The Response of Sovereign Bond Yields to U.S. Monetary Policy

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To provide further stimulus to the economy in response to a cascade of shocks that roiled financial markets in the latter part of 2008, the U.S. Federal Reserve started to aggressively employ unconventional monetary policy measures after the Federal Open Market Committee (FOMC) lowered the target for the federal funds rate to its effective lower bound on 16 December 2008. In this paper, we explore whether the Federal Reserve's unconventional monetary policy actions have significantly influenced asset markets beyond U.S. borders. Until recently, the empirical work on this question has been relatively limited. A few prior studies find evidence of cross-country spillovers in the international bond market, but they provide little insight into how the strength and scope of these spillovers compare with those during the conventional monetary policy period. The characteristics of the international spillovers across advanced economies and emerging economies are also an interesting topic with relatively little discussion so far.

Our aim in this paper is to quantify the transmission of U.S. monetary policy shocks to foreign countries, during both the

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conventional monetary policy regime and the unconventional policy period since late 2008. Specifically, we employ the empirical methodology of Gilchrist, López-Salido, and Zakrajšek (2015) to estimate the degree of U.S. monetary policy spillovers—during both the conventional and unconventional policy regimes—on foreign bond yields for a set of advanced foreign and emerging market economies.[1] To compare the efficacy of conventional and unconventional policy measures, we use changes in the two-year nominal U.S. Treasury yield on policy announcement days as a common instrument across the two policy regimes. These movements in the two-year Treasury yield—the "short" surprises—are calculated within a narrow window surrounding FOMC and other policy announcements and thus identify unanticipated changes in the stance of U.S. monetary policy.

To provide a more encompassing stance of monetary policy during the unconventional policy regime, 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. Specifically, we decompose the observed change in the ten-year nominal U.S. Treasury yield over a narrow window bracketing an FOMC announcement into two components: (1) an anticipated component that reflects the effects of policy-induced changes in the two-year U.S. Treasury yield on longer-term yields within that narrow window; and (2) a surprise component that is orthogonal to the changes in the two-year Treasury yield within the same time interval. The second component—the "long" surprise—is intended to capture the direct effect of U.S. unconventional policy measures on longer-term interest rates.

We focus on the impact of U.S. monetary policy actions on the yields of government bonds denominated in local currency issued by selected advanced and emerging economies.[2] The advanced economies are Australia, Canada, Germany, Italy, Japan, and the United Kingdom, while our panel of emerging market economies consists of Brazil, India, South Korea, Mexico, Singapore, and Thailand. Our results indicate that during the conventional policy regime, an unanticipated easing of monetary policy in the United States has a pronounced effect on both the short- and long-term interest rates for advanced foreign countries. In addition, the

1. This empirical approach is also similar to that used by Hanson and Stein (2015) and Gertler and Karadi (2015).

2. The analysis of the effects of U.S. monetary policy spillovers on yields and spreads on dollar-denominated bonds issued by emerging market economies is part of an ongoing project.

expansionary U.S. policy short surprise steepens the yield curve in those countries. For the emerging economies, except for Mexico, the short-term bond yields do not respond to the U.S. monetary policy action, whereas yields on longer-term bonds are more responsive to such short surprises.

During the U.S. unconventional policy regime, monetary stimulus engineered through the short-end of the yield curve has a mixed effect on short-term interest rates in advanced foreign economies. Yet this short policy shock has a significantly larger effect on the foreign long-term bond yields, implying a flattening of the yield curve in those countries. At the same time, an unconventional stimulus orchestrated vis-à-vis the long-end of the U.S. yield curve also has significant effects on the long-term interest rates in Australia, Canada, Germany, and Japan. Moreover, the impact of U.S. unconventional monetary policy on longer-term bond yields in the emerging market economies is similar. As a result, during the unconventional period, an easing of U.S. monetary policy flattens yield curves in both advanced and emerging market economies.

We also calculate the implied pass-through of the U.S. short monetary policy surprises to the longer-term foreign interest rates across the two policy regimes. Our estimates indicate that during the unconventional period, the degree of the pass-through across countries ranges between 50 and 90 percent of the domestic pass-through to the ten-year U.S Treasury yield. We find that, using such a pass-through metric, the degree of international transmission of U.S. policy shocks to long-term foreign bond yields is very similar across the two policy regimes, at least for advanced countries for which we are able to compute the relevant comparison.

Our analysis of the international effects of unconventional U.S. monetary policy on foreign asset prices contributes to a rapidly growing empirical literature that evaluates the transmission of such measures through financial markets. Much of this research focuses on the question of whether purchases of large quantities of Treasury coupon securities by the U.S. Federal Reserve and various forms of forward guidance have altered the level of longer-term Treasury yields. Employing a variety of approaches, Gagnon and others (2011), Krishnamurthy and Vissing-Jorgensen (2011), Swanson (2011), Christensen and Rudebusch (2012), D'Amico and others (2012), Campbell and others (2012), Hamilton and Wu (2012), Wright (2012), D'Amico and King (2013), Li and Wei (2013), and Bauer and Rudebusch (2014) present compelling evidence that the unconventional policy measures employed by the FOMC since the end of 2008 have

significantly lowered longer-term Treasury yields. Our paper is also related to the recent work of Nakamura and Steinsson (2013) and Hanson and Stein (2015), who analyze the effects of U.S. monetary policy on real and nominal Treasury yields over a period that includes both the conventional and unconventional policy regimes.

Regarding the international spillovers of U.S. monetary policy, Neely (2010) finds that the unconventional monetary policy actions by the FOMC substantially reduced international long-term bond yields and the spot value of the dollar. He adopts event-study methods to evaluate the joint effect of unconventional policies on nominal longer-term foreign bond yields denominated in local currencies and the corresponding exchange rates. Bauer and Neely (2014) use dynamic term structure models to uncover the extent to which those declines can be attributed to signaling and portfolio balance channels and find substantial effects of both channels. Bowman, Londoño, and Sapriza (2015) study the transmission of U.S. unconventional monetary policy to emerging market economies. On the study of the broader international effects of unconventional U.S. monetary policies on asset markets, Fratzscher, Lo Duca, and Straub (2013) analyze the global spillovers of the FOMC unconventional monetary policy measures. Rogers, Scotti, and Wright (2014) examine the effects of unconventional monetary policy by the U.S. Federal Reserve, the Bank of England, the European Central Bank, and the Bank of Japan on the corresponding bond yields, stock prices, and exchange rates.

The remainder of the paper is organized as follows. Section 1 outlines our empirical methodology, including a brief discussion of the identification of conventional U.S. monetary policy surprises and a presentation of our framework for estimating the causal effect of U.S. unconventional monetary policy on asset prices. Section 2 contains the estimation results comparing the effects of monetary policy on foreign bond yields across the two policy regimes. Section 3 concludes.

1. 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. As noted above, our approach follows Gilchrist, López-Salido, and Zakrajšek (2015). The key aspect of this 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 U.S. monetary policy actions on foreign bond yields.

Before delving into econometric details, we briefly discuss the dating of the two policy regimes. The sample period underlying our analysis runs from 6 February 1992 to 30 April 2014. We divide this period into two distinct monetary policy regimes: a conventional policy regime, a period in which the primary policy instrument was the federal funds rate; and 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 25 November 2008, when the FOMC announced—outside its regular schedule—that it would initiate a program to purchase the debt obligations of the government-sponsored enterprises (GSEs) and the mortgage-backed securities (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 purchasing of agency debt and MBS, it was also considering purchasing longer-term Treasury securities. With the global financial system in severe turmoil and faced with a rapidly deteriorating economic outlook, the FOMC announced at its 16 December meeting that it was lowering the target federal funds rate to a range of 0 to 0.25 percent—its effective lower bound—a decision ushering in the ELB period.

Given this sequence of events, we assume that the unconventional policy regime began on 25 November 2008 and that prior to that point, the conventional policy regime was in effect. Nearly all of the 143 announcements during the conventional policy period followed regularly scheduled FOMC meetings; only four were associated with intermeeting policy moves.[3] According to this chronology, the last

3. The four intermeeting moves occurred on 3 January 2001; 18 April 2001; 22 January 2008; and 8 October 2008. As is customary in this kind of analysis, we excluded the announcement made on 17 September 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.

FOMC meeting during the conventional policy regime took place on 29 October 2008, at which point the FOMC lowered its target for the federal funds rate 50 basis points, to 1.0 percent.

1.1 U.S. 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, Sack, and Swanson (2005), 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 (2015), Gertler and Karadi (2015), and Gilchrist, López-Salido, and Zakrajšek (2015) and reduce this two-dimensional aspect of conventional policy by assuming that the change in the two-year nominal Treasury yield over a narrow window bracketing an FOMC announcement reflects the confluence of the target and path surprises.[4] Under this assumption, the effect of unanticipated changes in the stance of conventional policy on foreign bond yields can be inferred from

$$\hat{\Delta} y_{i,t+1}(n) = \beta_i(n)\tilde{\Delta} y_t^{US}(2) + \varepsilon_{i,t+1}, \tag{1}$$

where $\hat{\Delta} y_{i,t+1}(n)$ denotes the two-day change in an n-year bond yield for country i, and $\tilde{\Delta} y_t^{US}(2)$ is the intraday change in the (on-the-run)

4. We examine the robustness of this assumption by decomposing the change in the two-year Treasury 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 two-year nominal Treasury yield bracketing FOMC announcements.

two-year nominal U.S. Treasury yield over a 30-minute window surrounding an FOMC announcement (10 minutes before to 20 minutes after) on day t. The stochastic disturbance $\varepsilon_{i,t+1}$ 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 next day. Compared with Gilchrist, López-Salido, and Zakrajšek (2015), the only difference is that we use the two-day change in foreign bond yields because markets in Asia and Europe are closed when the FOMC makes its policy announcements; therefore, we need to use the yield on day $t + 1$ to measure the response of these asset markets to the U.S. monetary policy actions.[5]

Using the sample of 143 FOMC announcements during the conventional policy regime, we estimate equation (1) by ordinary least squares (OLS). Underlying this empirical strategy is the assumption that movements in the two-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. As discussed by Gilchrist, López-Salido, and Zakrajšek (2015), this is a reasonable assumption because we are virtually certain that no other economic news was released within such a short interval of time.

1.2 U.S. Unconventional Monetary Policy

After bringing 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 FOMC 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 known as quantitative easing—in order to put further downward pressure on longer-term market interest rates.

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 16 December 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

5. For Canada, Mexico, and Brazil, we also calculated the one-day changes in yields and use them as a dependent variable in equation (1). All of our results were robust to this alternative measurement.

2009 meeting, the FOMC communicated 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."

Table 1. Key Unconventional Monetary Policy Actions[a]

Date	*Time*[b]	*FOMC*[c]	*Highlights*
25 Nov 2008	08:15	N	Announcement that starts LSAP-I.
01 Dec 2008	08:15	N	Announcement indicating potential purchases of Treasury securities.
16 Dec 2008	14:20	Y	Target federal funds is lowered to its effective lower bound; statement indicating that the Federal Reserve is considering using its balance sheet to further stimulate the economy; first reference to forward guidance: "economic conditions are likely to warrant exceptionally low levels of the federal funds rate for some time."
28 Jan 2009	14:15	Y	"Disappointing"This FOMC statement because of its lacked of concrete language regarding the possibility and timing of purchases of longer-term Treasuries.
18 Mar 2009	14:15	Y	Announcement to purchase Treasuries and increase the size of purchases of agency debt and agency MBS; also, first reference to extended period: "interests rates are likely to remain low for an extended period."
10 Aug 2010	14:15	Y	Announcement that starts LSAP-II.
27 Aug 2010	10:00	N	Chairman's speech at Jackson Hole.
21 Sept 2010	14:15	Y	Announcement reaffirming the existing reinvestment policy.
15 Oct 2010	08:15	N	Chairman's speech at the Federal Reserve Bank of Boston.
03 Nov 2010	14:15	Y	Announcement of additional purchases of Treasury securities.

Table 1. Continued

Date	Time[b]	*FOMC*[c]	*Highlights*
09 Aug 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."
29 Aug 2011	10:00	N	Chairman's speech at Jackson Hole.
21 Sept 2011	14:15	Y	Announcement of the Maturity Extension Program (MEP).
25 Jan 2012	12:30	Y	Second "calendar-based" forward guidance: "keep the federal funds rate exceptionally low at least through late 2014."
20 Jun 2012	12:30	Y	Announcement of continuation of the MEP through end of 2012.
31 Aug 2012	10:00	N	Chairman's speech at Jackson Hole.
13 Sept 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).
12 Dec 2012	12:30	Y	Announcement of an increase in LSAP-III (from $40 billion to $85 billion per month); first "threshold-based" forward guidance: maintain the funds rate near zero for as long as unemployment is above 6.5%, inflation (1-–2 years ahead) is below 2.5%, and long-term inflation expectations remain well -anchored.
19 Jun 2013	14:00	Y	Forward guidance lays out plans to start tapering asset purchases later that year (unemployment rate below 7.5%); and end LSAP-III by mid-2014, when the unemployment rate is around 7.0%.
17 Jul 2013	08:30	N	Chairman's semiannual Monetary Policy Report to the Congress.
18 Sept 2013	14:15	Y	"Asset purchases are not on a preset course."

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

The first round of purchases was completed in March 2010. 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 would maintain the elevated level of holdings of longer-term securities brought about by LSAP-I "by redeploying into longer-term Treasury investments the principal payments from agency securities held in the System Open Market Account (SOMA) portfolio." 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 Treasury securities. Subsequently, the FOMC decided to continue to maintain the level of security holdings attained under the first two purchase programs. 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 in longer-term Treasury securities.

Although these announcements clearly stated the amount of securities that the Federal Reserve anticipated 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 implemented an alternative approach in September 2012 by announcing a monthly rate at which the Federal Reserve would 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 would 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 influenced to an important extent 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 so-called preferred habitat models. 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 Treasury securities, 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 rates; 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 premiums 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 ELB period, changes in the two-year Treasury yield around policy announcements during that period will fail to capture the full impact of unconventional monetary policy on asset prices. Following Gilchrist, López-Salido, and Zakrajšek (2015), we capture this extra dimension of unconventional policy by assuming that

$$\tilde{\Delta} y_t^{US}(10) = \lambda \tilde{\Delta} y_t^{US}(2) + \tilde{\Delta} u_t^{US}, \tag{2}$$

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

As above, let $\hat{\Delta} y_{i,t+1}(n)$ denote the two-day change in the n-year bond yield for country i. Then the full impact of U.S. unconventional monetary policy on this asset can be inferred by estimating

$$\begin{aligned} \hat{\Delta} y_{i,t+1}(n) &= \beta_i(n) \tilde{\Delta} y_t^{US}(2) + \gamma_i(n) \tilde{\Delta} u_t^{US} + \nu_{i,t+1} \\ &= (\beta_i(n) - \gamma_i(n)\lambda) \tilde{\Delta} y_t^{US}(2) + \gamma_i(n) \tilde{\Delta} y_t^{US}(10) + \nu_{i,t+1}, \end{aligned} \tag{3}$$

where $v_{i,t+1}$ captures all nonpolicy shocks that can influence the behavior of asset prices on policy announcement days, and the coefficients $\beta_i(n)$ and $\gamma_i(n)$ determine the relative impact of the short and long U.S. unconventional policy shocks on the n-year bond yield for country i, respectively. The system implied by equations (2) and (4) 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 is similar to that put forth by Gürkaynak, Sack, and Swanson (2005). Specifically, they use a two-step estimation procedure, where the first step involves the use of the 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, however, identifies two orthogonal aspects of unconventional monetary policy—a short and a long policy surprise—using two interest rates and, therefore, relies on less information than is embedded in the entire term structure of interest rates. The advantage of our approach lies in the fact that it avoids the two-step estimation procedure and hence the need to adjust standard errors owing to the use of generated regressors in the second step.

We apply this methodology to a sample of 51 unconventional FOMC policy announcements that took place between 25 November 2008 and 30 April 2014. Our 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 and 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 market participants the strategic framework guiding their decisions. In many of these instances, the announcements represent the interpretation of statements and speeches—as opposed to conveying information about the numerical value of the target funds rate. Consequently, we use a wider 60-minute window surrounding an announcement (10 minutes before to 50 minutes after) to calculate the intraday changes in the two- and ten-year U.S. Treasury yields.[6]

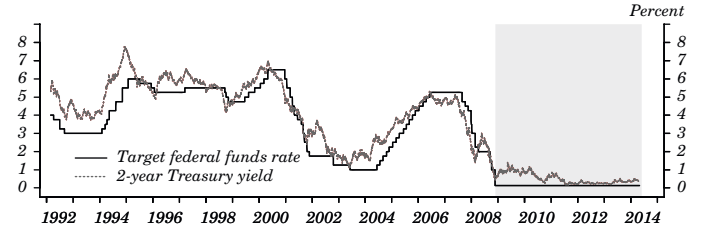
6. The use of a 60-minute window should allow the market a sufficient amount of time to digest the news contained in announcements associated with unconventional policy measures.

The figure shows the interest rate paths and the identified U.S. monetary policy shocks implied by our approach. Panel A shows the target federal funds rate and the two-year U.S. Treasury yield over the entire sample period. Clearly, our sample period is marked by substantial variation in shorter-term interest rates and contains a number of distinct phases of U.S. monetary policy: the 1994–95 tightening phase that followed the jobless recovery in the early 1990s; the tightening phase that preceded the bursting of the tech bubble in early 2001; the subsequent easing of policy in response to a rapid slowdown in economic activity and the emergence of substantial disinflationary pressures; the 2003–04 period of very low interest rates; the gradual removal of monetary accommodation that commenced in the spring of 2004; the aggressive reduction in the target federal funds rate in the early stages of the 2007–09 financial crisis; and the period when the federal funds rate was stuck at the zero lower bound.

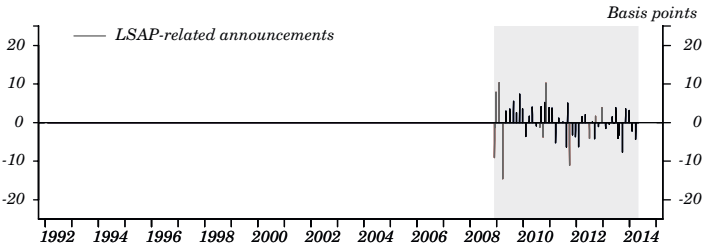
Panels B and C show our U.S. monetary policy surprises. Panel B depicts the sequence of short surprise—that is, the $\tilde{\Delta} y_t^{US}(2)$—associated with the FOMC actions across both the conventional and unconventional periods. Panel C depicts the sequence of long policy surprises, $\tilde{\Delta} y_t^{US}(10)$, measured during the unconventional period. Under the conventional policy regime, the largest (absolute) short policy surprises are associated with the intermeeting policy actions. As shown by the red spikes, the largest (absolute) short surprises during the unconventional policy regime correspond to the early LSAP announcements. Moreover, the largest short surprises during the unconventional period are associated with monetary policy easings. The volatility of this series is dampened over time, as the two-year U.S. Treasury yield reaches values close to zero. The largest movements in long surprises are also associated with LSAP announcements. In contrast to the short surprises, large long surprises are two-sided. In addition, the volatility of this series shows no evidence of attenuation, as the two-year U.S. Treasury yield approaches the zero lower bound.

Figure. The Stance of U.S. Monetary Policy

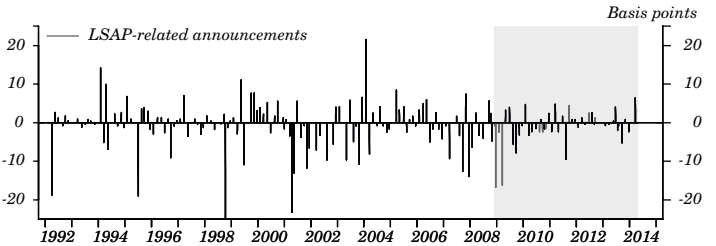
A. Selected U.S. interest rates



B. Short U.S. monetary policy shocks



C. Long U.S. monetary policy shocks



1.3 U.S. Monetary Policy and Domestic Asset Prices

Before we analyze the effects of U.S. monetary policy on foreign bond yields, it is helpful to present the impact of such actions on the asset prices in the United States. Table 2 presents the results using the intraday changes in the ten-year U.S. Treasury yield and the S&P 500 stock price index, as well as the corresponding two-day changes in the two assets. Clearly, the intraday narrow-window changes are much cleaner measures to study the effects of monetary policy surprises. Nevertheless, we also estimate these effects using the two-day changes, in order to compare the results with our benchmark estimation of changes in international bond yields.

Table 2. The Impact of U.S. Monetary Policy on Selected Domestic Asset Prices[a]

	Conventional[b]		*Unconventional*[c]		
Asset (window)	*Short*	R^2	*Short*	*Long*	R^2
Ten-yr Treasury (intraday)	0.533*** (0.058)	0.646	1.407*** (0.204)	-	0.590
Ten-yr Treasury (two-day)	0.506*** (0.122)	0.091	1.770*** (0.425)	-	0.276
S&P 500 (intraday)	–53.126*** (13.348)	0.165	–70.925*** (24.551)	–0.115 (18.686)	0.180
S&P 500 (two-day)	–10.248*** (2.145)	0.134	–14.454** (6.551)	12.240** (6.105)	0.164

* Statistically significant at the 10 percent level.
** Statistically significant at the 5 percent level.
*** Statistically significant at the 1 percent level.
a. For the conventional policy regime, the entries under the column heading "Short" denote the OLS estimates of the response coefficients to a U.S. policy-induced surprise in the two-year Treasury yield. For the unconventional policy regime, the entries under the column heading "Short" denote the NLLS estimates of the response coefficients to a U.S. policy-induced surprise in the two-year Treasury yield, while the entries under the column heading "Long" denote the estimates of the response coefficients to a policy-induced surprise in the ten-year Treasury yield that is orthogonal to the surprise in the two-year yield. All specifications include a constant (not reported). Heteroskedasticity-consistent asymptotic standard errors are reported in parentheses.
b. Sample period: 143 FOMC announcements between 06 February 1992 and 24 November 2008. Intraday asset price changes are measured using a 30-minute window bracketing a policy announcement.
c. Sample period: 51 LSAP- and non-LSAP-related FOMC announcements between 25 November 2008 and 30 April 2014. Intraday asset price changes are measured using a 60-minute window bracketing a policy announcement.

According to the entries in the table, an unanticipated easing of monetary policy that lowers the two-year nominal U.S. Treasury yield by 10 basis points induces a 5 basis point decline in the ten-year nominal U.S. Treasury yield during the conventional monetary policy period. During the unconventional policy period, this monetary stimulus leads to a 15 basis point reduction in the ten-year U.S. Treasury yield. These results are very much in line with the estimates of Hanson and Stein (2015) and Gilchrist, López-Salido, and Zakrajšek (2015).

Next, a monetary stimulus of this magnitude significantly boosts the domestic stock market, by a factor of 50 during the conventional policy regime according to the narrow window estimates and by a factor of 10 using the two-day window. The response of the S&P 500 stock price index to the U.S. short shock is even more pronounced in the unconventional policy period. In contrast, the U.S. long monetary policy shock does not seem to have a separate effect on broad equity prices.

2. U.S. Monetary Policy and Foreign Bond Yields

This section contains our main analysis regarding the effects of U.S. monetary policy shocks on the yields of foreign government bonds across the two policy regimes. We consider here the yields on local-currency-denominated bonds issued by governments of selected advanced and emerging market economies. The advanced countries are Australia, Canada, Germany, Italy, Japan, and the United Kingdom. The emerging market economies are Brazil, India, South Korea, Mexico, Singapore, and Thailand. The selection of the countries is based on data availability, particularly the coverage of the local-currency-denominated government bond yields during the conventional monetary policy regime.[7]

2.1 The Effects of U.S. Conventional Monetary Policy

The responses of foreign bond yields to U.S. monetary policy surprises under the conventional monetary policy regime are presented in tables 3 and 4. Table 3 shows the impact of U.S. monetary policy on government bond yields for the six advanced foreign economies, while

7. For emerging economies, a parallel analysis on dollar-denominated government bond yields is underway.

table 4 shows the results for the six emerging market economies. In both tables, panel A summarizes the estimation results for two-year nominal government bond yields, while those for the ten-year nominal government bond yields are shown in panel B.

As shown in panel A of table 3, a surprise cut in the two-year U.S. Treasury yield of 10 basis points leads to a decline of 4 to 10 basis points in the yields on short-term government bonds issued by advanced foreign economies. The one exception is Japan, which has had very low and stable short-term interest rates since the early 1990s. The strongest international effect of U.S. monetary policy actions is on Canadian bond yields, followed by Australian and U.K. yields. Canadian short-term government bond yields are the most sensitive to U.S. monetary policy moves during the conventional policy regime, a result that underscores the close connection between the two neighboring economies.

Table 3. U.S. Conventional Monetary Policy and Government Bond Yields: Selected Advanced Economies[a]

U.S.policy shock	*Australia*	*Canada*	*Germany*	*Italy*	*Japan*	*United Kingdom*
			A. Two-year nominal government bond yields			
Short	0.621***	0.972***	0.364***	0.427***	0.104	0.518**
	(0.182)	(0.144)	(0.089)	(0.094)	(0.067)	(0.238)
R^2	0.108	0.225	0.121	0.1	0.023	0.1
No. observations	143	143	143	143	143	143
			B. Ten-year nominal government bond yields			
Short	0.483***	0.435***	0.262***	0.348***	0.106	0.407*
	(0.162)	(0.127)	(0.099)	(0.117)	(0.066)	(0.218)
R^2	0.084	0.088	0.069	0.074	0.012	0.069
No. observations	143	143	143	131	122	143

* Statistically significant at the 10 percent level.
** Statistically significant at the 5 percent level.
*** Statistically significant at the 1 percent level.
a. Sample period: 143 FOMC announcements between 06 Februrary 1992 and 24 November 2008. The dependent variable is a two-day change bracketing an FOMC announcement in two-year the government bond yield (panel A) and the ten-year government bond yield (panel B) for the specified country. The entries labeled "Short" denote the OLS estimates of the response coefficients to a U.S. policy-induced surprise in the two-year Treasury yield. All specifications include a constant (not reported). Heteroskedasticity-consistent asymptotic standard errors are reported in parentheses.

Table 4. U.S. Conventional Monetary Policy and Government Bond Yields: Selected Emerging Economies[a]

U.S. policy shock	*Brazil*	*India*	*South Korea*	*Mexico*	*Singapore*	*Thailand*
A. Two-year nominal government bond yields						
Short	1.221	0.145	–0.103	0.678***	0.416***	0.161
	(1.279)	(0.156)	(0.103)	(0.186)	(0.119)	(0.127)
R^2	0.025	0.008	0.007	0.085	0.213	0.022
No. observations	73	59	70	49	92	71
B. Ten-year nominal government bond yields						
Short	3.440***	0.230***	–0.058	0.508*	0.146	0.455***
	(1.153)	(0.086)	(0.119)	(0.278)	(0.114)	(0.173)
R^2	0.233	0.05	0.002	0.025	0.02	0.107
No. observations	25	66	64	60	89	69

* Statistically significant at the 10 percent level.
** Statistically significant at the 5 percent level.
*** Statistically significant at the 1 percent level.
a. Sample period: 143 FOMC announcements between 06 Februrary 1992 and 24 November 2008. The dependent variable is a two-day change bracketing an FOMC announcement in the two-year government bond yield (panel A) and the ten-year government bond yield (panel B) for the specified country. The entries labeled "Short" denote the OLS estimates of the response coefficients to a U.S. policy-induced surprise in the two-year Treasury yield. All specifications include a constant (not reported). Heteroskedasticity-consistent asymptotic standard errors are reported in parentheses.

The response of the long-term government bond yields in advanced foreign economies to the policy-induced movement in the U.S. two-year Treasury yield is also significant, except for Japan. The estimates indicate that an easing of U.S. monetary policy during the conventional period generates an overall decline in foreign interest rates along the entire term structure. Moreover, the two-year foreign bond yields are more responsive to the U.S. short monetary policy shock than the ten-year bond yields. These results imply that a U.S. monetary policy easing induces a widening of the foreign yield spreads between long- and short-term nominal interest rates. With regard to the domestic impact of the U.S. monetary policy, the standard view is that in periods when the ELB is not binding, U.S. monetary policy influences the short end of the yield curve, and an easing steepens the yield curve. Our results point to a similar effect on the foreign government bond yield curves in major advanced foreign economies.

In comparison, as shown in table 4, the effects of conventional U.S. monetary policy on government bond yields in emerging economies is weaker and less pervasive. For short-term interest rates, a surprise cut in the two-year U.S. Treasury yield leads to a significant reduction in the two-year government bond yields in Mexico and Singapore. For the other emerging economies in our sample, the effect of the U.S. policy short shock is insignificant. For long-term interest rates, the ten-year bond yields for Brazil, India, and Thailand are most responsive to the U.S. monetary policy short shocks. The response coefficients for the Brazilian ten-year bond yield is especially large, which may reflect the short estimation period because the data are available only starting in 2006. Another remark regarding the results in table 4 is that the markets for emerging countries' government bonds denominated in local currency are significantly less developed, especially in the early part of our sample period. As a result, the limited liquidity of these bonds is a potential concern, which could influence our results.

2.2 The Effects of U.S. Unconventional Monetary Policy

As discussed above, narrow-window changes in the two-year U.S. Treasury yield bracketing FOMC announcements during the ELB period fail to capture the full impact of unconventional monetary policy on asset prices. The estimation results reported in tables 5 and 6 show the effects of both the short and long unconventional U.S. policy shocks on foreign bond yields.

As shown in panel A of table 5, Australia and the United Kingdom are the only two advanced foreign economies whose short-term interest rates move significantly in response to the short U.S. policy shock, as measured by a policy-induced change in the two-year U.S. Treasury yield during the unconventional period. By contrast, short-term interest rates in other advanced economies do not respond to the short U.S. policy shock. Moreover, the long U.S. policy shock does not affect the yields on short-term government bonds, except for those of Canada, where the estimate of the response coefficient is marginally significant. This result is consistent with the characterization of the two-dimensional U.S. unconventional policy shocks, as the long shock has—by construction—no effect on the U.S. shorter-term interest rates.

According to panel B, the response of the ten-year foreign bond yields to the short U.S. policy shock is significant for all countries in our sample. Overall, the estimated response coefficients are smaller than the estimate of the corresponding response coefficient on the

ten-year U.S. Treasury yield (table 2), although there is a significant heterogeneity across countries: in response to an unanticipated decline in the two-year U.S. Treasury yield of 10 basis points, the ten-year government bond yields decline as little as 2 basis points (Japan) and up to 13 basis points (Australia). The long U.S. policy shock also has significant impact on the foreign long-term interest rates, except for those in Italy and the United Kingdom, two countries that investors considered riskier among this group of countries after the global financial crisis.

Table 5. U.S. Unconventional Monetary Policy and Government Bond Yields: Selected Advanced Economies[a]

U.S. policy shock	*Australia*	*Canada*	*Germany*	*Italy*	*Japan*	*United Kingdom*
	A. Two-year nominal government bond yields					
Short	0.878***	0.29	0.555*	0.43	0.126	0.768***
	(0.212)	(0.260)	(0.315)	(0.384)	(0.090)	(0.236)
Long	0.224	0.329*	–0.024	0.032	–0.055	–0.1
	(0.184)	(0.181)	(0.200)	(0.296)	(0.052)	(0.170)
R^2	0.238	0.13	0.12	0.023	0.136	0.148
No. observations	51	51	51	51	51	51
	B. Ten-year nominal government bond yields					
Short	1.344***	0.872***	0.714***	1.045***	0.223***	0.891***
	(0.239)	(0.250)	(0.210)	(0.266)	(0.076)	(0.294)
Long	0.553**	0.904***	0.520**	0.305	0.151**	0.358
	(0.225)	(0.212)	(0.204)	(0.240)	(0.070)	(0.281)
R^2	0.384	0.478	0.217	0.206	0.188	0.171
No. observations	51	51	51	51	51	51

* Statistically significant at the 10 percent level.
** Statistically significant at the 5 percent level.
*** Statistically significant at the 1 percent level.
a. Sample period: 51 LSAP- and non-LSAP-related FOMC announcements between 25 November 2008 and 30 April 2014. The dependent variable is a two-day change bracketing an FOMC announcement in two-year the government bond yield (panel A) and the ten-year government bond yield (panel B) for the specified country. The entries labeled "Short" denote the NLLS estimates of the response coefficients to a U.S. policy-induced surprise in the two-year Treasury yield, while the entries labeled "Long" denote the estimates of the response coefficients to a policy-induced surprise in the ten-year Treasury yield that is orthogonal to the surprise in the two-year yield. All specifications include a constant (not reported). Heteroskedasticity-consistent asymptotic standard errors are reported in parentheses.

Table 6. U.S. Unconventional Monetary Policy and Government Bond Yields: Selected Emerging Economies[a]

U.S. policy shock	*Brazil*	*India*	*South Korea*	*Mexico*	*Singapore*	*Thailand*
	A. Two-year nominal government bond yields					
Short	1.733***	0.285	0.566	0.937**	0.116	1.028**
	(0.422)	(0.327)	(0.377)	(0.404)	(0.110)	(0.427)
Long	0.886**	0.838	0.177	−0.125	0.126	−0.136
	(0.453)	(0.581)	(0.301)	(0.289)	(0.177)	(0.236)
R^2	0.179	0.042	0.113	0.16	0.04	0.287
No. observations	44	43	51	51	51	48
	B. Ten-year nominal government bond yields					
Short	2.271***	0.918***	0.862***	1.479**	0.627***	1.792***
	(0.512)	(0.301)	(0.143)	(0.620)	(0.228)	(0.426)
Long	1.380**	0.399	0.456***	0.396	0.506**	0.579*
	(0.652)	(0.290)	(0.115)	(0.494)	(0.227)	(0.311)
R^2	0.169	0.306	0.4	0.19	0.296	0.415
No. observations	44	43	51	51	51	48

* Statistically significant at the 10 percent level.
** Statistically significant at the 5 percent level.
*** Statistically significant at the 1 percent level.
a. Sample period: 51 LSAP- and non-LSAP-related FOMC announcements between 25 November 2008 and 30 April 2014. The dependent variable is a two-day change bracketing an FOMC announcement in the two-year government bond yield (panel A) and the ten-year government bond yield (panel B) for the specified country. The entries labeled "Short" denote the NLLS estimates of the response coefficients to a U.S. policy-induced surprise in the two-year Treasury yield, while the entries labeled "Long" denote the estimates of the response coefficients to a policy-induced surprise in the ten-year Treasury yield that is orthogonal to the surprise in the two-year yield. All specifications include a constant (not reported). Heteroskedasticity-consistent asymptotic standard errors are reported in parentheses.

These results are consistent with the idea that bonds of certain countries provided a safe haven for investors in fixed-income markets during and following the global financial crisis. In particular, the results imply that the U.S. unconventional monetary policy surprises are transmitted to the long-term borrowing costs of advanced foreign economies whose long-term bonds are considered good substitutes for U.S. Treasury securities. Our findings also provide support for the relevance of a portfolio rebalancing channel of international spillovers. Because the impact of the long U.S. policy shock on the ten-year U.S. Treasury yield is normalized to one, the pass-through of this shock to the foreign government bond yields is, on average, about 50 percent.

In sum, when the ELB is binding, policy surprises to both the short- and long-term U.S. interest rates significantly influence the ten-year nominal government bond yields in advanced foreign economies. These findings indicate that the unconventional policy actions used by the FOMC during the current ELB period generate spillovers to the international markets for government bonds. The evidence on international spillovers to foreign yields from the two-dimensional policy surprise measure is consistent with the findings of Hausman and Wongswan (2011) and Bauer and Neely (2014), who measure the target and path U.S. monetary policy surprises and find that path surprises have significant and positive effects on foreign bond yields.

For the emerging market economies (table 6), the two- and ten-year government bond yields for some emerging market economies are also responsive to unanticipated changes in the stance of U.S. monetary policy stance during the unconventional U.S. monetary policy regime. The difference across countries is also evident. Mexico is the only country where movement in short-term interest rates are still in synchronization with the U.S. monetary policy actions, a result that underscores the tight economic linkages between the two economies, as well as the Mexican exchange rate policy. Brazil and Thailand are the other two countries where short-term interest rates respond to the short U.S. policy shock. As evidenced by panel B, our estimates imply that U.S. monetary policy announcements prompt significant movements in the long-term interest rates in emerging market economies. The ten-year bond yields for our sample of countries decline between 6 and 22 basis points in response to a 10 basis point policy-induced cut in the two-year U.S. Treasury yield. This result shows that the FOMC actions generate sizable movements in long-term interest rates for emerging economies. Moreover, a comparison of coefficient estimates in panel A relative to panel B again implies that during the unconventional period, a policy-induced cut in the two-year U.S. Treasury yield flattens the yield curve across the emerging market economies. This effect on the term spread is remarkably uniform across countries, varying from a low of 0.3 in the case of South Korea to a high of 0.76 in the case of Thailand. On average, a 10 basis point increase in the two-year U.S. Treasury implies a 5 basis point increase in the ten-year/two-year yield spread across the emerging market economies.

Although short U.S. policy shocks have significant effects on all emerging market long-term bond yields—and hence on the slope of the yield curve in these countries during the unconventional period—the transmission of the long U.S. policy shock to the ten-year bond yields

of emerging market economies during this period is more varied. The long shock has a significant effect on longer-term bond yields in Brazil, South Korea, Singapore, and Thailand, but it has a less pronounced effect on long-term bond yields in India and Mexico.

2.3 Comparison of the Implied Pass-through

Finally, we calculate the implied pass-through of the short U.S. monetary policy surprises to long-term foreign interest rates. Table 7 presents the results: panel A shows the estimates of the implied pass-through of U.S. monetary policy short surprises to the foreign ten-year government bond yield of advanced foreign economies during the conventional policy regime; panel B contains the estimates for the advanced during the unconventional regime; and panel C presents the results for emerging economies during the unconventional regime.[8] The implied pass-through is calculated as the ratio of the regression coefficient $\beta_i(10)$ for the two-day change in the foreign ten-year bond yield to the regression coefficient λ based on the intraday data as reported in table 2; we also report the p value of the test that the implied pass-through coefficient is equal to the response coefficient on the two-year government bond yields for the specific country.

According to our estimates, the level of the pass-through across countries ranges between 50 and 90 percent of the domestic pass-through to the ten-year U.S. Treasury yield for the advanced foreign economies, with the exception of Japan, where the implied pass-through is only about 20 percent. This suggests that the long end of the foreign yield curve is as responsive to the U.S. monetary policy short shock as the U.S. yield curve. Comparing panel A and panel B for the advanced foreign economies, one can see that the degree of international transmission of U.S. policy shocks to long-term foreign bond yields is very similar across the two policy regimes. As for the emerging market economies, the implied pass-through is also significant and ranges between 45 and 160 percent of that for the U.S. long-term interest rate. Lastly, although pass-through coefficient estimates are less than one, the test results indicate that for almost all the countries in our sample, one cannot reject one-for-one pass-through

8. Because the number of observations we have for both the two- and ten-year bond yields around the U.S. monetary policy action dates is very small, we do not compute the implied pass-through for the emerging market economies during the U.S. conventional monetary policy regime.

at the long end of the yield curve, in response to an unanticipated change in the U.S. monetary policy stance engineered vis-à-vis the short end of the yield curve.

Table 7: Pass-through of Short U.S. Policy Surprise to Ten-Year Foreign Bond Yields[a]

Period	*Australia*	*Canada*	*Germany*	*Italy*	*Japan*	*United Kingdom*
			A. Conventional monetary policy[b]			
	0.907***	0.816***	0.492***	0.632***	0.192*	0.764*
	(0.269)	(0.205)	(0.167)	(0.187)	(0.112)	(0.412)
Pr > W	0.729	0.371	0.002	0.049	0	0.567
			B. Unconventional monetary policy[c]			
	0.955***	0.620***	0.508***	0.743***	0.158**	0.633**
	(0.231)	(0.158)	(0.186)	(0.266)	(0.07)	(0.302)
Pr > W	0.846	0.016	0.008	0.334	0	0.225
	Brazil	*India*	*South Korea*	*Mexico*	*Singapore*	*Thailand*
	1.599***	0.647**	0.613***	1.051*	0.446***	1.249***
	(0.519)	(0.313)	(0.129)	(0.605)	(0.172)	(0.433)
Pr > W	0.248	0.26	0.003	0.932	0.001	0.566

* Statistically significant at the 10 percent level.
** Statistically significant at the 5 percent level.
*** Statistically significant at the 1 percent level.
a. The entries in the table denote the estimates of the implied pass-through of short U.S. monetary policy surprises to the ten-year government bond yield for advanced economies during the conventional policy regime (panel A) and the unconventional policy regime (panel B), as well as for emerging economies during the unconventional policy regime (panel C). Heteroskedasticity-consistent asymptotic standard errors are reported in parentheses. Pr > W denotes the p value of the test of the null hypothesis that the implied pass-through coefficient is equal to one.
b. Sample period: 143 FOMC announcements between Feb-06-1992 and Nov-24-2008.
c. Sample period: 51 LSAP- and non-LSAP-related FOMC announcements between Nov-25-2008 and Apr-30-2014.

3. Conclusion

This paper compares the impact of U.S. conventional monetary policy on foreign government bond yields with that of the unconventional measures employed after the target federal funds rate hit the effective lower bound. For this latter period, we identify two U.S. monetary policy surprises: changes in the two-year U.S. Treasury yield around FOMC announcements and changes in the ten-year U.S. Treasury yield that are orthogonal to those of the two-year yield. We find that the U.S. monetary policy has a pronounced effect on both the short- and long-term interest rates in advanced foreign countries. An expansionary U.S. monetary policy steepens the foreign yield curve during the conventional period and flattens the foreign yield curve during the unconventional period. While there is a significant degree of heterogeneity across advanced and emerging economies, our estimates of U.S. monetary policy pass-through imply that the average international spillover effect of U.S. unconventional policy is comparable to that of conventional policy.

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