International Spillovers of Monetary Policy: Conventional Policy vs. Quantitative Easing

Curcuru, Stephanie E., Steven B. Kamin, Canlin Li, and Marius Rodriguez

Please cite paper as:
Curcuru, Stephanie E., Steven B. Kamin, Canlin Li, and Marius Rodriguez (2018). International Spillovers of Monetary Policy: Conventional Policy vs. Quantitative Easing. International Finance Discussion Papers 1234.

https://doi.org/10.17016/IFDP.2018.1234

International Finance Discussion Papers
Board of Governors of the Federal Reserve System

Number 1234
August 2018

Board of Governors of the Federal Reserve System

International Finance Discussion Papers

Number 1234

August 2018

International Spillovers of Monetary Policy: Conventional Policy vs. Quantitative Easing

Stephanie E. Curcuru, Steven B. Kamin, Canlin Li, and Marius Rodriguez

International Spillovers of Monetary Policy: Conventional Policy vs. Quantitative Easing*

Stephanie E. Curcuru, Steven B. Kamin

Canlin Li and Marius Rodriguez

Board of Governors of the Federal Reserve System

August 2, 2018

Abstract

This paper evaluates the popular view that quantitative easing exerts greater international spillovers than conventional monetary policies. We employ a novel approach to compare the international spillovers of conventional and balance sheet policies undertaken by the Federal Reserve. In principle, conventional monetary policy affects bond yields and financial conditions by affecting the expected path of short rates, while balance-sheet policy is believed act through the term premium. To distinguish the effects of these two types of policies we use a term structure model to decompose longer-term bond yields into expected short-term interest rates and term premiums. We then examine the relative effects of changes in these two components of yields on changes in exchange rates and foreign bond yields. We find that the dollar is more sensitive to expected short-term interest rates than to term premia; moreover, the rise in the sensitivity of the dollar to monetary policy announcements since the GFC owes more to an increased sensitivity of the dollar to expected interest rates than to term premiums. We also find that changes in short rates and term premiums have similar effects on foreign yields. All told, our findings contradict the popular view that quantitative easing exerts greater international spillovers than conventional monetary policies.

Keywords: monetary policy, international spillovers, term premium

JEL Codes: E5, F3.

*We are grateful to attendees at the Hong Kong Monetary Authority, Federal Reserve Board, and Federal Reserve Bank of Atlanta Joint Conference: "Unconventional Monetary Policy: Lessons Learned" and seminar participants at Vanderbilt University and the Peterson Institute for International Economics for helpful comments and suggestions. We thank Chelsea Hunter for excellent research assistance. The views expressed are those of the authors and not necessarily those of the Federal Reserve Board or the Federal Reserve System.

I. Introduction

The years immediately following the global financial crisis (GFC) were marked by a surge in capital flows to emerging market economies (EMEs). Observers expressed concerns that these flows were contributing to loose financial conditions, excessive credit growth and unwanted exchange rate appreciation in the recipient economies. And because those flows coincided with the aggressive expansion of balance sheets (also known as quantitative easing, or QE) by central banks in the United Kingdom, United States, and eventually other advanced economies, many concluded that these balance sheet policies were especially influential in propelling those flows. For example, Brazilian President Dilma Rousseff referred to quantitative easing as a "monetary tsunami" that was leading to currency wars. (See discussion in Bernanke, 2015.)

In part reflecting these considerations, many observers take it as given that the international spillovers of quantitative easing, and in particular its effects on exchange rates and foreign interest rates, are greater than those of conventional monetary policy operating through changes in policy interest rates. However, the evidence for this view is scant, in part because it is difficult to estimate the spillover effects of balance sheet policies. Vector Auto regression (VAR) analyses based on central bank balance-sheet data generally suffer from severe identification problems, especially as much of the impact of balance sheet policies on asset prices takes place at the time of their announcement rather than during their subsequent implementation. Event studies focusing on announcement effects of balance-sheet policies on exchange rates of foreign interest rates avoid this pitfall, but the relative paucity of QE announcements in any one country reduces the accuracy of this approach. Rogers, Scotti and Wright (2016b) uses a hybrid "external instruments" approach which supplements the VAR with information from event studies to strengthen the identification of policy shocks. Finally, some event studies circumvent these

problems by comparing the effects of all monetary policy announcements in the pre- and post-GFC periods. For example, Glick and Leduc (2015), Ferrari, Kearns, and Schrimpf (2016), and Curcuru (2017) show that the responsiveness of the exchange rate to U.S. monetary policy announcements rose after the GFC. On the assumption that pre-GFC policy actions were mainly conventional while post-GFC actions were mainly unconventional, this could imply greater spillovers of unconventional policies such as quantitative easing. However, it is almost impossible to know how much any change in announcement effects owes to changes in policy and how much to the dramatic changes in the economic environment that followed the GFC.

In this paper, we employ a novel approach to comparing the international spillovers of conventional and balance sheet policy. We start by noting that longer-term bond yields can be decomposed into two components: the expected short-term interest rate over the period to maturity, and the term premium, which reflects compensation for the risk of holding the bond. In principle, conventional monetary policy affects bond yields and financial conditions more generally by affecting the current short-term interest rate and the expected path of short rates in the future. By comparison, balance-sheet policy – in particular, purchases of longer-maturity bonds – is believed to act by altering the supply/demand balance in the bond market and thus affecting the term premium.

This dichotomy is not always clear-cut in practice: conventional policy actions may affect term premiums (see Bhattari and Neely 2016) and quantitative easing announcements are believed to often signal future policy rates, as suggested in Woodford (2012). Nevertheless, it provides a useful benchmark for our analysis, and we show below that, in fact, conventional policies during the pre-GFC period mainly affected expected rates, while post-GFC actions when policy rates were pinned near zero mainly affected term premiums.

Based on these considerations, we examine the impact of Federal Reserve monetary policy announcements during the period 2002 to 2017. Focusing on the change in U.S. 10-year Treasury yields during one-day windows around the announcement dates, we use term structure models to decompose these moves into changes in expected short-term interest rates and changes in term premiums. We then examine the relative effects of changes in these two components of the 10-year Treasury yield on exchange rates and foreign bond yields during the same period.

Our findings clearly contradict the popular view that quantitative easing exerts greater international spillovers than conventional monetary policies. Turning first to effects of Federal Reserve announcements on the exchange rate, we find that a 1 percentage point rise in expected interest rates after announcements leads to a 7.5 percent rise in the Federal Reserve Board's trade-weighted dollar index against foreign advanced economies, whereas a 1 percentage point rise in the term premium boosts that measure of the dollar by only 2.3 percent (see Table 2). Similarly, the value of the dollar against United States' EME trading partners' currencies (excluding China and other countries that peg their currencies against the dollar) rises 4.4 percent after a 1 percentage point rise in U.S. expected interest rates, but rises only 1.4 percent in response to a comparably-sized rise in term premiums (see Table 2). Moreover, in regards to the finding, noted above, that the sensitivity of the dollar to monetary policy announcements has risen since the GFC, we find that most of this rise owes to an increased sensitivity of the dollar to expected interest rates rather than to term premiums.

Perhaps more surprisingly, we also find little evidence that quantitative easing exerts greater effects on foreign bond yields than conventional monetary policy actions. We focus on a small group of foreign economies: Germany, Canada, the United Kingdom, Korea, Mexico, and Brazil. Starting with our findings based on the entire 2002-2017 sample period, for Germany, the

United Kingdom, and Korea, changes in U.S. expected interest rates and term premiums have similar cross-border spillover effects: about a third of these changes pass through to long-term foreign bond yields. For Canada, Mexico, and Brazil, the pass-through of changes in U.S. expected rates to foreign yields is demonstrably greater than the pass-through from changes in U.S. term premiums. Notably, as in the case of exchange rates, foreign yields appear to have become more sensitive to U.S. monetary policy announcements after the GFC, and, again, in most cases that rise reflects a heightened sensitivity to U.S. expected rates rather than term premiums.

All told, our research suggests that changes in U.S. expected interest rates – whether stemming from conventional policy adjustments, forward guidance, or other forms of signaling – have been exerting effects on exchange rates and foreign financial conditions that are as large as or larger than the effects of our quantitative easing. These findings suggest that whatever challenges foreign economies faced as a result of heightened capital inflows after the GFC should not be attributed to quantitative easing *per se* in the United States and other advanced economies, but rather to the extent of monetary easing more generally in these economies or perhaps to factors entirely unrelated to advanced-economy policies.[1] They also have implications for the effects and efficacy of future policies. For example, Brainard (2017) shows how different combinations of conventional and balance sheet normalization by the Federal Reserve will lead to different outcomes for U.S. and foreign economic activity.

The decomposition of changes in bond yields can be used not only to compare the spillovers of different types of policies by the central bank initiating the monetary action; it can

[1]A number of papers, including Coulibaly, Clark, Converse, and Kamin (2016) (among others) argue that advanced-economy monetary easing was not the most important factor driving capital flows to EMEs after the GFC; high growth rates of EME GDP, high commodity prices, and bounce backs from the plunge in capital flows after the GFC are estimated to have been more important.

also be used to examine how these spillovers are transmitted to the economy receiving the spillovers, and this, too, may have important implications for policy. Thus, we examine the impact of Fed policy actions on expected interest rates and term premiums embedded in German bond yields; we also examine the impact of ECB policy actions on expected interest rates and term premiums embedded in U.S. Treasury bond yields. We find similar spillovers in both instances. For example, policy easings by the Fed have little effect on German expected interest rates, but lead to substantial declines in German term premiums; similarly, ECB policy easings have even less effect on U.S. expected rates, but substantially depress U.S. term premiums.

How can we reconcile large declines in term premiums and thus yields, which should stimulate demand, with no change in expected policy rates? Markets must expect that policy rate easings in one country are "beggar they neighbor" and actually depress economic activity in the other economy, perhaps by appreciating its currency, so lower yields are needed just to offset this contractionary effect. If the market's analysis is correct, central banks need not respond to spillovers from abroad that lower their yields by raising policy interest rates. However, conversely, if, as some analysis suggests, policy easings are not really "beggar they neighbor", central banks may need to respond to spillovers that lower their yields by tightening policy.

The findings described in this paper are preliminary, and further research is required to substantiate our results.

The plan of the paper is as follows. Section II reviews the literature on monetary policy spillovers, focusing mainly on studies attempting to compare the effects of conventional policy and quantitative easing. Section III describes the methodology used for our event studies and decomposition of bond yields into expected rates and term premiums. In Section IV, we analyze the effects of U.S. monetary policy on exchange rates, while Section V focuses on how U.S.

policy actions affect foreign bond yields. Section VI digs deeper into the transmission channels of these spillovers, examining how U.S. policy actions affect expected rates and term premiums in Germany, and how ECB actions affect those same variables in the United States. Section VII examines the robustness of our results to different means of decomposing yields into expected rates and term premiums, and section VIII concludes.

II. Literature Review

There is a broad literature on the effects of conventional and unconventional monetary policy.[2] Most articles focus on the effects of these policy actions on domestic asset prices and economic activity. Fewer papers examine their impacts on foreign assets and economies – that is to say, examine the spillovers of conventional and unconventional monetary policies. However, even here, there have been a number of papers on this topic and the literature is growing rapidly.[3] Some of the papers in this area explore the spillover effects of unconventional policies, without explicitly comparing these effects to those of conventional policies. (See, among others, Bhattarai et.al., 2018, Fratzscher et.al., 2018, Chen, Filardo, He, and Zhu, 2015, Gagnon et.al., 2017, and De los Rios and Shamloo, 2017.) Below, we review research in which more explicit attempts are made to compare spillovers from conventional and unconventional policy.

One approach to this issue focuses on model simulations to explore the different channels through which monetary policies spill over to foreign economies. For example, Alpanda and Kabaca (2015) develop a DSGE model to show that U.S. asset purchases that generate the same output effects as conventional policies lead to larger international spillovers due to stronger

[2] Bhattari and Neely (2016) provide a comprehensive survey on the empirical literature on U.S. unconventional monetary policy.
[3] See the survey by Claessens, Stracca, and Warnock (2016).

portfolio balance effects. Alternatively, most studies in this genre involve empirical analysis that is more closely focused on financial market effects. One approach here to is to use event studies – usually, the effect of FOMC announcements – to assess whether announcements of conventional policy actions have different effects on market variables than announcements of unconventional policies. Neely (2015) finds that Fed QE announcements have larger effects on the dollar and on foreign yields than non-QE announcements. However, this study does not control for the size of these announcements, as measured by their effects on domestic Treasury yields. Conversely, Rogers, Scotti, and Wright (2016a), Ferrari, Kearns, and Schrimpf (2017), Curcuru, De Pooter, and Eckerd (2018), and Gilchrist, Yue, and Zakrajsek (2018) measure of the size of the monetary policy action being announced by its impact on domestic sovereign yields, and then look at the sensitivity of foreign market variables to changes in those yields; for the most part, they find little difference in the response of the dollar and/or foreign yields to movements in domestic yields following QE-related and more conventional policy announcements. Bowman, Londono, and Sapriza (2015) likewise measure the responses of foreign sovereign yields to FOMC unconventional policy announcements; they find that these responses align well with the predictions of a model relating foreign to changes in U.S. yields, estimated over the period 2006-2013. All told, these studies find little evidence that spillovers of monetary policy to foreign markets differ, depending on whether the policy actions are conventional or unconventional.

However, one concern posed by event studies of unconventional monetary policy announcements is that there have been relatively few of them, reducing the reliability of the estimates. A somewhat different approach is pursued by Glick and Leduc (2015) that uses all FOMC meeting statements, including those without any explicit policy announcements. They

compare the effects on the dollar of FOMC statementss prior to the GFC, which were by definition conventional, with effects of FOMC statements in the post-GFC era, which included QE and forward guidance; they show that monetary policy surprises had much larger effects on the value of the dollar in the post-GFC era. Ferrari, Kearns, and Schrimpf (2017) and Curcuru (2017) also show that impact of monetary policy on exchange rates has been growing significantly. Chen, Mancini-Griffoli, and Sahay (2014), Chari, Stedman, and Lundblad (2017), and Albagli *et al* (2018) find that U.S. monetary policy spillovers to a range of emerging market asset prices and capital flows strengthened after the GFC. Rogers, Scotti, and Wright (2016b) find a similar strengthening of spillovers from U.S. policy to asset prices in advanced foreign economies

However, as noted in the introduction, comparing the effects of policy announcements before and after the GFC may not give a clear read on the comparison between unconventional versus conventional policies. First, post-GFC policy announcements were not exclusively unconventional; both conventional and unconventional policies were implemented by advanced-economy central banks in the post-GFC period.[4] Second, changes in the effect of monetary policy announcements after the GFC might have reflected the dramatic changes in the economic environment during that period.

Accordingly, as described in the introduction, in this paper we use term structure models to decompose yield changes surrounding FOMC meeting announcements into expected short rate and term premium components, and use these two components to compare the effects of conventional interest rate versus balance sheet policies. Our approach thus avoids the identification issues associated with comparisons of conventional and unconventional policy

[4] For example, forward guidance on interest rates was used extensively in the post-crisis period by the FOMC and ECB. ECB also adopted negative interest rate policy in 2014.

announcements or comparisons of pre- and post-GFC announcements. Our analysis is closest in spirit to Hatzius et.al. (2017), which regresses exchange rates on the components of the yield curve and finds, as we do, that the dollar is more sensitive to expected rates than to the term premium. A few other papers describe similar comparisons of the effects of expected rates and term premiums, but without ascribing those results to conventional and balance-sheet policies, respectively. For example, Ferrari, Kearns, and Schrimpf (2017) and Kearns, Schrimpf, and Xia (2018) look at spillovers to exchange rates and foreign yields, respectively, from changes in domestic yields following monetary policy announcements; they find similar spillovers for changes in expected U.S. interest rates and in domestic term premiums.

Other papers do not explicitly estimate shocks in expected short rate and term premiums, but instead construct measures which are related and have a similar interpretation. Chen, Mancini-Griffoli, and Sahay (2014) study the spillover effects of U.S. monetary policies on emerging markets by differentiating between "policy signal shocks" (which affect expectations of future short-term policy rates) and "market shocks" (which affect longer-term rates through a variety of channels); they find the former have larger effects on emerging market asset prices, consistent with our own results, as described below. Conversely, Stavrakeva and Tang (2015) study the linkage between monetary policy and exchange rate movements by separating out quarterly exchange rate changes into a component that is related to policy rate differentials and an expected excess return component (plus an expectation error term); they find that the importance of unconventional monetary policy for explaining exchange rate variations is larger while the importance of conventional monetary policy is lower in the post-GFC period. Similarly, Rogers, Scotti, and Wright (2016a) identify the first principal component of the U.S. Treasury yield curve as an "LSAP shock" and the second principal component as a "forward

guidance shock," and find that the LSAP shock exerts the stronger spillover effects, at least during the 2008-2013 period covered in the study. Finally, a number of studies, including Bauer and Neely (2014), Rogers, Scotti, and Wright (2016b), and Albagli *et al* (2018), analyze how monetary policy actions affect expected interest rates and/or term premiums in the economies *receiving* the spillovers, with mixed results.

III. Data and Methodology

Data sources

For our event studies, we use data on daily changes in exchange rates and sovereign bond yields on FOMC and ECB meeting dates. We include meetings between January 2002 and December 2017, for 130 FOMC meetings and 181 ECB meetings. We present results for the entire sample and also two sub-samples, a pre and post GFC period. We define the meeting dates prior to 2007 as the pre-GFC period, and the post-GFC period as meetings starting in January 2010. The sub-sample analysis will help us identify changes to the monetary policy transmission channels pre- versus post-crisis. In addition, the financial markets were very volatile during the GFC period, so we exclude meetings in 2008 and 2009 in the sub-period analysis.

Most of our data is obtained from Bloomberg. We use daily closing values for exchange rates for the euro, Mexican peso, and Brazilian *real*, as well as benchmark 10-year government bond par yields for the United States, United Kingdom, Canada, Germany, Korea, Mexico, and Brazil. We also pull German zero-coupon yields at maturities of 3 months, 6 months, and 1 to 10-years from Bloomberg, and U.S. zero-coupon yields at similar maturities from the Federal Reserve Board[5]. We use two trade-weighted dollar indexes, the advanced economy index and emerging

[5] The zero-coupon yields for the U.S. are derived from the methodology presented in Gurkaynak et al. (2006).

economy index. We create an advanced economy index by applying the trade weights published by the Federal Reserve board for the major currencies index to the Bloomberg daily closing exchange rate values.

Design of event study

We use the event study approach to examine the spillovers from FOMC policy announcements to dollar exchange rates and foreign yields. For each FOMC announcement day, we examine 1-day changes in U.S. and foreign 10-year yields bracketing policy announcements; for the U.S., we decompose these changes into changes in their respective expected short-rate and term premium components. We then use regression analysis to estimate the amount of spillover to the dollar and foreign yields from changes in U.S. expected short rates and term premiums for FOMC announcements. In a later section of the paper, we also decompose German yields into their expected short-rate and term premium components, and examine whether these two components react differently to FOMC policy surprises. Finally, we undertake a similar regression analysis for ECB announcements; we decompose changes in German yields following ECB announcements into their expected rate and term premium components, and compare how these two components affect U.S. yields.

In our paper, we focus on 1-day changes bracketing central bank announcements because the zero-coupon yields needed to estimate the term structure models and thus calculate changes in expected rates and term premiums for shorter windows are not available at a higher frequency. It is possible that this 1-day window may be too wide and there could other important events (e.g. economic data releases) besides the central bank announcements within this 1-day window that would contaminate the yield reactions to central bank announcements.

To mitigate concern about contamination during the event window, we use a robust regression approach in our study. The robust regression is based on the Huber loss function, which is less sensitive to outliers in data than the quadratic error loss function used for ordinary least square regression. The Huber loss function is quadratic for small values of regression fitting error, and linear for large values. So it is approximately a mixture of ordinary least square regression and absolute least deviation regression. Following the literature, to decompose changes in yields into their expected-rates and term premium components, we fit an affine term structure model to U.S. zero coupon yields and German zero coupon yields, respectively. [6] There are several types of estimation methods used in the literature. In this paper we opt for the method presented in Adrian *et al* (2013) (hence, ACM) for its ease of computation.[7] More specially, we assume the yields are driven by five pricing factors that follow a VAR(1) process with Gaussian shocks, and we use yield principal components as the underlying factors. As shown in ACM, the model parameters can then be estimated easily by using a three-step linear regression approach. More specifically, in the first step, the pricing factors are regressed on the lagged factors to estimate the factor VAR(1) parameters and the factor shocks; in the second step, zero-coupon bond returns are regressed on these factor shocks to estimate their loadings or sensitivities; in the final step, risk premium parameters are estimated by using a cross-sectional regression of risk premiums on these factor loadings. Given the estimated model parameters, we can then decompose yields at any maturity into an expected short rate and a term premium

[6] Term structure models are typically estimated on zero coupon yields instead of par-coupon yields because the decomposition of long-term yields into expected short rates and term premiums only hold exactly in zero coupon yields.
[7] We are working on incorporating survey data into the model estimation and will include the results in the next version of the paper.

components. As shown in Table 1, the correlation between our ACM-model-based and alternative model-free measures of the expected short rates and term premiums are very high.

Data timing issues

As also noted above, our analysis is based on 1-day changes around FOMC announcement, measured using end-of-day yield data. German yields have an end-of-day time-stamp of 5pm European central time, which is either 11 am or 12 noon U.S. Eastern Time on the same day, depending on whether the U.S. Eastern time is daylight savings time or not. This 11am or 12 noon Eastern Time is before the usual FOMC policy announcement time of 2:00pm. Therefore, to capture the reaction of German and U.K. yields to FOMC policy announcements, we shift German yields 1-day back so we are effectively using next-day's German closing yields for each FOMC announcement day.

For ECB announcements, there is no need to do such day shift because ECB announcements are typically at around 1:45 pm European central time, which is 6:45am or 7:45am Eastern Time on the same day, during which the U.S. bond market is already open.

As noted above, all exchange rate data are also end-of-day (U.S. Eastern time) values except for the EME exchange rate index and South Korean won, which are recorded at 12:00 pm Eastern time. Therefore, as with the German yield data, we shift the data for these two exchange rates one-day back for FOMC announcements.

Econometric analysis of spillovers

We first study the spillover effects of FOMC policies to the dollar. Specifically, we run a set of regressions on FOMC announcement days of changes in the dollar exchange rates (FX) on changes in the U.S. 10-year par yield (Y_{US})

$$dFX_{i,t} = \alpha + \beta_i dY_{US,t} + \epsilon_{i,t} \quad (1)$$

where i={AFE, EME, EUR, KRW, MXN, and BRL}

We then extend our original regression to regress the same changes in these exchange rates on the corresponding changes in U.S. 10-year par yield's expected short rate (SR) and term premium (TP) components.

$$dFX_{i,t} = \alpha + \beta_{1,i} dSR_{US,t} + \beta_{2,i} dTP_{US,t} + \epsilon_{i,t} \quad (2)$$

We then run a similar set of regressions on FOMC announcement days of changes in foreign 10-year par yields (Y_i) on changes in the U.S. 10-year par yield to study the spillover effects of FOMC policies to foreign yields.

$$dY_{i,t} = \alpha + \beta_i dY_{US,t} + \epsilon_{i,t} \quad (3)$$

$$dY_{i,t} = \alpha + \beta_{1,i} dSR_{US,t} + \beta_{2,i} dTP_{US,t} + \epsilon_{i,t} \quad (4)$$

where *i*={Germany, Canada, United Kingdom, Korea, Mexico, and Brazil}

We next drill down deeper into the spillover effects of FOMC's policies on foreign yields, assessing how foreign expected policy rates and term premiums react to FOMC policies. We use the German yield as an example. To use the German yield's expected short rate and term premium components, we switch from the German 10-year par yield to German 10-year zero coupon yield. We regress the Germany 10-year zero coupon yield and its two components on the U.S. 10-year zero coupon yield's two components:

$$dY_{Germany,t} = \alpha + \beta_1 dSR_{US,t} + \beta_2 dTP_{US,t} + \epsilon_{Germany,t} \quad (5)$$

$$dSR_{Germany,t} = \alpha + \beta_{1,SR} dSR_{US,t} + \beta_{2,SR} dTP_{US,t} + \epsilon_{SR,t} \quad (6)$$

$$dTP_{Germany,t} = \alpha + \beta_{1,TP} dSR_{US,t} + \beta_{2,TP} dTP_{US,t} + \epsilon_{TP,t} \quad (7)$$

We use an analogous analysis to assess the spillover from German to U.S. yields following ECB policy actions.

IV. Monetary Policy Effects on the Dollar

Figure 1 depicts the simplest version of our event study, with each dot corresponding to an FOMC announcement. The X-axis shows the change in 10-year U.S. Treasury yields following the announcement, while the Y-axis depicts the change in the value of the dollar against the currencies of advanced foreign economies (AFEs). The trend line through the data, estimated using equation (1), suggests that a policy-induced 100 basis point change in 10-year bond yields led, on average, to a 4.1 percent appreciation of the AFE dollar index. Figure 2 shows a similar scatter plot for the EME dollar index. The slope of the trend line is shallower, implying index appreciation of 2.1 percent, which is not surprising given that many EM countries actively manage their exchange rates.

Further details on these relationships are provided in Table 2, which also expands the analysis to our sample of bilateral exchange rates. The table shows the results of the estimation of equations (1) and (2) for the full sample, pre- and post-crisis periods. Looking down the first column of results, for most currencies we observe increased sensitivity in the post-crisis period. For example, the sensitivity of the euro jumps from 2.7 percent per 100 basis points in the pre-crisis period to 5.6 percent per 100 basis points in the post crisis period. The observed increase in the sensitivities for the other currencies are of a similar magnitude.

We can use our yield curve decomposition to separately observe the exchange rate effects of changes in the short rate and term premium. Figure 3 breaks down the effect of yields

on the advanced economy index, which was shown in Figure 2, into the separate effects of expected interest rates and term premium. From the figures it appears that changes in short rates have a much larger effect on changes in the dollar. We can also see this in Table 2, which reports the coefficient estimates from equation (2) which includes both the short rate and term premium in the regression. The coefficient on the U.S. expected interest rate is reported in the third column of the table, and the term premium in the fourth column. Looking across the columns, we observe that exchange rates usually react more strongly to changes in the expected interest rate. In addition, this difference is always more pronounced in the post crisis period, as the coefficient on the expected rate rises more after the crisis than the coefficient on the term premium. For example, when the dependent variable is changes in the euro, the coefficient on the expected short rates is 13.6 in the post crisis period, while the coefficient on the term premium is 3.0. We also show the results of a T-test for equality of the coefficients on the expected short rate and term premium; for every currency the difference between the two coefficients is highly statistically significant in the post crisis period.

While the effect of the term premium on the exchange rate rises less (from pre- to post-GFC) than that of the expected short rate, it does rise. In fact, the effect of the term premium on the exchange rate appears to be solely a post-crisis phenomenon. In all the regressions, the coefficient on the term premium is not statistically significant in the pre-crisis period, with the exception of the Mexican peso—which exhibits the unusual behavior of depreciating when the U.S. term premium increases during the pre-crisis period.

Discussion

Our finding that the dollar is more sensitive to expected interest rates than to term premiums may contradict conventional wisdom, but should not be surprising. As noted earlier, the term premium represents compensation for the risk of holding a bond. Consider a rise in the term premium on U.S. Treasury bonds, for example, that reflects an increase in its perceived riskiness. Such a development should not boost the demand for dollar-denominated assets, and hence should not boost the value of the dollar, at least not to an extent commensurate with the effect of a rise in expected interest rates. Alternatively, consider a rise in the U.S. term premium that reflects a balance-sheet action by the Federal Reserve, such as a reduction in its asset holdings. This action, by increasing the supply of dollar-denominated bonds, also would not be expected to boost the value of the dollar, or, again, not as much as a rise in expected interest rates.

Another issue raised by our findings is why the dollar's sensitivity to monetary policy announcements, and especially its sensitivity to increases in expected interest rates, rose after the GFC. Ferrari, Kearns, and Schrimpf (2016) conjecture that the higher sensitivity of the dollar to monetary policy may reflect structural changes such as the shift to unconventional monetary policy actions, which some argue are targeted at exchange rates given the compression of domestic interest rates. Another possibility the authors present is that reduced liquidity and intermediation ability of dealers may lead investors to shy away from inventory risk. However, Curcuru (2017) shows that the sensitivity of the dollar to interest rates does not rise smoothly over time, but fluctuates widely. This suggests that the heightened sensitivity of the dollar in the post-GFC period may reflect particular macroeconomic circumstances rather than persistent structural changes.

V. Monetary Policy Spillovers to Foreign Yields

As noted in the introduction, quantitative easing has been criticized not only for exerting undue appreciation pressures on foreign currencies, but also for causing foreign financial conditions to loosen excessively. To assess this hypothesis, we examine the response of foreign interest rates in a number of important foreign economies to U.S. monetary policy announcements. Figure 4 repeats the event study shown in Figure 1, but examines the reaction of the German 10-year Bund yield to changes in U.S. Treasury yields following FOMC announcements. It indicates that over the entire sample, a little more than a third of the post-announcement change in U.S. Treasury yields passed through to German yields. The spillover to German yields appears to be only slightly stronger in the post-crisis period, as can be seen in Figure 5.

How do conventional monetary policies compare to balance sheet policies in affecting German yields? Figure 5 suggests that the effect of changes in U.S. term premiums on German yields, on the right, is slightly stronger than the effect of changes in U.S. expected short rates. To better understand this relationship, Table 3 shows the results of estimating equations (3) and (4). They indicate that over the entire 2002-2017 sample, as well as in the pre- and post-crisis sample, changes in U.S. term premiums had a similar effect on German and U.K yields as changes in expected interest rates. The difference between the multivariate regression results in this table and the univariate regressions in Figure 6 arises from correlation between changes in the U.S. expected short rate and term premium. In Canada, yields react a little more strongly to changes in U.S. expected short rates.

The remainder of Table 3 addresses the impact of changes in the U.S. 10-year Treasury yield and its two components on the long yields of the three important EMEs discussed earlier:

Korea, Mexico, and Brazil. It is worth noting that in the pre-GFC period, except for Korea, the impact of U.S. Treasury yield components on these EME yields is not statistically significant and explains very little of their variation. Conversely, in the post-GFC period, U.S. yield components explain a material share of the movement in the EME yields. Moreover, for all three EMEs, the impact of expected interest rates is considerably greater than that of term premiums, and to a statistically significant extent in Mexico and Brazil.

Discussion

All told, these findings again contradict the conventional wisdom that balance sheet policies are especially forceful in spilling over to foreign financial conditions. Changes in U.S. expected interest rates appear to exert as much or more influence on foreign yields than changes in term premiums. That U.S. expected rates have at least as strong an effect on foreign yields as term premiums is not very surprising: Changes in either U.S. expected rates or term premiums, by changing the rate of return on U.S. assets, should lead to similar changes in portfolio allocations that trigger similar movements in foreign yields. It is less clear why U.S. expected rates should exert much larger effects on foreign yields than changes in term premiums, as in the case of the EMEs we studied. One possible explanation is EME bonds are more risky and less substitutable with U.S. bonds than AFE bonds; therefore, there may be weaker portfolio rebalancing effects between U.S. and EME bonds, and this may manifest itself in weaker linkages through term premiums.

Another question posed by these results, similar to those for the dollar, is why spillovers to foreign yields appear to be stronger in the post-crisis period. Again, this remains an important question for future research.

The next section drills down a little deeper into the process by which U.S. yields affect foreign yields, and vice-versa.

VI. Channels of Yield Spillovers

Impact of U.S. monetary policies on German yields, expected interest rates, and term premiums

So far, we have distinguished between expected interest rates and term premiums in the economies originating the monetary policy shocks, that is, the United States. In this section, we deepen our understanding of the spillovers of these shocks by looking at how they affect the term structure components of the yields in the economies receiving these shocks. We focus on Germany, where a long history of liquid bond markets allows us to decompose German bond yields into expected interest rates and term premiums.

Table 4 present the results of estimating equations (5)-(7). In particular, the top set of results in Table 4 reproduces the results in Table 3 that link German 10-year yields to U.S. 10-year yields, but uses the zero-coupon yields instead of par-coupon yields. It also shows the results that link German 10-year yields to U.S. 10-year yields' expected short rates and term premiums components around Federal Reserve announcements. The second set of results presents results for equations that essentially repeat these analyses, but focusing on the behavior of German expected rates alone. Finally, the last set of results presents the analogous regression results for the behavior of German term premiums.

As noted above, the first set of results reproduces the analysis shown in Table 3, but using German zero-coupon yields rather than par-coupon yields. The results are little changed, confirming that changes in both the U.S. expected short rate and the U.S. term premium have significant, similar spillover effects on the German 10-year yield.

The middle section results focuses on spillovers to German expected interest rates alone. It indicates that changes in the U.S. 10-year yield have small but statistically significant spillover effects on the German expected interest rate in both the pre- and post-GFC subsamples. They also show that changes in the U.S. 10-year yield's expected short rate component has a small effect on German expected short rate in both subsamples, while changes in the U.S. 10-year's term premium component has a statistically significant effects on German expected short rate only in the post-GFC subsample.[8] This suggests that market participants expect the ECB would at most make only a small adjustment in its policy rate in response to the FOMC's interest rate and balance sheet policies.

The bottom section of Table 4 focuses on spillovers to German term premiums. The results show that changes in the U.S. 10-year yield, as well as changes in both of its components, have more pronounced effects on the German term premium than on German expected rates. One explanation is that U.S. easing increases expectations for additional QE in the euro area, which lowers the German term premium. Alternatively, this spillover effect could arise as investors rebalance their portfolios in response to FOMC policy actions. For example, FOMC easing actions, whether through a rate cut or through an asset purchase program, lead to lower long-term yields in the U.S. and thus heightened investor demand for German bonds, which in turn leads to lower German yields. The lower German yields would occur through lower German term premiums because investors expect little change in the euro area policy rate path in response to FOMC actions, as we discussed above.

Discussion

[8] Note: the FOMC used only interest rate policy in the pre-GFC period.

The results shown here may have important implications for appropriate ECB policy. Our analysis suggests that U.S. monetary easing, for example, may have lowered German bond term premiums and loosened euro area financial conditions. All else equal, this should have boosted prospects for euro area economic conditions and inflation, thus calling for a corresponding tightening in ECB policy. Yet, the regression results indicate that U.S. easing would have led to only a small reduction in German expected interest rates. One way to understand this outcome is that markets assessed a U.S. easing as likely to exert contractionary effects on the euro area economy, perhaps by depreciating the dollar against the euro and thus depressing the euro-area trade balance. If this contractionary effect were large enough, it would require both a decline in the term premium and a slight easing action by the ECB to offset it.

Of course, if this interpretation is correct, it depends on a U.S. easing indeed boosting the euro against the dollar sufficiently to depress the euro-area trade balance. It is unclear that a U.S. easing would indeed have that effect. Ammer *et al* (2016) present evidence showing that while a U.S. easing should depress foreign trade balances by depreciating the dollar, it should improve foreign trade balances by increasing U.S. demand for imports. These forces fully offset each other, leaving trade balances here and abroad unchanged. If that is the case, then a U.S. easing, by reducing the term premium abroad, should prove expansionary for foreign economies. Such an expansionary effect, in turn, would call for a tightening of monetary policy by the affected foreign economies.

Impact of ECB monetary policies on U.S. yields, expected interest rates, and term premiums

So far in this paper, we have focused on international spillovers from U.S. monetary policy actions. However, in recent years, observers and policymakers have become increasingly

attuned to the effect of foreign policies on U.S. financial conditions. In particular, foreign monetary easing is believed to be playing an important role in depressing U.S. long-term yields. To shed some light on these effects, we repeat the analysis above, but focusing on the effects of ECB announcements on U.S. yields. We use German yields as the benchmark for how ECB policies affect "domestic" (i.e., euro-area) financial conditions, and examine how these pass through to U.S. yields following ECB announcements.

Our findings are presented in Table 5, which show the results of estimating the equivalent of equations (5)-(7), but for the spillover from German to U.S. bonds following ECB events. As with the spillover effects from FOMC monetary policies shown in the top section of Table 4, the top section of Table 5 shows that ECB monetary policy actions' spillover effects on U.S. yields are also large and significant and comparable in the pre- and post-GFC periods. Further, the spillover effects on U.S. yields from both types of ECB policies are broadly similar.

The rest of Table 5 show the responses of the U.S. 10-year yield's two components to ECB policy surprises. The middle section of the table show the spillover results on the U.S. expected short rate. As was the case with German expected short rates, we find that U.S. expected short rates react very little to changes in either German expected short rates or term premiums. In contrast, the results in the bottom section of the table show that changes in the German 10-year yield, as well as changes in both of its components, have large and significant spillover effects on the U.S. term premium. These results are similar to the spillover effect of FOMC policies on the German term premium, shown in Table 4; as noted above, this spillover effect could reflect either portfolio balance channels or investor expectations of changes in Fed QE policy.

Discussion

Our above results suggest that ECB monetary easing, for example, doesn't seem to affect investor expectations for the U.S policy rate, despite the stimulative effect on the U.S. economic activity from lower U.S. term premiums and thus overall yields. This finding is exactly analogous to our estimate of the spillover of U.S. easing to German yields, and could be rationalized by the same considerations: investors may expect the stimulative effect of lower U.S. yields to be offset by the contractionary effect of ECB easing on the U.S. trade balance, leaving little net effect on U.S. economic activity or inflation. Alternatively, investors might expect the FOMC to respond to ECB easing with additional QE rather than a change in policy rates, which would lower the U.S. term premium.

If the investors' analysis of ECB easing having little net effect on U.S. economic activity or inflation is correct, the appropriate response of U.S. policy interest rates to ECB easing is to do nothing. But as noted earlier, analysis by Ammer *et al* (2016) suggests that foreign easing might have little net impact on U.S. trade, since the adverse of a higher dollar would be offset by the beneficial effects of higher euro-area activity and thus demand for U.S. exports. Under these circumstances, with the U.S. trade balance unchanged but U.S. term premiums and yields lower, the net effect of an ECB easing for U.S. demand and activity would be expansionary. This would potentially call for an offsetting tightening by the Federal Reserve.

VII. Robustness Checks

As noted earlier, there is no consensus approach to decomposing bond yields into their respective expected-rates and term-premium components. As a robustness check, we use two alternative model-free decomposition methods, and repeat our analysis of the spillovers to

exchange rates and yields. More specifically, we use the 2-year yield as a proxy for the expected short rate, and pair it with two model-free measures of the term premium -- the difference between the 10-year and 2-year yield, and the residuals from a regression of the 10-year yield on the 2-year yield. For each of these measures of the expected short rate and term premium, we fit equation (2) using both OLS and the robust method we use in the earlier tables.

Appendix A shows that the results of our regressions of the dollar on term structure components estimated using the ACM method are generally robust to other decomposition methods, as well as to whether OLS or robust regression is used. In all cases, the estimated sensitivity of the AFE dollar to expected rates exceeds that of its sensitivity to the term premium, albeit not always to a statistically significant extent. The sensitivity of the EME dollar to expected rates also generally exceeds its sensitivity to the term premium. In addition, our estimated yield curve spillovers following both FOMC and ECB meetings are very close to the estimates using the 2-year yield proxy for the expected short rate and both the slope and residuals proxies for the term premium. In sum, our estimated sensitivities appear robust to alternative model-free decompositions of the yield curve.

VIII. Conclusion

In summary, we use models to decompose longer-term yields into expected short rate and term premium components and compare the spillover effects of different monetary policies by examining their impact on these two components. We find that interest rate policies have larger effects on exchange rates than do balance sheet policies, and increased sensitivity of the dollar to expected interest rates accounts for most of the rise in the overall sensitivity of the dollar to monetary policy following the global financial crisis. We also find that interest rate and balance

sheet monetary policies seem to have broadly similar spillover effects on foreign yields in the post-crisis period. All told, these findings contradict the popular wisdom that balance sheet policies exert unusually large spillovers.

In this paper, we also drilled down deeper into the process by which monetary policy actions spill over to other economies. We found that U.S. policy actions exerted little effect on the expected interest rates embedded in German long-term yields, but large effects on German term premiums. Symmetrically, we found that ECB announcements also had no effect on U.S. expected interest rates but large effects on U.S. term premiums. These results pose something of a conundrum, since if foreign monetary policy actions alter term premium, and thus financial conditions more generally, one would think they would elicit offsetting changes in expectations of policy rates as central banks strove to offset these effects.

We have also used model-free decompositions of longer-term yields and performed additional robustness checks and found our results broadly hold. That said, we caution our findings are based on event studies and subject to the typical caveats associated with event studies. More research on this topic is needed.

VIIII. References

Adrian, T., Crump, R. K. and Moench E. (2013), "Pricing the Term Structure with Linear Regressions," *Journal of Financial Economics* 110(1), 110-38.

Albagli, E., Ceballos, L., Claro, S., and Romero, D. (2018), "Channels of US Monetary Policy Spillovers to International Bond Markets," BIS Working Papers No. 719, May.

Alpanda, S. and Kabaca, S. (2015), "International Spillovers of Large-Scale Asset Purchases," Bank of Canada Working Paper 2015-2.

Bauer, M. D., and Neely, C. J. (2014), "International Channels of the Fed's Unconventional Monetary Policy," *Journal of International Money and Finance* 44, 24-46.

Bernanke, B.S. (2015), "Federal Reserve Policy in an International Context," Paper presented at 16th Jacques Polak Annual Research Conference, International Monetary Fund, Washington, DC, November 5-6.

Bhattari, S., and Neely, C. J. (2016), "A Survey of the Empirical Literature on the U.S. Unconventional Monetary Policy," Federal Reserve Bank of St. Louis Working Paper 2016-021A.

Bhattarai, S., Chatterjee, A., and Park, W.Y. (2018), "Effects of US Quantitative Easing on Emerging Market Economies," Asian Development Bank Institute Working Paper No. 803, January.

Bowman, D., Londono, J., and Sapriza, H. (2015). "U.S. Unconventional Monetary Policy and Transmission to Emerging Market Economies," *Journal of International Money and Finance*, vol. 55, pp. 27-59.

Brainard, L. (2017), "Cross Border Spillovers of Balance Sheet Normalization," Speech presented at "Normalizing Central Banks' Balance Sheets: What Is the New Normal?" a conference sponsored by Columbia University's School of International and Public Affairs and the Federal Reserve Bank of New York, New York, New York, July.

Chari, A., Stedman, K.D., and Lundblad, C. (2017), "Taper Tantrums: QE, its Aftermath, and Emerging Market Capital Flows," *NBER Working Paper* 23474, June.

Chen, J., Mancini-Griffoli, T., and Sahay, R. (2014), "Spillovers from United States Monetary Policy on Emerging Markets: Different This Time?" IMF Working Paper No. 14/240.

Chen, Q., Filardo, A., He, D., and Zhu, F. (2015), "Financial Crisis, US Unconventional Monetary Policy and International Spillovers," IMF Working Paper.

Claessens, S., Stracca, L., and Warnock, F.E. (2016), "International Dimensions of Conventional and Unconventional Monetary Policy," *Journal of International Money and Finance* 67, 1-7.

Craine, R. and Martin, V. L. (2008), "International monetary policy surprise spillovers," *Journal of International Economics* 75(1), 180–196.

Curcuru, S. (2017), "The Sensitivity of the U.S. Dollar Exchange Rate to Changes in Monetary Policy Expectations," Federal Reserve Board IFDP Notes 2017-09-22.

Curcuru, S., De Pooter, M., and Eckerd, G. (2018), "Measuring Monetary Policy Spillovers between U.S. and German Bond Yields," Federal Reserve Board IFDP 2018-1226.

De los Rios, A. D., and Shamloo, M. (2017), "Quantitative Easing and Long-Term Yields in Small Open Economies," IMF Working Paper No. 17/212.

Ferrari, M., Kearns, J., and Andreas, S. (2017), "Monetary Policy's Rising FX Impact in the Era of Ultra-Low Rates," BIS Working Paper.

Fratzscher, M., Lo Duca, M. and Straub, R. (2018), "On the international spillovers of U.S. quantitative easing," *The Economic Journal*, 128, 330-377.

Gagnon, J., Bayoumi, T., Londono, J.M., Saborowski, C., and Sapriza, H. (2017), "Direct and Spillover Effects of Unconventional Monetary and Exchange Rate Policies," IMF Working Paper WP/17/56, March.

Georgiadis, G. (2015), "Determinants of Global Spillovers from U.S. Monetary Policy," *Journal of International Money and Finance* 67, 41-61.

Gilchrist, S., Yue, V., and Zakrajsek, E. (2018), "U.S. Monetary Policy and International Bond Markets," FEDS Working Paper 2018-014.

Glick, R., and Leduc, S. (2015), "Unconventional Monetary Policy and the Dollar: Conventional Signs, Unconventional Magnitudes," Federal Reserve Bank of San Francisco, Working Paper 2015-18.

Gurkaynak, R.S., Sack, B. and Wright J. H. (2006), "The U.S. Treasury Yield Curve: 1961 to the Present," FEDS Working Papers 2006-28.

Hatzius, J., Stehn, S.J., Fawcett, N., and Reichgott, K. (2017), "Policy Rate vs. Balance Sheet Spillovers," Goldman Sachs Economics Research, Global Economics Analyst, July 28.

Hausman, J.K., and Wongswan, J. (2011), "Global asset prices and FOMC announcements", *Journal of International Money and Finance* 30(3), 547-571.

Inoue, A., and Rossi, B. (2018), "The Effects of Conventional and Unconventional Monetary Policy: A New Approach," Working Paper.

Kearns, J., Schrimpf, A., and Xia, D. (2018), "Explaining Monetary Spillovers: The Matrix Reloaded," SSRN Working Paper.

Neely, C. J. (2015), "Unconventional Monetary Policy Had Large International Effects," *Journal of Banking and Finance*, 52, 101-111.

Rogers, J. H., Scotti, C. and Wright, J. H. (2016a), "Evaluating Asset-market Effects of Unconventional Monetary Policy: A Multi-country Review," *Economic Policy*, 29(80), 749–799.

Rogers, J. H., Scotti, C. and Wright, J. H. (2016b), "Unconventional Monetary Policy and International Risk Premia," Federal Reserve Board IFDP 2016-1172.

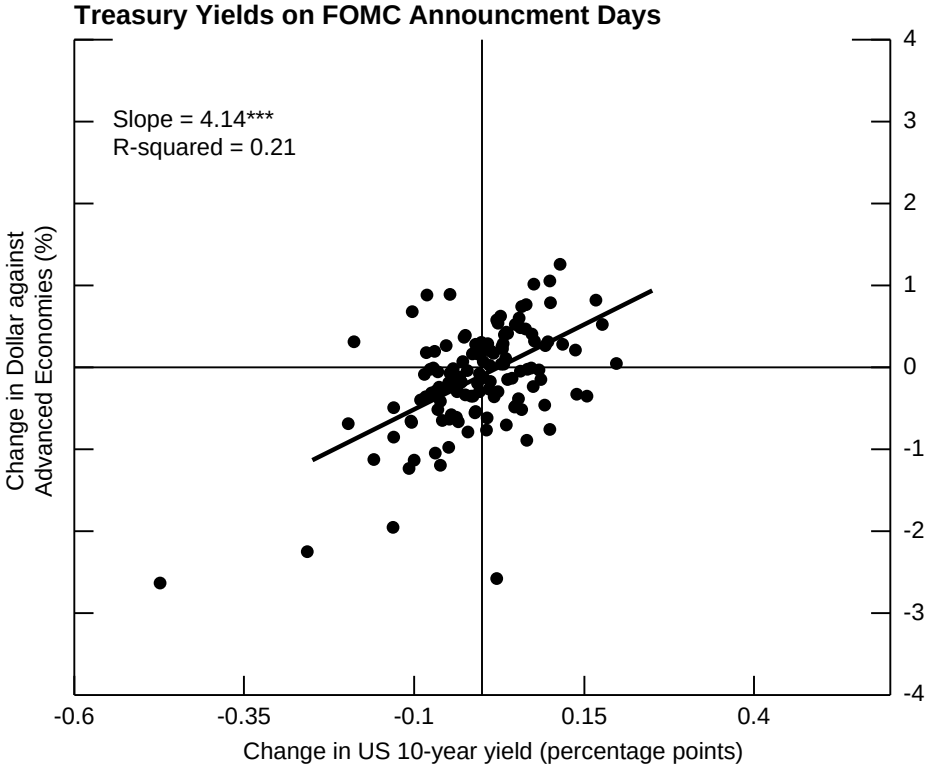
Stavrakeva, V., and Tang, J. (2015), "Exchange Rates and Monetary Policy," Federal Reserve Bank of Boston Working Paper.

Swanson, E.T., and Williams, J. C. (2015), "Measuring the Effect of the Zero Lower Bound on Medium- and Longer-Term Interest Rates," Federal Reserve Bank of San Francisco Working Paper.

Woodford, M. (2012), "Methods of Policy Accommodation at the Interest-Rate Lower Bound," Working Paper.

Exhibit 1

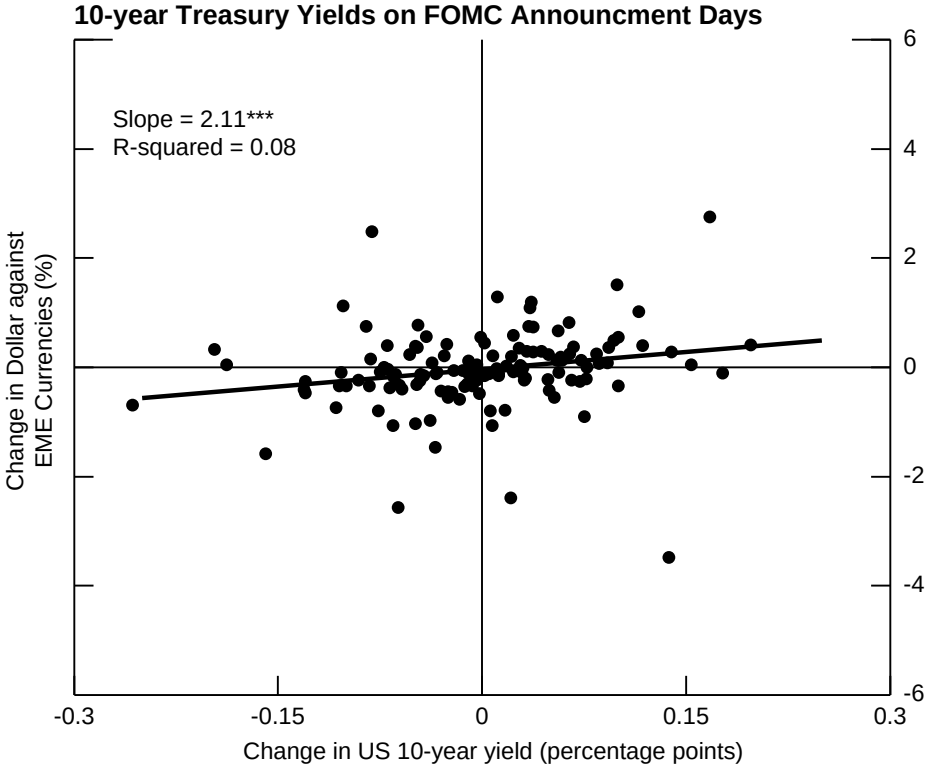
Figure 1: Changes in the Advanced Dollar Index and U.S. 10-year Treasury Yields on FOMC Announcment Days



The data are changes in a one-day window around FOMC announcement dates. The full sample is from 2002-2017. The US 10-year yield is the generic government bond yield from Bloomberg. ***, **, and * denote significance at the 1, 5, and 10 percent levels, respectively.

Exhibit 2

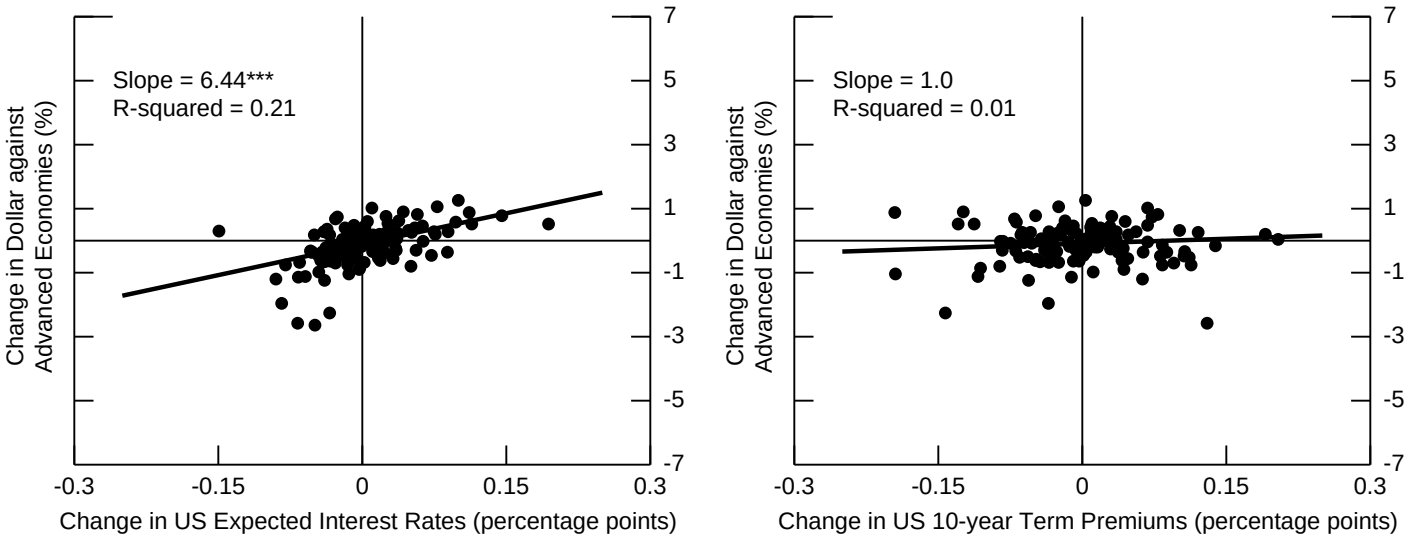
Figure 2: Changes in the Emerging Market Dollar Index and U.S. 10-year Treasury Yields on FOMC Announcment Days



The data are changes in a one-day window around FOMC announcement dates. The full sample is from 2002-2017. The US 10-year yield is the generic government bond yield from Bloomberg. Only floating rate EME currencies are included. ***, **, and * denote significance at the 1, 5, and 10 percent levels, respectively.

Exhibit 3

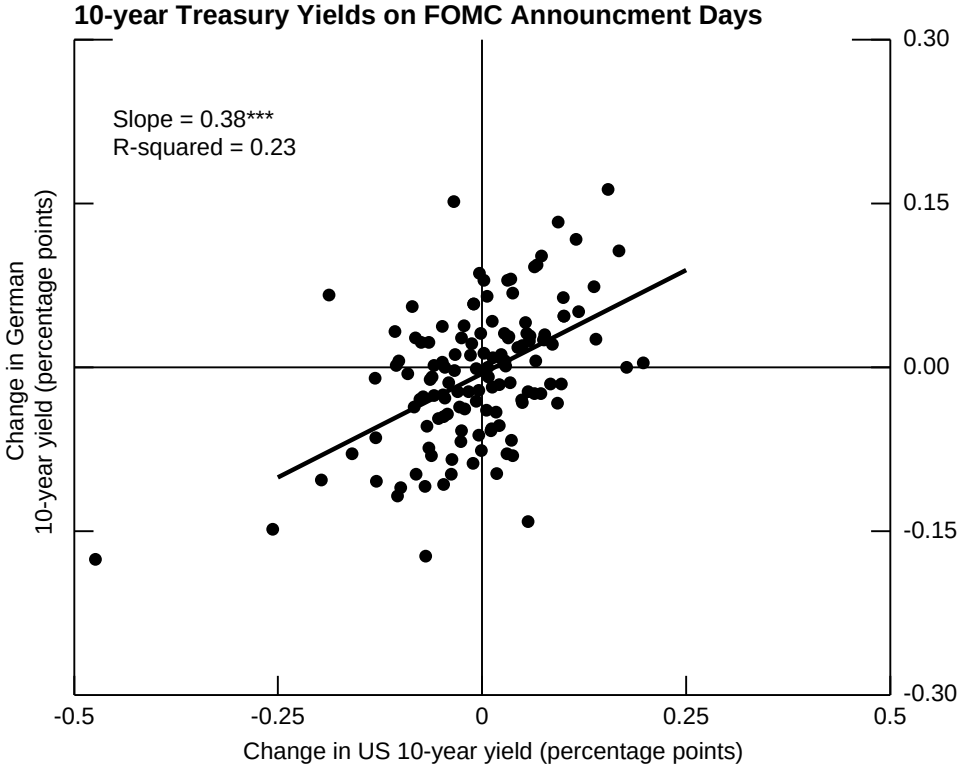
Figure 3: Changes in the Advanced Dollar Index and U.S. Expected Interest Rates and Term Premiums on FOMC Announcment Days



The data are changes in a one-day window around FOMC announcement dates. The full sample is from 2002-2017. Estimates of term premia and expected short rates are based on an estimated affine term structure model. ***, **, and * denote significance at the 1, 5, and 10 percent levels, respectively.

Exhibit 4

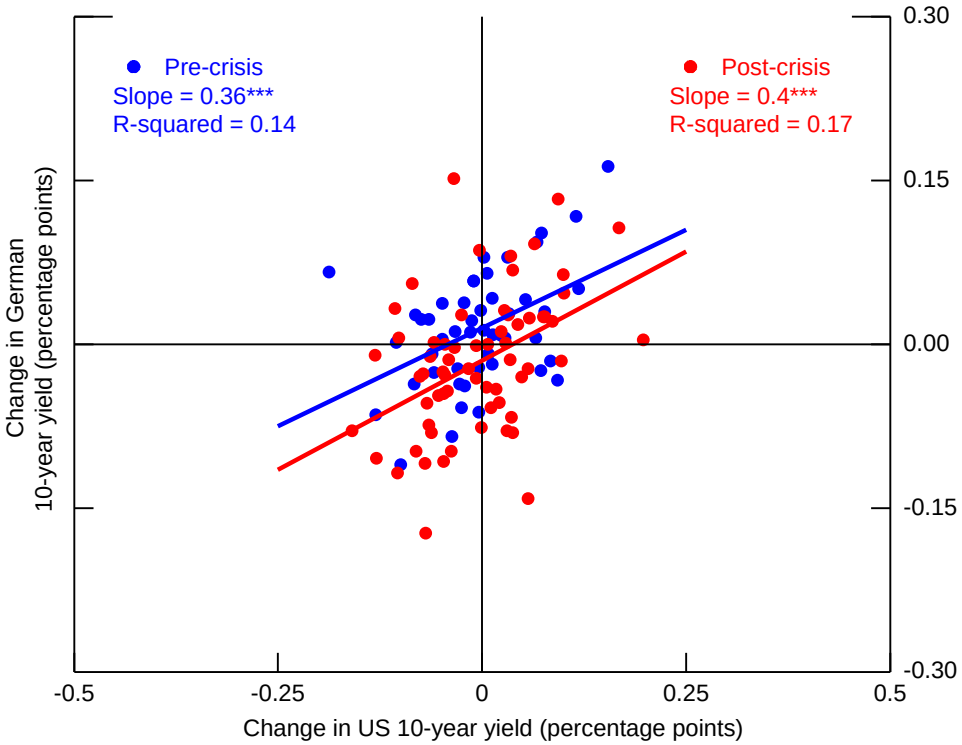
Figure 4: Changes in the German 10-year Bund Yield and U.S. 10-year Treasury Yields on FOMC Announcment Days



The data are changes in a one-day window around FOMC announcement dates. The full sample is from 2002-2017. The 10-year yields are the generic government bond yield from Bloomberg. ***, **, and * denote significance at the 1, 5, and 10 percent levels, respectively.

Exhibit 5

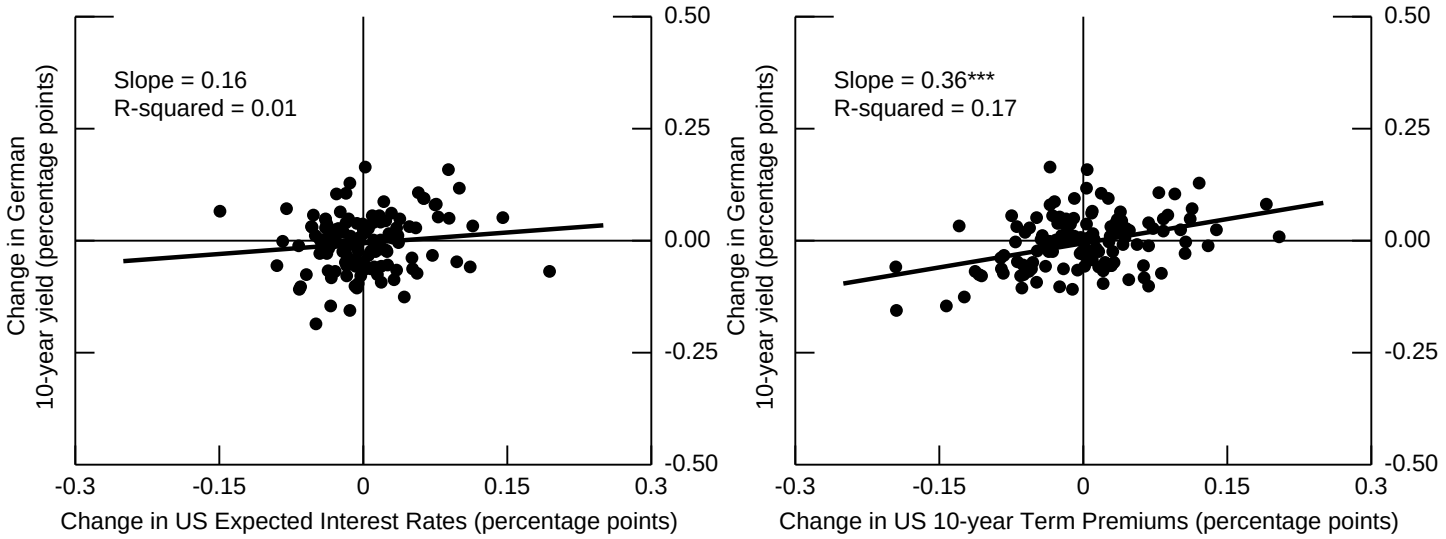
Figure 5: Changes in the German 10-year Bund Yield and U.S. 10-year Treasury Yields on FOMC Announcment Days, Pre- and Post-crisis Periods



The data are changes in a one-day window around FOMC announcement dates. The full sample is from 2002-2017. The pre-crisis sample is from 2002-2007. The post-crisis sample is from 2010-2017. The 10-year yields are the generic government bond yields from Bloomberg. ***, **, and * denote significance at the 1, 5, and 10 percent levels, respectively.

Exhibit 6

Figure 6: Changes in the German 10-year Bund Yield and U.S. Expected Interest Rates and Term Premiums on FOMC Announcment Days



The data are changes in a one-day window around FOMC announcement dates. The full sample is from 2002-2017. The German 10-year yield is the zero-coupon yield from Bloomberg. Estimates of term premia and expected short rates are based on an estimated affine term structure model.
***, **, and * denote significance at the 1, 5, and 10 percent levels, respectively.

Table 1: Correlation between Alternative Measures of U.S. Term Premiums and Expected Short Rates

Correlation of Measures of U.S. Term Premiums, Full Sample

	Slope (10 year minus 2 year)	Residual (10 year on 2 year)	Model-based Term Premium
Slope (10 year minus 2 year)	1	0.714	0.739
Residual (10 year on 2 year)		1	0.968
Model-based Term Premium			1

Correlation of Measures U.S. Expected Interest Rates, Full Sample

	2 year yield	Model-based Expected Interest Rates
2 year yield	1	0.958
Model-based Expected Interest Rates		1

The slope measure of term premium is defined as the difference between the 10 and the 2-year treasury yields, and the corresponding expected short rate is the yield on a 2-year treasury.
The residual measure is based on a regression of 10-year treasury yields on 2-year treasury yields. The term premium estimates are the residuals from this regression and the 2-year treasury yields serve as expected short rates.
The model-based measures of term premia and expected short rates are based on an estimated affine term structure model, similar to that proposed in Adrian *et al* (2013).

Table 2: Regression Results for Exchange Rate Spillovers, FOMC Announcement Days

Dependent Variable	U.S. Explanatory Variables; Changes in:				
Exchange Rate Changes	10-year Yield	Expected Interest Rate	Term Premium	SR=TP t-test	R-squared
AFE Index					
Full Sample	4.142***				0.21
Pre-GFC	1.639*				0.05
Post-GFC	4.922***				0.27
Full Sample		7.548***	2.333***	5.373***	0.27
Pre-GFC		2.253*	2.037	0.120	0.06
Post-GFC		11.836***	2.673***	8.279***	0.52
EUR					
Full Sample	5.187***				0.22
Pre-GFC	2.732***				0.08
Post-GFC	5.608***				0.25
Full Sample		8.838***	2.66***	5.519***	0.25
Pre-GFC		3.154**	2.413	0.352	0.06
Post-GFC		13.562***	3.018***	7.858***	0.47
EME Index*					
Full Sample	2.107***				0.08
Pre-GFC	1.542**				0.09
Post-GFC	4.275***				0.12
Full Sample		4.379***	1.381**	3.110***	0.10
Pre-GFC		2.894***	0.068	1.941*	0.13
Post-GFC		9.495***	2.214*	3.304***	0.19
KRW					
Full Sample	2.843***				0.05
Pre-GFC	1.81**				0.06
Post-GFC	4.535***				0.13
Full Sample		4.001***	2.425***	1.132	0.06
Pre-GFC		1.912	1.413	0.285	0.04
Post-GFC		9.919***	2.822**	2.854***	0.20
MXN					
Full Sample	1.034				0.01
Pre-GFC	-2.019**				0.06
Post-GFC	4.162***				0.08
Full Sample		4.947***	0.242	3.879***	0.07
Pre-GFC		-1.174	-4.161***	1.715*	0.09
Post-GFC		13.425***	1.681	5.653***	0.30
BRL					
Full Sample	3.228***				0.05
Pre-GFC	1.638				0.01
Post-GFC	4.703***				0.09
Full Sample		6.233***	1.557	2.618***	0.07
Pre-GFC		3.003	-5.216	1.968**	0.05
Post-GFC		9.976***	2.53*	2.808***	0.15

* EME exchange rate index includes only floating rates.

Notes: The data are changes in a one-day window around FOMC announcement dates. The full sample is from 2002-2017. The pre-crisis sample is from 2002-2007. The post-crisis sample is from 2010-2017. Estimates of term premia and expected short rates are based on an estimated affine term structure model. The 10-year yields are generic government bond yields from Bloomberg. ***, **, and * denote significance at the 1, 5, and 10 percent levels, respectively. Significance of the t-test is a rejection of the hypothesis that the expected interest rate and term premium coefficients are the same.

Table 3: Regression Results for Bond Yield Spillovers, FOMC Announcement Days

Dependent Variable	U.S. Explanatory Variables; Changes in:				
10-year Yield Changes	10-year Yield	Expected Interest Rate	Term Premium	SR=TP t-test	R-squared
AFE					
Germany					
Full Sample	0.38***				0.23
Pre-GFC	0.362***				0.14
Post-GFC	0.401***				0.17
Full Sample		0.362***	0.378***	-0.136	0.20
Pre-GFC		0.275*	0.564***	-1.309	0.16
Post-GFC		0.433**	0.453***	-0.117	0.22
Canada					
Full Sample	0.578***				0.71
Pre-GFC	0.67***				0.70
Post-GFC	0.632***				0.82
Full Sample		0.729***	0.544***	3.965***	0.66
Pre-GFC		0.855***	0.627***	2.058**	0.59
Post-GFC		0.701***	0.601***	1.859*	0.77
U.K.					
Full Sample	0.377***				0.18
Pre-GFC	0.318***				0.10
Post-GFC	0.567***				0.23
Full Sample		0.362***	0.37***	-0.062	0.16
Pre-GFC		0.253*	0.583***	-1.518	0.16
Post-GFC		0.758***	0.532***	1.091	0.24
EME					
Korea					
Full Sample	0.299***				0.21
Pre-GFC	0.156*				0.05
Post-GFC	0.387***				0.33
Full Sample		0.352***	0.286***	0.900	0.18
Pre-GFC		0.152	0.321**	-1.189	0.07
Post-GFC		0.503***	0.383***	1.120	0.36
Mexico					
Full Sample	0.255***				0.04
Pre-GFC	0.05				0.00
Post-GFC	0.361***				0.15
Full Sample		0.335***	0.192***	1.200	0.04
Pre-GFC		0.095	0.162	-0.214	0.00
Post-GFC		0.616***	0.27***	2.432**	0.17
Brazil					
Full Sample	0.409***				0.06
Pre-GFC	0.461				0.12
Post-GFC	0.692***				0.15
Full Sample		1.171***	0.225	3.677***	0.13
Pre-GFC		0.69	-1.058	2.001**	0.30
Post-GFC		1.366***	0.295	3.079***	0.21

Notes: The data are changes in a one-day window around FOMC announcement dates. The full sample is from 2002-2017. The pre-crisis sample is from 2002-2007. The post-crisis sample is from 2010-2017. Estimates of term premia and expected short rates are based on an estimated affine term structure model. Brazil 10-year yield data begins Jan. 4, 2006. The 10-year yields are generic government bond yields from Bloomberg. ***, **, and * denote significance at the 1, 5, and 10 percent levels, respectively. Significance of the t-test is a rejection of the hypothesis that the expected interest rate and term premium coefficients are the same.

Table 4: Regression Results for Bond Yield Spillovers, FOMC Announcement Days

Dependent Variable	U.S. Explanatory Variables; Changes in:				
Changes in:	10-year Yield	Expected Interest Rate	Term Premium	SR=TP t-test	R-squared
German 10-year Yield					
Full Sample	0.385***				0.22
Pre-GFC	0.405***				0.11
Post-GFC	0.463***				0.25
Full Sample		0.307***	0.402***	-0.841	0.22
Pre-GFC		0.268*	0.538***	-1.181	0.13
Post-GFC		0.396**	0.478***	-0.454	0.25
German Expected Interest Rate					
Full Sample	0.048***				0.04
Pre-GFC	0.126***				0.11
Post-GFC	0.094***				0.14
Full Sample		0.121***	0.029	2.800***	0.07
Pre-GFC		0.161***	0.076	1.247	0.13
Post-GFC		0.081**	0.098***	-0.462	0.14
German Term Premium					
Full Sample	0.307***				0.18
Pre-GFC	0.213**				0.07
Post-GFC	0.337***				0.16
Full Sample		0.164*	0.342***	-1.920*	0.20
Pre-GFC		0.07	0.422***	-2.035**	0.13
Post-GFC		0.31*	0.344***	-0.206	0.16

Notes: The data are changes in a one-day window around FOMC announcement dates. The full sample is from 2002-2017. The pre-crisis sample is from 2002-2007. The post-crisis sample is from 2010-2017. Estimates of term premia and expected short rates are based on an estimated affine term structure model. The German 10-year yields are zero-coupon yields from Bloomberg. The U.S. 10-year yields are zero-coupon yields from the Federal Reserve Board. ***, **, and * denote significance at the 1, 5, and 10 percent levels, respectively. Significance of the t-test is a rejection of the hypothesis that the expected interest rate and term premium coefficients are the same.

Table 5: Regression Results for Bond Yield Spillovers, ECB Announcement Days

Dependent Variable	German Explanatory Variables; Changes in:				
Changes in:	10-year Yield	Expected Interest Rate	Term Premium	SR=TP t-test	R-squared
U.S. 10-year Yield					
Full Sample	0.742***				0.35
Pre-GFC	0.691***				0.29
Post-GFC	0.745***				0.42
Full Sample		0.812***	0.73***	0.864	0.35
Pre-GFC		0.889***	0.571***	1.482	0.30
Post-GFC		0.941***	0.693***	1.635	0.42
U.S. Expected Interest Rate					
Full Sample	0.115***				0.03
Pre-GFC	0.174**				0.05
Post-GFC	0.0				0.00
Full Sample		0.192***	0.08*	1.695*	0.04
Pre-GFC		0.233*	0.118	0.671	0.04
Post-GFC		0.077	-0.023	1.022	0.01
U.S. Term Premium					
Full Sample	0.617***				0.25
Pre-GFC	0.509***				0.22
Post-GFC	0.732***				0.36
Full Sample		0.546***	0.657***	-1.093	0.25
Pre-GFC		0.689***	0.392***	1.729*	0.25
Post-GFC		0.833***	0.716***	0.661	0.35

Notes: The data are changes in a one-day window around ECB announcement dates. The full sample is from 2002-2017. The pre-crisis sample is from 2002-2007. The post-crisis sample is from 2010-2017. Estimates of term premia and expected short rates are based on an estimated affine term structure model. The German 10-year yields are zero-coupon yields from Bloomberg. The U.S. 10-year yields are zero-coupon yields from the Federal Reserve Board. ***, **, and * denote significance at the 1, 5, and 10 percent levels, respectively. Significance of the t-test is a rejection of the hypothesis that the expected interest rate and term premium coefficients are the same.

Appendix A Tables: Regression Results on Central Bank Meeting Dates Using Alternative Measures of Expected Rates and Term Premiums

Table A1a: AFE index on US Interest Rate Decomposition on FOMC Announcement Days, Full Sample

		Intercept	Short Rate	Term Premium	SR=TP t-test	R-squared
OLS	ACM	−0.14 ***	7.54***	2.42***	3.55***	0.35
		(0.05)	(1.41)	(0.77)		
	Slope (10yr - 2yr)	−0.12 **	4.60***	2.45**	1.59	0.32
		(0.05)	(0.88)	(0.99)		
	Residual (10yr on 2yr)	−0.13 ***	4.30***	2.45**	1.27	0.32
		(0.05)	(0.90)	(0.99)		
Robust	ACM	−0.12 ***	7.55***	2.33***	5.37***	0.27
		(0.04)	(0.90)	(0.55)		
	Slope (10yr - 2yr)	−0.10 **	4.74***	2.51***	2.48**	0.24
		(0.04)	(0.57)	(0.80)		
	Residual (10yr on 2yr)	−0.11 **	4.23***	2.51***	1.67*	0.24
		(0.04)	(0.56)	(0.80)		

The ACM measures of term premia and expected short rates are based on an estimated affine term structure model, similar to that proposed in Adrian et al (2013).
The slope measure of term premium is defined as the difference between the 10 and the 2-year treasury yields, and the corresponding expected short rate is the yield on a 2-year treasury.
The residual measure is based on a regression of 10-year treasury yields on 2-year treasury yields. The term premium estimates are the residuals from this regression and the 2-year treasury yields serve as expected short rates.

Table A1b: AFE index on US Interest Rate Decomposition on FOMC Announcement Days, Pre-GFC

		Intercept	Short Rate	Term Premium	SR=TP t-test	R-squared
OLS	ACM	−0.10 *	2.89	1.78	0.49	0.11
		(0.06)	(1.86)	(1.76)		
	Slope (10yr - 2yr)	−0.10 *	1.85	0.63	0.63	0.10
		(0.06)	(1.17)	(1.89)		
	Residual (10yr on 2yr)	−0.11 *	1.77	0.63	0.54	0.10
		(0.06)	(1.13)	(1.89)		
Robust	ACM	−0.09	2.25*	2.04	0.12	0.06
		(0.06)	(1.27)	(1.63)		
	Slope (10yr - 2yr)	−0.10	1.65*	1.11	0.35	0.05
		(0.06)	(0.90)	(1.87)		
	Residual (10yr on 2yr)	−0.10 *	1.43*	1.11	0.17	0.05
		(0.06)	(0.75)	(1.87)		

Table A1c: AFE index on US Interest Rate Decomposition on FOMC Announcement Days, Post-GFC

		Intercept	Short Rate	Term Premium	SR=TP t-test	R-squared
OLS	ACM	−0.06	11.44***	2.57***	6.32***	0.59
		(0.05)	(1.39)	(0.62)		
	Slope (10yr - 2yr)	−0.07	8.95***	0.06	4.49***	0.53
		(0.05)	(1.22)	(1.34)		
	Residual (10yr on 2yr)	−0.07	8.94***	0.06	4.20***	0.53
		(0.05)	(1.27)	(1.34)		
Robust	ACM	−0.06	11.84***	2.67***	8.28***	0.52
		(0.04)	(1.10)	(0.63)		
	Slope (10yr - 2yr)	−0.07	9.47***	0.68	5.18***	0.45
		(0.06)	(1.12)	(1.16)		
	Residual (10yr on 2yr)	−0.07	9.33***	0.68	4.61***	0.45
		(0.05)	(1.17)	(1.16)		

Table A2a: EME index on US Interest Rate Decomposition on FOMC Announcement Days, Full Sample

		Intercept	Short Rate	Term Premium	SR=TP t-test	R-squared
OLS	ACM	−0.06	4.95**	0.04	2.76***	0.10
		(0.07)	(1.93)	(1.51)		
	Slope (10yr - 2yr)	−0.04	2.37**	1.20	0.72	0.06
		(0.07)	(0.96)	(1.61)		
	Residual (10yr on 2yr)	−0.05	2.22**	1.20	0.57	0.06
		(0.07)	(0.92)	(1.61)		
Robust	ACM	−0.04	4.38***	1.38**	3.11***	0.10
		(0.04)	(0.89)	(0.55)		
	Slope (10yr - 2yr)	−0.03	2.22***	1.90**	0.37	0.08
		(0.04)	(0.56)	(0.79)		
	Residual (10yr on 2yr)	−0.04	1.84***	1.90**	−0.05	0.08
		(0.04)	(0.55)	(0.79)		

Table A2b: EME index on US Interest Rate Decomposition on FOMC Announcement Days, Pre-GFC

		Intercept	Short Rate	Term Premium	SR=TP t-test	R-squared
OLS	ACM	−0.10 **	3.15**	−0.14	2.22**	0.20
		(0.05)	(1.33)	(1.07)		
	Slope (10yr - 2yr)	−0.09 *	1.70**	−0.62	1.64	0.19
		(0.05)	(0.83)	(1.42)		
	Residual (10yr on 2yr)	−0.09 *	1.77**	−0.62	1.53	0.19
		(0.05)	(0.79)	(1.42)		
Robust	ACM	−0.11 **	2.89***	0.07	1.94*	0.13
		(0.05)	(1.02)	(1.32)		
	Slope (10yr - 2yr)	−0.09 **	1.62**	0.04	1.33	0.12
		(0.05)	(0.70)	(1.44)		
	Residual (10yr on 2yr)	−0.09 **	1.61***	0.04	1.08	0.12
		(0.05)	(0.58)	(1.44)		

Table A2c: EME index on US Interest Rate Decomposition on FOMC Announcement Days, Post-GFC

		Intercept	Short Rate	Term Premium	SR=TP t-test	R-squared
OLS	ACM	0.06	11.53***	2.04	2.94***	0.30
		(0.09)	(3.24)	(1.43)		
	Slope (10yr - 2yr)	0.06	7.27***	1.74	1.26	0.19
		(0.09)	(2.44)	(3.19)		
	Residual (10yr on 2yr)	0.05	7.05***	1.74	1.13	0.19
		(0.09)	(2.55)	(3.19)		
Robust	ACM	0.06	9.49***	2.21*	3.30***	0.19
		(0.09)	(2.20)	(1.25)		
	Slope (10yr - 2yr)	0.05	5.56***	2.53	1.14	0.13
		(0.09)	(1.77)	(1.81)		
	Residual (10yr on 2yr)	0.04	5.06***	2.53	0.86	0.13
		(0.09)	(1.85)	(1.81)		

Table A3a: German 10-year Yield on US Interest Rate Decomposition on FOMC Announcement Days, Full Sample

		Intercept	Short Rate	Term Premium	SR=TP t-test	R-squared
OLS	ACM	−0.01	0.36***	0.37***	−0.08	0.25
		(0.00)	(0.12)	(0.06)		
	Slope (10yr - 2yr)	0.00	0.34***	0.44***	−0.96	0.26
		(0.00)	(0.07)	(0.08)		
	Residual (10yr on 2yr)	−0.01	0.28***	0.44***	−1.37	0.26
		(0.00)	(0.07)	(0.08)		
Robust	ACM	−0.01	0.36***	0.38***	−0.14	0.20
		(0.01)	(0.11)	(0.07)		
	Slope (10yr - 2yr)	−0.01	0.34***	0.46***	−1.26	0.23
		(0.00)	(0.06)	(0.09)		
	Residual (10yr on 2yr)	−0.01	0.24***	0.46***	−1.90 *	0.23
		(0.00)	(0.06)	(0.09)		

Table A3b: German 10-year Yield on US Interest Rate Decomposition on FOMC Announcement Days, Pre-GFC

		Intercept	Short Rate	Term Premium	SR=TP t-test	R-squared
OLS	ACM	0.02***	0.32	0.60***	−1.42	0.22
		(0.01)	(0.23)	(0.16)		
	Slope (10yr - 2yr)	0.02***	0.37**	0.77***	−2.62 ***	0.28
		(0.00)	(0.16)	(0.17)		
	Residual (10yr on 2yr)	0.01***	0.27*	0.77***	−3.01 ***	0.28
		(0.01)	(0.15)	(0.17)		
Robust	ACM	0.02**	0.28*	0.56***	−1.31	0.16
		(0.01)	(0.16)	(0.20)		
	Slope (10yr - 2yr)	0.01**	0.31***	0.74***	−2.45 **	0.21
		(0.01)	(0.10)	(0.21)		
	Residual (10yr on 2yr)	0.01*	0.17**	0.74***	−2.71 ***	0.21
		(0.01)	(0.08)	(0.21)		

Table A3c: German 10-year Yield on US Interest Rate Decomposition on FOMC Announcement Days, Post-GFC

		Intercept	Short Rate	Term Premium	SR=TP t-test	R-squared
OLS	ACM	−0.01 *	0.42***	0.43***	−0.03	0.23
		(0.01)	(0.15)	(0.12)		
	Slope (10yr - 2yr)	−0.01 *	0.37***	0.40***	−0.13	0.18
		(0.01)	(0.14)	(0.15)		
	Residual (10yr on 2yr)	−0.01 **	0.32**	0.40***	−0.35	0.18
		(0.01)	(0.14)	(0.15)		
Robust	ACM	−0.02 **	0.43**	0.45***	−0.12	0.22
		(0.01)	(0.17)	(0.10)		
	Slope (10yr - 2yr)	−0.02 **	0.37**	0.44***	−0.32	0.17
		(0.01)	(0.15)	(0.15)		
	Residual (10yr on 2yr)	−0.02 **	0.28*	0.44***	−0.65	0.17
		(0.01)	(0.16)	(0.15)		

Table A4a: US 10-year Yield on German Interest Rate Decomposition on ECB Announcement Days, Full Sample

		Intercept	Short Rate	Term Premium	SR=TP t-test	R-squared
OLS	ACM	0.01**	0.78***	0.76***	0.09	0.39
		(0.00)	(0.14)	(0.08)		
	Slope (10yr - 2yr)	0.01**	0.73***	0.76***	−0.29	0.41
		(0.00)	(0.08)	(0.10)		
	Residual (10yr on 2yr)	0.01***	0.44***	0.76***	−2.17 **	0.41
		(0.00)	(0.08)	(0.10)		
Robust	ACM	0.01**	0.72***	0.74***	−0.20	0.34
		(0.00)	(0.10)	(0.07)		
	Slope (10yr - 2yr)	0.01**	0.68***	0.73***	−0.61	0.35
		(0.00)	(0.06)	(0.09)		
	Residual (10yr on 2yr)	0.01**	0.43***	0.73***	−2.94 ***	0.35
		(0.00)	(0.05)	(0.09)		

Table A4b: US 10-year Yield on German Interest Rate Decomposition on ECB Announcement Days, Pre-GFC

		Intercept	Short Rate	Term Premium	SR=TP t-test	R-squared
OLS	ACM	0.01	0.92***	0.55***	1.23	0.30
		(0.00)	(0.22)	(0.18)		
	Slope (10yr - 2yr)	0.01	0.68***	0.17	1.54	0.33
		(0.00)	(0.13)	(0.38)		
	Residual (10yr on 2yr)	0.01	0.61***	0.17	0.95	0.33
		(0.00)	(0.13)	(0.38)		
Robust	ACM	0.00	0.83***	0.51***	1.28	0.24
		(0.01)	(0.19)	(0.16)		
	Slope (10yr - 2yr)	0.00	0.63***	0.23	1.80*	0.27
		(0.01)	(0.12)	(0.25)		
	Residual (10yr on 2yr)	0.00	0.55***	0.23	1.06	0.27
		(0.01)	(0.11)	(0.25)		

Table A4c: US 10-year Yield on German Interest Rate Decomposition on ECB Announcement Days, Post-GFC

		Intercept	Short Rate	Term Premium	SR=TP t-test	R-squared
OLS	ACM	0.00	0.97***	0.63***	1.41	0.44
		(0.00)	(0.22)	(0.09)		
	Slope (10yr - 2yr)	0.01*	0.74***	0.66***	0.41	0.49
		(0.00)	(0.13)	(0.11)		
	Residual (10yr on 2yr)	0.01*	0.49***	0.66***	−0.73	0.49
		(0.00)	(0.15)	(0.11)		
Robust	ACM	0.01	0.82***	0.65***	1.08	0.40
		(0.00)	(0.13)	(0.09)		
	Slope (10yr - 2yr)	0.01*	0.66***	0.66***	0.03	0.43
		(0.00)	(0.08)	(0.10)		
	Residual (10yr on 2yr)	0.01*	0.44***	0.66***	−1.69 *	0.43
		(0.00)	(0.08)	(0.10)		