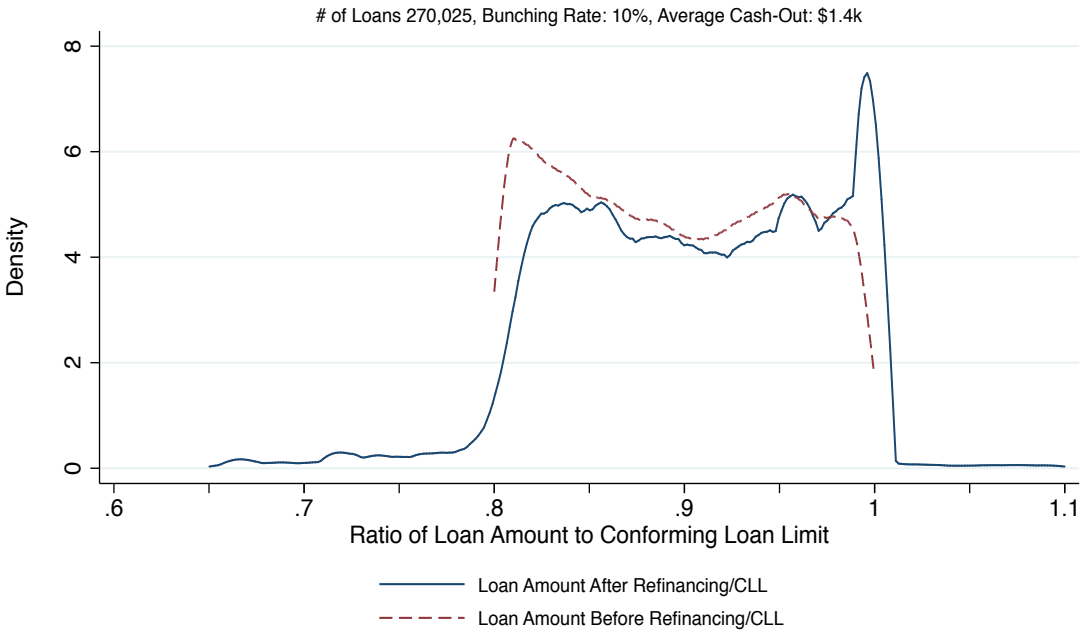
Notes: Figures report the distribution of borrower LTV ratios before and after refinancing during QE1 and after the introduction of HARP (June 2009 - Mar. 2010). Panel I includes loans for which we observe the predecessor loan with imputed LTVs of 80-90%, while Panel II includes loans for which we observe the predecessor loan with imputed LTVs of 70-0%. The dashed lines represent the imputed loan-to-value ratio distribution for mortgages that will be refinanced during the time period. To account for rolling closing costs into the balance of the new loan, we add average refinancing costs ($3,000) to the loan balance before the refinance. The solid blue lines report the distribution of actual LTV ratios for originated refinance mortgages. The bunching rate is the number of refinance mortgages with an 80% or lower (higher) LTV ratio at origination divided by the total number of loans with an imputed LTV ratio exceeding (below) 80% that refinance. Reported average cash-in (cash-out) is the average amount borrowers refinancing an above (below) 80%-LTV ratio mortgage provide at the closing of their new refinance mortgage.

Figure 11. Conforming Loan Limit Bunching

Panel I. Distribution of Loan Size/CLL for Original Balances 100-140% of CLL



Panel II. Distribution of Loan Size/CLL for Original Balances 80-100% of CLL



Notes: Figures plot distribution of loan sizes relative to the local conforming loan limit (CLL). The dashed line plots the distribution of normalized loan sizes for those borrowers with loan sizes above the CLL who refinanced one quarter prior to refinancing. The solid line shows the distribution of normalized loan sizes for the refinance mortgages of the borrowers whose predecessor loans are represented by the dashed line. The sample consists of refinance loans originated during 2008-2013 for which we observe the predecessor loan with outstanding principal between 100 and 140% of the local CLL (panel I) and loan whose outstanding balance (adjusted for expected refinancing costs) is between 80 and 100% of the CLL.

Table 1. Summary Statistics

				Percentile				
	Count	Mean	Std. Dev.	1st	10th	50th	90th	99th
Panel I. Below-Conforming Loan Limit Loans								
LTV	7,308,119	66.69	18.09	27.40	40.70	69.24	88.18	109.20
FICO	7,308,076	751.90	51	594	681	766	804	819
Interest Rate	6,374,466	4.56	0.96	2.75	3.38	4.50	5.75	7.13
Balance	7,308,119	211,335	117,725	44,000	83,000	185,000	388,000	590,000
Panel II. Jumbo Loans								
LTV	172,212	64.73	14.70	28.50	43.22	67.23	80.00	95.80
FICO	150,730	761.30	36.02	660	709	770	800	814
Interest Rate	172,182	4.10	1.14	1.88	2.75	3.88	5.63	7.25
Balance	172,212	959,771	693,231	440,000	536,000	813,000	1,475,000	3,265,000
Panel III. Spreads and Yields								
Guarantee fees	72	34.05	11.03	23.80	25.70	28.92	56.07	61.20
Aaa Yields	72	4.74	0.74	3.40	3.73	4.95	5.57	6.28
Baa Yields	72	6.08	1.13	4.51	4.85	5.97	8.06	9.21
Baa-Aaa Spread	72	1.34	0.62	0.75	0.84	1.18	2.52	3.38

Notes: Panel I & Panel II report loan-level summary statistics on conforming and jumbo loans from Equifax's CRISM database which merges McDash Analytics mortgage servicing records from Lender Processing Services with Equifax credit bureau data. Panel III reports summary statistics for time series controls used in robustness checks, including guarantee fees from Fuster et al. (2013) and bond yields from Federal Reserve Economic Data (FRED) at the Federal Reserve Bank of St. Louis.

Table 2. Effect of QE Campaign Beginning on Interest Rates: 3-Month Window

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Program	QE1		QE2		MEP		QE3		Tapering	
Program Indicator	-107.514***		-35.232**		-43.259***		-18.039**		25.265	
	(13.549)		(10.338)		(7.020)		(5.908)		(13.656)	
Program x Jumbo	48.562***	41.809***	-3.812	-1.800	4.996***	4.715	-0.013	-1.022	-21.153*	-24.829**
	(6.441)	(7.485)	(5.927)	(5.964)	(1.141)	(2.375)	(1.506)	(1.739)	(8.415)	(8.216)
Jumbo Indicator	29.946***	33.178***	46.548***	47.363***	20.755***	23.204***	25.964***	28.176***	-1.706	0.63
	-5.466	-5.516	-3.739	-2.842	-1.152	-2.019	-1.131	-1.258	-3.359	-3.197
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
County x Month FEs		Yes		Yes		Yes		Yes		Yes
Observations	331,895	331,895	292,290	292,290	180,055	180,055	201,060	201,060	262,493	262,493
R-squared	0.564	0.669	0.297	0.457	0.364	0.462	0.219	0.336	0.203	0.383

Notes: The table reports regression coefficients relating loan-level mortgage interest rates (in basis points) to the quantitative easing programs and to the other monetary policy programs. QE, MEP ("Maturity Extension Program"), and Tapering Indicators are dummy variables equal to one after the introduction of each program (see Appendix Table 1). The sample includes single-family, first lien, 30-year term, fixed rate, non-interest only, non-balloon, and non-FHA refinance mortgages with no prepayment penalties and less than or equal to 80% LTV. Controls include binned original LTV and binned credit score. Jumbo Indicator is a dummy equal to one for jumbo loans. Program x Jumbo is the interaction between the program dummies and Jumbo Indicator. The sample includes single-family, first lien, non-FHA refinance mortgages. The event window includes the three months before/after the beginning month of each program period (e.g. QE1 sample is Sep2008-Feb2009). All specifications control for 5-point LTV bins, 20-point FICO bins, and an indicator for missing FICO. Even columns control for county by month fixed effects. Standard errors are clustered at the month level. Asterisks denote significance levels (***=1%, **=5%, *=10%).

Table 3. Effect of QE Campaign Beginning on Interest Rates: 6-Month Window

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Program	QE1		QE2		MEP		QE3		Tapering	
Program Indicator	-128.508***		-45.511***		-60.346***		-32.475***		50.168***	
	(9.444)		(8.374)		(6.724)		(5.830)		(14.362)	
Program x Jumbo	55.942***	52.780***	-1.837	-1.324	10.885***	10.058***	-3.331	-4.799	-33.257***	-35.631***
	(6.515)	(5.841)	(5.577)	(5.309)	(2.236)	(2.407)	(3.056)	(2.944)	(7.815)	(6.683)
Jumbo Indicator	16.849**	20.154***	44.125***	52.756***	17.125***	19.849***	25.421***	27.578***	7.092	8.752*
	(5.565)	(4.724)	(2.650)	(8.614)	(1.844)	(2.100)	(1.232)	(0.801)	(4.379)	(4.244)
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
County*Month FEs		Yes		Yes		Yes		Yes		Yes
Observations	789,945	789,945	568,776	568,776	351,042	351,042	438,201	438,201	470,820	470,820
R-squared	0.669	0.745	0.362	0.493	0.478	0.576	0.304	0.428	0.360	0.567

Notes: The table reports regression coefficients relating loan-level mortgage interest rates (in basis points) to the quantitative easing programs and to the other monetary policy programs. QE, MEP ("Maturity Extension Program"), and Tapering Indicators are dummy variables equal to one after the introduction of each program (see Appendix Table 1). The sample includes single-family, first lien, 30-year term, fixed rate, non-interest only, non-balloon, and non-FHA refinance mortgages with no prepayment penalties and less than or equal to 80% LTV. Controls include binned original LTV and binned credit score. Jumbo Indicator is a dummy equal to one for jumbo loans. Program x Jumbo is the interaction between the program dummies and Jumbo Indicator. The sample includes single-family, first lien, non-FHA refinance mortgages. The event window includes the six months before/after the beginning month of each program period (e.g. QE1 sample is Sep2008-Feb2009). All specifications control for LTV bins, FICO bins, and an indicator for missing FICO. Even columns control for county by month fixed effects. Standard errors are clustered at the month level. Asterisks denote significance levels (***=1%, **=5%, *=10%).

Table 4. Effect of QE Campaign Beginning on Refinance Origination Volumes: 3-Month Window

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Program	QE1		QE2		MEP		QE3		Tapering	
Program Indicator	1.007**		0.497**		0.537***		0.151		-0.343*	
	(0.290)		(0.153)		(0.076)		(0.087)		(0.145)	
Program x Jumbo	-0.863***	-0.863**	0.116	0.116	-0.045	-0.045	0.037	0.037	0.399**	0.399
	(0.208)	(0.294)	(0.130)	(0.183)	(0.117)	(0.166)	(0.031)	(0.043)	(0.147)	(0.208)
Jumbo Indicator	-2.186***	-2.186***	-2.358***	-2.358***	-1.848***	-1.848***	-1.587***	-1.587***	-1.503***	-1.503***
	(0.067)	(0.095)	(0.086)	(0.122)	(0.062)	(0.087)	(0.007)	(0.010)	(0.024)	(0.033)
County*Month FEs		Yes		Yes		Yes		Yes		Yes
Observations	576	576	576	576	576	576	576	576	576	576
R-squared	0.651	0.927	0.584	0.936	0.462	0.929	0.362	0.915	0.307	0.906

Notes: Table reports regression coefficients relating county-month-mortgage segment log refinancing volumes to unconventional monetary policy programs. The left-hand side variable is the log dollar volume of refinanced mortgages at the county-month level as reported in the CRISM data. QE, MEP ("Maturity Extension Program"), and Tapering Indicators are dummy variables equal to one after the introduction of each program (see Appendix Table 1). Jumbo Indicator is a dummy equal to one for jumbo loans. Program x Jumbo is the interaction between the program dummies and Jumbo Indicator. The sample includes single-family, first lien, non-FHA refinance mortgages. Counties are included in the sample if they have a positive number of jumbo originations in every sample month. The event window includes the three months before/after each QE period (e.g. QE1 sample is Sep2008-Feb2009). In all even columns, we control for the interaction between county and month fixed effects. Standard errors are clustered at the month level; asterisks denote conventional significance levels (***=1%, **=5%, *=10%).

Table 5. Effect of QE Campaign Beginning on Refinance Origination Volumes: 6-Month Window

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Program	QE1		QE2		MEP		QE3		Tapering	
Program Indicator	1.138***		0.463**		0.519***		0.322***		-0.739***	
	(0.201)		(0.164)		(0.088)		(0.082)		(0.185)	
Program x Jumbo	-1.029***	-1.029***	0.253	0.253	-0.022	-0.022	-0.025	-0.025	0.560***	0.560***
	(0.128)	(0.182)	(0.142)	(0.201)	(0.083)	(0.117)	(0.032)	(0.045)	(0.091)	(0.129)
Jumbo Indicator	-1.999***	-1.999***	-2.238***	-2.238***	-1.792***	-1.792***	-1.568***	-1.568***	-1.569***	-1.569***
	(0.087)	(0.123)	(0.071)	(0.100)	(0.052)	(0.073)	(0.015)	(0.021)	(0.034)	(0.048)
County*Month FEs		Yes		Yes		Yes		Yes		Yes
Observations	1,152	1,152	1,152	1,152	1,152	1,152	1,152	1,152	1,152	1,152
R-squared	0.628	0.933	0.548	0.929	0.449	0.927	0.379	0.916	0.309	0.912

Notes: Table reports regression coefficients relating relating county-month-mortgage segment log refinancing volumes to unconventional monetary policy programs. The left-hand side variable is the log dollar volume of refinanced mortgages at the county-month level as reported in the CRISM data. QE, MEP ("Maturity Extension Program"), and Tapering Indicators are dummy variables equal to one after the introduction of each program (see Appendix Table 1). Jumbo Indicator is a dummy equal to one for jumbo loans. Program x Jumbo is the interaction between the program dummies and Jumbo Indicator. The sample includes single-family, first lien, non-FHA refinance mortgages. Counties are included in the sample if they have a positive number of jumbo originations every sample month. The event window includes the six months before/after each QE period (e.g. QE1 sample is Sep2008-Feb2009). In all even columns, we control for the interaction between county and month fixed effects. Standard errors are clustered at the month level; asterisks denote conventional significance levels (***=1%, **=5%, *=10%).

Table 6. Robustness to Controlling for G-Fees and Credit Spreads: 3-Month Window

Program	(1) QE1	(3) QE2	(5) MEP	(7) QE3	(9) Tapering
		Panel I. Interest Rates			
Program x Jumbo	29.259**	-0.576	-4.564	5.878	-22.961**
	(7.555)	(5.201)	(3.295)	(3.003)	(7.414)
Jumbo Indicator	-35.321***	9.242	-4.417	10.396***	10.823***
	(2.261)	(4.596)	(2.318)	(0.918)	(1.670)
Controls	Yes	Yes	Yes	Yes	Yes
County*Month FEs	Yes	Yes	Yes	Yes	Yes
Observations	331,895	292,290	180,055	201,060	262,493
R-squared	0.668	0.450	0.462	0.326	0.381
		Panel II. Refinance Origination Volumes			
Program x Jumbo	-0.711*	0.056	0.160	-0.108	0.339
	(0.351)	(0.185)	(0.205)	(0.091)	(0.183)
Jumbo Indicator	-2.419***	-2.432***	-2.363***	-2.044***	-3.178***
	(0.172)	(0.140)	(0.110)	(0.022)	(0.016)
County*Month FEs	Yes	Yes	Yes	Yes	Yes
Observations	576	576	576	576	576
R-squared	0.930	0.938	0.941	0.933	0.960

Notes: Panel I reports regression coefficients relating interest rates to the quantitative easing programs and to the other monetary policy programs. The sample includes single-family, first lien, 30-year term, fixed rate, non-interest only, non-balloon, and non-FHA refinance mortgages with no prepayment penalties and less than or equal to 80% LTV. Controls include binned original LTV and binned credit score. In all columns, we first subtract the contribution of the interaction of the Jumbo Indicator with a measure of Credit Spread (i.e. BBB to AAA spread from St. Louis Fed), with guarantee fees from Fuster et al. (2013), and county x month fixed effects as described in section 6.1.4. Panel II reports regression coefficients relating refinancing volume to the quantitative easing programs and to the other monetary policy programs. The left hand side variable is defined as the log of the dollar volume of refinanced mortgages as reported in the CRISM data. The sample includes single-family, first lien, non-FHA refinance mortgages. Counties are included in the quantity sample if they have greater than one jumbo origination in every month. All columns control for county x month fixed effects. We again subtract the contribution of the interaction of the jumbo indicator with credit spread and with guarantee fees as described in section 6.1.4. QE, MEP ("Maturity Extension Program"), and Tapering Indicators are dummy variables equal to one after the introduction of each program. MEP begins in Sept. 2011. Tapering begins in June 2013. Jumbo Indicator is a dummy equal to one for jumbo loans. QE x Jumbo is the interaction between the program dummies and Jumbo Indicator. The event window includes the three months prior to and after the beginning month of each QE period. For example, QE1 begins in December 2008, and the event window lasts from September 2008 through March 2009. Standard errors are clustered at the month level, and are reported in parentheses. Asterisks denote significance levels (***=1%, **=5%, *=10%).

Table 7. Hazard Model Estimates of QE1 Effect on Refinancing

	(1)	(2)	(3)
December 2008 Indicator	0.151***	0.114**	0.108*
	(0.033)	(0.057)	(0.063)
January 2009 Indicator	0.812***	0.954***	0.950***
	(0.027)	(0.046)	(0.051)
February 2009 Indicator	1.245***	1.367***	1.372***
	(0.025)	(0.043)	(0.047)
Current LTV $>$ .9 x December 2008		-0.064	-0.063
		(0.086)	(0.099)
Current LTV $>$ .9 x January 2009		-0.447***	-0.379***
		(0.072)	(0.081)
Current LTV $>$ .9 x February 2009		-0.429***	-0.376***
		(0.065)	(0.073)
December 2008 x Jumbo		0.120	0.017
		(0.086)	(0.097)
January 2009 x Jumbo		-0.190**	-0.212**
		(0.076)	(0.083)
February 2009 x Jumbo		-0.203***	-0.227***
		(0.069)	(0.075)
Loan Controls	Yes	Yes	Yes
Borrower Controls			Yes
Observations	1,691,380	1,691,380	1,407,066

Notes: Table reports maximum-likelihood estimates of the prepayment hazard model described in Section 6.2.1. All specifications include a cubic function of loan age as a non-parametric baseline hazard. Loan-level controls include current LTV, loan size at origination, indicators for current LTV between 80 and 90%, current LTV over 90%, and current balance over the conforming loan limit. Borrower controls include DTI, a missing DTI indicator, and FICO bins. Jumbo is an indicator for loan amount at least $60,000 above the CLL to account for cash-in refinancingRobust standard errors in parentheses.

Appendix

A Additional TBA Market Details

On the day a TBA contract is traded, the buyer and seller fix the basic characteristics of the MBS to be delivered, with a 0.01% allowed variance in the par value at delivery. Sellers in the TBA market are primarily mortgage originators seeking to lock in interest rates to hedge short-run interest-rate risk. Buyers in this market include MBS sponsors who are assembling Collateralized Mortgage Obligations for new securitizations. Generally, only six parameters of the mortgages to be delivered are specified: agency (Fannie, Freddie, or Ginnie), weighted-average maturity, weighted-average coupon (in 50 basis-point increments), price, par amount, and settlement date.[18] A separate (much smaller) market exists called the Stipulated (STIP) market where CMOs with detailed information disclosures are traded. For this reason, when there is information to disclose about a MBS that enhances its value (e.g., predictors of lower early-termination risk), the STIP market is a more favorable trading platform.[19] Two days prior to TBA settlement date, the seller informs the buyer of the specific pools to be delivered and the trade is settled on an Agency-determined settlement date. To deliver these pools, the seller has either acquired or originated Agency-eligible mortgages and paid the necessary upfront fees (known as g-fees) to have them assembled into an Agency-guaranteed pool. For a variety of reasons, the vast majority of mortgages comprising TBAs are recent originations. Payment history information about seasoned mortgages can make them more valuable to trade on the STIP market (in the case of good news) or ineligible for TBA inclusion (in the case of missed payments, etc.). Adverse selection arising from the superior information set of the seller as to the termination risk of the mortgages to be delivered is mitigated by "cheapest-to-deliver" expectations and pricing by buyers and sellers (see Downing et al., 2009). This TBA contract standardization effectively commoditizes the MBS traded in TBAs, providing the TBA market with a degree of liquidity unmatched by any other secondary mortgage market, meaning that even legal requirements aside, purchasing TBAs was the only feasible option at the time.[20]

[18] For example, a TBA contract might be simply specified FN3060, meaning that it represents a Fannie Mae-guaranteed MBS whose weighted average maturity and coupon are 30 years and 4.0%, respectively. Although rare, some additional characteristics may be specified, for example, the number of pools in a security, geographic composition, etc.

[19] In the Agency market, due to the default guarantees provided by Fannie, Freddie, and Ginnie, the value of MBS will primarily vary with the degree of termination risk borne by the investor since to the holder of a Agency-guaranteed mortgage, the cash flows from default and prepayment look identical. This risk may be a function of other features of the MBS not stipulated on the TBA forward contract, such as FICO, DTI, geographic location, etc.

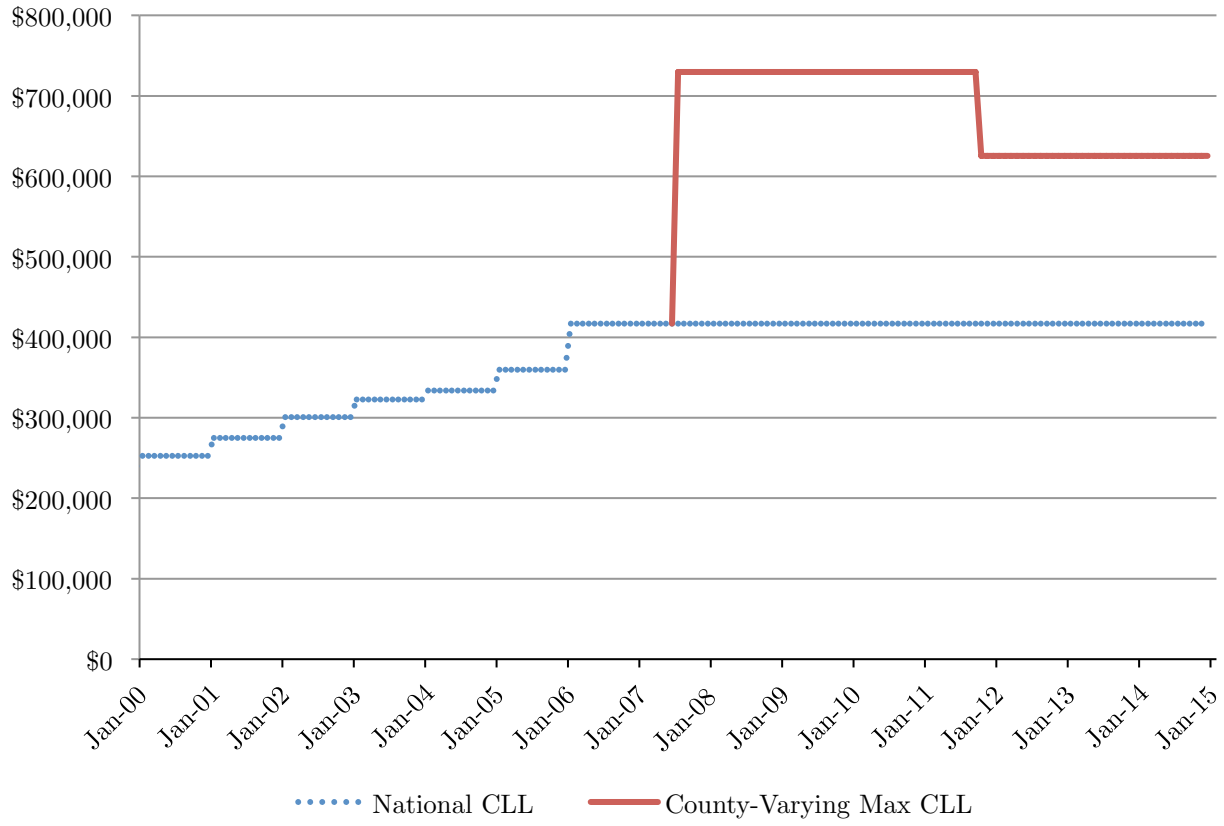
[20] While each mortgage is a highly differentiated product, all mortgages in a given TBA contract are essentially behind a veil of ignorance and can thus be traded as a commodity. For market participants, the risk management and valuation exercises are simplified as they need consider only the risks associated with the main characteristics of the MBS. See Vickery and Wright (2013), who quantify the magnitude of the liquidity benefits of the TBA market, and Glaeser and Kallal (1997) and Vanasco (2014) for theoretical treatments of this benefit. However, this fungibility is temporary. Upon settlement and delivery, the buyer observes the complete set of characteristics of each loan pool and the market value of delivered mortgage-backed securities will incorporate this information.

B Robustness to Increasing Conforming Loan Limits

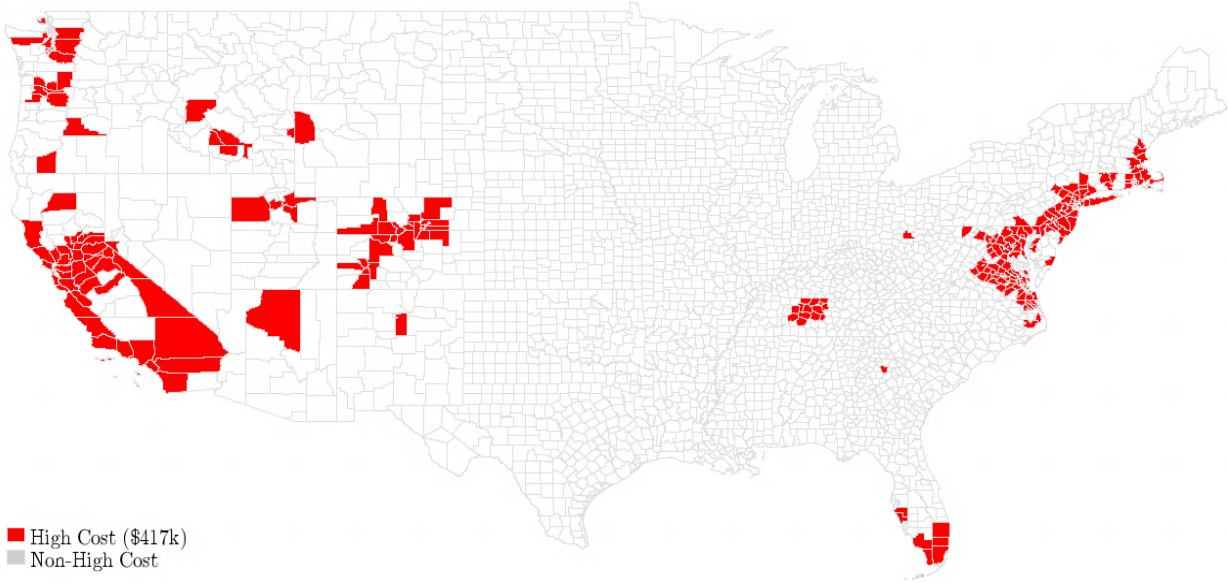
In this appendix, we investigate the concern that the stronger response of GSE-eligible originations relative to jumbo originations around QE event dates simply reflects the establishment of high-cost area designations. The conforming loan limit increased from about $400,000 to $700,000 for certain high-cost areas over time (see Panel I of Appendix Figure 1). As mapped in Panel II of Appendix Figure 1, these areas are mainly counties on the coasts that have higher land values. Although this increase occurred nearly a year before the beginning of QE1, expanding the size of the conforming market by increasing the CLL in certain areas should tilt originations from the jumbo segment to the GSE-eligible segment. To address this concern, we restrict our attention to the counties that remained exclusively in the low-cost areas that have had no increase in their CLLs since 2006. Appendix Figure 2 shows that even when we restrict attention to these areas, we observe a significant and differential increase in the origination of conforming loans around QE1. We find that for the period before the expiration the jumbo and conforming segments track each other closely, except for the QE1 period.

Appendix Figure 1. Conforming Loan Limits

Panel I. National and Maximum High-Cost Area Conforming Loan Limits

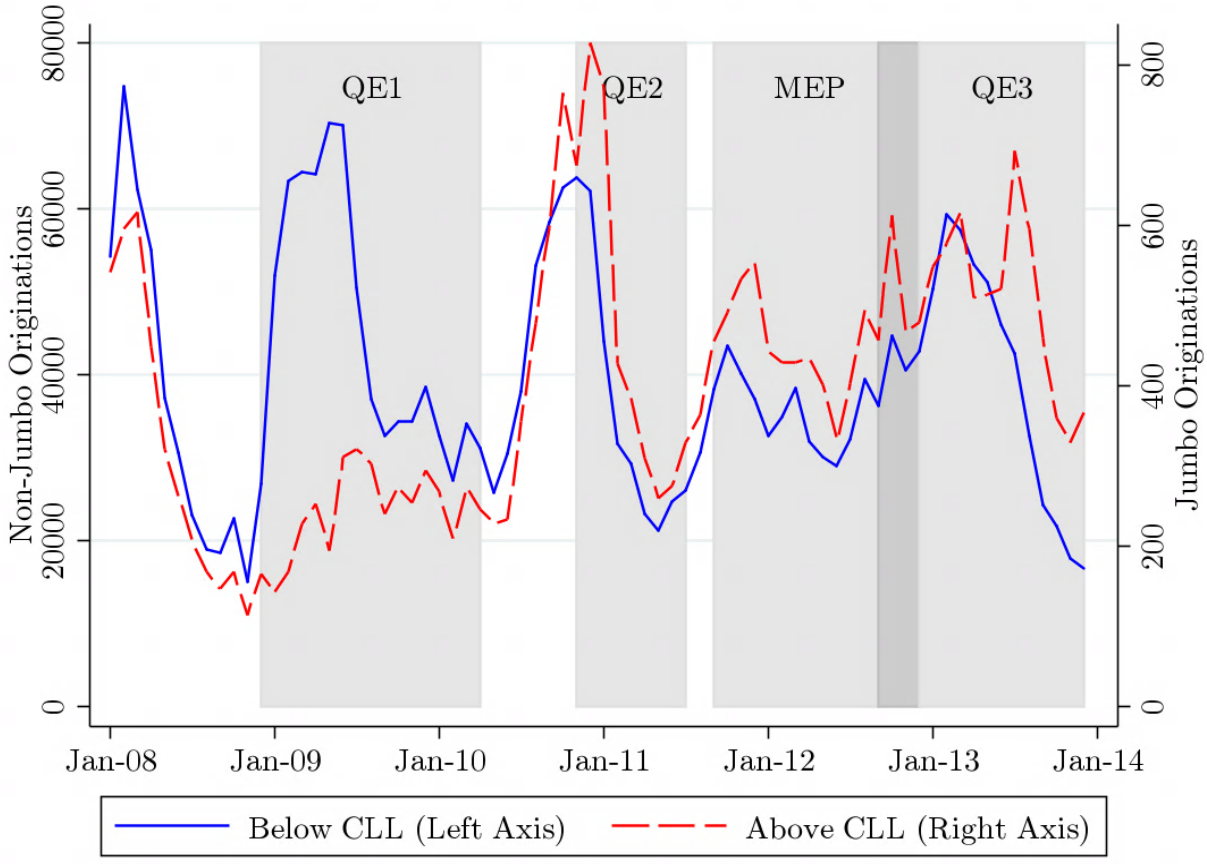


Panel II. The Geography of High-Cost County Designation



Notes: Panel I plots the national conforming loan limit over time and its maximal increase among certain high-cost counties in early 2008. Some of these temporary high-cost exemptions expired on October 1, 2011. Panel II plots all counties in the contiguous state. Darkly shaded areas indicate counties designated as high cost, defined as counties with conforming loan limits greater than $417,000.

Appendix Figure 2. Refinance Origination Count in Low-Cost Areas



Notes: Figure plots the count of refinance mortgage originations in low-cost areas recorded by LPS for loans below and above the GSE conforming loan limit (CLL). See notes for Figure 6.

Appendix Table 1. Fed Unconventional Monetary Policy Announcement Dates and Dates Used in Analysis

Episode	Announcement Date	Event	Event Date
QE1.1	25-Nov-08	QE 1 Start	Dec-2008
QE1.2	1-Dec-08		
QE1.3	16-Dec-08		
QE1.4	28-Jan-09		
QE1.5	18-Mar-09		
QE1.6	23-Sep-09	QE 1 End	Apr-2010
QE2.1	10-Aug-10	QE 2 Start	Sep-2010
QE2.2	21-Sep-10	QE 2 End	Jul-2011
FG.1	9-Aug-11	MEP Start	Sep-2011
FG.2	25-Jan-12		
QE3.1	13-Sep-12	QE 3 Start	Sep-2012
QE3.2	22-May-13		
QE3.3	19-Jun-13	Tapering	Jun-2013
QE3.4	10-Jul-13		
QE3.5	18-Sep-13	QE 3 End	Oct-2014

Note: Table reports the timing of Federal Reserve Quantitative Easing announcements from Krishnamurthy and Vissing-Jorgensen (2011) and Krishnamurthy and Vissing-Jorgensen (2013) as well as the dates used in the paper for each LSAP program.

Appendix Table 2. Robustness to G-Fees and Credit Spreads: 6-Month Window

Program	(1) QE1	(2) QE2	(3) MEP	(4) QE3	(5) Tapering
		Panel I. Interest Rates			
Program x Jumbo	26.039***	-1.594	2.015	12.839***	-25.011***
	(4.124)	(4.654)	(3.865)	(3.015)	(5.065)
Jumbo Indicator	-32.950***	6.599*	-10.550**	5.174*	12.100***
	(2.718)	(3.220)	(3.661)	(2.616)	(1.138)
Controls	Yes	Yes	Yes	Yes	Yes
County x Month FEs	Yes	Yes	Yes	Yes	Yes
Observations	789,945	568,776	351,042	438,201	470,820
R-squared	0.744	0.489	0.577	0.419	0.569
		Panel II. Refinance Origination Volumes			
Program x Jumbo	-0.788***	0.239	0.166	-0.337**	0.239
	(0.180)	(0.184)	(0.158)	(0.126)	(0.148)
Jumbo Indicator	-2.318***	-2.374***	-2.258***	-1.957***	-3.053***
	(0.103)	(0.088)	(0.110)	(0.060)	(0.105)
Controls	Yes	Yes	Yes	Yes	Yes
County x Month FEs	Yes	Yes	Yes	Yes	Yes
Observations	1,152	1,152	1,152	1,152	1,152
R-squared	0.939	0.934	0.938	0.933	0.958

Notes: Panel I reports regression coefficients relating interest rates to the quantitative easing programs and to the other monetary policy programs. The sample includes single-family, first lien, 30-year term, fixed rate, non-interest only, non-balloon, and non-FHA refinance mortgages with no prepayment penalties with less than or equal to 80% LTV. Controls include binned original LTV and credit score. In all columns, we subtract the contribution of an interaction of the Jumbo Indicator with a measure of Credit Spread (i.e. BBB to AAA spread) and with guarantee fees as described in section 6.1.4 as well as county by month fixed effects. Panel II reports regression coefficients relating refinancing volume to the quantitative easing programs and to the other monetary policy programs. The left hand side variable is defined as the log of the dollar volume of refinanced mortgages as reported in the CRISM data. The sample includes single-family, first lien, non-FHA refinance mortgages. Counties are included in the sample that have positive jumbo originations every month. In all odd columns, we control for the interaction between county fixed effects and the Jumbo Indicator, while in all even columns, we control for county by month fixed effects. In both Panel I & II for all columns, we control for the interaction of the jumbo indicator with a measure of Credit Spread (i.e. BBB to AAA spread) and with guarantee fees. QE, MEP ("Maturity Extension Program"), and Tapering Indicators are dummy variables equal to one after the introduction of each program. MEP begins in Sept. 2011. Tapering begins in July 2013. Jumbo Indicator is a dummy equal to one for jumbo loans. QE x Jumbo is the interaction between the program dummies and Jumbo Indicator. The event window includes the six months prior to and after the beginning month of each QE period. For example, QE1 begins in December 2008, and the event window lasts from June 2008 through June 2009. Standard errors are clustered at the month level, and are reported in parentheses. Asterisks denote significance levels (***=1%, **=5%, *=10%).

Appendix Table 3. Coefficients on AAA-BBB Spread and Guarantee Fee

	(1) QE1	(2) QE2	(3) MEP	(4) QE3	(5) Tapering
			Panel I. Interest Rates		
AB Spread × Jumbo	25.19***	20.45***	17.71***	19.51***	20.40***
	(6.01)	(2.84)	(2.68)	(2.62)	(2.68)
G-Fee × Jumbo	-1.48***	-1.43***	-1.61***	-1.61***	-1.32***
	(0.16)	(0.19)	(0.17)	(0.17)	(0.31)
Jumbo Indicator	48.33***	50.33***	62.71***	55.87***	47.32***
	(9.88)	(8.73)	(7.64)	(6.92)	(9.40)
County-Month FEs	Yes	Yes	Yes	Yes	Yes
Observations	2,618,508	2,839,677	3,057,411	2,970,252	2,937,633
R-squared	0.781	0.799	0.788	0.740	0.748
			Panel II. Refinance Origination Volume		
AB Spread × Jumbo	-0.25	-0.45***	-0.42***	-0.44***	-0.45***
	(0.18)	(0.08)	(0.09)	(0.08)	(0.08)
G-Fee × Jumbo	0.03***	0.02***	0.03***	0.03***	0.04***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
County-Month FEs	Yes	Yes	Yes	Yes	Yes
Observations	5,760	5,760	5,760	5,760	5,760
R-squared	0.937	0.929	0.931	0.930	0.93

Notes: Each column estimates the relationship between interest rates (panel I) and origination volumes (panel II) to credit spreads and guarantee fees for all months between 2008-2013 except for the three months before/after the indicated program. The sample for panel I includes loans with LTV less than or equal to 80%, controlling for county by month fixed effects. The sample for panel II has two observations for each county-month: log of total refinance origination below the conforming loan limit and above the conforming loan limit for counties that had non-zero refinancing activity in both the jumbo and non-jumbo segments throughout the sample period. We control for county by month fixed effects. QE1 begins in December 2008, QE2 begins in September 2010, MEP begins in September 2011, QE3 begins in September 2012, and Tapering begins in June 2013. Clustered standard errors are reported in parentheses. Asterisks denote significance levels (***=1%, **=5%, *=10%).