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ABSTRACT

Monetary Policy and Real Borrowing Costs at the Zero Lower Bound*

This paper compares the effects of conventional monetary policy on real borrowing costs with those of the unconventional measures employed after the target federal funds rate hit the zero lower bound (ZLB). For the ZLB period, we identify two policy surprises: changes in the 2-year Treasury yield around policy announcements and changes in the 10-year Treasury yield that are orthogonal to those in the 2-year yield. The efficacy of unconventional policy in lowering real borrowing costs is comparable to that of conventional policy, in that it implies a complete pass-through of policy-induced movements in Treasury yields to comparable-maturity private yields.

JEL Classification: E43 and E52
Keywords: corporate bond yields, forward guidance, LSAPs, mortgage interest rates, term premia and unconventional monetary policy

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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 manipulating short-term nominal interest rates in an effort to influence the real borrowing costs faced by businesses and households.[1] Under this so-called dual mandate, policymakers respond to a slowdown in economic activity by lowering short-term nominal interest rates, thereby inducing a decline in real borrowing costs. According to a textbook description of the monetary transmission mechanism, businesses respond by boosting 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 works through open market operations, which directly affect the overnight federal funds rate. As emphasized by Gürkaynak et al. (2005a), policy actions affect both the current target rate and its expected future trajectory. Through its influence on expectations, a policy easing lowers interest rates throughout the term structure, 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. In addition to influencing the expected path of short-term nominal interest rates, monetary policy may also affect term premia associated with longer-term financial assets. If assets across different maturities are imperfect substitutes, altering the mix of assets available to investors directly influences the premium associated with holding long- 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 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 et al., 2012).

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 compare the efficacy of conventional and unconventional policy measures, our empirical approach builds on Hanson and Stein (2012) and Gertler and Karadi (2013) and uses daily changes in the 2-year nominal Treasury yield on policy announcement days as a common instrument across the two policy regimes. In contrast to the above two papers, we

[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, for instance, Mishkin (1995) and Bernanke and Gertler (1995) for detailed description of the various channels through which monetary policy can affect macroeconomic outcomes.

rely on movements in the 2-year Treasury yield within a narrow window surrounding FOMC and other policy announcements to identify unanticipated policy actions.[3]

Measuring the stance of monetary policy during the unconventional policy regime is complicated by the fact that the Federal Reserve implemented different forms of forward guidance regarding the future path of the federal funds rate, as well as a number of Large-Scale Asset Purchase programs (LSAPs), the primary goal of which was to influence longer-term yields on Treasury and MBS securities through direct purchases of those assets. These policy actions were introduced to the public via announcements, either following the regularly-scheduled FOMC meetings or in special announcements outside the regular FOMC schedule.[4] 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 little or no such information.

Because many of these unconventional policy measures were intended to directly influence longer-term interest rates, changes in the 2-year Treasury yield around policy announcements during the ZLB period are insufficient to fully summarize the impact of unconventional monetary policy on asset prices. To provide a more complete accounting of the effects of unconventional monetary policy on real borrowing costs, we adopt an identification scheme that allows for an additional unanticipated component of policy, a component that has an independent effect on longer-term interest rates. We do so by decomposing the observed change in the 10-year nominal Treasury yield over a narrow window surrounding a policy announcement into two components: (1) an anticipated component that reflects the effects of changes in the 2-year Treasury yield on longer-term yields within that narrow window; and (2) a surprise component that is orthogonal to the changes in the 2-year Treasury yield within the narrow window and is intended to capture the direct effect of unconventional policy measures on longer-term interest rates.[5]

Our results indicate that during the conventional policy regime, an unanticipated easing of monetary policy steepens the yield curve but, nonetheless, has a pronounced effect on longer-term real interest rates. In particular, an unanticipated easing of monetary policy that lowers the 2-year nominal Treasury yield 10 basis points induces a 4 basis point decline in the 10-year nominal Treasury yield. This policy easing has very little effect on inflation compensation (i.e., breakeven inflation rates) as measured by TIPS. Consequently, such a policy easing leads to a

[3] As discussed more fully below, this approach allows us to rule out the potential reverse causality, a situation in which the daily changes in the 2-year Treasury yield—even on policy announcement days—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 our approach is that movements in Treasury yields in a narrow window surrounding a policy announcement are predominantly due to the unanticipated changes in the stance of monetary policy or communication regarding the path for policy going forward.

[4] In contrast to the standard event-style analysis, our results are best thought of as capturing the average effect of unconventional monetary policy on real borrowing costs.

[5] As shown by Swanson and Williams (2013), yields on nominal Treasury securities with a year or more to maturity responded to economic news throughout the 2008–10 period, indicating that monetary policy was likely to have been about as effective as usual during this period. By the end of 2011, however, the 2-year Treasury yield has largely stopped responding to news as result of the binding ZLB constraint. The 10-year Treasury yield, in contrast, has continued to respond to news after that, suggesting a significant scope for monetary policy to affect real borrowing costs by directly influencing the long-end of the yield curve.

4 basis point decline in the 10-year TIPS yield, a result that is in line with the estimates provided by Hanson and Stein (2012); consistent with their findings, we also find that lower term premia account for a majority of the decline in longer-term rates.

In addition, the conventional monetary stimulus significantly lowers real borrowing costs faced by businesses and households. During the conventional policy period, a 10 basis point reduction in the 2-year nominal Treasury yield leads to a 7 basis point decline in the real 3-year corporate bond yield for investment-grade nonfinancial firms; such policy stimulus also lowers real long-term (10-year) corporate borrowing costs 5 basis points. In the residential mortgage markets, a conventional policy easing of that magnitude is estimated to lower the real 30-year agency MBS yield almost 7 basis points.

During the unconventional policy period, monetary stimulus engineered through the short-end of the yield curve flattens the yield curve and in the process has an even more pronounced effect on real longer-term interest rates. Policy surprises that reduce the 2-year nominal Treasury yield 10 basis points induce a 16 basis point decline in longer-term nominal interest rates and the same-sized reduction in their real counterparts. Lower term premia again account for the substantial majority of the decline in those rates. An unconventional stimulus of the same magnitude but orchestrated vis-à-vis the long-end of the yield curve also has economically large effects, especially on longer-term interest rates.

Our results highlight that both dimensions of unconventional monetary policy have economically significant effects on real borrowing costs. A 10 basis point policy-induced decline in the 2-year nominal Treasury yield leads to a 15 basis point reduction in real investment-grade corporate bond yields across the maturity spectrum. Thus, monetary expansions during the unconventional policy period engineered vis-à-vis the short-end of the yield curve imply an effect on real corporate borrowing costs that is twice as large as that implied by a conventional policy easing of the same magnitude. Similarly, a 10 basis point surprise reduction in the long-end of the yield curve implies a 10 basis point drop in real corporate borrowing rates.

The two dimensions of unconventional monetary policy are also very effective in changing real mortgage borrowing costs. An unconventional policy easing of 10 basis points put through the short-end of the yield curve is estimated to reduce the real 30-year MBS yield almost 12 basis points, while the same-sized stimulus delivered through the long end lowers the real MBS yield 10 basis points. At the same time, the unconventional monetary stimulus engineered through the 2-year Treasury yield appears not to be as effective as that during the conventional policy regime. According to our estimates, such a policy easing implies a moderate and statistically significant increase in the option-adjusted MBS-Treasury spread, whereas a conventional policy easing causes the option-adjusted MBS-Treasury spread to narrow somewhat.

The comparison of the efficacy of monetary policy between the conventional and unconventional periods may be confounded by the fact that movements in the short-end of the yield curve are constrained by the zero lower bound. This anchoring of the short-end of the yield curve would imply an attenuation bias in the response of short-term nominal interest rates to economic news,

a fact documented by Swanson and Williams (2013) for the behavior of the 2-year Treasury yield since the end of 2011. An alternative way to compare the effectiveness of monetary policy across the two regimes is to focus on the pass-through from nominal Treasury yields to real borrowing costs at comparable maturities. By this metric, we find that the efficacy of unconventional policy measures in lowering real business borrowing costs is comparable to that of conventional monetary policy, in that it implies an almost complete pass-through of policy-induced movements in Treasury yields to comparable-maturity corporate bond yields, leaving credit spreads essentially unchanged.

Despite the complete pass-through of monetary policy to real borrowing costs across the two regimes, our results indicate that the source of monetary policy shocks during the unconventional period differs significantly from that during the conventional period. In particular, during the ZLB period, a significant fraction of the variation in real long-term borrowing costs—on the order of 40 to 50 percent—is attributable to policy surprises that induce movements in longer-term interest rates and that are orthogonal to surprises in the 2-year Treasury yield. Thus, both forward guidance and the LSAP-related policy announcements influence real borrowing costs by inducing changes in longer-term Treasury yields that are independent of the unanticipated policy-induced shifts in the short-end of the yield curve.

Our analysis of the effects of unconventional monetary policy on real borrowing costs contributes to a rapidly growing empirical literature that evaluates the effects of unconventional policy measures on asset prices. Much of this research focuses on the question of whether purchases of large quantities of Treasury coupon securities by the Federal Reserve and various forms of forward guidance have altered the level of longer-term Treasury yields. Employing a variety of approaches, Gagnon et al. (2011), Krishnamurthy and Vissing-Jorgensen (2011), Swanson (2011), Hamilton and Wu (2012), Christensen and Rudebusch (2012), D'Amico et al. (2012), Justiniano et al. (2012), Wright (2012), D'Amico and King (2013), Li and Wei (2013), and Bauer and Rudebusch (2013) present compelling evidence that the unconventional policy measures employed by the FOMC since the end of 2008 have significantly lowered longer-term Treasury yields.[6] Our paper is also related to the recent work of Hanson and Stein (2012) and Nakamura and Steinsson (2013), who analyze the effects monetary policy on the real and nominal Treasury yields over a period that includes both the conventional and unconventional policy regimes.

Although a number of the above studies also find a considerable pass-through from policy-induced changes in Treasury yields to private yields, there is considerably more uncertainty surrounding the effects of unconventional monetary policy on borrowing costs faced by businesses and households. For example, Stroebel and Taylor (2012) attribute a relatively small and uncertain portion of the decline in mortgage interest rate spreads to the Federal Reserve's programs involving purchases of the mortgage-backed securities (MBS). The uncertainty of these estimates is echoed in the work of Fuster and Willen (2010), who document a wide dispersion in the response of (nominal) primary mortgage rates to the announcements involving large-scale purchases of MBS. On

[6] Using a common methodology to compare the efficacy of unconventional policy measures across major industrialized countries, Rogers et al. (2013) document similar effects for the unconventional policies employed by the Bank of England, European Central Bank, and the Bank of Japan.

the other hand, Hancock and Passmore (2011, 2012) and Krishnamurthy and Vissing-Jorgensen (2011); Krishnamurthy and Vissing-Jorgensen (2013) provide extensive evidence that these programs significantly eased financial conditions in mortgage markets.

At the same time, Krishnamurthy and Vissing-Jorgensen (2013) argue that LSAPs were relatively ineffective in lowering (nominal) corporate bond yields, especially those associated with riskier credits. Gilchrist and Zakrajšek (2013), in contrast, find that LSAP announcements significantly reduced the cost of insurance against a broad-based incidence of defaults—both in the investment- and speculative-grade segments of the corporate sector—implying a widespread reduction in business borrowing costs. In addition, Justiniano et al. (2012) find little difference in the response of corporate bond yields to policy announcements between the conventional and unconventional policy regimes.

The remainder of the paper is organized as follows: Section 2 outlines our empirical methodology—in subsection 2.1, we briefly discuss the identification of conventional monetary policy surprises, while subsection 2.2 presents our framework for estimating the causal effect of unconventional monetary policy on asset prices. Section 3 contains the estimation results comparing the effects of monetary policy on nominal and real Treasury yields across the two policy regimes, results that serve as useful benchmark for gauging the effects of monetary policy on private yields. In Section 4, we present our main results: subsection 4.1 contains the estimates for real corporate borrowing costs, while subsection 4.2 contains the estimates for real mortgage borrowing costs; subsection 4.3 details the relative importance of "short" and "long" policy surprises associated with the unconventional monetary policy. Section 5 concludes.

2 Empirical Framework

In this section, we present the empirical approach used to estimate the impact of monetary policy on market interest rates during both the conventional and unconventional policy regimes. The key aspect of our approach involves the use of *intraday* data to directly infer monetary policy surprises associated with policy announcements. In combination with the daily data on market interest rates, these high-frequency policy surprises allow us to estimate the causal impact of policy actions on the real borrowing costs faced by businesses and households.

Before delving into econometric details, we briefly discuss the dating of the two policy regimes. The sample period underlying our analysis runs from January 4, 1999 to October 31, 2013. The starting date is dictated by the availability of TIPS data, which provide the market-based measures of inflation compensation used to measure real borrowing costs. We divide this period 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 during which the funds rate has 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 in mid-September. One 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 the global financial system in severe turmoil 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 events, we assume that the unconventional policy regime began on November 25, 2008 and that prior to that point, the conventional policy regime was in effect. Nearly all of the 83 announcements during the conventional policy period followed regularly-scheduled FOMC meetings; only four were associated with the intermeeting policy moves.[7] According to this chronology, the last FOMC meeting during the conventional policy regime took place on October 29, 2008, at which point the FOMC lowered its target for the federal funds rate 50 basis points, to 1 percent.

2.1 Conventional Monetary Policy

Changes in the stance of conventional monetary policy have typically been characterized by a single factor—the "target" surprise or the unanticipated component of the change in the current federal funds rate target (see Cook and Hahn, 1989; Kuttner, 2001; Cochrane and Piazzesi, 2002; Bernanke and Kuttner, 2005). As emphasized by Gürkaynak et al. (2005a), however, this characterization of monetary policy is incomplete, and another factor—namely, changes in the future policy rates that are independent of the current target rate—is needed to fully capture the impact of conventional monetary policy on asset prices. This second factor, commonly referred to as a "path" surprise, is closely associated with the FOMC statements that accompany changes in the target rate and represents a communication aspect of monetary policy that assumed even greater importance after the target rate was lowered to its effective lower bound in December 2008.

To facilitate the comparison of the efficacy of conventional and unconventional monetary policy, we follow Hanson and Stein (2012) and Gertler and Karadi (2013) and reduce this two-dimensional aspect of conventional policy by assuming that the change in the 2-year nominal Treasury yield over a narrow window bracketing an FOMC announcement reflects the confluence of the target and path surprises.[8] Under this assumption, the effect of unanticipated changes in the stance of

[7] The four intermeeting moves occurred on January 3, 2001; April 18, 2001; January 22, 2008; and October 8, 2008. As is customary in this kind of analysis, we excluded 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. 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.

[8] In Appendix A, we examine the robustness of this assumption by decomposing the change in the 2-year Treasury

conventional policy on real borrowing costs can be inferred from

$$\Delta \mathbf{s}_t = \boldsymbol{\alpha} \tilde{\Delta} y_t(2) + \mathbf{u}_t, \tag{1}$$

where $\Delta \mathbf{s}_t$ denotes the *daily* change in a vector of market interest rates that are relevant for the calculation of real borrowing costs faced by economic agents, and $\tilde{\Delta} y_t(2)$ is the *intraday* change in the (on-the-run) 2-year nominal Treasury yield over a 30-minute window surrounding an FOMC announcement (10 minutes before to 20 minutes after) on day t. The vector of stochastic disturbances $\mathbf{u}_t$ captures the information that possibly was released earlier in the day as well as noise from other financial market developments that took place throughout the day.

Using the sample of 83 FOMC announcements during the conventional policy regime, we estimate the equation (1) by OLS. Underlying this empirical strategy is the assumption that movements in the 2-year Treasury yield in a 30-minute window surrounding FOMC announcements are due entirely to the unanticipated changes in the current stance of monetary policy. By any measure, this is a reasonable assumption because we are virtually certain that no other economic news was released within such a short interval of time.

At the same time, however, it is also conceivable that these announcements reveal some private information the Federal Reserve may have about the economy, which would invalidate the interpretation of intraday changes in Treasury yields as exogenous policy shocks. As a simple test of this reverse causality hypothesis, we regressed the (log) return on the S&P500 stock price index on our posited monetary policy surprises, where the returns were calculated over the same 30-minute window as the policy surprise $\tilde{\Delta} y_t(2)$. This regression yielded a coefficient of -60.74 on $\tilde{\Delta} y_t(2)$ (robust standard error of 19.27), indicating that FOMC announcements that lower expected future short-term interest rates lead to an economically and statistically significant *increase* in broad equity prices. The estimated response of equity prices is thus inconsistent with the view that FOMC announcements reveal some private information the Federal Reserve may have about the economy because the Committee is presumably unlikely to ease policy when it has favorable information about the economic outlook.

2.2 Unconventional Monetary Policy

After having brought the target 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 on longer-term market interest rates.

yield into the target and path surprises. Our results indicate that the first-order effects of conventional monetary policy actions can be summarized adequately by the intraday changes in the 2-year nominal Treasury yield bracketing FOMC announcements.

Table 1: Key Unconventional Monetary Policy Actions

Date	Time[a]	FOMC[b]	Highlights
Nov-25-2008	08:15	N	Announcement that starts LSAP-I.
Dec-01-2008	08:15	N	Announcement indicating potential purchases of Treasury securities
Dec-16-2008	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; first reference to forward guidance: "... economic conditions are likely to warrant exceptionally low levels of the federal funds rate for some time."
Jan-28-2009	14:15	Y	"Disappointing" FOMC statement because of its lack of concrete language regarding the possibility and timing of purchases of longer-term Treasuries.
Mar-18-2009	14:15	Y	Announcement to purchase Treasuries and increase the size of purchases of agency debt and agency MBS; also, first reference to extended period: "... interests rates are likely to remain low for an extended period ..."
Aug-10-2010	14:15	Y	Announcement that starts LSAP-II.
Aug-27-2010	10:00	N	Chairman's speech at Jackson Hole.
Sep-21-2010	14:15	Y	Announcement reaffirming the existing reinvestment policy.
Oct-15-2010	08:15	N	Chairman's speech at the Federal Reserve Bank of Boston.
Nov-03-2010	14:15	Y	Announcement of additional purchases of Treasury securities.
Aug-09-2011	14:15	Y	First "calendar-based" forward guidance: "... anticipates that economic conditions are likely to warrant exceptionally low levels for the federal funds rate at least through mid-2013."
Aug-29-2011	10:00	N	Chairman's speech at Jackson Hole.
Sep-21-2011	14:15	Y	Announcement of the Maturity Extension Program (MEP).
Jan-25-2012	12:30	Y	Second "calendar-based" forward guidance: "... keep the federal funds rate exceptionally low at least through late 2014."
Jun-20-2012	12:30	Y	Announcement of continuation of the MEP through end of 2012.
Aug-31-2012	10:00	N	Chairman's speech at Jackson Hole.
Sep-13-2012	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.
Jun-19-2013	14:00	Y	Forward guidance lays out plans to start tapering asset purchases later that year (unemployment rate below 7.5%); and end LSAP-III by mid-2014, when the unemployment rate is around 7%.
Jul-17-2013	08:30	N	Chairman's semiannual Monetary Policy Report to the Congress.
Sep-18-2013	14:15	Y	"Asset purchases are not on a preset course ..."

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

As shown 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 on December 16, 2008, in which it indicated that economic conditions were "likely to warrant exceptionally low levels of the federal funds rate for some time." Starting with the March 2009 meeting, the FOMC referred to its expectation that an exceptionally low funds rate would be in force "for an extended period." 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. As noted in Table 1, 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, investors are inclined to keep a fraction of their 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' preferences 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. In other words, purchases of Treasuries, agency debt, and agency-guaranteed MBS by the Federal Reserve lower longer-term nominal interest rates, as investors find themselves demanding more government debt than is available on the market at the existing configuration of interest rate; conversely, an increase in the stock of government debt held by the private sector boosts bond yields. This adjustment mechanism hinges importantly on the presumption that the term premia are sensitive to the volume of long-term debt outstanding, so that longer-term interest rates are affected by purchases even if expectations for the future path of the policy rate remain unchanged.

Because asset purchases were an integral part of the unconventional policy measures employed by the FOMC during the ZLB period, changes in the 2-year Treasury yield around policy announcements during that period period will fail to capture the full impact of unconventional monetary policy on asset prices. To capture this extra dimension of unconventional policy, we assume that

$$\tilde{\Delta} y_t(10) = \lambda_U \tilde{\Delta} y_t(2) + \tilde{\Delta} m_t^L, \tag{2}$$

where $\tilde{\Delta} y_t(10)$ denotes the change in the (on-the-run) 10-year nominal Treasury yield over a narrow window surrounding a policy announcement on day t, $\tilde{\Delta} y_t(2)$ is the change over the same window in the (on-the-run) 2-year Treasury yield, and $\tilde{\Delta} m_t^L$ represents the unanticipated component of the unconventional policy that potentially has an independent effect on longer-term interest rates.

As above, letting Δs_{it} denote the daily change in the price of a financial asset i, the full impact of unconventional monetary policy on its price can be inferred by estimating

$$\begin{aligned} \Delta s_{it} &= \beta_{i,S} \tilde{\Delta} y_t(2) + \beta_{i,L} \tilde{\Delta} m_t^L + u_{it} \\ &= \beta_{i,S} \tilde{\Delta} y_t(2) + \beta_{i,L} \left[\tilde{\Delta} y_t(10) - \lambda_U \tilde{\Delta} y_t(2) \right] + u_{it}, \end{aligned} \tag{3}$$

[9] Recently, these theories have received renewed attention and rigorous micro foundations in the work of Andrés et al. (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; Yellen, 2011).

where u_{it} captures all nonpolicy shocks that can influence the behavior of asset prices on policy announcement days, and the coefficients $\beta_{i,S}$ and $\beta_{i,L}$ determine the relative impact of the "short" and "long" unconventional policy shocks, respectively. Thus, for any vector of the daily market interest rates $\mathbf{s}_t$ that are relevant for determining the real borrowing costs faced by businesses and households, the resulting system implied by equations (2) and (3) can be estimated jointly by nonlinear least squares (NLLS), thereby taking into account the specified cross-equation restrictions.

This empirical approach of quantifying the multi-dimensional aspect of monetary policy differs from that put forth by Gürkaynak et al. (2005a). Specifically, they use a principal components analysis to extract two latent factors from a panel of narrow-window changes in short-term interest rates, which—after a suitable rotation and normalization—are interpreted as the "target" and "path" surprises associated with FOMC announcements during the conventional policy regime. Our approach, by contrast, identifies an orthogonal policy innovation affecting the long-end of the yield curve during the unconventional regime using a single long-term interest rate. While this simplifying assumption may throw out some potentially useful information contained in the term structure of longer-term interest rates, its advantage lies in the fact that it avoids the two-step estimation procedure, which uses generated regressors in the second step.

We apply this methodology to a sample of 47 unconventional policy announcements that took place between November 25, 2008 and October 31, 2013. It is important to emphasize that the sample includes announcements containing communication about LSAPs, the various forms of forward guidance used during this period, or both. The sample also includes several key speeches/testimonies through which the policymakers elaborated on the various aspects of unconventional policy measures being employed by the FOMC, in an effort to elucidate for the market participants the strategic framework guiding their decisions. Because in many of these instances, the announcements considered represent the interpretation of statements and speeches—as opposed to conveying information about the numerical value of the target funds rate—we use a wider 60-minute window surrounding an announcement (10 minutes before to 50 minutes after) to calculate the intraday changes in the 2- and 10-year Treasury yields.[10] In an attempt 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 the 12 announcements most closely identified with the asset purchase programs (see Table 1 for details).

[10]The use of a 60-minute window should allow the market a sufficient amount of time to digest the news contained in announcements associated with unconventional policy measures. To ensure that the "short" and "long" policy shocks reflect the unanticipated changes in monetary policy, we regressed the 60-minute S&P500 (log) return on the two posited policy shocks. The resulting system estimation yielded coefficients of -65.7 on $\tilde{\Delta}y_t(2)$ (robust standard error of 26.4) and -5.88 on $\tilde{\Delta}m_t^L$ (robust standard error 18.7). As in the conventional policy regime, these responses are consistent with our maintained hypothesis that the intraday changes in the 2- and 10-year Treasury yields on the announcement days are predominantly due to the unanticipated changes in the stance of monetary policy.

3 Monetary Policy and Treasury Yields

In order to quantify the effects of monetary policy on the real borrowing costs faced by business and households, it is important to understand how well anchored are long-run inflation expectations and whether changes in the stance of monetary policy influence those expectations. As emphasized by Gürkaynak et al. (2005b), significant movements in inflation expectations in response to policy actions would imply a more limited impact of monetary policy on longer-run real rates, a crucial determinant of economic output in most macro models. Accordingly, this section is devoted to the analysis of the effects of monetary policy shocks on the nominal and real Treasury yield curves across the two different policy regimes.

3.1 Nominal and Real Yields

To obtain a set of benchmark estimates of how the nominal and real Treasury yields respond to policy announcements, we first consider a system where the elements of the vector $\Delta \mathbf{s}_t$ correspond to the daily changes in the 3-, 5-, and 10-year nominal Treasury yields and the 3-, 5-, and 10-year TIPS yields.[11] The results of this exercise for the three sample periods used in our analysis are presented in Table 2.

According to the entries in the table, the reaction of real rates to the unanticipated changes in the target funds rate during the conventional policy regime is roughly similar to that of their nominal counterparts. A surprise cut in the 2-year Treasury yield of 10 basis points leads to a decline between 6 and 8 basis points in the yields on short- and intermediate-dated nominal Treasuries, while the comparable-maturity TIPS yields decline about 1 to 2 basis points less than their nominal counterparts. As a result, such a policy easing leaves the breakeven inflation rates over the medium term roughly unchanged. Yields on long-term TIPS yields also decline about as much as those on their nominal counterparts, implying no change in longer-run inflation compensation in response to a conventional policy easing.

These estimates indicate that a broad-based easing of monetary policy during the conventional period generates a decline in nominal and real interest rates along the entire term structure. Because the impact of policy on the long end is considerably less pronounced, a monetary stimulus orchestrated to lower short-term interest rates causes the Treasury yield curve to steepen appreciably. These results comport with the standard view that in periods when the ZLB is not binding, monetary policy exerts 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 two columns contain the results for the unconventional policy regime. Note that the responses of nominal and real interest rates to policy-induced movements in the 2-year Treasury yield during the unconventional period are much larger than the responses of interest rates to the changes in the 2-year Treasury yield during the conventional policy regime. In addition, when

[11] All zero-coupon (continuously compounded) nominal Treasury yields are derived from the daily estimates of the U.S. Treasury yield curve estimated by Gürkaynak et al. (2007); the zero-coupon (continuously-compounded) TIPS yields are based on the estimates of the real yield curve due to Gürkaynak et al. (2010).

Table 2: Monetary Policy and Nominal and Real Treasury Yields

	Conventional[a]	Unconventional[b]		Non-LSAP[c]	
Dependent Variable	Short	Short	Long	Short	Long
Treasury yield (3y)	0.802	1.263	0.732	1.095	0.689
	(0.092)	(0.292)	(0.153)	(0.218)	(0.107)
Treasury yield (5y)	0.661	1.638	1.184	1.433	1.245
	(0.095)	(0.428)	(0.177)	(0.401)	(0.161)
Treasury yield (10y)	0.387	1.617	1.536	1.228	1.535
	(0.084)	(0.516)	(0.114)	(0.511)	(0.184)
TIPS yield (3y)	0.606	1.611	0.734	1.181	0.796
	(0.111)	(0.374)	(0.174)	(0.300)	(0.222)
TIPS yield (5y)	0.567	1.858	1.121	1.469	1.199
	(0.091)	(0.467)	(0.181)	(0.361)	(0.209)
TIPS yield (10y)	0.386	1.561	1.273	1.116	1.123
	(0.063)	(0.444)	(0.158)	(0.324)	(0.150)
IC response[d]					
3-year	0.196	−0.347	−0.003	−0.086	−0.108
	(0.115)	(0.153)	(0.123)	(0.250)	(0.198)
5-year	0.094	−0.219	−0.063	−0.036	0.046
	(0.096)	(0.121)	(0.099)	(0.226)	(0.164)
10-year	0.002	0.056	0.263	0.112	0.412
	(0.060)	(0.134)	(0.080)	(0.280)	(0.161)

NOTE: For the conventional policy regime, entries under the column heading "Short" denote the OLS estimates of the response coefficients to an unanticipated change in the 2-year Treasury yield. For the unconventional policy regime, entries under the column heading "Short" denote the NLLS estimates of the response coefficients to an unanticipated change in the 2-year Treasury yield, while entries under the column heading "Long" denote the estimates of the response coefficients to an unanticipated change in the 10-year Treasury yield that is orthogonal to the surprise in the 2-year Treasury yield. 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] 47 LSAP- and non-LSAP-related policy announcements (Nov-25-2008–Oct-31-2013).

[c] 35 non-LSAP-related policy announcements (Nov-25-2008–Oct-31-2013).

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

the ZLB is binding, policy surprises to both the short- and longer-term interest rates significantly influence the level and shape of the Treasury yield curve. Importantly, an unconventional easing of monetary policy—through both types of policy surprises—significantly flattens the nominal yield curve. For example, in response to an unanticipated reduction in the 2-year Treasury yield of 10 basis points, the 10/3-year term spread narrows almost 4 basis points, whereas a policy-induced decline in the 10-year Treasury yield of the same magnitude narrows the 10/3-year term spread 8 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 interest rates.

The last two columns of Table 2 report 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 nominal and real yields to the overall stance of unconventional monetary policy, as measured by both the short- and long-run policy surprises. It does, however, damp the impact of unconventional measures on longer-term interest rates, especially through the short-end policy surprises. For the sample that excludes the LSAP-related announcements, the estimates reported in column "Short" indicate that other unconventional policy actions had the greatest impact on short- and intermediate-term 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 larger response coefficient on the 10-year Treasury yield (as measured by the sum of both surprises), compared with the estimate based on the sample that excludes such announcements.

Finally, in response to an unconventional policy easing, yields on short- and intermediate-dated TIPS decline about as much as their nominal counterparts, leaving inflation compensation at those horizons roughly unchanged; although point estimates of the response coefficients on the breakeven rates at the 3- and 5-year horizon are negative and economically nontrivial, the estimates are statistically indistinguishable from zero. At the 10-year maturity, however, our estimates imply a moderate and statistically significant increase in inflation compensation in response to an unconventional policy easing engineered through a surprise in the 10-year Treasury yield. In combination, these results imply that monetary policy had a noticeably greater effect on real long-term interest rates during the unconventional policy period compared with the conventional policy regime.[12]

3.2 Term Premia

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 (see 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.

While term premia cannot be observed directly, they can be inferred from term structure models

[12] A potential problem with using TIPS prices to infer movements in breakeven inflation rates during this period is that liquidity in the secondary market for TIPS deteriorated markedly during the crisis. An increase in the liquidity discount will boost the observed TIPS yields—reflecting an increase in compensation investors demand for holding securities that may be difficult to sell—thereby overstating the decline in inflation compensation; indeed, as shown by D'Amico et al. (2010) and Christensen et al. (2010), such time-varying liquidity premia significantly affect the usefulness of breakeven inflation rates for assessing inflation expectations. In our analysis, the use of daily changes in TIPS yields on policy announcement days should help to mitigate these concerns somewhat, given that a significant portion of the variation in the estimated TIPS liquidity premia appears to occur at lower frequencies. Nonetheless, as a robustness check, we re-did the exercises for the unconventional policy regime reported in Table 2 using rates on inflation swaps—derivatives used widely by market participants to hedge inflation risk—and the results were quantitatively and qualitatively very similar.

Table 3: Monetary Policy, Interest Rate Expectations, and the Term Premia

	Conventional[a]	Unconventional[b]		Non-LSAP[c]	
Dependent Variable	Short	Short	Long	Short	Long
Term premium (10y)	0.193	1.288	1.161	1.103	1.253
	(0.084)	(0.401)	(0.128)	(0.408)	(0.146)
Expectations effect[d]					
	0.194	0.329	0.375	0.125	0.282
	(0.025)	(0.133)	(0.056)	(0.136)	(0.076)

NOTE: For the conventional policy regime, entries under the column heading "Short" denote the OLS estimates of the response coefficients to an unanticipated change in the 2-year Treasury yield. For the unconventional policy regime, entries under the column heading "Short" denote the NLLS estimates of the response coefficients to an unanticipated change in the 2-year Treasury yield, while entries under the column heading "Long" denote the estimates of the response coefficients to an unanticipated change in the 10-year Treasury yield that is orthogonal to the surprise in the 2-year Treasury yield. 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] 47 LSAP- and non-LSAP-related policy announcements (Nov-25-2008–Oct-31-2013).

[c] 35 non-LSAP-related policy announcements (Nov-25-2008–Oct-31-2013).

[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.

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 et al., 2007). 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 by the staff at the Federal Reserve Board.[13]

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 10-year term premium about 2 basis points. These economically and statistically significant movements in term premia prompted by FOMC announcements account for one-half of the decline in the 10-year Treasury yield during this period, while the remainder can be attributed to the expectations component.

During the unconventional policy period, by contrast, an unanticipated policy shock to the 2-year Treasury yield of the same size and magnitude is estimated to lower the 10-year term premium almost 13 basis points.[14] Although the response of longer-term Treasury yields to policy

[13] Kim and Wright (2005) consider a standard latent three-factor Gaussian term structure model, which is estimated using 1-, 2-, 4-, 7-, and 10-year Treasury yields from the Gürkaynak et al. (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.

[14] 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.

announcements during this period is commensurately greater, these estimates imply that more than three-quarters of the policy-induced decline in longer-term rates brought about by changes in the 2-year Treasury yield can be attributed to a reduction in term premia. These magnitudes are roughly similar if the unconventional policy easing is engineered through the long-end of the yield curve. Likewise, these effects are about the same 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 significant majority of the decline in those rates. Despite the sizable response of term premia to the policy 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 interest rates. 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.

4 Monetary Policy and Real Borrowing Costs

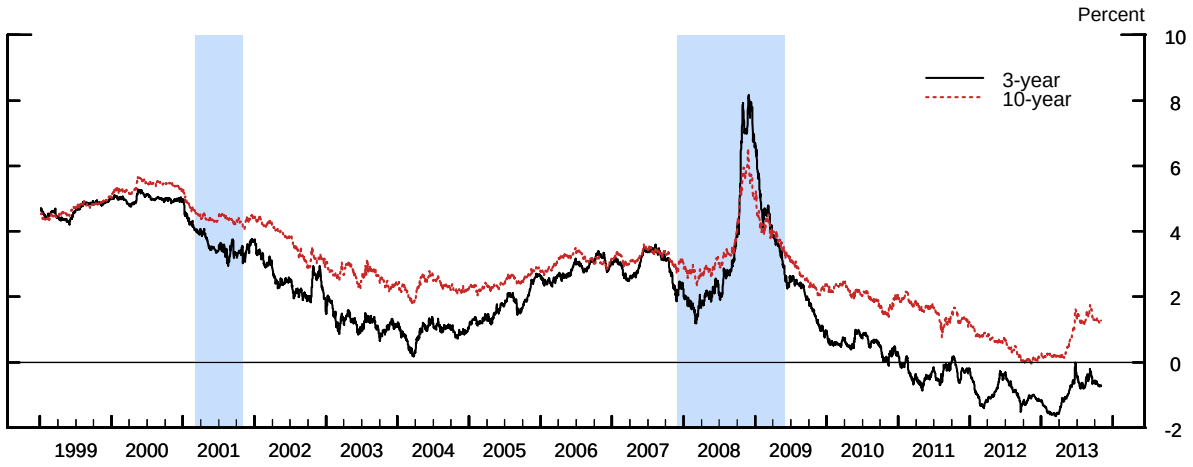
4.1 Real Business Borrowing Costs

In the analysis of business borrowing costs, we consider the U.S. nonfinancial corporate sector and restrict the sample to bonds issued by A- 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.[15] Moreover, given that the median rating in the nonfinancial corporate sector is BBB, this means that our analysis is likely capturing the impact of monetary policy on the borrowing costs of the representative firm.

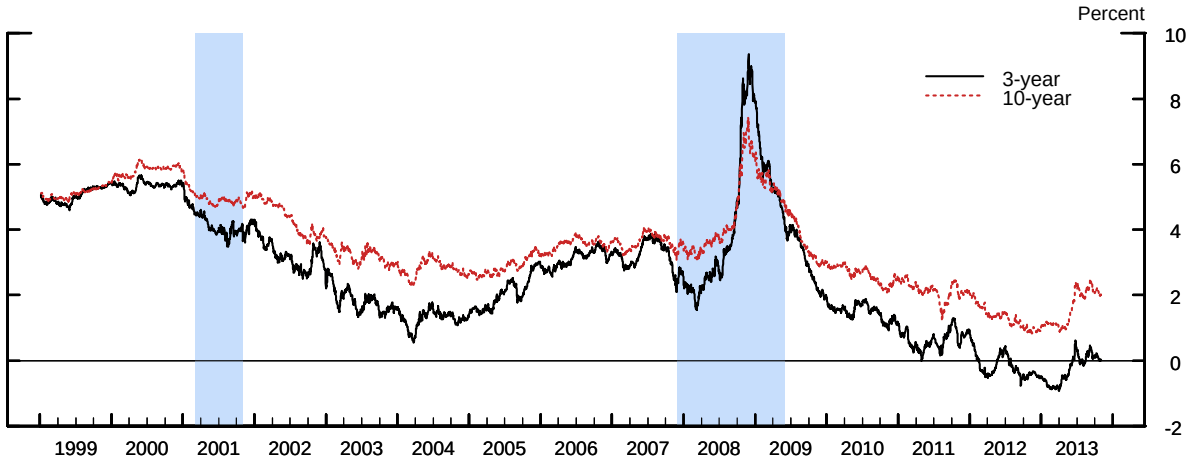
As shown by Faust et al. (2012), a vast majority of corporate bonds issued by nonfinancial corporations are callable; that is, the issuer has—under certain pre-specified conditions—the right to "call" (i.e., redeem) the security prior to its maturity. If a firm's outstanding bonds are callable, policy-induced movements in the Treasury yields will, by changing the value of the embedded call option, have an independent effect on bond prices, complicating the interpretation of the behavior of bond yields and the associated credit spreads (see Duffee, 1998). To abstract from the fluctuations in the embedded call options, we use the option-adjusted corporate bond yields based

[15] 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 et al., 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 market.

Figure 1: Real Corporate Borrowing Costs



(a) A-rated nonfinancial firms



(b) BBB-rated nonfinancial firms

NOTE: Sample period: Jan-04-1999 to Oct-31-2013. Panel (a) depicts the real 3- and 10-year option-adjusted corporate bond yields for A-rated nonfinancial firms, while panel (b) depicts the real 3- and 10-year option-adjusted corporate bond yields for BBB-rated nonfinancial firms. The option adjustment is based on the Bloomberg Fair Value (BFV) model. Real yields are defined as nominal yields less comparable-maturity inflation compensation based on TIPS (see the text for details). The shaded vertical bars represent the NBER-dated recessions.

on the Bloomberg Fair Value (BFV) model to measure corporate borrowing costs.[16] To construct approximate real borrowing costs faced by nonfinancial firms, we subtract from nominal (option-adjusted) corporate bond yields comparable-maturity inflation compensation derived from TIPS; that is, an m-year real corporate borrowing rate is defined as the m-year nominal option-adjusted

[16] As a robustness check, we re-did the analysis using the unadjusted corporate bond yield indexes constructed internally at the Federal Reserve Board and obtained very similar results. We thank Ibraheem Catovic, Eric Engstrom, and Bin Wei for their generous help with the daily corporate bond data.

corporate bond yield less m-year breakeven inflation rate.

The top panel of Figure 1 shows the short-term (3-year) and long-term (10-year) real borrowing costs for A-rated nonfinancial firms, while those of their BBB-rated counterparts are shown in the panel below. Note that between 1999 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 real 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 real corporate 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 real 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, which raises a natural question of how successful were the unconventional policy measures used by the FOMC in lowering real corporate borrowing costs.

The effects of monetary policy on short- and long-term corporate borrowing costs are summarized in Tables 4 and 5, respectively. During the conventional policy regime, the short- and long-term investment-grade nominal corporate bond yields are both highly sensitive to the 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. If anything, an easing of monetary policy during the conventional period implies a small narrowing of credit spreads, especially those on longer-term corporate debt. In economic terms, a conventional easing engineered to reduce the 2-year nominal Treasury yield by 10 basis points leads to a decline of more than 7 basis points in real short-term corporate borrowing costs, while the long-term real borrowing costs are estimated to decline about 6 basis points.

As discussed above, during the unconventional policy regime, movements in longer-term Treasury yields prompted by policy 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 the policy-induced changes in the long-end of the yield curve have an economically and statistically significant effect on both the short- and long-term nominal and real corporate bond yields. According to our estimates, an unconventional policy easing of 10 basis points put through the long-end of the yield curve lowers the real 3-year corporate bond yields for investment-grade firms about 6 basis points, while the impact of such a policy action on long-term corporate borrowing costs is even larger: the real 10-year corporate bond yields for A-rated firms drop 11 basis points, while those of the BBB-rated firms decline almost 10 basis points.

In terms of the total effect of unconventional policy on corporate borrowing costs, the results in Tables 4 and 5 indicate almost a complete pass-through of the unconventional policy actions to business borrowing rates during the ZLB period. For example, an unconventional policy an-

Table 4: Monetary Policy and Short-Term Corporate Borrowing Costs

	Conventional[a]	Unconventional[b]		Non-LSAP[c]	
Dependent Variable	Short	Short	Long	Short	Long
A yield (3y)	0.924	1.134	0.633	1.020	0.512
	(0.110)	(0.285)	(0.163)	(0.311)	(0.238)
BBB yield (3y)	0.947	0.918	0.547	1.014	0.543
	(0.097)	(0.286)	(0.130)	(0.282)	(0.219)
Real yield response[d]					
A (3y)	0.727	1.481	0.635	1.106	0.619
	(0.150)	(0.400)	(0.209)	(0.524)	(0.342)
BBB (3y)	0.751	1.266	0.549	1.100	0.651
	(0.120)	(0.378)	(0.182)	(0.495)	(0.327)
Credit spread response[e]					
A (3y)	0.122	−0.130	−0.099	−0.075	−0.177
	(0.071)	(0.142)	(0.154)	(0.357)	(0.190)
BBB (3y)	0.145	−0.345	−0.185	−0.081	−0.145
	(0.054)	(0.132)	(0.117)	(0.331)	(0.180)

NOTE: For the conventional policy regime, entries under under the column heading "Short" denote the OLS estimates of the response coefficients to an unanticipated change in the 2-year Treasury yield. For the unconventional policy regime, entries under the column heading "Short" denote the NLLS estimates of the response coefficients to an unanticipated change in the 2-year Treasury yield, while entries under the column heading "Long" denote the estimates of the response coefficients to an unanticipated change in the 10-year Treasury yield that is orthogonal to the surprise in the 2-year Treasury yield. 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] 47 LSAP- and non-LSAP-related policy announcements (Nov-25-2008–Oct-31-2013).

[c] 35 non-LSAP-related policy announcements (Nov-25-2008–Oct-31-2013).

[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.

nouncement that reduces the 2-year Treasury yield 10 basis points leaves all credit spreads—other than the 3-year BBB spread—unchanged; the short-term BBB spread, by contrast, is estimated to increase about 4 basis points. An easing of the same magnitude orchestrated through the long-end of the yield curve also leads to no change in most credit spreads—implying a complete pass-through of monetary policy—the one exception being the 10-year BBB credit spread, which is estimated to widen about 3 basis points in response to such a policy easing.

The exclusion of the LSAP-related announcements from the unconventional policy sample yields very similar conclusions regarding the efficacy of unconventional monetary policy. Indeed in that case, the pass-through of policy to short- and long-term borrowing rates is estimated to be one-to-one across the investment-grade corporate sector, as both the "short" and "long" policy surprises imply no movements in credit spreads. The differential behavior of BBB credit spreads between the two unconventional policy samples likely reflects the fact that the full sample contains the LSAP announcements made at the nadir of the financial crisis in late 2008, a period characterized by poor

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

	Conventional[a]	Unconventional[b]		Non-LSAP[c]	
Dependent Variable	Short	Short	Long	Short	Long
A yield (10y)	0.559	1.535	1.374	1.881	1.206
	(0.106)	(0.489)	(0.227)	(0.396)	(0.276)
BBB yield (10y)	0.565	1.425	1.241	1.987	1.253
	(0.104)	(0.418)	(0.173)	(0.399)	(0.255)
Real yield response[d]					
A (10y)	0.557	1.479	1.111	0.769	0.794
	(0.101)	(0.474)	(0.247)	(0.522)	(0.334)
BBB (10y)	0.563	1.369	0.978	0.875	0.840
	(0.088)	(0.406)	(0.208)	(0.522)	(0.315)
Credit spread response[e]					
A (10y)	0.172	−0.082	−0.162	−0.346	−0.329
	(0.072)	(0.265)	(0.171)	(0.538)	(0.270)
BBB (10y)	0.177	−0.192	−0.295	−0.240	−0.283
	(0.057)	(0.248)	(0.119)	(0.532)	(0.263)

NOTE: For the conventional policy regime, entries under the column heading "Short" denote the OLS estimates of the response coefficients to an unanticipated change in the 2-year Treasury yield. For the unconventional policy regime, entries under the column heading "Short" denote the NLLS estimates of the response coefficients to an unanticipated change in the 2-year Treasury yield, while entries under the column heading "Long" denote the estimates of the response coefficients to an unanticipated change in the 10-year Treasury yield that is orthogonal to the surprise in the 2-year Treasury yield. 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] 47 LSAP- and non-LSAP-related policy announcements (Nov-25-2008–Oct-31-2013).

[c] 35 non-LSAP-related policy announcements (Nov-25-2008–Oct-31-2013).

[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.

liquidity in many asset markets. A resulting deterioration in the functioning of asset markets is consistent with the less than a complete pass-through of policy to BBB spreads evidenced in the full unconventional policy sample.

In sum, our estimates imply that the policy-induced declines in the 2-year nominal Treasury yield during the conventional policy regime led to a statistically significant, though economically relatively modest, reductions in real corporate borrowing rates for investment-grade firms—between 5 and 7 basis points in response to a 10 basis point decline in the 2-year Treasury yield. During the unconventional period, by contrast, the responses of real corporate interest rates to such policy moves are more than twice as large, on balance. Finally, the results indicate that a significant portion of the movements in long-term real corporate borrowing rates—around 10 basis points—can be attributed to policy announcements that had an independent impact on the long-end of the

Treasury yield curve.[17]

4.2 Real Mortgage Borrowing Costs

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, which makes it difficult to gauge directly the impact of monetary policy on mortgage borrowing costs faced by the household sector. 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).[18] A widely used benchmark to price and value residential mortgages that is available at the daily frequency is the yield on the 30-year current-coupon agency MBS.

The two series, however, exhibit a high degree of comovement. In fact, a regression of the weekly change in the 30-year FRM rate based on the PMMS 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 0.704 (robust standard error of 0.051) for the unconventional policy period; in both cases, movements in the MBS yield explain almost 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.

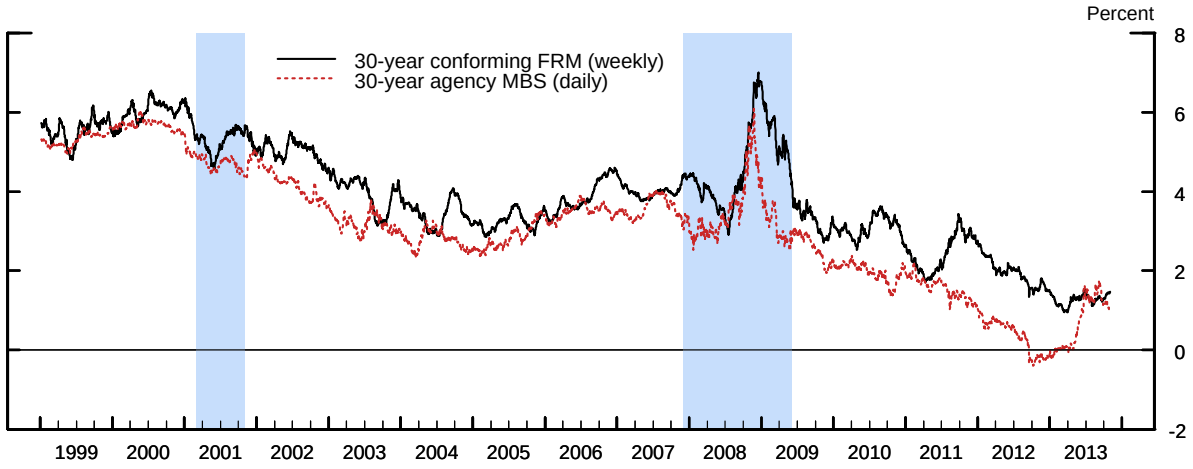
The solid line in the top panel of Figure 2 shows the real (weekly) 30-year FRM rate from the PMMS, while the dotted line shows the daily real yield on the 30-year current-coupon agency MBS. To construct these approximate real mortgage borrowing costs, we subtracted from both nominal interest rates 7-year TIPS-based inflation compensation, thus implicitly assuming that the duration of residential mortgages is seven years, on average. Note that by the end of 2012, real mortgage borrowing costs, according to these two measures, fell to extraordinarily low levels by recent historical standards, a pattern consistent with the empirical evidence of Hancock and Passmore (2011, 2012), who find that the unconventional policy measures employed by the FOMC significantly eased financial conditions in mortgage markets.

As emphasized by Hancock and Passmore (2011, 2012) and Stroebel and Taylor (2012), an alternative way to gauge financial conditions in mortgage markets is to look at the option-adjusted spread (OAS) on the 30-year agency MBS, which is shown in the bottom panel of Figure 2. This spread is measured relative to the yield on comparable-duration Treasury securities and attempts

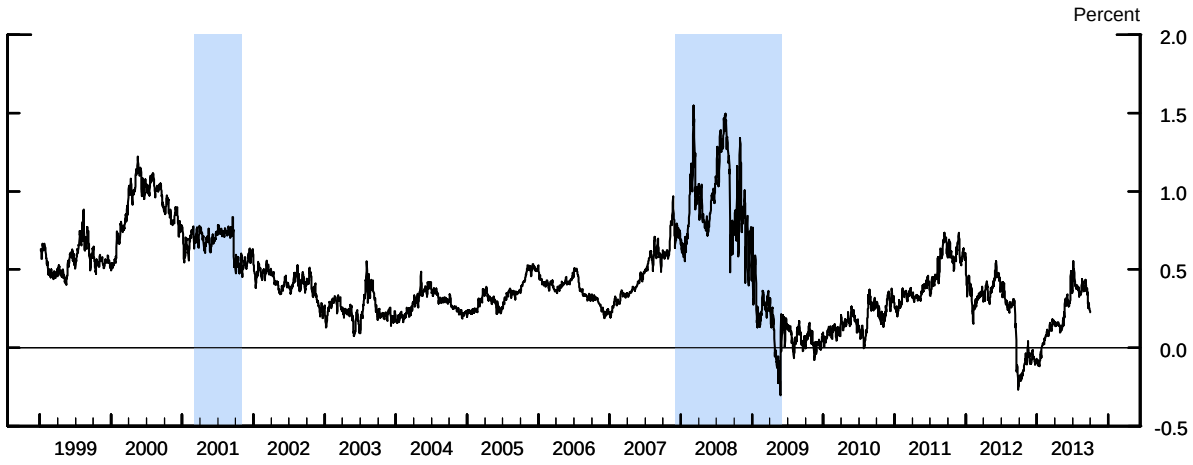
[17] A potential concern with this analysis is that it relies on a 1-day window to measure policy-induced movements in corporate bond yields. Because many corporate bonds trade relatively infrequently, "stale" pricing data will cause the response coefficients based on the 1-day changes to underestimate the impact of policy surprises on corporate bond yields. On the other hand, using multi-day changes in interest rates has its own shortcomings because one runs the risk of capturing other events within the multi-day window. Nonetheless, we also estimated the specifications in Tables 4 and 5 using both the 2- and 5-day changes in interest rates. Though less sharp, the results from this analysis are, on balance, similar to those reported above—we still find a significant impact, in both economic and statistical terms, of policy surprises on real corporate bond yields.

[18] 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 2: Selected Residential Mortgage Market Indicators



(a) Real mortgage market interest rates



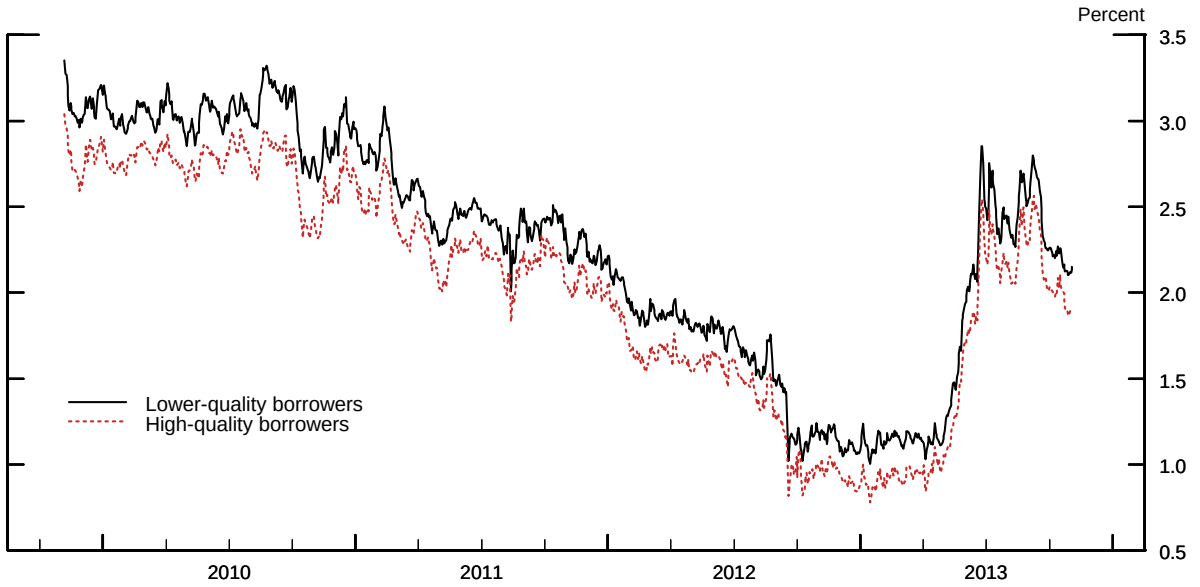
(b) Option-adjusted spread on the 30-year agency MBS

NOTE: Sample period: Jan-04-1999 to Oct-31-2013. The solid line in panel (a) depicts the average real interest rate on the 30-year conforming FRM published by Freddie Mac at a weekly frequency, while the dotted line depicts the daily real 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. Real yields are defined as nominal yields less 7-year inflation compensation based on TIPS (see the text for details). The shaded vertical bars represent the NBER-dated recessions.

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 policy period, the OAS averaged about 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 reflect-

Figure 3: Real Mortgage Interest Rates



NOTE: Sample period: Nov-04-2009 to Oct-31-2013. The solid line depicts the real interest rate on the 30-year conforming FRM for lower-quality borrowers (FICO score between 680 and 750); the dotted line depicts the real interest rate on the 30-year conforming FRM for high-quality borrowers (FICO score of 750 and above). Mortgage interest rates are calculated daily using the LoanSifter data. Real FRM rates are defined as nominal mortgage rates less 7-year inflation compensation based on TIPS (see text for details).

ing 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.[19] Specifically, the staff collects daily rate quotes for standard mortgage products, which are then used to construct benchmark 30-year FRM interest rates. Figure 3 shows the real 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+).[20] 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 residential mortgage markets.

According to Table 6, a conventional policy action that lowers the 2-year nominal Treasury

[19] 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.

[20] To construct these real rates, we again subtracted 7-year TIPS-based inflation compensation from nominal FRM rates.

Table 6: Monetary Policy and Residential Mortgage Market Indicators

	Conventional[a]	Unconventional[b]		Non-LSAP[c]	
Dependent Variable	Short	Short	Long	Short	Long
Agency MBS yield (30y)	0.681	1.099	1.251	0.955	1.011
	(0.085)	(0.261)	(0.379)	(0.314)	(0.193)
OAS Agency MBS	0.140	−0.392	0.177	0.052	0.065
	(0.054)	(0.186)	(0.376)	(0.155)	(0.131)
Real yield response[d]					
Agency MBS yield (30y)	0.639	1.185	1.090	0.922	0.787
	(0.102)	(0.284)	(0.375)	(0.322)	(0.261)

NOTE: For the conventional policy regime, entries under the column heading "Short" denote the OLS estimates of the response coefficients to an unanticipated change in the 2-year Treasury yield. For the unconventional policy regime, entries under the column heading "Short" denote the NLLS estimates of the response coefficients to an unanticipated change in the 2-year Treasury yield, while entries under the column heading "Long" denote the estimates of the response coefficients to an unanticipated change in the 10-year Treasury yield that is orthogonal to the surprise in the 2-year Treasury yield. 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] 47 LSAP- and non-LSAP-related policy announcements (Nov-25-2008–Oct-31-2013).

[c] 35 non-LSAP-related policy announcements (Nov-25-2008–Oct-31-2013).

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

yield 10 basis points is estimated to reduce the 30-year MBS yield almost 7 basis points. Given the estimate of the pass-through coefficient from the secondary to the primary mortgage market of about 0.80, this translates into a reduction in the nominal 30-year FRM rate of about 6 basis points, about the same as in real terms. Note that such an unanticipated policy easing also causes the option-adjusted spread to narrow—though the decline in the spread is statistically significant, it is relatively small in economic terms.

As was the case in the corporate bond market, policy announcements associated with unconventional policy measures have a noticeably larger effects on financial conditions in mortgage markets. 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 almost 12 basis points. Given the estimate of the pass-through coefficient of about 0.7 during this period, this implies a decrease in the 30-year real FRM rate of about 8 basis points. Note that an unconventional policy easing brought about through the long-end of the yield curve has very similar effects on real mortgage borrowing costs.

In spite of a significant reduction in the current-coupon MBS yield in response to a policy stimulus put through the short-end of the yield curve, this dimension of unconventional monetary policy appears to be not as effective as during the conventional policy regime. Though the size of this effect is subject to a considerable uncertainty, the option-adjusted MBS spread is estimated to widen almost 4 basis points in response to a 10 basis point policy-induced decline in the 2-year Treasury yield during the ZLB period. In contrast, an unconventional policy easing engineered through the long-end of the yield curve implies no change in the option-adjusted spread.

Table 7: Unconventional Monetary Policy and Mortgage Interest Rates
(*2-day Changes in Interest Rates*)

	Unconventional[a]		Non-LSAP[b]	
Dependent Variable	Short	Long	Short	Long
FRM rate (30y; FICO $\geq$ 750)	1.465	0.675	1.613	0.926
	(0.572)	(0.321)	(0.652)	(0.300)
FRM rate (30y; 680 $\leq$ FICO $<$ 750)	1.688	0.816	2.184	0.884
	(0.716)	(0.404)	(0.652)	(0.281)
Real FRM rate response[c]				
FICO $\geq$ 750	2.402	0.426	2.433	0.922
	(0.616)	(0.298)	(0.690)	(0.323)
680 $\leq$ FICO $<$ 750	2.625	0.567	3.003	0.880
	(0.677)	(0.279)	(0.712)	(0.305)
Credit spread response[d]				
FICO $\geq$ 750	-0.124	-0.418	-0.202	-0.328
	(0.309)	(0.186)	(0.251)	(0.174)
680 $\leq$ FICO $<$ 750	0.099	-0.278	0.369	-0.370
	(0.261)	(0.163)	(0.231)	(0.187)

NOTE: Entries under the column heading "Short" denote the NLLS estimates of the response coefficients to an unanticipated change in the 2-year Treasury yield, while entries under the column heading "Long" denote the estimates of the response coefficients to an unanticipated change in the 10-year Treasury yield that is orthogonal to the surprise in the 2-year Treasury yield. All specifications include a constant (not reported); heteroskedasticity-consistent asymptotic standard errors are reported in parentheses.
[a] 38 LSAP- and non-LSAP-related policy announcements (Nov-04-2009–Oct-31-2013).
[b] 31 non-LSAP-related policy announcements (Nov-04-2009–Oct-31-2013).
[c] The response of the (approximate) 30-year real FRM interest rate is computed as the difference between the estimated response of the 30-year nominal FRM rate and that of the 7-year inflation compensation.
[d] The response of the FRM-Treasury spread is computed as the difference between the estimated response of the 30-year FRM rate and that of the 7-year nominal Treasury yield.

It is also worth noting that by excluding the LSAP-related announcements from the sample, the estimated effects of the "short" and "long" policy surprises on the option-adjusted spread are economically and statistically indistinguishable from zero, implying a complete pass-through from Treasury yields to the option-adjusted MBS yields. The difference in the estimates between the two samples likely reflects the fact that the most significant LSAP-related announcements were made in late 2008 and 2009, a period in which the calculation of the option-adjusted spread was very difficult. As emphasized by Hancock and Passmore (2011), falling home values, uncertainty about how rising unemployment would affect mortgage defaults, and the lack of homeowner refinancings of mortgages in response to low interest rates (primarily due to homeowners' deteriorating financial conditions) repeatedly surprised MBS investors and impaired their ability to reliably estimate prepayment speeds. As a result, the duration of MBS holdings became difficult to predict, a factor that significantly distorted the functioning of mortgage markets and would imply a less than a complete pass-through of Treasury yields to the option-adjusted MBS yields.

Table 7 reports the estimates of the direct impact of unconventional policy on primary mortgage

interest rates, using the more limited sample of LoanSifter data. In this exercise, we use 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 policy 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 0.78, respectively.

According to the entries in the table, policy announcements associated with unconventional policy measures led to an economically large and statistically significant declines in real mortgage borrowing costs for households of both lower and higher credit quality. The estimates indicate that a policy-induced reduction in the 2-year nominal Treasury yield of 10 basis points lowered the real 30-year FRM rate for both types of applicants about 25 basis points over the two-day window. In contrast, the impact of a similarly-sized easing put through the long-end of the yield curve is about one-third of that engineered solely vis-à-vis the 2-year Treasury yield; moreover, the former effect is estimated rather imprecisely. Excluding the LSAP-related announcements from the sample does not appreciably alter the results, although in that case, a policy-induced decline in the long-end of the yield curve leads to a more precisely estimated effect of "long" policy surprises on the 2-day changes in FRM rates. In general, judging by the estimated response of the FRM-Treasury credit spreads, the pass-through from the policy-induced changes in Treasury yields to primary mortgage rates is essentially one-to-one during the ZLB period.

4.3 Monetary Policy and the Variability of Real Interest Rates

In this section, we present estimates of the proportion of variability of selected real interest rates that is accounted for by monetary policy surprises in the two policy regimes. Specifically, we summarize the relative impact of the "short" and "long" policy surprises by calculating their respective contribution to the total variation in selected real interest rates on policy announcement days. The entries under the column heading "Short & Long" in Table 8 represent the fraction (expressed in percent) of the total variance in the daily change of the specified real interest rate on policy announcement days that can be attributed to the two policy innovations; the entries under the column heading "% Long" denote the portion of that variance that is accounted for by policy surprises designed to directly affect the long-end of the yield curve.

Three comments about these results are in order. First, the overall contribution of monetary policy surprises to the variation in real interest rates is much smaller during the conventional period compared with the ZLB period.[21] Second, the proportion of the variability in real interest rates

[21] Note that this does not imply that policy actions during the conventional policy regime are any less important.

Table 8: Monetary Policy and the Variability of Selected Real Interest Rates

	Conventional[a]		Unconventional[b]	
Real Interest Rate	Short & Long	% Long	Short & Long	% Long
TIPS yield (3y)	17.9	3.9	67.1	22.8
A yield (3y)	21.1	15.2	52.1	20.7
BBB (3y)	25.3	13.4	47.7	21.2
TIPS yield (10y)	17.9	2.2	74.2	48.7
A yield (10y)	19.5	0.0	57.5	44.5
BBB (10y)	22.1	0.0	57.3	42.1
MBS yield (30y)	24.3	3.7	39.2	54.6

NOTE: Entries under the column heading "Short & Long" denote the percentage of total variance in the specified daily real interest rate that can be attributed to the two monetary policy surprises on the policy announcement days: Short = unanticipated change in the 2-year Treasury yield; and Long = unanticipated change in the 10-year Treasury yield that is orthogonal to the surprise in the 2-year Treasury yield. Entries under the column heading "% Long" denote the portion of the variability in the specified real interest rate induced by monetary policy that is due solely to the long-end surprise; see the text for details.

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

[b] 47 LSAP- and non-LSAP-related policy announcements (Nov-25-2008–Oct-31-2013).

accounted for by surprises to the long-end of the yield curve is quite small, on balance, during the conventional policy regime.[22] And lastly, during the unconventional policy regime, policy surprises engineered to have an independent effect on longer-term interest rates account for about one-fifth of the policy-induced variability in shorter-term real interest rates, but almost one-half of the policy-induced variability in their longer-term counterparts. All told, these results are consistent with our previous findings, which document that both the "short" and "long" aspects of the unconventional monetary policy played an important role in the substantial reduction in real borrowing costs observed during the ZLB period.

5 Conclusion

In this paper, we analyze the effects of monetary policy on real borrowing costs measured as the difference between nominal interest rates on corporate bonds and mortgage-related instruments and the comparable-maturity TIPS-based inflation compensation. We estimate the impact 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 overnight federal funds rate; and the unconventional policy regime, a period in which the funds rate was stuck at

This exercise is concerned only with the unanticipated component of monetary policy, and it is entirely possible—in fact, highly likely—that conventional monetary policy has been more systematic and predictable, implying a smaller role for policy surprises.

[22] As shown in Table A-2 in the appendix, the estimates of coefficients associated with the "long" shocks are statistically indistinguishable from zero—especially at long maturities—during this period. This result is consistent with our maintained hypothesis that narrow-window changes in the 2-year Treasury yield bracketing FOMC announcements are sufficient to quantify the impact of monetary policy on real interest rates during the conventional policy regime.

the zero lower bound, and the FOMC conducted policy through a combination of forward guidance and asset purchases. To compare the efficacy of monetary policy across these two regimes, we use changes in the 2-year Treasury yield in a narrow window bracketing policy announcements as policy instrument common to both periods. For the ZLB period, however, we identify an additional policy surprise—namely changes in the 10-year Treasury yield that are orthogonal to the changes in the 2-year yield—an aspect of the unconventional monetary policy that has an independent effect on the long-end of the yield curve.

Our results show that during the conventional policy regime, monetary policy operates by altering shorter-term interest rates relative to long-term interest rates. For example, a 10 basis point policy-induced reduction in the 2-year Treasury yield implies a decline in the 10-year Treasury yield of about 4 basis points. As a result, conventional expansionary monetary policy steepens the yield curve. During the ZLB period, in contrast, an unconventional policy easing of 10 basis points engineered vis-à-vis the the 2-year Treasury yield leads to a 16 basis points 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, the unconventional monetary stimulus delivered through the short-end of the yield curve flattens the yield curve. In combination with the fact that policy surprises to the long-end of the yield curve have economically and statistically significant effects of the entire term structure, there results imply that unconventional policy—through a combination of forward guidance and asset purchases—is very effective in influencing longer-term interest rates.

According to our results, the unanticipated component of both the conventional and unconventional policy measures has essentially no effect on breakeven inflation rates. This implies that nearly all of the policy-induced movement in nominal rates is 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 a model-based measure of the 10-year term premium, our results indicate that policy announcements significantly influence the expected future path of short-term nominal interest rates and that this signaling mechanism appears to be more important during the conventional policy regime.

The effects of both types of monetary policy actions are transmitted fully to real business borrowing costs. A policy-induced decline in the 2-year nominal Treasury yield of 10 basis points during the conventional policy regime is estimated to lower real corporate borrowing rates for investment-grade firms between 5 and 7 basis points. During the ZLB period, by contrast, the responses of real corporate interest rates to such policy moves are more than twice as large, on balance. In addition, a significant portion of the total response in long-term real corporate borrowing rates can be attributed to long-end policy surprises. In terms of the total effect of unconventional policy on real business borrowing costs, our results indicate essentially a complete pass-through of the unconventional policy measures to business borrowing rates during the ZLB period.

The effects of monetary policy on real 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, judging by the implied

response of the option-adjusted MBS-Treasury spread. That said, when we exclude the portion of the unconventional policy sample associated with the most severe dislocations in mortgage markets, the estimated responses of the FRM-Treasury credit spreads imply essentially a one-to-one pass-through from the policy-induced changes in Treasury yields to primary mortgage rates during the ZLB period.

Overall, our analysis indicates that to the extent that monetary policy affects nominal Treasury yields, its effects are also directly transmitted to TIPS yield and passed through to businesses and households in terms of lower real borrowing costs. Importantly, we find no meaningful difference in the efficacy of conventional and unconventional policy measures, as measured by the impact of monetary policy on real borrowing costs. The primary difference in the transmission mechanism between the conventional and unconventional policy regimes appears in the manner through which expansionary monetary policy influences the Treasury yield curve—by steepening the 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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Appendices

A Sensitivity Analysis

This appendix contains two robustness checks of our results. First, we consider a two-dimensional characterization of conventional monetary policy, whereby FOMC announcements affect asset prices vis-à-vis two orthogonal shocks: the "target" and a "path" surprise. The target surprise corresponds to the unexpected change in the target federal funds rate associated with FOMC announcement, whereas the "path" surprise occurs when the FOMC statement contain communication about the likely trajectory of future policy rates. The second robustness examine the role of the "long" shocks during the conventional policy regime.

A.1 Conventional Monetary Policy: A 2-Factor Model

Letting $\tilde{\Delta} y_t(2)$ denote the intraday change in the (on-the-run) 2-year nominal Treasury yield over a 30-minute window surrounding an FOMC announcement (10 minutes before to 20 minutes after) on day t, we assume that

$$\tilde{\Delta} y_t(2) = \lambda_C \tilde{\Delta} m_t^T + \tilde{\Delta} m_t^P, \tag{A-1}$$

where $\tilde{\Delta} m_t^T$ is the target surprise and $\tilde{\Delta} m_t^P$ is the path surprise, assumed to be orthogonal to the unanticipated change in the target federal funds rate. As in Kuttner (2001), the target surprise $\tilde{\Delta} m_t^T$ is constructed as the difference between the announced new target rate and the expectation thereof derived from federal funds futures contracts.[23] Specifically, the target surprise is calculated as the change—with standard adjustments—in the current-month federal funds futures contract rate in the same 30-minute window around the FOMC announcement.[24] Note that our assumptions imply that the path surprise $\tilde{\Delta} m_t^P$ corresponds to the OLS residual from a regression of $\tilde{\Delta} y_t(2)$ on the target surprise $\tilde{\Delta} m_t^T$.

If Δs_{it} denotes the daily change in the price of a financial asset i, then, consistent with our approach characterizing the multi-dimensional aspect of unconventional policy, the impact of conventional monetary policy on its price can then be inferred by estimating

$$\begin{aligned} \Delta s_{it} &= \beta_{i,T} \tilde{\Delta} m_t^T + \beta_{i,P} \tilde{\Delta} m_t^P + u_{it} \\ &= \beta_{i,T} \tilde{\Delta} m_t^T + \beta_{i,P} \left[\tilde{\Delta} y_t(2) - \lambda_C \tilde{\Delta} m_t^T \right] + u_{it}, \end{aligned} \tag{A-2}$$

where u_{it} captures all nonpolicy shocks that can influence the behavior of asset prices on the FOMC announcement days, and the coefficients $\beta_{i,T}$ and $\beta_{i,P}$ determine the relative impact of the target and path shocks, respectively. Using the sample of 83 FOMC announcements during the conventional policy regime and the same set of asset prices as before, we estimate the parameters of the system implied by equations (A-1)–(A-2) jointly by NLLS.

[23] Piazzesi and Swanson (2008) find some evidence of the risk premia in the prices of federal funds futures contracts—as a result, these prices may not represent unbiased expectations of the future trajectory of the funds rate. However, they also show that constructing policy expectations using the method of Kuttner (2001) does not suffer from this bias because the risk premium embedded in futures prices—which fluctuates primarily at business cycle frequencies—is effectively differenced out.

[24] 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).

Table A-1: Conventional Monetary Policy and Selected Interest Rates and Spreads

	2-Factor Model				1-Factor Model	
Dependent Variable	Target	Path	Total	R^2	Total	R^2
Treasury yield (3y)	0.200	0.800	1.000	0.37	0.802	0.37
	(0.166)	(0.152)	(0.119)		(0.092)	
Treasury yield (5y)	0.081	0.714	0.795	0.30	0.661	0.28
	(0.174)	(0.155)	(0.120)		(0.095)	
Treasury yield (10y)	−0.039	0.475	0.435	0.20	0.387	0.15
	(0.134)	(0.121)	(0.108)		(0.084)	
TIPS yield (3y)	0.258	0.535	0.793	0.19	0.606	0.17
	(0.107)	(0.138)	(0.136)		(0.111)	
TIPS yield (5y)	0.213	0.519	0.733	0.22	0.567	0.21
	(0.097)	(0.125)	(0.110)		(0.091)	
TIPS yield (10y)	0.121	0.369	0.490	0.18	0.386	0.18
	(0.075)	(0.097)	(0.071)		(0.063)	
A yield (3y)	0.358	0.839	1.197	0.39	0.924	0.37
	(0.196)	(0.181)	(0.146)		(0.111)	
BBB yield (3y)	0.411	0.831	1.243	0.41	0.947	0.37
	(0.205)	(0.184)	(0.149)		(0.097)	
A yield (10y)	0.082	0.595	0.677	0.20	0.559	0.20
	(0.169)	(0.150)	(0.140)		(0.109)	
BBB yield (10y)	0.129	0.571	0.670	0.20	0.565	0.20
	(0.176)	(0.154)	(0.139)		(0.104)	
MBS yield (30y)	0.269	0.615	0.884	0.33	0.681	0.31
	(0.163)	(0.149)	(0.117)		(0.085)	
OAS MBS[a]	0.169	0.053	0.221	0.23	0.140	0.07
	(0.041)	(0.040)	(0.062)		(0.054)	

NOTE: Sample: 83 FOMC announcements (Jan-04-1999–Nov-24-2008). For the 2-factor model, entries under the column heading "Target" denote the NLLS estimates of the response coefficients to an unanticipated change in the target federal funds rate; entries under the column heading "Path" denote the estimates of the response coefficients to an unanticipated change in the 2-year Treasury yield that is orthogonal to the surprise in target federal funds rate; and entries under the column heading "Total" are the estimates of the combined effect of the two policy surprises. For the 1-factor model—the baseline model used in the paper—entries under the column heading "Total" denote the OLS estimates of the response coefficients to an unanticipated change in the 2-year Treasury yield. All specifications include a constant (not reported); heteroskedasticity-consistent asymptotic standard errors are reported in parentheses.
[a] Option-adjusted spread on the current-coupon 30-year agency MBS.

The results of this exercise are summarized in Table A-1. For comparison purposes, the table also contains the corresponding estimates from the 1-factor model used in the main part of the paper.[25] Several comments are in order. First, over our sample period, the impact of conventional monetary policy on asset prices occurs primarily through path surprises, a dimension of policy that directly influences the near- and medium-term trajectory of the federal funds rate. Second, the combined effect of the two policy surprises on market interest rates is quantitatively very similar to that from

[25] In terms of the notation from equation (1), the 1-factor model is given by $\Delta s_{it} = \alpha_i \tilde{\Delta} y_t(2) + u_{it}$, which imposes the restriction that $\beta_{i,T} - \beta_{i,P}\lambda_C = 0$. Formal tests indicate that we are unable to reject this restriction at conventional significance levels for any asset listed in Table A-1.

Table A-2: The Impact of "Short" and "Long" Shocks on Selected Real Interest Rates During the Conventional Policy Regime

Real Interest Rate	Short	Long	R^2
TIPS yield (3y)	0.606	−0.284	0.18
	(0.111)	(0.312)	
A yield (3y)	0.727	−0.707	0.21
	(0.150)	(0.391)	
BBB yield (3y)	0.751	−0.676	0.25
	(0.120)	(0.410)	
TIPS yield (10y)	0.386	0.129	0.18
	(0.063)	(0.242)	
A yield (10y)	0.557	−0.019	0.20
	(0.101)	(0.313)	
BBB yield (10y)	0.563	−0.048	0.22
	(0.088)	(0.354)	
MBS yield (30y)	0.639	−0.286	0.24
	(0.102)	(0.408)	

NOTE: Sample: 83 FOMC announcements (Jan-04-1999–Nov-24-2008). Entries under the column heading "Short" denote the NLLS estimates of the response coefficients to an unanticipated change in the 2-year Treasury yield, while entries under the column heading "Long" denote the estimates of the response coefficients to an unanticipated change in the 10-year Treasury yield that is orthogonal to the surprise in the 2-year Treasury yield (see the main text for details). All specifications include a constant (not reported); heteroskedasticity-consistent asymptotic standard errors are reported in parentheses.

the 1-factor model, which implicitly combines the effect of the two policy shocks. And lastly, both models explain about the same fraction of the policy-induced variability in both the government and private bond yields on the FOMC announcement days. In sum, these results indicate that the first-order effects of conventional monetary policy actions can be summarized adequately by the intraday changes in the 2-year nominal Treasury yield bracketing FOMC announcements.

A.2 "Long" Shocks During the Conventional Monetary Policy Regime

Table A-2 provides some further detail on the results reported in Table 8 of the main text. Specifically, it reports the estimates of coefficients associated with the "short" and "long" policy surprises during the conventional policy regime.