Monetary Policy and Real Borrowing Costs at the ZLB

Simon Gilchrist* David López-Salido† Egon Zakrajšek‡

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Abstract

We investigate the effect of monetary policy surprises on Treasury yields and borrowing costs of businesses and households, as measured by interest rates on corporate bonds and mortgage-related instruments. We compare the effects of policy surprises on market interest rates during the period of conventional policy actions and during the period in which the target federal funds rate is at the zero lower bound. In the conventional policy regime, a policy surprise that reduces the 2-year nominal Treasury yield 10 basis points induces a 5 basis point decline in longer-term nominal Treasury yields and a 4 basis point decline in the comparable-maturity TIPS yield. In the unconventional policy period, by contrast, an unanticipated easing that has the same effect on the 2-year yield causes a 20 basis point decline in long-term nominal Treasury yields and a 18 basis point decline in TIPS yields—that is, expansionary monetary policy flattens the nominal yield curve. We also document that expansionary monetary policy significantly reduces real borrowing costs for investment-grade firms and that policy easings during the unconventional policy period imply an effect on real corporate borrowing costs that is three times as large as during the unconventional policy regime for a commensurate movement in the 2-year Treasury yield. Monetary policy also reduces the real cost of household finance, as measured by movements in the real yields on mortgage-related instruments. While the pass-through from Treasury yields to real corporate yields is roughly one-for-one, the pass-through to household borrowing costs is substantially lower—on the order of 5 basis points for a 10 basis point decline in a comparable-maturity Treasury yield.

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*Department of Economics, Boston University and NBER. E-mail: sgilchri@bu.edu
†Division of Monetary Affairs, Federal Reserve Board. E-mail: david.j.lopez-salido@frb.gov
‡Division of Monetary Affairs, Federal Reserve Board. E-mail: egon.zakrajsek@frb.gov

1 Introduction

For the better part of the past 35 years, the Federal Reserve attempted to achieve its statutory objectives for monetary policy—maximum employment, stable prices, and moderate long-term interest rates—by influencing short-term nominal interest rates in an effort to affect the real borrowing costs faced by businesses and households.[1] Under this so-called dual mandate, the policymakers will, when faced with a slowdown in economic activity, ease monetary policy by lowering short-term nominal interest rates, inducing a decline in real borrowing costs. In response, businesses boost capital expenditures, while households increase purchases of durable goods and real estate assets, expansionary demand effects that then lead to rising employment and output.[2]

The ability of the Federal Reserve to influence real borrowing costs, however, is indirect. Conventional monetary policy operates through open market operations, which directly affect the overnight federal funds rate. As emphasized by Gürkaynak, Sack, and Swanson [2005a], policy actions affect both the current funds rate and its expected future trajectory. Through its influence on expectations, a policy easing lowers longer-term nominal interest rates, and, to the extent that nominal prices do not adjust fully, it also reduces longer-term real interest rates, the key determinant of real borrowing costs faced by economic agents. In addition to influencing the expected path of short-term interest rates, monetary policy may also affect risk and term premia associated with longer-term financial assets. If assets across different maturities are imperfect substitutes, then altering the mix of assets available to investors will directly influence the premium associated with holding long-term rather than short-term investments.

In the wake of the extraordinary events associated with the height of the financial crisis in the latter part of 2008, the Federal Open Market Committee (FOMC) lowered the target federal funds rate to its effective lower bound. With short-term nominal interest rates constrained by the zero lower bound (ZLB), the effectiveness of monetary policy depends entirely on its ability to influence the expected path of future short-term nominal interest rates or to affect term premia directly through asset-substitution mechanisms, the two prongs of the unconventional monetary policy strategy employed by the FOMC since the funds rate hit the ZLB in December 2008; see D'Amico, English, López Salido, and Nelson [2012] for detailed discussion.

In this paper, we study the effects of monetary policy actions—both conventional and unconventional—on the nominal and real Treasury yields and on the real borrowing costs faced by businesses and households. To make a meaningful comparison between the conventional and unconventional policy regimes, we follow Hanson and Stein [2012] and Gertler and Karadi [2013] and use the 2-year nominal Treasury yield as the policy instrument in both regimes. In effect, we assume that the Federal Reserve conducts open market operations to directly induce changes in

[1] The Full Employment and Balanced Growth Act of 1978—more commonly known as the Humprey-Hawkins Act—established price stability and full employment as national economic policy objectives.

[2] See Mishkin [1995] and Bernanke and Gertler [1995] for detailed description of the various channels through which monetary policy can affect macroeconomic outcomes.

the 2-year Treasury yield. More precisely, to identify unanticipated policy actions, we rely on high-frequency intraday data surrounding FOMC announcements. In particular, we measure surprise movements in Treasury yields in a narrow 20-minute window bracketing FOMC announcements, which are then used as instruments for the daily change in the 2-year nominal Treasury yield. This approach is that it allows us to rule out the potential reverse causality, a situation in which the daily changes in the 2-year Treasury yield—even on the days of FOMC announcements—may not reflect solely changes in the stance of monetary policy, but also the endogenous response of policy to changes in the economic outlook or other common shocks. In essence, the identifying assumption underlying this approach is that movements in Treasury yields in a narrow window surrounding a policy announcement are due entirely to unanticipated changes in the current stance of monetary policy or communication regarding the path for policy going forward.

In comparing the effects of conventional monetary policy actions to those associated with unconventional policy measures, we are faced with the problem that during the unconventional period, the Federal Reserve implemented a number of Large-Scale Asset Purchase programs (LSAPs), whose primary goal was to influence longer-term yields on Treasury and MBS securities through the direct purchase of those assets. These purchase programs were introduced to the public via announcements, either following the regularly-scheduled FOMC meetings or in special announcements and speeches. During the unconventional policy regime, therefore, we attempt to distinguish between monetary policy actions that include direct information about the LSAPs versus actions that provided no such information.

Our results indicate that during the conventional policy regime, policy surprises that reduce the 2-year nominal Treasury yield 10 basis points cause a 4 basis point decline in the 10-year nominal Treasury yield and the decline of the same magnitude in the comparable-maturity TIPS yield. In effect, an unanticipated conventional policy easing steepens the yield curve but, nonetheless, has a pronounced effect on longer-term real interest rates. The expansionary effects of monetary policy also reduce real borrowing costs for investment-grade nonfinancial firms: During the conventional policy regime, a 10 basis point policy-induced reduction in the 2-year nominal Treasury yield leads to a 8 basis point decline in the real 3-year corporate bond yield, while lowering real long-term (10-year) borrowing costs about 5 basis points.

During the unconventional policy period, in contrast, policy surprises that reduce the 2-year nominal Treasury yield 10 basis points cause a 20 basis point decline in the longer-term nominal interest rates and an 18 basis point decline in their real counterparts. In effect, during the unconventional period, expansionary monetary policy flattens the yield curve, and in the process has an even more pronounced effect on real long-term interest rates. Our results also imply that the unconventional policy easings substantially lower the real borrowing costs faced by investment-grade nonfinancial firms: A 10 basis point policy-induced decline in the 2-year nominal Treasury yield leads to a 15 basis point reduction in real corporate bond yields across the maturity spectrum.

Thus, monetary expansions during the unconventional policy period imply an effect on real corporate borrowing costs that is three times as large as that implied by a conventional policy easing. In contrast to our findings for real corporate borrowing costs, we find that while expansionary monetary policy reduces nominal rates on mortgage-related instruments, it appears to have no immediate impact on real mortgage interest rates.

The inclusion of the LSAP-related announcement dates in the unconventional period results in substantially larger responses of both long-term Treasury and corporate bond yields. This result reflects the fact that LSAP announcements have a stronger direct effect on long-term real Treasury yields, as well as that during the unconventional policy period, corporate bond yields were particularly sensitive to movements in the term spread rather than the general level of interest rates.

Our paper is related to a large literature that seeks to identify the effect of monetary policy actions on financial asset prices. Kuttner [2001] proposed using surprise movements in the federal funds rates on the FOMC announcement days to identify monetary policy shocks, while Bernanke and Kuttner [2005] exploit the information in these surprises to trace out the effect of monetary policy on the stock market. In related work, Rigobon and Sack [2004] adopt a heteroskedasticity-based estimation procedure to estimate the causal effect of policy announcements on asset prices. Gürkaynak, Sack, and Swanson [2005a] extend the approach of Kuttner [2001] by identifying both federal funds rate target and path surprises on policy announcement days to gauge the effect of monetary policy on financial asset prices. Our paper is also closely related to the recent work of Justiniano, Evans, Campbell, and Fisher [2012], who apply the methodology Gürkaynak, Sack, and Swanson [2005a] to trace out the effect of monetary policy surprises on nominal Treasury yields and corporate bond yields during the unconventional policy period.

This paper is also related to a rapidly growing literature that tries to evaluate empirically the effects of the various asset purchase programs on financial asset prices. The initial phase of this research has focused on the question of whether purchases of large quantities of Treasury coupon securities have altered the level of longer-term Treasury yields. Employing a variety of different empirical approaches Gagnon, Raskin, Remache, and Sack [2011], Krishnamurthy and Vissing-Jorgensen [2011], Swanson [2011], Christensen and Rudebusch [2012], D'Amico, English, López Salido, and Nelson [2012], Wright [2012], D'Amico and King [2013], and Bauer and Rudebusch [2013] present compelling evidence that the Federal Reserve's LSAP announcements had economically and statistically significant effects on Treasury yields. Consistent with this evidence, Greenwood and Vayanos [2010a], Gagnon, Raskin, Remache, and Sack [2011], Krishnamurthy and Vissing-Jorgensen [2011], and Hamilton and Wu [2012] also show that Treasury supply factors have important effects on Treasury yields and the associated term premia at lower frequencies and over longer sample periods.[3]

[3]These findings are consistent with the work of Laubach [2009] and Krishnamurthy and Vissing-Jorgensen [2012], who find that fluctuations in the total supply of Treasury debt—conditional on the standard yield curve factors—have appreciable explanatory power for movements in Treasury yields. Relatedly, Greenwood and Vayanos [2010a,b] and

2 Measuring Changes in the Stance of Monetary Policy

The sample period underlying our analysis runs from January 2, 1997 to August 30, 2013.[4] This period is divided into two distinct monetary policy regimes: (1) a *conventional* policy regime, a period in which the primary policy instrument was the federal funds rate; and (2) an *unconventional* policy regime, a period during which the funds rate has for the most part been stuck at the zero lower bound, and the FOMC conducted monetary policy primarily by altering the size and composition of the Federal Reserve's balance sheet and by issuing various forms of forward guidance regarding the future trajectory for the federal funds rate.

The dating of these two regimes is relatively straightforward. The key date in our analysis is November 25, 2008, when the FOMC announced—outside its regular schedule—that it will initiate a program to purchase the debt obligations of the GSEs and MBS issued by those agencies in an effort to support housing markets and counteract the massive tightening of financial conditions sparked by the collapse of Lehman Brothers investment bank in mid-September. A mere week later, the FOMC announced—again outside its regular schedule—that in addition to purchases of agency debt and MBS, it is also considering purchasing longer-term Treasuries. With severe turmoil raging through the global financial system and faced with a rapidly deteriorating economic outlook, the FOMC announced at its December 16 meeting that it is lowering the target federal funds rate to a range of 0 to 0.25 percent—its effective lower bound—a decision ushering in the ZLB period. Given this sequence of event, we assume that the unconventional policy regime began on November 25, 2008. Up to that point, the presumption is that the conventional policy regime was in effect.[5]

2.1 Conventional Policy: Targeting Short-Term Nominal Interest Rates

In this section, we argue that high-frequency changes in the 2-year nominal Treasury yield are sufficient to summarize monetary policy shocks arising in a conventional policy regime. The top panel of Figure 1 depicts the path of the target federal funds rate—the primary policy instrument

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Hamilton and Wu [2012] show that changes in the maturity structure of Treasury debt outstanding have a similar effect.

[4]The starting date of our analysis is dictated by the availability of daily secondary market prices on corporate bonds.

[5]According to our chronology, the last FOMC meeting during the conventional policy regime took place on October 29, 2008, at which the FOMC lowered its target for the federal funds rate 50 basis points, to 1 percent. As a robustness check of our results, we also considered a more abbreviated conventional policy regime. The end date of this alternative regime, August 8, 2007, corresponds to the beginning of the 2007–09 financial crisis, which, by most accounts, began on August 9, 2007, when the French bank BNP Paribas terminated withdrawals from three of its hedge funds in response to a liquidity squeeze, a decision that roiled the interbank funding markets. Although, the FOMC continued to use the federal funds rate as its main policy instrument during the early phases of the crisis, many of its policy decisions at that time also involved direct liquidity support of key credit markets, actions that had a significant influence on financial asset prices; see Bernanke [2009] for an exposition of the Federal Reserve's policy response to the crisis. In order to provide a "cleaner" benchmark for the effects on unconventional policy on market interest rates, we thus omitted the first part of the crisis from the analysis. However, the results based on this abbreviated conventional policy regime were very similar to those obtained using the full sample.

used by the FOMC during the conventional policy regime—and the 2-year Treasury yield over our sample period. In the pre-ZLB period, the two short-term nominal interest rates are clearly highly positively correlated. To provide a more rigorous test of our assertion, we decompose the observed change in the target federal funds rate for each FOMC announcement during this period—denoted by Δff_t—into two components:

$$\Delta ff_t = \Delta ff_t^e + \Delta ff_t^u,$$

where Δff_t^e represents the expected change and Δff_t^u the unexpected change in the target rate associated with the FOMC announcement on day t. Following Kuttner [2001], the "target" surprise Δff_t^u is constructed as the the difference between the announced new target rate and the expectation thereof derived from federal funds futures contracts. Specifically, the target surprise Δff_t^u is calculated as the change—with minor adjustments—in the current-month federal funds futures contract rate in a 20-minute window (5 minutes before to 15 minutes after) around the FOMC announcement.[6]

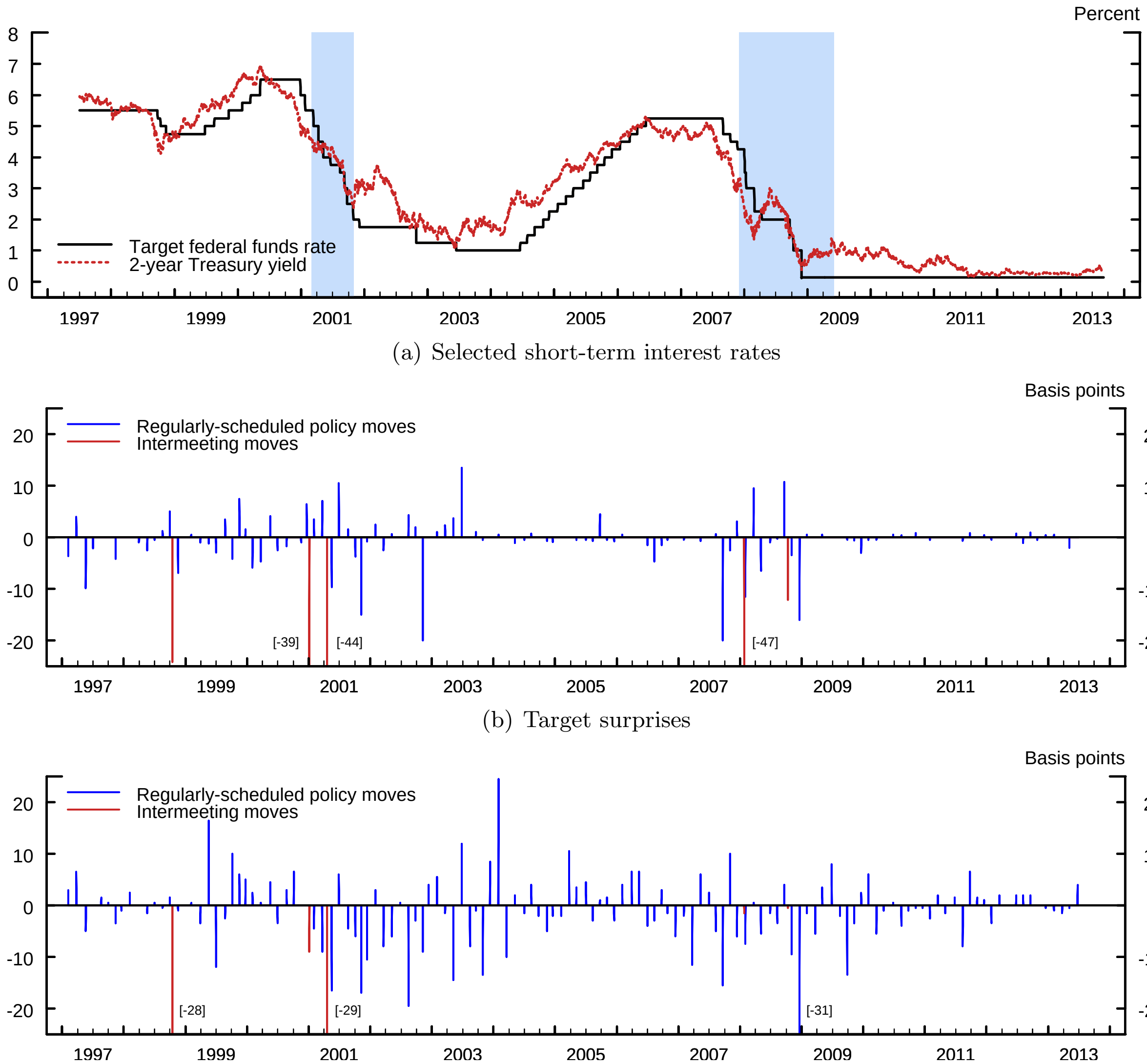
These "target" surprises, as they are commonly referred to in the literature, have been used extensively to examine the effects of monetary policy on asset prices (cf. Gürkaynak, Sack, and Swanson [2005a], Bernanke and Kuttner [2005], and Ammer, Vega, and Wongswan [2010]).[7] In addition to target surprises, we also consider "path" surprises, which occur when the FOMC statements contain communication about the likely trajectory of future policy rates, information that, consequently, has an immediate impact on longer-term interest rates; see, Gürkaynak, Sack, and Swanson [2005a] for detailed discussion. These policy surprises are calculated as the change—measured over the same 20-minute window as those for the target surprise—in the implied rate on the fourth eurodollar futures contract (ED4), a proxy for expectations about the stance of monetary policy about 12 months ahead.

The path and target surprises are shown in the middle and bottom panels of Figure 1, respectively. As indicated by the red spikes in the middle panel, the largest (absolute) level surprises

[6]Because federal funds futures contracts have a payout that is based on the average effective funds rate that prevails over the calendar month specified in the contract, we adjust the federal funds futures rate by a factor related to the number of days in the month affected by the change in the target rate; see Kuttner [2001] for details. As is customary in this kind of analysis, we also exclude the announcement made on September 17, 2001, which was made when trading on major stock exchanges resumed after it was temporarily suspended following the 9/11 terrorist attacks. Nearly all of the 138 announcements during our sample period followed regularly-scheduled FOMC meetings; only five were associated with the intermeeting policy moves. The five intermeeting moves occurred on October 15, 1998; January 3, 2001; April 18, 2001; January 22, 2008; and October 8, 2008. Most of the FOMC announcements took place at 2:15 pm (Eastern Standard Time); however, announcements for the intermeeting policy moves were made at different times of the day. We obtained all the requisite times from the Office of the Secretary of the Federal Reserve Board.

[7]Piazzesi and Swanson [2008], however, find some evidence of the risk premia in the prices of federal funds futures contracts, which implies that these prices may not represent unbiased expectations of the future trajectory of the funds rate. Importantly, they also show that the method due to Kuttner [2001] does not suffer from this bias because any constant risk premium embedded in futures prices is effectively differenced out. And although there is evidence that this risk premium is in fact time varying, it appears to fluctuate primarily at business cycle frequencies, a frequency that is far too low to matter over the the 20-minute window used to calculate the target surprises.

Figure 1: Selected Interest Rates and Monetary Policy Surprises



(a) Selected short-term interest rates

(b) Target surprises

(c) Path surprises

NOTE: Sample period: daily data from Jan-02-1997 to Aug-30-2013 (excluding the Sep-17-2001 intermeeting policy move). The target surprise corresponds to an unexpected change in the target federal funds rate calculated using futures data in the 20-minute window bracketing the FOMC announcement; the path surprise is defined as the change—during the 20-minute window bracketing the FOMC announcement—in the year-ahead eurodollar futures rate. Numbers in square brackets indicate the magnitude of the two interest rate surprises outside the $[-25, 25]$ basis-point range. The shaded vertical bars in the top panel represent the NBER-dated recessions.

during the pre-ZLB period are associated with the intermeeting policy actions, a pattern that also characterizes the corresponding path surprises. Note that in many instances during our sample period, policy announcements generated a path surprise in the absence of a corresponding level surprise, reflecting the fact that these FOMC statements contained information about the likely path of future policy rates, information that, consequently, would have had an immediate impact on policy expectations and thus on longer-term interest rates.

To gauge the extent to which changes in the 2-year Treasury yield reflect unanticipated policy actions—and thus serve as a useful summary of policy shocks—we estimate the following regression on the sample of 100 FOMC announcements during the period of conventional monetary policy:

$$\Delta y_t^{ON}(2) = \theta_0 + \theta_1 \Delta ff_t^u + \theta_2[\Delta \mathrm{ED4}_t - \Delta ff_t^u] + \epsilon_t,$$

where $\Delta y_t^{ON}(m)$ denotes the 20-minute change bracketing the FOMC announcement in the (on-the-run) m-year Treasury yield. This exercise yields $\hat{\theta}_1 = 0.640$ (robust standard error of 0.043), implying that an unanticipated decrease in the federal funds rate of 25 basis points—with no surprise change in the year-ahead euro-dollar rate—is estimated to lower the 2-year Treasury yield about 15 basis points. Because the path surprise enters the regression relative to the target surprise (i.e., $[\Delta \mathrm{ED4}_t - \Delta ff_t^u]$), a negative surprise to the funds rate in the above specification represents a parallel downward shift of the short-end of the yield curve.

An unanticipated move in the near-term slope of the yield curve, in contrast, can arise because an unexpected change in the federal funds rate target of a given magnitude was associated with a smaller move in the expected future short-term rates, or because FOMC communication about the likely future course of policy caused a shift in policy expectations in the absence of a surprise to the target rate. Given that $\hat{\theta}_2 = 0.692$ (robust standard error of 0.036), a negative slope surprise of 25 basis points is estimated to lower the 2-year Treasury yield almost 17 basis points. In addition to being economically large and statistically highly significant, these unanticipated changes in the stance of monetary policy explain about 85 percent of the variation in the 20-minute changes of the 2-year Treasury yield on the days of FOMC announcements during the conventional policy period.[8] All told, these results strongly support our argument that changes in the 2-year Treasury yield bracketing FOMC announcements provide a sufficient summary of policy shocks during the period when the federal funds rate was the primary instrument of monetary policy.

2.2 Unconventional Policy: Forward Guidance and LSAPs

After having brought the nominal federal funds rate down to its effective lower bound in December 2008, the FOMC has taken numerous steps to provide further monetary accommodation to the U.S. economy. As part of its efforts to stimulate economic activity and ease broad financial conditions, the Committee has employed different forms of forward guidance regarding the future path of the federal funds rate and has undertaken large-scale purchases of longer-term securities—a policy commonly referred to as "quantitative easing"—in order to put further downward pressure

[8]It is worth noting that these results are virtually the same if the three intermeeting policy moves are dropped from the sample.

Table 1: Key Unconventional Monetary Policy Actions

Date	Time[a]	FOMC[b]	Event Description
25-Nov-2008	08:15	N	Announcement that starts LSAP-I
01-Dec-2008	08:15	N	Announcement indicating potential purchases of Treasury securities
16-Dec-2008	14:20	Y	Target federal funds is lowered to its effective lower bound; statement indicating that the Federal Reserve is considering using its balance sheet to further stimulate the economy
28-Jan-2009	14:15	Y	"Disappointing" FOMC statement because of its lack of concrete language regarding the possibility and timing of purchases of longer-term Treasuries in the secondary market
18-Mar-2009	14:15	Y	Announcement to purchase Treasuries and increase the size of purchases of agency debt and agency MBS; also, first reference to forward guidance: "... interest rates are likely to remain low for an extended period ..."
10-Aug-2010	14:15	Y	Announcement that starts LSAP-II
21-Sep-2010	14:15	Y	Announcement reaffirming the existing reinvestment policy
03-Nov-2010	14:15	Y	Announcement of additional purchases of Treasury securities
09-Aug-2011	14:15	Y	First "calendar-based" forward guidance: "... anticipates that that economic conditions are likely to warrant exceptionally low levels for the federal funds rate at least through mid-201."
21-Sep-2011	14:15	Y	Announcement of the Maturity Extension Program (MEP)
25-Jan-2012	12:30	Y	Second "calendar-based" forward guidance: "... keep the federal funds rate exceptionally low at least through late 2014"
20-Jun-2012	12:30	Y	Announcement of continuation of the MEP through end of 2012
13-Sep-2012	12:30	Y	Third "calendar-based" forward guidance: "... likely maintain the federal funds rate near zero at least through mid-2015." In addition, first forward guidance regarding the pace of interest rates after lift-off: "... likely maintain low rates for a considerable time after the economic recovery strengthens," and announcement of LSAP-III (flow-based; $40 billion per month of agency MBS)
Dec-12-2012	12:30	Y	Announcement of an increase in LSAP-III (from $40 billion to $85 billion per month); first "threshold-based" forward guidance: maintain the funds rate near zero for as long as unemployment is above 6.5%, inflation (1–2 years ahead) is below 2.5%, and long-term inflation expectations remain well-anchored
19-Jun-2013	14:00	Y	Forward guidance lays out plans to start tapering asset purchases later that year (unemployment below 7.5% threshold; and end LSAP-III by mid-2014, when the unemployment rate fall below the 7% threshold

NOTE: Dates in bold correspond to the LSAP-related announcements (see text for details).
[a] Y = an announcement associated with a regularly-schedule FOMC meeting; N = an intermeeting policy announcement.
[b] All announcements are at Eastern Standard Time.

on longer-term market interest rates. The summary of key unconventional policy actions employed by the Federal Reserve during the ZLB period is presented in Table 1.

The provision of guidance about the likely future path of the policy rate has evolved significantly from the Committee's initial statement in March 2009, in which it indicated that economic conditions were "likely to warrant exceptionally low levels of the federal funds rate for an extended period." Subsequently, the FOMC had referred for several months to its expectation that an exceptionally low funds rate would be in force "for some time." This calendar-based approach was clarified in August 2011, when the Committee changed the statement language from "for an extended period" to "at least through mid-2013," and then again in January 2012, when the calendar-dependent forward guidance was changed to "at least through late 2014."

The policymakers, however, were concerned that the use of a date—even if explicitly conditional on economic conditions—could be misunderstood by the public. As a result, the Committee in December 2012 changed the statement language to make the maintenance of a very low federal funds rate explicitly conditional on economic conditions—that is, a state-contingent form of forward guidance. Specifically, it indicated that the "exceptionally low range for the federal funds rate will be appropriate at least as long as the unemployment rate remains above 6.5 percent, inflation between one and two years ahead is projected to be no more than a half percentage point above the Committee's 2 percent longer-run goal, and longer-term inflation expectations continue to be well anchored."

The FOMC has also made use of unconventional policy tools other than forward guidance to bring about more accommodative financial conditions. Most notably, the Committee has provided additional monetary stimulus by authorizing a series of large-scale purchases of longer-term securities. The first asset purchase program (LSAP-I) was announced on November 25, 2008—the start of the unconventional policy regime, according to our chronology—from which time the Federal Reserve purchased large quantities of agency debt and agency-guaranteed MBS. In March 2009, the Committee stepped up the pace of asset purchases and broadened the program to include purchases of Treasury coupon securities.

The first round of purchases was completed in March 2010, and the next development in the Federal Reserve's balance sheet policy (LSAP-II) was launched with the FOMC's announcement in August 2010 of reinvestment arrangements, under which the Federal Reserve "by redeploying into longer-term Treasury investments the principal payments from agency securities held in the System Open Market Account (SOMA) portfolio" would maintain the elevated level of holdings of longer-term securities brought about by LSAP-I. As a result, from November 2010 through the end of June 2011, the Federal Reserve was engaged in the program involving the purchase of $600 billion of longer-term Treasuries. Subsequently, the FOMC decided to continue to maintain the level of securities holdings attained under the first two purchase programs, and in September 2011, the Committee made further adjustments to its investment policy, which included an extension of the average maturity of its Treasury securities portfolio (MEP) and reinvesting principal payments from agency securities in MBS rather than longer-term Treasuries.

Although these announcements clearly stated the amount of securities the Federal Reserve anticipates purchasing, they were nevertheless vague about the conditions that might lead the policymakers to change that amount. In an effort to resolve this ambiguity, the FOMC in September 2012 implemented an alternative approach by announcing a monthly rate at which the Federal

Reserve will purchase securities. The expectation was that such a “flow-based” balance sheet policy, if clearly communicated, might lead market participants and the public more generally to expect that the Committee will pursue the program as long as appropriate to achieve its mandated goals.

The rationale underlying LSAPs was predicated on the assumption that the relative prices of financial assets are to an important extent influenced by the quantity of assets available to investors. Economic theory suggests that changes in the central bank’s holdings of long-term securities will affect long-term interest rates if private investors have a preference for keeping a portion of their portfolios in the form of such securities, a notion formalized by the “preferred habitat” models.[9] According to this view, the private sector is inclined to keep a fraction of its investments in the form of long-term fixed-interest debt such as Treasury securities, on the grounds that these assets have characteristics not shared by alternative longer-term investments—namely, the absence of default risk and a high degree of marketability. In light of investors’ preference for longer-term government paper, defined broadly to include securities issued or guaranteed by the GSEs, a reduction in the supply of long-term government debt relative to the supplies of other financial assets will, all else equal, lead to a decline in government bond yields in order to induce investors to decrease their holdings of such obligations; conversely, an increase in the supply of long-term government debt will boost bond yields.

According to this view, purchases of Treasuries, agency debt, and agency-guaranteed MBS by the Federal Reserve will lower longer-term nominal interest rates by reducing the stock of government debt held by the private sector. In particular, investors find themselves demanding more government debt than is available on the market at the existing configuration of interest rates, and the subsequent bidding needed to clear the market induces a decline in long-term interest rates. A key aspect of this adjustment process is that long-term rates are affected by purchases even if expectations for the future path of the policy rate are unchanged because it is the term premium that is sensitive to the volume of long-term debt outstanding.

These arguments also imply that changes in the 2-year nominal Treasury bracketing FOMC announcements are likely insufficient to fully summarize the impact of unconventional monetary policy on financial asset prices. Accordingly, as discussed more fully below, our estimation strategy incorporates—in addition to the high-frequency changes in the 2-year Treasury yield—narrow-window changes in the long-term Treasury yields in order to capture the unanticipated component of the unconventional policy that potentially had a separate effect on the long end of the yield curve.

[9]Recently, these theories have received renewed attention and rigorous micro foundations in the work of Andrés, López Salido, and Nelson [2004] and Vayanos and Vila [2009]; early treatment of these ideas can be found in Tobin [1961, 1963] and Modigliani and Sutch [1966, 1967]. More to the point, policymakers, in their communication of the likely effects of LSAPs on longer-term interest rates, have repeatedly invoked the preferred-habitat models of interest rate determination, as the canonical arbitrage-free term structure framework leaves essentially no scope for the relative supply of deeply liquid financial assets—such as nominal Treasuries—to influence their prices (see Kohn [2009] and Yellen [2011]).

3 Empirical Methodology and Benchmark Results

In this section, we present the empirical approach used to estimate the impact of monetary policy on market interest rates. We begin by considering the impact of both conventional and unconventional monetary policy actions on the benchmark nominal Treasury yields. We then examine the extent to which policy-induced movements in nominal yields reflect expected movements in future short rates versus movements in term premia obtained from standard term-structure models. Finally, we examine the effect of monetary policy shocks on real interest rates as reflected in the TIPS yields. Simultaneously estimating the effect of monetary policy surprises on the nominal and real yield curves also allows us to identify the effect of monetary policy on inflation compensation computed as the differential response of nominal relative to real yields.

We illustrate the key principles of our estimation strategy by comparing the response of nominal Treasury yields to changes in the stance of monetary policy across the different policy regimes. Specifically, we consider the following system of regression equations:

$$
\begin{aligned}
\Delta y_t(3) &= \alpha_1 + \beta_1 \Delta y_t(2) + \epsilon_{1t};\\
\Delta y_t(5) &= \alpha_2 + \beta_2 \Delta y_t(2) + \epsilon_{2t};\\
\Delta y_t(10) &= \alpha_3 + \beta_3 \Delta y_t(2) + \epsilon_{3t};
\end{aligned} \tag{1}
$$

where $\Delta y_t(m)$ denotes the daily change in the m-year (zero-coupon, continuously-compounded) Treasury yield.[10]

The system in (1) is estimated using three samples. The first sample corresponds to the period of conventional monetary policy and contains 100 FOMC announcement days between January 2, 1997 and November 24, 2008. The second sample, the unconventional policy period, consists of 40 FOMC announcements that took place between November 25, 2008 and August 30, 2013. It is important to emphasize that this sample combines announcements that contained FOMC communication about the LSAPs, the various forms of forward guidance used during this period, or both. As in Wright [2012], the estimates of β_1, β_2, and β_3 based on this sample are best thought of as capturing the average effect of unconventional monetary policy on the Treasury yield curve. In an effort to separate the effect of balance sheet policies from other forms of unconventional policy, we also consider a subsample of the unconventional policy period, which excludes 11 announcements most closely identified with the asset purchase programs (see Table 1).

We estimate the system (1) using instrumental variable (IV) techniques. Specifically, we exploit the *intraday* variation in interest rates to construct instruments for the daily change in the 2-year Treasury yield, the proxy for the change in the stance of monetary policy. This approach allows us to control for the potential reverse causality, whereby the daily changes in the 2-year Treasury

[10] All Treasury yields are derived from the daily estimates of the U.S. Treasury yield curve estimated by Gürkaynak, Sack, and Wright [2007].

yield—even on the days of FOMC announcements—may not reflect solely exogenous shifts in the stance of monetary policy, but also the endogenous response of policy to changes in the economic outlook or other common shocks. The identifying assumption underlying this approach is that fluctuations in nominal Treasury yields in a narrow window surrounding policy announcements are due entirely to unanticipated changes in the current stance of monetary policy or communication regarding the path for policy going forward. To provide a point of comparison for IV estimates, we also estimate the system by OLS, an approach consistent with Hanson and Stein [2012], who use the 1-day changes in the 2-year Treasury yield as a proxy for changes in the stance of monetary policy over a period encompassing both conventional and unconventional policy actions.

When using IV techniques, we consider three sets of instruments. The most basic set—denoted by **IV-1**—contains only the 20-minute changes in the 2-year (on-the-run) Treasury yield around each FOMC announcement, essentially a measure of a monetary policy shock.[11] The second instrument set, denoted by **IV-2**, expands the IV-1 set by including higher-order moments (i.e., squares and cubes) of the 20-minute changes in the 2-year Treasury yield. These higher-order terms turn out to be especially helpful as predictors of the daily changes in the 2-year Treasury yield on the FOMC announcement days during the conventional policy period. The marginal predictive power of these higher-order terms in the first-stage regressions associated with the IV estimation techniques captures the notion that fluctuations in interest rates—or asset prices more generally—might depend on the specific characteristics of the announcement. For example, regression analysis suggests that it is important to distinguish between the different sizes of policy shocks—as in regularly-scheduled versus intermeeting policy moves—an aspect of the announcement that is captured partly by including the squared changes of the intraday movements in interest rates in the instrument set. The inclusion of third-order terms, by contrast, captures the sign of the underlying policy surprise—that is, "easing" versus "tightening" shocks.[12]

Under our identifying assumptions, the IV-1 and IV-2 instrument sets should be sufficient to estimate the structural coefficient measuring the response nominal Treasury yields to unanticipated changes in the stance of monetary policy during the conventional policy regime, in which the primary policy instrument was the short-term nominal interest rate. During the ZLB period, however, the actions by the FOMC—through direct purchases of longer-term assets and various forms of forward guidance—likely had separate effects on the short- and long-end of the yield curve. To take into account both aspects of the unconventional policy, we also consider an instrument set—denoted by **IV-2′**—which consists of the 20-minute changes in the 2- and 10-year (on-the-run) Treasury yields bracketing each FOMC announcement, as well as the square of the 20-minute change in the 2-year yield.[13] In the context of the system (1), the use of the IV-1 instrument set

[11] All 20-minute changes are measured from 5 minutes before to 15 minutes after the announcement.

[12] The use of these higher-order terms as instruments is also consistent with Hausman and Wongswan [2011], who show that the effect of the unanticipated changes in the stance of U.S. monetary policy on global asset prices depends importantly on the size and sign of the underlying policy surprise.

[13] Over such a narrow window, changes in longer-term interest rates most likely reflect only the unexpected changes

results in an exactly-identified system, which we estimate using 2SLS; the use of the IV-2 and IV-2′ instrument sets, by contrast, implies six over-identifying restrictions and thus the system can be estimated efficiently by GMM.

3.1 The Impact of Monetary Policy on Nominal Treasury Yields

Table 2 contains the estimates of the structural response coefficients β_1, β_2, and β_3 from the system (1). As shown in the first two columns of the top panel, a conventional policy induced increase in the 2-year Treasury yield of 10 basis points—a few basis points more that a move of one standard deviation during this period—is estimated to boost the 3-year yield by the same amount, while the 5- and 10-year Treasury yields rise about 8 and 4 basis points, respectively. The two sets of IV estimates are nearly identical, though the precision of the response coefficients based on the IV-2 instrument set is somewhat greater. In addition to generating more precise coefficient estimates, the over-identifying restrictions implied by the IV-2 instrument set are not rejected, an indication that the changes in the 2-year Treasury yield in a narrow window bracketing FOMC announcements—and their higher-order moments—are valid instruments. Compared with both sets of IV estimates, the magnitude of the OLS estimates of the response coefficients is somewhat greater, especially at longer maturities, suggesting that they may be biased.

In sum, these estimates indicate that a conventional easing of monetary policy generates a decline in nominal interest rates along the entire yield curve. Because the impact of policy on the long end is considerably less pronounced, a monetary stimulus engineered to lower short-term interest rates causes the Treasury yield curve to steepen appreciably: A decline of 10 basis points in the 2-year Treasury yield prompted by an FOMC announcement is estimated to increase the 10/2-year term spread about 5 basis points. These results comport with the standard view that in periods when the ZLB is not binding, monetary policy works primarily through its influence on the short-end of the yield curve and that a policy easing induces a widening of the yield spread between long- and short-term nominal interest rates.

The middle panel contains the results for the unconventional policy regime. The estimates of the response coefficients during this period differ significantly from those of the conventional policy period in two dimensions. First, the overall response of nominal interest rates to changes in the two-year treasury yield is much larger: Comparing the estimates in the IV-2 column (top panel) with those in IV-2′ column indicates that the response coefficient on the 3-year Treasury yield increases from about 1.0 to 1.3, whereas that of the 10-year yield jumps from 0.4 to 2.0. Second, an unconventional easing of monetary policy significantly flattens the yield curve, as the 10/2-year term spread narrows 10 basis points in response to a 10 basis point policy-induced reduction in the

in the stance of monetary policy; for example, an expected change in the 10-year Treasury yield of a mere one-tenth of a basis point over a 20-minute window bracketing an FOMC announcement would correspond to an expected change in the bond price of about 0.2 to 0.8 basis points, depending on the bond's maturity and coupon. Annualized, this would imply an expected rate of return between 40 and 300 percent.

Table 2: Monetary Policy and Nominal Treasury Yields

	Conventional Policy[a]		
Dependent Variable	IV-1	IV-2	OLS
Treasury yield (3y)	0.953	0.955	0.990
	(0.028)	(0.018)	(0.021)
Treasury yield (5y)	0.789	0.789	0.874
	(0.059)	(0.045)	(0.049)
Treasury yield (10y)	0.443	0.427	0.589
	(0.087)	(0.076)	(0.070)
$\Pr > J_T$[d]	.	0.609	.
	Unconventional Policy[b]		
Dependent Variable	IV-1	IV-2′	OLS
Treasury yield (3y)	1.281	1.338	1.345
	(0.055)	(0.028)	(0.036)
Treasury yield (5y)	1.591	1.805	1.764
	(0.162)	(0.067)	(0.092)
Treasury yield (10y)	1.578	2.026	1.825
	(0.282)	(0.076)	(0.170)
$\Pr > J_T$[d]	.	0.455	.
	Unconventional Policy (excl. LSAPs)[c]		
Dependent Variable	IV-1	IV-2′	OLS
Treasury yield (3y)	1.327	1.319	1.459
	(0.117)	(0.065)	(0.091)
Treasury yield (5y)	1.595	1.558	1.964
	(0.339)	(0.181)	(0.239)
Treasury yield (10y)	1.436	1.384	1.987
	(0.533)	(0.260)	(0.326)
$\Pr > J_T$[d]	.	0.204	.

NOTE: The dependent variables are the daily changes in the 3-, 5-, and 10-year nominal Treasury yields. Entries in the table denote the estimates of the response coefficients to a daily change in the 2-year nominal Treasury yield induced by the FOMC announcements. IV-1 = system 2SLS estimates with IV-1 instrument set; IV-2 = system GMM estimates with the IV-2 instrument set; IV-2′ = system GMM estimates with IV-2′ instrument set; and OLS = (single-equation) OLS estimates. (See text for details.) All specifications include a constant (not reported). Heteroskedasticity-consistent asymptotic standard errors are reported in parentheses.

[a] 100 FOMC announcements (Jan-02-1997–Nov-24-2008).

[b] 40 LSAP- and non-LSAP-related FOMC announcements (Nov-25-2008–Aug-30-2013).

[c] 29 non-LSAP-related FOMC announcements (Nov-25-2008–Aug-30-2013).

[d] p-value for the Hansen [1982] J-test of the over-identifying restrictions.

2-year Treasury yield; during the conventional policy period, by contrast, a policy easing of such magnitude increases the term spread about 5 basis points. These findings indicate that the unconventional policy actions used by the FOMC during the current ZLB period successfully reduced the level of longer-term nominal interest rates.

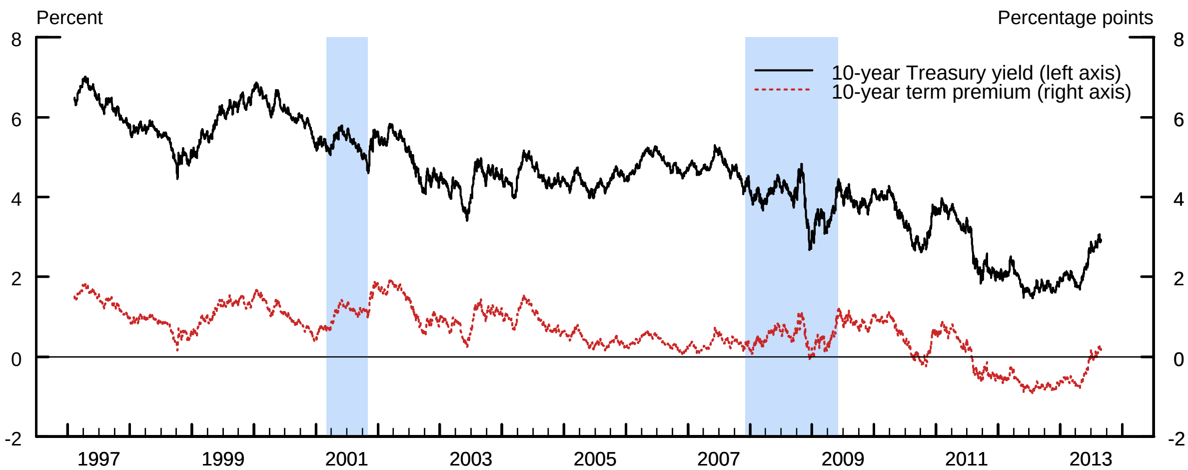
It is worth noting that the estimates of the coefficients based on the IV-1 instrument set indicate a significantly lessened sensitivity of longer-term interest rates to unconventional policy actions. This finding is consistent with the notion that the unconventional policy measures implemented by the FOMC during this period exerted separate effects on the short and long end of the yield curve and that failing to control for the policy shocks at the long end results in biased estimates. In fact, as indicated by the p-value of the J-test, the over-identifying restrictions implied by the IV-2$'$ instrument set are not rejected, which indicates that changes in the 2- and 10-year Treasury yields in a narrow window bracketing FOMC announcements are valid instruments during the unconventional policy regime.

The bottom panel reports the results for the subsample of the unconventional policy period that excludes the key LSAP-related announcements. Excluding these announcements does not appreciably change the response of the short-end of the yield curve to changes in the stance of monetary policy. It does, however, substantially dampen the impact of unconventional policy on the longer-term interest rates. By excluding the LSAP announcement days from the sample, the estimates reported in column IV-2$'$ indicate that other unconventional policy actions had the greatest impact on the medium-term (i.e., 5-year) Treasury yields, rather than on longer-term interest rates. This finding is consistent with the stated aim of the LSAPs, which was to put downward pressure on longer-term market interest rates through direct purchases of longer-term assets. As expected, therefore, the inclusion of the LSAP-related announcements in the unconventional policy sample implies a substantially larger response coefficient on the 10-year Treasury yield, compared with the estimate based on the sample that excludes such announcements.

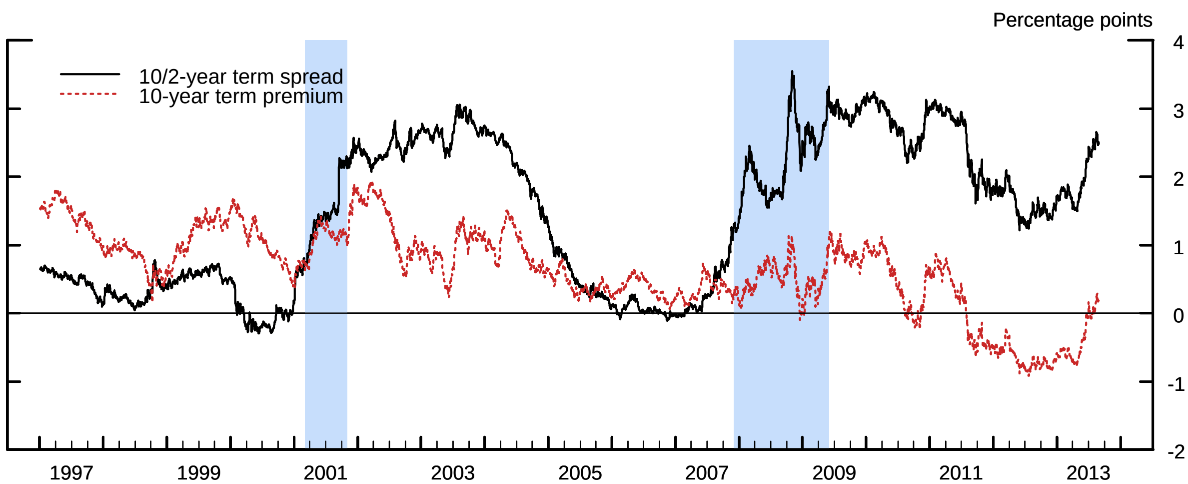
It is of substantial interest to academics and policymakers to understand whether monetary policy, both conventional and unconventional, works primarily by affecting the future path of short-term nominal rates or by influencing the term premia—that is, the extra compensation demanded by investors for their exposure to interest rate risk inherent in longer-term Treasury securities (cf. Wright [2011], Hanson and Stein [2012], Christensen and Rudebusch [2012], Bauer and Rudebusch [2013]). While this is not the main topic of the paper, it is nevertheless instructive to compare the response of term premia to changes in the stance of monetary policy across our three samples. We do so by estimating a two-equation variant of the system given by (1), in which the two dependent variables are the daily changes in the 10-year nominal Treasury yield and the 10-year term premium ($tp_t(10)$):

$$\begin{aligned} \Delta tp_t(10) &= \alpha_1 + \beta_1 \Delta y_t(2) + \epsilon_{1t}; \\ \Delta y_t(10) &= \alpha_2 + \beta_2 \Delta y_t(2) + \epsilon_{2t}. \end{aligned} \tag{2}$$

Figure 2: Long-Term Interest Rates, Term Spread, and the Term Premium



(a) Long-term interest rates and the term premium



(b) Term spread and the term premium

NOTE: Sample period: daily data from Jan-02-1997 to Aug-30-2013. The estimate of the 10-year term premium is based on the Kim and Wright [2005] term structure model; the term spread is calculated as the difference between the 10- and 2-year Treasury yields. The shaded vertical bars represent the NBER-dated recessions.

While term premia cannot be observed directly, they can be inferred from term structure models that incorporate both macroeconomic and financial market data. Although a variety of different term structures models has been proposed in the literature, the different models share a robust feature in that they all generate remarkably similar estimates of the term premia; see Rudebusch, Sack, and Swanson [2007] for detailed discussion. In our analysis, we rely on the 10-year term premium estimates implied by the model developed by Kim and Wright [2005], which is estimated on an ongoing basis by the staff at the Federal Reserve Board.[14] The top panel of

[14]Kim and Wright [2005] consider a standard latent three-factor Gaussian term structure model, which is estimated

Figure 2 shows the daily estimate of the 10-year term premium along with the 10-year nominal Treasury yield. The pronounced downward trend in the 10-year Treasury yield during the unconventional policy regime is also reflected in the significant decline in the term premium, which, until the recent backup in interest rates, was firmly in the negative territory. In general, changes in the 10-year Treasury yield are due almost entirely to fluctuations in the term premium, as the correlation between the daily changes in the two series is almost 0.98.

The bottom panel plots the 10-year term premium against the 10/2-year term spread—the observed difference between the 10- and 2-year Treasury yields. The term spread reflects a confluence of two components: investors' expectations about future short-term interest rates—the expectations component—and the term premium. The correlation between the daily changes in the two series is about 0.5, which indicates that changes in the expectations component—which includes inflation expectations and real rate expectations—exert a significance influence on the shape of the yield curve.[15] Note that in system (2), the implied response of the expectations component to unanticipated changes in the stance of monetary policy can be calculated as $\beta_2 - \beta_1$.

Consistent with our identifying assumptions, the IV-2 instrument set is used for the conventional policy regime and the IV-2$'$ set for the unconventional policy period. According to Table 3, a policy-induced decline in the 2-year nominal Treasury yield of 10 basis points during the conventional policy period lowers the the 10-year term premium about 3 basis points. These economically and statistically significant movements in term premia prompted by the FOMC announcements account for 60% of the decline in the 10-year Treasury yield during this period, whereas the remaining 40% can be attributed to the expectations component.

During the unconventional policy period, by contrast, an unanticipated policy easing of the same magnitude is estimated to lower the 10-year term premium almost 16 basis points.[16] Although the response of longer-term Treasury yields to policy announcements during this period is commensurately greater, these estimates imply that three-quarters of the policy-induced decline in longer-term rates can be attributed to a reduction in term premia. The magnitude of these effects

using 1-, 2-, 4-, 7-, and 10-year Treasury yields from the Gürkaynak, Sack, and Wright [2007] database, as well as 3- and 6-month T-bill rates. In addition to the daily interest rates, the model is augmented with monthly data on the six- and twelve-month-ahead forecasts of the 3-month T-bill rate from Blue Chip Financial Forecasts and semi-annual data on the average expected 3-month T-bill rate six to eleven years ahead from the same source. As emphasized by Kim and Orphanides [2012], the inclusion of the low-frequency survey-based data on interest rate expectations improves the identification of the latent factors, which mitigates the small-sample problems arising from the highly persistent nature of interest rates. An alternative approach to deriving term premia that does not involve term structure models is due to Cochrane and Piazzesi [2005], who show that the term premium can be estimated as a linear function of forward Treasury rates.

[15] The term premium also includes both inflation-related and real factors; Durham [2006], for example, uses a term structure model to decompose nominal rates into the expected real rate, expected inflation, the real term premium, and the inflation risk premium.

[16] These results, however, must be interpreted with a certain degree of caution. Because the Kim and Wright [2005] term structure model does not explicitly impose the zero lower bound on nominal interest rates in the estimation, the model-implied term premia may be biased, though at the 10-year maturity, the degree of bias is likely to be very small; moreover, if it is constant, it will be differenced out in our estimation.

Table 3: Monetary Policy, Long-Term Interest Rates, and the Term Premium

Dependent Variable	Conventional[a]	Unconventional[b]	Non-LSAP[c]
Term premium (10y)	0.301	1.546	1.228
	(0.047)	(0.070)	(0.250)
Treasury yield (10y)	0.514	2.024	1.526
	(0.063)	(0.067)	(0.301)
Expectations effect[d]	0.213	0.448	0.298
	(0.030)	(0.030)	(0.066)
$\Pr > J_T$[e]	0.638	0.178	0.259

NOTE: The dependent variables are the daily changes in the 10-year term premium—based on the Kim and Wright [2005] three-factor model—and the daily changes in the 10-year nominal Treasury yield. Entries in the table denote the system GMM estimates of the response coefficients to a daily change in the 2-year nominal Treasury yield induced by the FOMC announcements. The IV-2 instrument set is used for the conventional policy sample, while the IV-2′ instrument set is used in the other two cases; see text for details. All specifications include a constant (not reported). Heteroskedasticity-consistent asymptotic standard errors are reported in parentheses.

[a] 100 FOMC announcements (Jan-02-1997–Nov-24-2008).

[b] 40 LSAP- and non-LSAP-related FOMC announcements (Nov-25-2008–Aug-30-2013).

[c] 29 non-LSAP-related FOMC announcements (Nov-25-2008–Aug-30-2013).

[d] The implied expectations effect is computed as the difference between the estimated response of the 10-year Treasury yield and that of the 10-year term premium.

[e] p-value for the Hansen [1982] J-test of the over-identifying restrictions.

is roughly similar if we exclude the LSAP-related announcements from the sample.

All told, the results in Tables 2 and 3 imply that the unconventional policy measures employed by the FOMC in recent years led to a significant reduction in longer-term nominal interest rates, with lower term premia accounting for a substantial portion of the decline in those rates. Despite the sizable response of term premia to the FOMC announcements during this period, the estimates of the implied expectations effect indicate that the so-called signaling channel—in which announcements of asset purchases or forward guidance provide information to market participants about current or future economic conditions or monetary policy—played an economically significant part in the lowering of longer-term rates. In fact, the difference in the estimates of the expectations effect implied by the sample that excludes the LSAP-related announcements suggests that the impact of unconventional policy through the signaling channel importantly reflected announcements that changed the size and composition of the Federal Reserve's balance sheet.

3.2 The Impact of Monetary Policy on Real Treasury Yields

The availability of high-frequency data on both the real and nominal Treasury yields have led to renewed interest among economists into the question of how well anchored are long-run inflation expectations and whether changes in the stance of monetary policy influence those expectations.

Table 4: Monetary Policy and Nominal and Real Treasury Yields

Dependent Variable	Conventional[a]	Unconventional[b]	Non-LSAP[c]
Treasury yield (3y)	0.948	1.339	1.389
	(0.016)	(0.021)	(0.051)
Treasury yield (5y)	0.780	1.804	1.760
	(0.036)	(0.057)	(0.138)
Treasury yield (10y)	0.433	2.009	1.657
	(0.060)	(0.079)	(0.198)
TIPS yield (3y)	0.775	1.583	1.481
	(0.096)	(0.139)	(0.186)
TIPS yield (5y)	0.696	1.914	1.738
	(0.069)	(0.140)	(0.156)
TIPS yield (10y)	0.454	1.794	1.362
	(0.040)	(0.106)	(0.129)
Inflation compensation[d]			
3-year	0.173	−0.245	−0.092
	(0.108)	(0.131)	(0.172)
5-year	0.084	−0.110	0.022
	(0.093)	(0.102)	(0.127)
10-year	−0.021	0.215	0.295
	(0.068)	(0.049)	(0.130)
$\Pr > J_T$[e]	0.820	0.670	0.332

NOTE: The dependent variables are the daily changes in the 3-, 5-, and 10-year nominal Treasury yields and the 3-, 5-, and 10-year TIPS yields. Entries in the table denote the system GMM estimates of the response coefficients to a daily change in the 2-year nominal Treasury yield induced by the FOMC announcements. The IV-2 instrument set is used for the conventional policy sample, while the IV-2′ instrument set is used in the other two cases; see text for details. All specifications include a constant (not reported). Heteroskedasticity-consistent asymptotic standard errors are reported in parentheses.

[a] 83 FOMC announcements (Jan-04-1999–Nov-24-2008).

[b] 40 LSAP- and non-LSAP-related FOMC announcements (Nov-25-2008–Aug-30-2013).

[c] 29 non-LSAP-related FOMC announcements (Nov-25-2008–Aug-30-2013).

[d] The response of inflation compensation is computed as the difference between the estimated response of the m-year Treasury yield and that of the m-year TIPS yield.

[e] p-value for the Hansen [1982] J-test of the over-identifying restrictions.

Significant movements in inflation expectations would imply a more limited impact of monetary policy on longer-run real rates, a crucial determinant of economic output in most macro models (see Gürkaynak, Sack, and Swanson [2005b]). To obtain a set of benchmark estimates of how real Treasury yields respond to policy announcements, we estimate an extended version of regression system (1), whereby the three equations for the nominal Treasury yields are augmented with the equations for the (zero-coupon, continuously-compounded) 3-, 5-, and 10-year TIPS yields based on the estimates of the real yield curve due to Gürkaynak, Sack, and Wright [2010].

The results of this exercise for the three sample periods used in our analysis are presented in

Table 4.[17] These estimates imply that the reaction of real rates to changes in the 2-year nominal Treasury yield prompted by the FOMC announcements during the period of conventional policy is roughly similar to that of their nominal counterparts. A policy announcement that induces a 10 basis point decline in the 2-year nominal Treasury yield leads to a decline in real rates between 8 and 5 basis points along the maturity spectrum. As a result, such a policy easing leaves inflation compensation, or break-even rates, essentially unchanged.

The unconventional policy period, by contrast, paints a somewhat different picture. As in the conventional policy regime, short- and medium-term real rates decline about as much as their nominal counterparts, leaving inflation compensation at those horizons roughly unchanged; although point estimates of the response coefficients on break-even rates at the 3- and 5-year horizon are negative and economically sizable, the estimates are statistically indistinguishable from zero. At the 10-year maturity, however, the estimates imply a moderate and statistically significant increase in inflation compensation in response to a policy easing. Nonetheless, the response of real long-term yields to the two-year nominal Treasury yield is still sizable. In combination, these results imply that for a given policy-induced movement in the 2-year nominal Treasury yield, monetary policy had a noticeably greater effect on real long-term interest rates during the unconventional policy period compared with the conventional policy regime.

4 Measuring Borrowing Costs

With these benchmark results in hand, we now turn to the effects of monetary policy on market interest rates that are most relevant for businesses and households. This section describes the high-frequency data used in our analysis.

4.1 Nonfinancial Corporate Sector

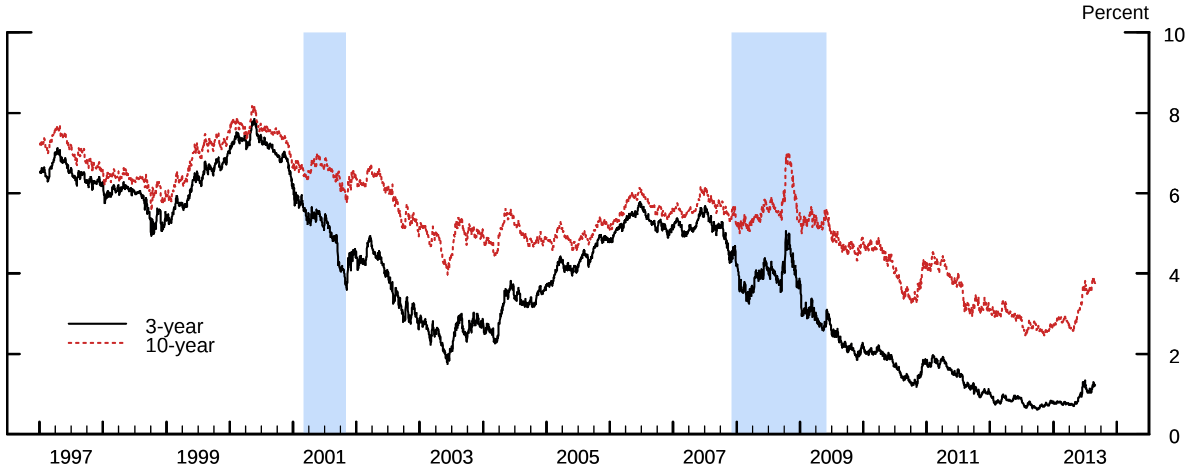
To construct a set of benchmark interest rates for the nonfinancial corporate sector, we rely on daily prices of individual corporate bonds traded in the secondary market. These data come from the Bank of America/Merrill Lynch (BofA/ML) database, a source of virtually all secondary market prices of dollar-denominated bonds publicly issued in the U.S. corporate cash market.[18] The staff at the Federal Reserve uses the security-level market prices to estimate a zero-coupon corporate yield curve employing the methodology developed by Nelson and Siegel [1987].

Given the comprehensive coverage of the corporate cash market, we exploit the cross-sectional heterogeneity of the underlying micro data by estimating the corporate yield curves separately for financial and nonfinancial issuers and for the various credit rating categories. In the analysis, we

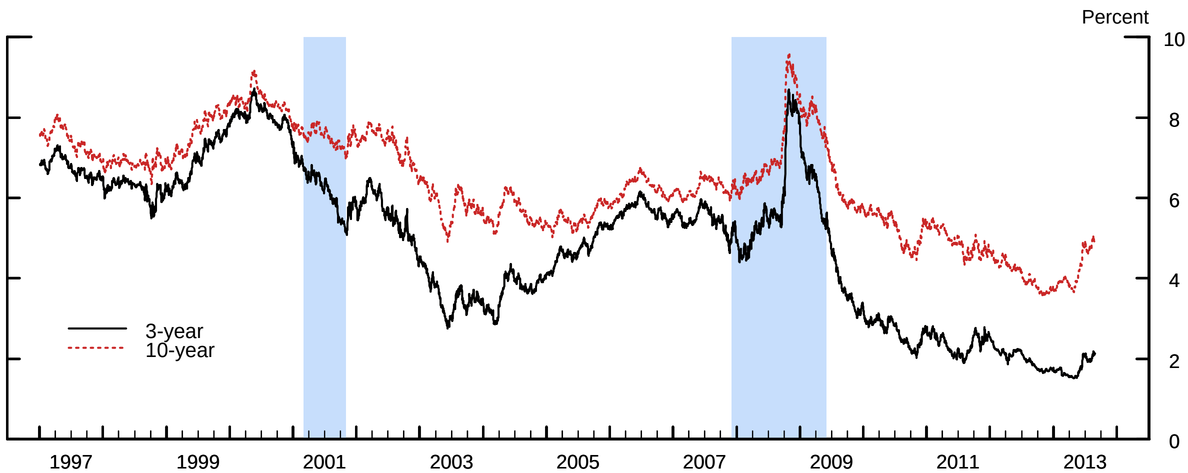
[17] Because the TIPS were only issued starting in 1999, the conventional policy sample in this exercise contains 83 FOMC announcements.

[18] These prices are used to construct the benchmark corporate bond return indexes, which are widely used by the financial market participants.

Figure 3: Corporate Bond Yields



(a) AA-rated nonfinancial firms



(b) BBB-rated nonfinancial firms

NOTE: Sample period: daily data from Jan-02-1997 to Aug-30-2013. Panel (a) depicts the 3- and 10-year corporate bond yields for AA-rated nonfinancial firms, while panel (b) depicts the 3- and 10-year corporate bond yields for BBB-rated nonfinancial firms. The shaded vertical bars represent the NBER-dated recessions.

focus on the nonfinancial corporate sector and restrict the sample to bonds issued by AA- and BBB-rated firms. By focusing on the upper and lower rungs of the investment-grade spectrum, we avoid the more limited liquidity of the secondary market for speculative-grade securities, which can significantly influence the behavior of their yields.[19] Moreover, given that the median rating in the

[19]While corporate bonds are actively traded, the volume of transactions—especially for lower-rated securities—is significantly lower than in the Treasury market (see Edwards, Harris, and Piwowar [2007]). Nevertheless, using high-frequency bond transaction prices of U.S. firms, Hotchkiss and Ronen [2002] find that the informational efficiency of corporate bond prices—especially those of higher-quality securities—is similar to that of the underlying stocks, suggesting that liquidity issues are much less of a concern in the investment-grade segment of the corporate bond

nonfinancial corporate sector is BBB, this means that we are are likely capturing borrowing costs for the representative firm.

The top panel of Figure 3 shows the 3- and 10-year bond yields for AA-rated nonfinancial firms, while those of their BBB-rated counterparts are shown in the panel below. Note that between 1997 and the end of 2000 and between the latter part of 2005 and mid-2007—two periods corresponding to the latter stages of their respective economic expansions—there is little difference in corporate borrowing costs, both in the maturity and credit-quality dimensions. Cyclical downturns and early stages of economic recoveries, by contrast, are characterized by a significant dispersion in interest rates within each credit rating category, as well as by a noticeable widening of comparable-maturity yields between lower- and higher-quality firms—the so-called quality spreads. And although investment-grade corporate bond yields have declined to exceptionally low levels by recent historical standards, the tiering of yields across maturities and credit quality has been especially pronounced and persistent during the ZLB period. This raises a natural question of how successful were the unconventional policy measures used by the FOMC in lowering corporate borrowing costs.

4.2 Residential Mortgage Market

Despite the well-documented sensitivity of housing markets to fluctuations in interest rates, there is a paucity of high-frequency data on primary mortgage market interest rates. For most of our sample period, the only available interest rate on the 30-year (conforming) fixed-rate mortgage (FRM) is the one published by Freddie Mac in their Weekly Primary Mortgage Market Survey (PMMS).[20] The solid black line in the top panel of Figure 4 shows the weekly 30-year FRM rate from the PMMS. As a point of comparison, the dotted line shows the daily yield on the 30-year current-coupon agency MBS, a widely used benchmark to price and value residential mortgages.

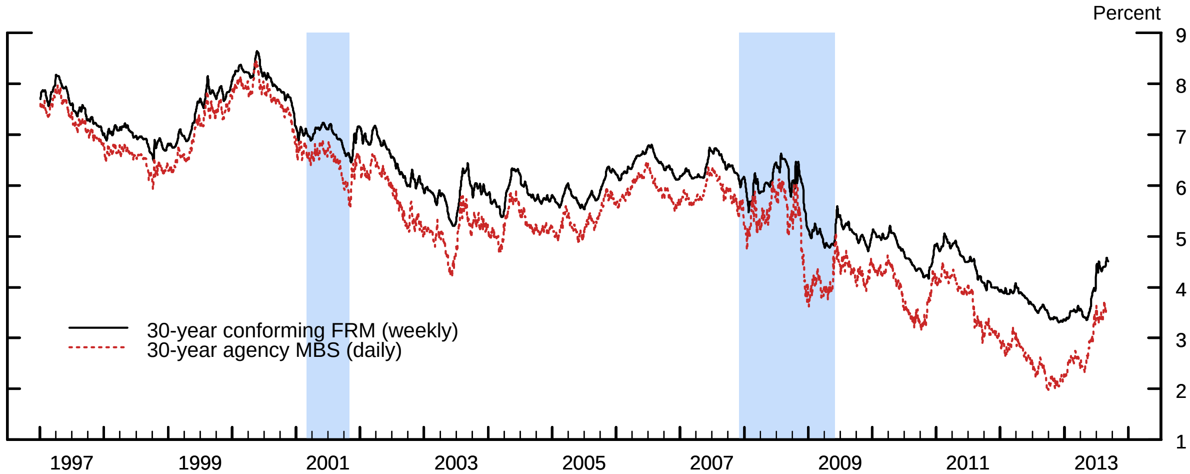
The two series clearly co-move closely together. In fact, the regression of the weekly change in the 30-year FRM rate on the weekly change in the 30-year MBS yield implies a pass-through coefficient from the secondary to the primary market of 0.795 (robust standard error of 0.026) for the conventional policy period and 0.703 (robust standard error of 0.052) for the unconventional policy period; in both cases, movements in the MBS yield explain about 80 percent of the variation in the 30-year FRM rate. This evidence suggests that we can gauge—up to first order—the effects of both conventional and unconventional monetary policy on primary mortgage interest rates by using the yield on the 30-year current-coupon agency MBS.

As emphasized by Stroebel and Taylor [2012], an alternative way to gauge mortgage market conditions is to look at the option-adjusted spread (OAS) on the 30-year agency MBS, which is

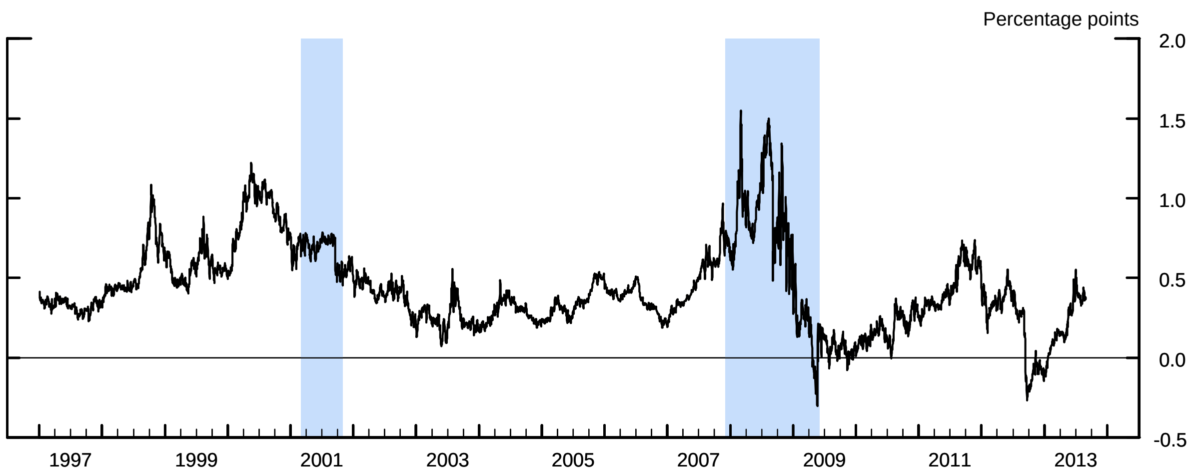
market.

[20]The PMMS surveys mortgage lenders each week on the rates (and points) for their most popular products. The survey covers first-lien prime conventional conforming mortgages with a loan-to-value of 80 percent. The survey data are collected from Monday through Wednesday and the average rates for each product are posted on Thursdays.

Figure 4: Selected Residential Mortgage Market Indicators



(a) Mortgage market interest rates

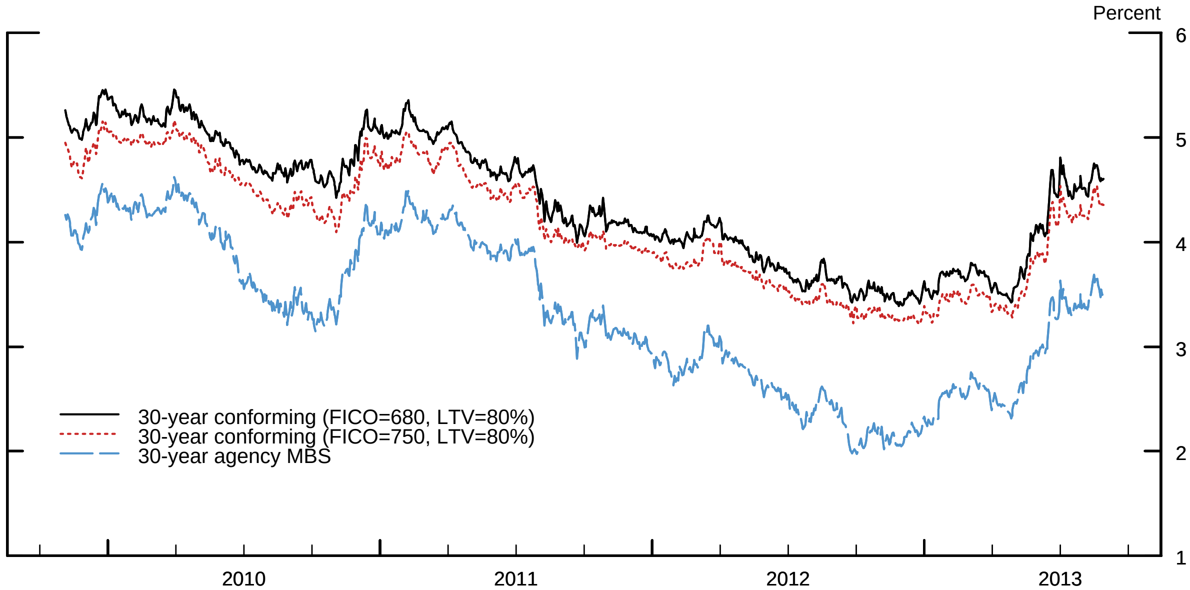


(b) Option-adjusted spread on the 30-year agency MBS

Note: Sample period: Jan-02-1997 to Aug-30-2013. The solid line in panel (a) depicts the average interest rate on the 30-year conforming FRM published by Freddie Mac at a weekly frequency, while the dotted line depicts the daily yield on the (current-coupon) 30-year agency MBS. Panel (b) depicts the daily estimate of the option-adjusted spread on the (current-coupon) 30-year agency MBS based on the Barclay's prepayment model. The shaded vertical bars represent the NBER-dated recessions.

shown in the bottom panel of Figure 4. This spread is measured relative to the yield on comparable-duration Treasury securities and attempts to strip out—using a prepayment model—the option value associated with the right of property owners, whose mortgages back the MBS, to prepay the full mortgage amount. By separating out prepayment risk, the OAS provides a cleaner measure of the compensation demanded by investors for credit risk associated with the exposure to the housing market. During the period of conventional monetary policy, the OAS averaged about

Figure 5: Mortgage Interest Rates by Borrower's Credit Quality



NOTE: Sample period: daily data from Nov-04-2009 to Aug-30-2013. The solid line depicts the interest rate on the 30-year conforming FRM for borrowers with a FICO score between 680 and 750, while the dotted line depicts the interest rate on the 30-year conforming FRM for borrowers with a FICO score of 750 and above (both FRM interest rates are calculated daily using the LoanSifter data). The dashed line depicts the yield on the (current-coupon) 30-year agency MBS.

50 basis points with a standard deviation of 25 basis points. While the volatility of the OAS has stayed roughly the same, the average OAS during the unconventional policy period is about 25 basis points, a decline reflecting the explicit government guarantee of the GSEs since they have been placed into government conservatorship in September of 2008. Given that a significant portion of unconventional policy measures employed by the FOMC during this period was aimed at making financial conditions in housing markets more accommodative, we use both the MBS yield and the OAS in the empirical analysis.

Partly in response to the dearth of high-frequency data on the primary mortgage market interest rates, the Federal Reserve Board in late 2009 launched its own data collection using LoanSifter.[21] Specifically, the staff collects daily rate quotes for standard mortgage products, which are then used to construct benchmark 30-year FRM interest rates. Figure 5 shows the 30-year conformable FRM mortgage interest rates for two categories of borrowers: a "higher" risk borrowers (borrowers with a FICO score between 680 and 750); and "low" risk borrowers (FICO score of 750+); again, as a point of comparison, the figure also depicts the 30-year (current-coupon) agency MBS yield.

[21]LoanSifter provides a highly customizable website utilities that collect actual daily mortgage rates from a large number of correspondents; see Fuster and Willen [2010] for a recent empirical application using the LoanSifter utilities.

Though available only for the portion of the unconventional policy period, we also use these data to estimate the impact of monetary policy on borrowing costs in the residential housing market.

5 The Impact of Monetary Policy on Borrowing Costs

Our analysis is geared towards assessing the impact of monetary policy on real borrowing costs, which we approximate by subtracting the comparable-maturity inflation compensation from the relevant nominal interest rates. To allow for the fact that unconventional policy measures during the ZLB period had a separate effect on the short- and long-end of the yield curve, we allow private interest rates during this period to respond to the 2-year nominal Treasury yield and the 10/2-year term spread.

5.1 Business Borrowing Costs

To estimate the effects of conventional monetary policy on real corporate borrowing costs, we estimate the following regression system:

$$\begin{aligned}\Delta y_t^{TIPS}(m) &= \alpha_R + \beta_R \Delta y_t(2) + \epsilon_t^{TIPS};\\ \Delta y_t(m) &= \alpha_1 + \beta_1 \Delta y_t(2) + \epsilon_{1t};\\ \Delta y_t^{AA}(m) &= \gamma_1 + \theta_1 \Delta y_t(2) + \nu_{1t};\\ \Delta y_t^{BBB}(m) &= \gamma_2 + \theta_2 \Delta y_t(2) + \nu_{2t};\end{aligned} \tag{3}$$

where $y_t^{TIPS}(m)$ is the m-year TIPS yield, $y_t(m)$ is the comparable-maturity nominal Treasury yield, and $y_t^{AA}(m)$ and $y_t^{BBB}(m)$ denote the m-year yields on AA- and BBB-rated corporate bonds, respectively. Within this system, the implied responses of (approximate) m-year real corporate borrowing rates can be calculated as $\theta_i - \beta_1 + \beta_R$, while the implied credit spread responses are given by $\theta_i - \beta_1$, $i = 1, 2$.

To allow corporate bond yields to respond separately to policy-induced shifts in the short- and long-end of the Treasury yield curve during the unconventional policy regime, the system (3) is modified as

$$\begin{aligned}\Delta y_t^{TIPS}(m) &= \alpha_R + \beta_R \Delta y_t(2) + \epsilon_t^{TIPS};\\ \Delta y_t(m) &= \alpha_1 + \beta_1 \Delta y_t(2) + \epsilon_{1t};\\ \Delta y_t(10) &= \alpha_2 + \beta_2 \Delta y_t(2) + \epsilon_{2t};\\ \Delta y_t^{AA}(m) &= \gamma_1 + \theta_1 \Delta y_t(2) + \lambda_1[\Delta y_t(10) - \Delta y_t(m)] + \nu_{1t};\\ \Delta y_t^{BBB}(m) &= \gamma_2 + \theta_2 \Delta y_t(2) + \lambda_2[\Delta y_t(10) - \Delta y_t(m)] + \nu_{1t}.\end{aligned} \tag{4}$$

Within this system, the total response of real corporate borrowing costs to a policy-induced change in the 2-year nominal Treasury yield is given by $\theta_i - \lambda_i(1-\beta_2) - \beta_1 + \beta_R$, while the implied response of credit spreads can be calculated as $\theta_i - \lambda_i(1 - \beta_2) - \beta_1$, $i = 1, 2$. For the conventional policy period, we estimate the system (3) by GMM using the IV-2 instrument set; for the two samples associated with the unconventional policy, the system (4) is estimated by GMM using the IV-2′ instrument set.

The estimation results for the short-term ($m = 3$) and long-term ($m = 10$) corporate borrowing costs are presented in Tables 5 and 6, respectively.[22] During the conventional policy regime, the short- and long-term investment-grade corporate bond yields are both highly sensitive to unanticipated changes in the stance of monetary policy. In fact, as evidenced by the implied responses of credit spreads, our estimates imply that corporate borrowing rates for investment-grade firms move in lockstep with the policy-induced changes in the comparable-maturity Treasury yields. In economic terms, a conventional easing of policy engineered to reduce the 2-year nominal Treasury yield by 10 basis points leads to a decline of almost 9 basis points in real short-term corporate borrowing costs, while the long-term real borrowing costs are estimated to decline 5 to 6 basis points.

As discussed above, during the unconventional policy regime, movements in longer-term Treasury yields prompted by the FOMC announcements are to a large extent attributable to changes in the term premia and much less to changes in the short-term nominal interest rates. This pattern is echoed in the corporate bond market, where policy-induced changes in the long-end of the yield curve have a significant effect on both short- and long-term corporate bond yields. The fact that AA corporate bond yields are much more sensitive to fluctuations in the slope of the yield curve than BBB yields is consistent with notion that highly-rated corporate bonds are substitutes—albeit imperfect—for Treasury securities; see Krishnamurthy and Vissing-Jorgensen [2012] for related evidence and analysis.

In terms of the total effect of unconventional policy on corporate bond yields, our results indicate almost a complete pass-through of policy actions on corporate borrowing rates, especially at shorter maturities. For example, an unconventional policy announcement that reduces the 2-year Treasury yield 10 basis points is estimated to lower the 3-year corporate bond rate for BBB-rated firms 12 basis points, while inducing a decline in the 3-year nominal Treasury yield of almost 15 basis points, leaving credit spreads just slightly wider; the 10-year borrowing costs are estimated to drop 18 basis points, about 3 basis points less than the decline in a comparable-maturity Treasury yield.

Consistent with the fact that the LSAPs have a noticeably larger impact on real Treasury yields, the sample that excludes the LSAP-related announcements implies a significantly smaller reaction of longer-term real corporate bond rates, compared with the responses based on the full unconventional policy sample. Indeed, the inclusion of the LSAP-related announcements in the unconventional policy sample boosts the estimated response of the 10-year real corporate borrowing

[22] Note that when $m = 10$, the system (4) contains two equations capturing the response of the 10-year nominal Treasury yield to changes in the 2-year Treasury yield. In that case, the first equation is dropped from the system.

Table 5: Monetary Policy and Short-Term Corporate Borrowing Costs

	Conventional[a]	Unconventional[b]		Non-LSAP[c]	
Dependent Variable	Level	Level	Slope	Level	Slope
AA yield (3y)	0.973	0.393	1.081	0.673	1.081
	(0.037)	(0.163)	(0.123)	(0.203)	(0.105)
BBB yield (3y)	0.993	1.014	0.214	0.978	0.197
	(0.036)	(0.124)	(0.090)	(0.205)	(0.146)
Treasury yield (3y)	0.940	1.352	.	1.356	.
	(0.017)	(0.026)		(0.056)	
Treasury yield (10y)	.	2.046	.	1.539	.
		(0.072)		(0.221)	
TIPS yield (3y)	0.823	1.581	.	1.467	.
	(0.093)	(0.153)		(0.216)	
Real yield response[d]					
AA yield (3y)	0.856	1.752		1.366	
	(0.121)	(0.213)		(0.237)	
BBB yield (3y)	0.876	1.465		1.195	
	(0.122)	(0.191)		(0.164)	
Credit spread response[e]					
AA spread (3y)	0.032	0.171		−0.101	
	(0.042)	(0.093)		(0.075)	
BBB spread (3y)	0.053	−0.115		−0.272	
	(0.041)	(0.060)		(0.219)	
$\Pr > LR_{GMM}$[f]	.	0.000		0.000	
$\Pr > J_T$[g]	0.478	0.360		0.260	

NOTE: The dependent variables are the daily changes in the 3-year AA and BBB nominal corporate bond yields, the 3- and 10-year nominal Treasury yields, and the 3-year TIPS yield. Entries under the column heading "Level" denote the system GMM estimates of the response coefficients to a daily change in the 2-year nominal Treasury yield induced by the FOMC announcements; entries under the column heading "Slope" denote the system GMM estimates of the response coefficients to a daily change in the 10/2-year term spread induced by the FOMC announcements. The IV-2 instrument set is used for the conventional policy sample, while the IV-2′ instrument set is used in the other two cases; see text for details. All specifications include a constant (not reported). Heteroskedasticity-consistent asymptotic standard errors are reported in parentheses.

[a] 83 FOMC announcements (Jan-04-1999–Nov-24-2008).

[b] 40 LSAP- and non-LSAP-related FOMC announcements (Nov-25-2008–Aug-30-2013).

[c] 29 non-LSAP-related FOMC announcements (Nov-25-2008–Aug-30-2013).

[d] The response of the (approximate) 3-year real corporate bond yield is computed as the difference between the estimated response of the 3-year nominal corporate bond yield and that of the 3-year inflation compensation.

[e] The response of the credit spread is computed as the difference between the estimated response of the 3-year nominal corporate bond yield and that of the 3-year nominal Treasury yield.

[f] p-value for the test of the null hypothesis that the response coefficients on the 10/2-year term spread in the two corporate bond yield equations are jointly equal to zero.

[g] p-value for the Hansen [1982] J-test of the over-identifying restrictions.

Table 6: Monetary Policy and Long-Term Corporate Borrowing Costs

	Conventional[a]	Unconventional[b]		Non-LSAP[c]	
Dependent Variable	Level	Level	Slope	Level	Slope
AA yield (10y)	0.547	−0.100	1.816	0.887	1.100
	(0.072)	(0.245)	(0.169)	(0.222)	(0.135)
BBB yield (10y)	0.500	0.362	1.354	0.211	2.172
	(0.057)	(0.180)	(0.117)	(0.494)	(0.184)
Treasury yield (10y)	0.402	2.064	.	1.380	.
	(0.068)	(0.082)		(0.238)	
TIPS yield (10y)	0.466	1.835	.	1.245	.
	(0.048)	(0.094)		(0.171)	
Real yield response[d]					
AA yield (10y)	0.611	1.603		1.169	
	(0.075)	(0.161)		(0.132)	
BBB yield (10y)	0.564	1.573		0.901	
	(0.071)	(0.119)		(0.211)	
Credit spread response[e]					
AA spread (10y)	0.145	−0.232		−0.076	
	(0.053)	(0.127)		(0.191)	
BBB spread (10y)	0.098	−0.262		−0.344	
	(0.034)	(0.071)		(0.275)	
$\Pr > LR_{GMM}$[f]	.	0.000		0.000	
$\Pr > J_T$[g]	0.713	0.378		0.318	

NOTE: The dependent variables are the daily changes in the 10-year AA and BBB nominal corporate bond yields, the 10-year nominal Treasury yield, and the 10-year TIPS yield. Entries under the column heading "Level" denote the system GMM estimates of the response coefficients to a daily change in the 2-year nominal Treasury yield induced by the FOMC announcements; entries under the column heading "Slope" denote the system GMM estimates of the response coefficients to a daily change in the 10/2-year term spread induced by the FOMC announcements. The IV-2 instrument set is used for the conventional policy sample, while the IV-2′ instrument set is used in the other two cases; see text for details. All specifications include a constant (not reported). Heteroskedasticity-consistent asymptotic standard errors are reported in parentheses.

[a] 83 FOMC announcements (Jan-04-1999–Nov-24-2008).

[b] 40 LSAP- and non-LSAP-related FOMC announcements (Nov-25-2008–Aug-30-2013).

[c] 29 non-LSAP-related FOMC announcements (Nov-25-2008–Aug-30-2013).

[d] The response of the (approximate) 10-year real corporate bond yield is computed as the difference between the estimated response of the 10-year nominal corporate bond yield and that of the 10-year inflation compensation.

[e] The response of the credit spread is computed as the difference between the estimated response of the 10-year nominal corporate bond yield and that of the 10-year nominal Treasury yield.

[f] p-value for the test of the null hypothesis that the response coefficients on the 10/2-year term spread in the two corporate bond yield equations are jointly equal to zero.

[g] p-value for the Hansen [1982] J-test of the over-identifying restrictions.

costs 6 basis points, relative to the estimates based on the sample that excludes those dates.

In sum, our estimates imply that the policy-induced declines in the 2-year nominal Treasury yield during the period of conventional policy led to a statistically significant, though economically relatively modest, reductions in real corporate borrowing rates for investment-grade firms—on the order of 5 basis points in response to a 10 basis point decline in the 2-year nominal Treasury yield. During the unconventional period, by contrast, the responses of real corporate interest rates are about three times larger. Finally, the results indicate that a significant portion of the movements in long-term real corporate borrowing rates—around 6 basis points—can be attributed to the Federal Reserve's balance sheet policies.

5.2 Mortgage Borrowing Costs

To estimate the impact of conventional monetary policy on mortgage market indicators, we estimate the following regression system:

$$\begin{aligned}
\Delta y_t^{\mathit{TIPS}}(7) &= \alpha_R + \beta_R \Delta y_t(2) + \epsilon_t^{\mathit{TIPS}}; \\
\Delta y_t(7) &= \alpha_1 + \beta_1 \Delta y_t(2) + \epsilon_{1t}; \\
\Delta y_t^{\mathit{MBS}} &= \gamma_1 + \theta_1 \Delta y_t(2) + \nu_{1t}; \\
\Delta s_t^{\mathit{MBS}} &= \gamma_2 + \theta_2 \Delta y_t(2) + \nu_{2t};
\end{aligned} \tag{5}$$

where y_t^{MBS} is the yield on the (current-coupon) 30-year agency MBS and s_t^{MBS} denotes the option-adjusted MBS spread. Note that when computing the (approximate) real MBS yield $(\theta_1 - \beta_1 + \beta_R)$ or the unadjusted MBS-Treasury spread $(\theta_1 - \beta_1)$, we are implicitly assuming that the average weighted maturity of mortgages underlying the MBS is seven years.

To gauge the impact of unconventional policy actions on these mortgage market indicators, we modify the system (5) as

$$\begin{aligned}
\Delta y_t^{\mathit{TIPS}}(7) &= \alpha_R + \beta_R \Delta y_t(2) + \epsilon_t^{\mathit{TIPS}}; \\
\Delta y_t(7) &= \alpha_1 + \beta_1 \Delta y_t(2) + \epsilon_{1t}; \\
\Delta y_t(10) &= \alpha_2 + \beta_2 \Delta y_t(2) + \epsilon_{2t}; \\
\Delta y_t^{\mathit{MBS}} &= \gamma_1 + \theta_1 \Delta y_t(2) + \lambda_1[\Delta y_t(10) - \Delta y_2(2)] + \nu_{1t}; \\
\Delta s_t^{\mathit{MBS}} &= \gamma_2 + \theta_2 \Delta y_t(2) + \lambda_2[\Delta y_t(10) - \Delta y_2(2)] + \nu_{2t}.
\end{aligned} \tag{6}$$

As before, this allows us to calculate the impact of a policy-induced change in the 2-year nominal Treasury yield on the real MBS yield as $\theta_1 - \lambda_1(1 - \beta_2) - \beta_1 + \beta_R$, while the implied response of the raw MBS-Treasury spread is given by $\theta_1 - \lambda_1(1 - \beta_2) - \beta_1$; the total effect on the option-adjusted spread is given simply by $\theta_2 - \lambda_2(1 - \beta_2)$.

According to Table 7, a conventional policy action that lowers the 2-year nominal Treasury

Table 7: Monetary Policy and Residential Mortgage Market Indicators

	Conventional[a]	Unconventional[b]		Non-LSAP[c]	
Dependent Variable	Level	Level	Slope	Level	Slope
Agency MBS yield (30y)	0.758	0.444	0.544	0.308	1.149
	(0.042)	(0.376)	(0.338)	(0.174)	(0.174)
OAS Agency MBS	0.166	−0.804	0.153	−0.397	−0.067
	(0.059)	(0.436)	(0.408)	(0.168)	(0.187)
Treasury yield (7y)	0.626	2.023	.	1.605	.
	(0.049)	(0.065)		(0.231)	
Treasury yield (10y)	.	1.999	.	1.452	.
		(0.064)		(0.256)	
TIPS yield (7y)	0.587	1.980	.	1.581	.
	(0.054)	(0.121)		(0.140)	
Real yield response[d]					
Agency MBS yield (30y)	0.719	0.945		0.803	
	(0.111)	(0.187)		(0.137)	
Credit spread response[e]					
Unadjusted	0.132	−1.035		−0.777	
	(0.073)	(0.102)		(0.185)	
Option-adjusted	.	−0.650		−0.427	
		(0.096)		(0.139)	
$\Pr > LR_{GMM}$[f]	.	0.000		0.000	
$\Pr > J_T$[g]	0.868	0.199		0.419	

NOTE: The dependent variables are the daily changes in the 30-year (current coupon) nominal agency MBS yield, the option-adjusted spread on the 30-year agency MBS, the 7- and 10-year nominal Treasury yields, and the 7-year TIPS yield. Entries under the column heading "Level" denote the system GMM estimates of the response coefficients to a daily change in the 2-year nominal Treasury yield induced by the FOMC announcements; entries under the column heading "Slope" denote the system GMM estimates of the response coefficients to a daily change in the 10/2-year term spread induced by the FOMC announcements. The IV-2 instrument set is used for the conventional policy sample, while the IV-2′ instrument set is used in the other two cases; see text for details. All specifications include a constant (not reported). Heteroskedasticity-consistent asymptotic standard errors are reported in parentheses.

[a] 83 FOMC announcements (Jan-04-1999–Nov-24-2008).

[b] 40 LSAP- and non-LSAP-related FOMC announcements (Nov-25-2008–Aug-30-2013).

[c] 29 non-LSAP-related FOMC announcements (Nov-25-2008–Aug-30-2013).

[d] The response of the (approximate) 30-year real MBS yield is computed as the difference between the estimated response of the 30-year nominal MBS yield and that of the 7-year inflation compensation.

[e] The response of the unadjusted credit spread is computed as the difference between the estimated response of the 30-year agency MBS yield and that of the 7-year nominal Treasury yield.

[f] p-value for the test of the null hypothesis that the response coefficient on the 10/2-year term spread in the mortgage market indicator equations are equal to zero.

[g] p-value for the Hansen [1982] J-test of the over-identifying restrictions.

yield 10 basis points is estimated to reduce the 30-year MBS yield almost 8 basis points. Given the estimate of the pass-through coefficient from the secondary to the primary mortgage market of about 0.80 (see the discussion in Section 4.2), this translates into a reduction in the 30-year FRM rate of about 6 basis points, essentially the same as the implied decline in the 7-year nominal Treasury yield—the benchmark interest rate. In other words, such an unanticipated policy easing leaves the FRM-Treasury credit spread unchanged, a result consistent with the implied response of the option-adjusted spread, which is also estimated to remain unchanged. Because the 7-year TIPS yield is declines about as much as its nominal counterpart, these results imply a reduction of 6 basis point in the real 30-year FRM rate.

The impact of the FOMC announcements associated with unconventional policy actions has a similar effect on the real borrowing costs in the residential mortgage market. In that case, a policy-induced reduction in the 2-year Treasury yield of 10 basis points leads to a decline in the real MBS yield of about the same magnitude. Given the estimate of the pass-through coefficient of about 0.7 during this period, this implies a roughly 6 basis point decrease in the 30-year real FRM rate. Because the corresponding policy-induced declines in the longer-term Treasury yields are considerably larger during this period, our estimates also imply a considerable increase in both the unadjusted MBS-Treasury yield spread and its option-adjusted counterpart.

To estimate the impact of unconventional policy actions directly on primary mortgage interest rates, we consider the following regression system:

$$\begin{aligned}
\tilde{\Delta} y_t^{TIPS}(7) &= \alpha_R + \beta_R \Delta y_t(2) + \epsilon_t^{TIPS};\\
\tilde{\Delta} y_t(7) &= \alpha_1 + \beta_1 \Delta y_t(2) + \epsilon_{1t};\\
\Delta y_t(10) &= \alpha_2 + \beta_2 \Delta y_t(2) + \epsilon_{2t};\\
\tilde{\Delta} y_t^{FRM\text{–}750} &= \gamma_1 + \theta_1 \Delta y_t(2) + \lambda_1[\Delta y_t(10) - \Delta y_2(2)] + \nu_{1t};\\
\tilde{\Delta} y_t^{FRM\text{–}680} &= \gamma_2 + \theta_2 \Delta y_t(2) + \lambda_2[\Delta y_t(10) - \Delta y_2(2)] + \nu_{2t};
\end{aligned} \tag{7}$$

where $y_t^{FRM\text{–}750}$ and $y_t^{FRM\text{–}680}$ denote the 30-year FRM interest rates for "high-quality" mortgage applicants (FICO $\geq$ 750) and "lower-quality" applicants (680 $\leq$ FICO $<$ 750), respectively. The difference operator $\tilde{\Delta} x_t \equiv x_{t+1} - x_{t-1}$ denotes 2-day—as opposed to 1-day—changes in interest rates, an assumption reflecting the fact that the LoanSifter rate quotes are sticky and do not react immediately to policy-induced changes in the benchmark market interest rates.

The assumption that the primary mortgage markets do not fully price in the information contained in the FOMC announcements within the one-day window of the baseline analysis is consistent with the empirical relationship between changes in the FRM rates calculated using the LoanSifter data and changes in the MBS yield. For example, a regression of the daily change in the FRM rate on the daily change in the (current-coupon) 30-year agency MBS yield implies a pass-through coefficient of 0.56 for the high-quality borrowers and 0.69 for their lower-quality counterparts. Using 2-day changes of mortgage rates, in contrast, boosts the two pass-through coefficients to 0.68 and

Table 8: Unconventional Monetary Policy and Mortgage Interest Rates
(*2-day Interest Rate Changes*)

	Unconventional[a]		Non-LSAP[b]	
Dependent Variable	Level	Slope	Level	Slope
FRM rate (30y; FICO $\geq$ 750)	1.026	0.450	0.467	1.564
	(0.208)	(0.137)	(0.405)	(0.110)
FRM rate (30y; 680 $\leq$ FICO $<$ 750)	1.757	0.210	2.267	0.340
	(0.282)	(0.189)	(0.265)	(0.130)
Treasury yield (7y)	2.147	.	2.290	.
	(0.259)		(0.254)	
Treasury yield (10y)	1.354	.	1.778	.
	(0.414)		(0.217)	
TIPS yield (7y)	2.591	.	3.459	.
	(0.332)		(0.208)	
Real FRM rate response[c]				
FICO $\geq$ 750	1.630		2.853	
	(0.405)		(0.225)	
680 $\leq$ FICO $<$ 750	2.278		3.701	
	(0.518)		(0.280)	
Pr $> LR_{GMM}$[d]	0.000		0.000	
Pr $> J_T$[e]	0.412		0.332	

NOTE: The dependent variables are the 2-day changes in the 30-year FRM interest rates (by selected FICO scores), the 7-year nominal Treasury yield, and the 7-year TIPS yield; changes in the 10-year nominal Treasury yield are daily. Entries under the column heading "Level" denote the system GMM estimates of the response coefficients to a 1-day change in the 2-year nominal Treasury yield induced by the FOMC announcements; entries under the column heading "Slope" denote the system GMM estimates of the response coefficients to a 1-day change in the 10/2-year term spread induced by the FOMC announcements. The IV-2′ instrument set is used in both cases; see text for details. All specifications include a constant (not reported). Heteroskedasticity-consistent asymptotic standard errors are reported in parentheses.

[a] 31 LSAP- and non-LSAP-related FOMC announcements (Nov-04-2009–Aug-30-2013).

[b] 25 non-LSAP-related FOMC announcements (Nov-4-2009–Aug-30-2013).

[c] The response of the (approximate) 30-year FRM real interest rate is computed as the difference between the estimated response of the 30-year FRM interest rate and that of the 7-year inflation compensation.

[d] p-value for the test of the null hypothesis that the response coefficients on the 10/2-year term spread in the two FRM-rate equations are jointly equal to zero.

[e] p-value for the Hansen [1982] J-test of the over-identifying restrictions.

0.78, respectively.[23]

According to Table 8, the FOMC announcements associated with unconventional policy actions led to economically large and statistically significant declines in real mortgage borrowing costs for

[23] The use of 2-day changes is also consistent with Fuster and Willen [2010], who document a wide variation in the LoanSifter rate quotes around the announcement of the MBS purchase program; in particular, they report an interest rate response ranging from a decline of 40 basis points to and increase of 10 basis points.

households of both lower and higher credit quality. Our estimates indicate that a policy-induced reduction in the 2-year nominal Treasury yield of 10 basis points lowered the (approximate) real 30-year FRM rate about 16 basis points for applicants with the FICO score of 750 or above; for lower-quality credits ($680 \leq \text{FICO} < 750$), the decline is estimated to be more than 20 basis points. The exclusion of the LSAP-related announcements from the sample yields even larger effects. In that case, such a policy easing is estimated to lower real mortgage borrowing costs between 30 and 35 basis points. These sizable effects are consistent with Hancock and Passmore [2011], who present evidence that the MBS purchase program led to a large reduction in mortgage rates in the month following the announcement.

6 Conclusion

In this paper, we examine the effect of monetary policy on the real borrowing costs faced by businesses and households. Real borrowing costs are measured as the difference in nominal interest rates on corporate bonds and mortgage-related instruments and the inflation compensation implied by movements in the TIPS yields relative to yields on their comparable-maturity nominal counterparts. We estimate the impact of monetary policy actions on such borrowing cost across two distinct policy regimes: The conventional policy regime, a period in which monetary policy operated by influencing the level and future path of the federal funds rate; and the unconventional policy regime, a period in which the funds rate was stuck at the zero lower bound, and the FOMC conducted policy through a combination of forward guidance and asset substitution mechanisms that alter term premia.

Our results imply that during the conventional policy regime, monetary policy operates by altering shorter-term interest rates relative to long-term interest rates. According to our estimates, a 10 basis point policy-induced reduction in the 2-year Treasury yield implies a 5 basis point decline in the 10-year Treasury yield. As a result, conventional expansionary monetary policy steepens the yield curve. During the unconventional period, in contrast, a policy-engineered decline in the 2-year Treasury yield of 10 basis points leads to a 20 basis point decline in the 10-year yield—a three-fold increase in the effect on long-term rates relative to that for the conventional policy regime. Thus, unconventional expansionary monetary policy flattens the yield curve, a result consistent with the notion that such policy "targets" the long-end of the yield curve through a combination of forward guidance and asset purchases.

Consistent with Hanson and Stein [2012], our results also imply that in both the conventional and unconventional policy regimes, monetary policy has economically important effects on real interest rates. Indeed, we find that monetary policy has little effect on inflation compensation, which implies that nearly all of the implied movements in nominal rates are reflected in real rates, a result that argues in favor of the notion that the effectiveness of monetary policy is due in large part to its ability to alter term premia. Nevertheless, using model-based measures of term premia, we also find that both the LSAP-related announcements and forward guidance significantly influence the expected future path of the policy rate, though this signaling mechanism appears to be more important during the conventional policy regime. During that period, the policy-induced change in expectations regarding the future trajectory of short-term rates accounts for 40 percent of the overall movement in the 10-year Treasury yield. During the unconventional policy period, by contrast, changes in expected future short rates account for only 25 percent of the overall implied movement in long-term interest rates.

The effects of monetary policy actions on the TIPS yields are transmitted one-for-one to real corporate borrowing costs, as measured by the inflation-compensation adjusted response of corporate bond yields. This reflects two distinct findings. First, during the unconventional policy period, corporate bond yields became more sensitive to changes in longer-term Treasury yields, which move to a much greater extent relative to short-term rates. This result is strikingly apparent in the response of high-quality short-term corporate rates, which one might plausibly expect to be influenced primarily by the short-term Treasury yields; in fact, movements in long-term Treasury yields account for nearly all of the response of the AA 3-year corporate bond yield during the unconventional policy period. Second, we find little evidence that monetary policy actions have a significant effect on credit spreads—the difference in yields between corporate and Treasury securities of comparable maturity. As a result, the "pass-through" from Treasury yields to corporate bond yields is roughly one-for-one.

The effects of monetary policy on real long-term interest rates are also transmitted in a significant way to real borrowing costs faced by households in mortgage markets. However, this transmission mechanism appears to be more potent during the conventional policy regime. Using the 30-year agency MBS yield as a proxy for mortgage-related borrowing costs, our results imply that a conventional policy easing engineered to reduce the 7-year TIPS yield by 10 basis points leads to a 10 basis point decline in real 30-year FRM interest rates. During the unconventional policy period, the implied decline in real FRM rates is roughly 5 basis points. Nonetheless, to the extent that unconventional policy is more effective in influencing longer-term interest rates, the expansionary policies pursued by the Federal Reserve since 2008 have undoubtedly lowered real borrowing costs associated with housing purchases.

All told, our results imply that to the extent that monetary policy actions influence nominal Treasury yields, they are also directly transmitted to TIPS yield and passed on to businesses and households in terms of lower real borrowing costs. The primary difference in the transmission mechanism between the conventional and unconventional policy regimes appears in the manner in which expansionary monetary policy influences the nominal Treasury yield curve—by steepening the yield curve in conventional times and by flattening the curve through unconventional measures—rather than in the way such movements in the yield curve affect real borrowing costs.

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