

Unconventional Monetary Policy, (A)Synchronicity and the Yield Curve

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ABSTRACT

This paper examines unconventional monetary policy (UMP) spillovers between advanced economies, exploiting the asynchronous timing of policy normalization to shed light on the term structure implications of UMP divergence. Using high frequency data to identify monetary policy and contemporaneous news, I find that spillovers increase during UMP and strengthen during asynchronous normalization. In fact, these spillovers in the asynchronous period appear to drive the increase in post-Lehman spillovers found elsewhere in the literature. Using a shadow rate term structure model, I find that international spillovers manifest through term premia, particularly at the effective lower bound. Identifying target, forward guidance, and Quantitative Easing (QE) shocks suggests term premium effects arise from QE and forward guidance, while target shocks do not generate spillovers.

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1 Introduction

The speed of economic recovery in the aftermath of the Global Financial Crisis (GFC) differed markedly among advanced economies, leading to increasingly divergent monetary conditions by the end of 2019. While the Euro area and Japan increased their unconventional monetary stimulus through 2019, the United States and the United Kingdom began monetary policy normalization and subsequently saw a gradual inversion of the domestic yield curve. These dynamics fueled extant interest in the process of exiting from unconventional monetary policy (UMP) and in the role of monetary policy spillovers in explaining patterns of domestic and foreign asset prices at and away from the zero lower bound (ZLB) in general.¹ The implications of UMP divergence for the efficacy of monetary policy are not well understood. On the one hand, coordinated policy actions are thought to be particularly potent. On the other, shifts in monetary policy in an environment of large interest rate differentials can lead to out-sized market responses (Forbes 2019).

In particular, observed patterns in long-term interest rates in these advanced economies suggest that the divergence of monetary policy normalization amplifies monetary policy's international spillovers across the term structure of interest rates. Large expansionary spillovers to the long end of the yield curve have the potential to dampen the effectiveness of domestic monetary policy normalization, particularly if normalization operates chiefly at the short end of the term structure. A unilateral or asynchronous exit from unconventional monetary policy thus has the potential to flatten or invert the domestic yield curve, while monetary policy normalization has the potential to impact the effectiveness of ongoing quantitative easing (QE) in other countries. Therefore, the timing, overlap, and intensity of unconventional monetary policies among the largest advanced economy central banks warrants specific attention, in light of the unique conditions generated by the ZLB and the likelihood it will bind repeatedly in the future as it does at the time of writing.

While an abundant literature documents the effect of the Federal Reserve's unconventional policies, the scale and scope of spillovers from other advanced economy central banks pursuing quantitative easing has received less study.² As a consequence, little research has been done to suggest how these policies might interact within the asset price space and to what extent the end outcomes depend on joint pursuit, if not coordination, of UMP. To that end, in this paper I document the magnitude of cross-border spillovers between the four largest central banks with policies of quantitative easing—the Federal Reserve, the ECB, the Bank of

¹ Although the term “spillovers” could be used to denote the impact of foreign policy on any number of variables, throughout the text I use “spillovers” to refer to the effect of one central bank's monetary policy surprises on another country's sovereign yield curve.

² For spillovers from the Federal Reserve, see for example Krishnamurthy and Vissing Jorgensen (2011), Bauer and Rudebusch (2014), Neely (2015), Fratzscher et al. (2013), Christensen and Rudebusch (2012), Gagnon et al. (2011), Hamilton and Wu (2012), D'Amico and King (2013), and Wright (2012). A small but growing body of literature treats spillover effects from the ECB. Fratzscher et al. (2014), Falagiarda et al. (2015), Bluwstein and Canova (2016), Ciarlone and Colabella (2016) explore the effects of the ECB's asset purchase programs on emerging and non-euro European markets, while Georgiadis and Gräb (2015), Fratzscher et al. (2014), and Curcucu et al. (2018) examine spillovers from ECB monetary policy on advanced economy assets.

Japan, and the Bank of England. I further exploit asynchronous shifts away from unconventional monetary policy, or a return to short-rate-based monetary policy, to understand the implications of this policy divergence for domestic and international transmission.

I focus on three key questions. First, how does monetary policy at the zero lower bound differ from conventional periods in its effect on the shape of the term structure, both domestically and internationally? Second, what role do term premia play in domestic and international transmission compared to more conventional channels? Finally, how do spillover dynamics change when unconventional monetary policy conditions diverge?

To answer these questions, I use high frequency identification to extract monetary policy surprises from futures contracts on the dates of monetary policy announcements in the manner of Kuttner (2001), Gürkaynak et al. (2005) and others. I take a novel approach incorporating contemporaneous advanced economy monetary policy and macroeconomic news surprises to examine the effects of both unconventional monetary policy and normalization by advanced central banks on the term structure of zero coupon bond yields. Controlling for these concurrent surprises on the dates of monetary policy announcements decreases news contamination in the absence of intraday data and enables direct comparisons between central banks. To evaluate the influence of synchronicity, I separate the sample into four distinct periods based on announcement and effective end dates of these central banks' QE programs. I focus on announcements related to QE entry and exit because these programs represent the most direct targeting of unconventional (particularly long-duration) asset prices. In so doing, my paper differs from others comparing the time-varying spillovers of the four largest central banks, which to date address differential effects between the pre- and post-crisis periods only.

Focusing first on the term structure itself, I find that spillovers from monetary policy on the sovereign yield curves of advanced economies not only shift from short maturities to long ones at the zero lower bound, but that they also increase in overall magnitude. In addition, these spillovers increase further in the period of asynchronous monetary policy normalization. In the case of the Federal Reserve, spillovers to the UK, the Euro area, and Japan during the period of normalization dominate those observed during the period of peak US UMP. Moreover, contravening a focus in the spillover literature on the Federal Reserve, I find that the ECB and Bank of England generate substantial spillovers to the long end of the US yield curve during the most divergent episode in the sample, following the announcement of the ECB's policy of quantitative easing, the Extended Asset Purchase Program (EAPP) (e.g., Ehrmann and Fratzscher 2005; Fratzscher et al. 2016; Brusa et al. 2017; Mueller et al. 2017; Rogers et al. 2014).³ More importantly, I find that each central bank's measured spillovers in

³Throughout this paper, I follow Bernanke (2009) and others and define quantitative easing as a central bank balance sheet expansion focused on the mix of loans and securities that the central bank holds, with explicit consideration on the effect this composition of assets affects credit conditions. This definition distinguishes the experience of the ECB from the Fed, the Bank of England, and the Bank of Japan. In contrast to these other central banks, the ECB's balance sheet expansion during its early crisis response mainly reflects its increased intermediation role and the growth of its lending to banks, which play a crucial part in financing the Euro area's private sector. While the other central banks orchestrated the growth of their balance sheets as part of their policies of quantitative easing, in the case of the ECB, the discretion of commercial banks and their need for refinancing drove balance sheet

the post-Lehman era actually derive in large part from increases following the start of monetary policy divergence.

Second, to pinpoint the importance of the term premium for international transmission, I decompose each market's zero coupon bond yield into an expected path of short rates and a term premium using the shadow rate term structure model (SRTSM) of Wu and Xia (2016).⁴ Results from this yield decomposition suggest that, in most subsamples and most sender-recipient pairings, the term premium drives the bulk of spillovers. I find that these term premium spillovers are strongest in the period of asynchronous monetary policy normalization both in absolute terms (i.e., compared to term premium spillovers in other subsamples) and in comparison to the expected path of short rates. By contrast, the expected path of short rates drives (modest) spillovers in the pre-crisis period.

The strength of the term premium channel further underscores the uniqueness of unconventional monetary policy both in terms of spillovers and in driving domestic interest rate pass-through.⁵ Domestic transmission channels map onto the maturity structure of interest rate pass-through: periods of unconventional monetary policy correspond to a larger impact on the long end of the yield curve through term premia, while periods of conventional monetary policy largely act on shorter interest rates through expectations of future policy rates. However, normalization only partially reestablishes conventional channels.

Finally, I trace the dynamic impact of these monetary policy spillovers to long-term sovereign bond yields using local projections (Jordà 2005; Stock and Watson 2018). While contemporaneous spillovers to the US increase in magnitude during the period of asynchronous normalization, these effects dissipate within a week's time. By contrast, spillovers from the Federal Reserve typically last for more than a month, often matching the persistence of domestic pass-through. The persistence of US monetary policy surprises, compared to the more transitory nature of spillovers from other central banks, supports findings in existing literature that emphasizes the uniqueness of the Federal Reserve (Brusa et al. 2017; Gerko and Rey 2017; Mueller et al. 2017 and Rogers et al. 2014).

These increased spillovers, concentrated on the long end of the yield curve, may complicate the independent conduct of monetary policy in the pursuit, or unwinding, of unconventional monetary policy. While conventional monetary policy generates vanishingly small spillovers that are concentrated in the short end of the yield curve, unconventional monetary policy and its unwinding uniquely generate conditions under which central banks may face challenges in implementing independent monetary policy, due to its impact on long-term bond yields, which tend to move together. The concentration of spillovers in the term pre-

expansion. The contraction of the ECB's balance sheet that began in 2012 reflected the banks' declining need for liquidity following the reduction in financial fragmentation in the Euro area (de Sola Perea and Van Nieuwenhuyze, 2014).

⁴The choice of a shadow rate term structure model with daily data further distinguishes this paper from the existing literature by taking into account the influence of the zero lower bound on the expected path of short rates (Kearns et al. 2018; Rogers et al. 2014; Shah 2018).

⁵Periodically throughout the paper, I use the term "pass-through" to denote the effect of domestic monetary policy surprises on the domestic sovereign yield curve.

mium similarly carries potential implications for the conduct of unconventional monetary policy—in its absence, both quantitative easing and normalization may be more effective domestically because of the potential for portfolio balance effects.

The paper proceeds as follows. Section 2 briefly describes the related literature on monetary policy spillovers and reviews the transmission mechanisms of unconventional monetary policy. Section 3 presents stylized facts from the data to motivate the main approach. Section 4 presents the baseline model for estimating the effects of monetary policy surprises on zero coupon bond yields, including the decomposition of these yields into a rational expectations-implied path of short rates and a term premium to test their relative importance in monetary policy transmission. Section 5 presents further evidence on the channels of passthrough to term premia in greater depth and discusses a number of robustness checks. Section 6 concludes and outlines future directions for research.

2 Motivation: Spillovers at the Zero Lower Bound

2.1 Related Literature

An abundant literature on the international impact of US quantitative easing programs on a number of asset classes contrasts its effects with those of conventional monetary policy.⁶ However, the nearest neighbors of this paper compare the magnitude of sovereign bond yield spillovers from unconventional monetary policy among multiple advanced economy central banks (Rogers et al. 2014, 2016; Kearns et al. 2018; Shah 2018; Zhang 2018). While Rogers et al. (2014), Fratzscher et al. (2017) and Shah (2018) find that the Federal Reserve uniquely propagates cross-border yield curve spillovers, Rogers et al. (2018), Kearns et al. (2018) Curcuro et al. (2018a), and Zhang (2018) find a role for other advanced economy central banks in influencing long-term bond yields internationally.

My paper contributes to this “parallel spillovers” literature by showing that the pre-crisis/post-crisis dynamics therein derive in large part from spillovers increasing under divergent monetary policy conditions. I find that conventional and unconventional monetary policy act, internationally and domestically, in a manner consistent with these previous papers in terms of the size of spillovers under UMP. However, I go a step further to show that

⁶For example, Neely (2011), Wright (2012), Fratzscher et al. (2017), Bauer and Neely (2014), and Rogers et al. (2016) find that QE’s international impact distinguishes unconventional from conventional monetary policy, Curcuro et al. (2018b) find that QE does not exert larger international spillovers. Taking time-varying impacts further into the period of monetary policy normalization, Chari, Dilts Stedman, and Lundblad (2020) find that asset price spillovers from monetary policy in the US do not differ substantially between the conventional and unconventional periods, but that the normalization of US monetary policy had substantial consequences for emerging market asset prices. Mueller et al. (2017) document that a trading strategy that is short in the U.S. dollar and long in other currencies exhibits larger excess returns on days with scheduled Federal Reserve announcements—a pattern which is shared only by the Bank of Japan. Examining excess equity returns, Brusa et al. (2017) find that there is an equity premium associated with Fed announcement days that is not shared by any other central bank. A vast literature documents the impact of monetary policy spillovers on bank lending channels (Hofmann and Takáts 2015; Bruno and Shin 2015; Cetorelli and Goldberg 2012; Fratzscher et al. 2016, Chen et al. 2016; Morais et al. (2019)).

these UMP spillovers grow larger and more ubiquitous when these central banks are out of sync. Furthermore, by decomposing the effect into a term premium and expected path of short rates, and by dissecting the term structure of the monetary policy shock itself, I find that “normal” monetary policy following a period of domestic and global unconventional measures causes short-rate based policy to reflect both conventional and unconventional mechanisms. To my knowledge, this is the first paper to document changes in these international mechanisms through the process of unwinding.

This paper also relates to the literature on identification of monetary policy asset price pass-through using high frequency identification of monetary policy shocks (Kuttner 2001; Gökaynak, Sack and Swanson 2005, 2007; Gertler and Karadi 2015; Leombroni et al. 2017; Gorodnichenko and Weber 2016; Ozdagli and Weber 2017). I extend the methodology used in this literature to generate a daily monetary policy surprise measure that is consistent between central banks and that maintains variation at the zero lower bound. Furthermore, I depart from the existing literature by jointly estimating spillovers from multiple central banks instead of censoring concurrent observations. Although announcements of any kind seldom overlap with FOMC releases, keeping shared dates in the sample proves important for estimating the impact of spillovers from the ECB or the Bank of England. Censoring these observations in the daily data would necessitate the exclusion of more than 25% of all ECB and BoE announcements from the sample.

2.2 Mechanisms of Transmission: Conventional versus Unconventional Monetary Policy

In typical circumstances, central banks conduct monetary policy by buying and selling short-term debt and, in most instances, target short-term interest rates. However, at the zero lower bound, the availability of cash as an asset negates stimulus from decreasing the short-term policy rate indefinitely below zero. Beyond the effective lower bound of interest rates, recent years saw central banks pursue policies such as direct lending, liquidity provision to key credit markets, and large-scale asset purchases. These large-scale asset purchases, coupled with forward guidance regarding the path of policy, aim specifically to lower long-term interest rates through heavier management of expectations and adjustments to term premia.⁷ Thus, to distinguish between conventional and unconventional monetary policy, it is convenient to consider the yield on an n -period risk-free bond as the average level of short-term interest rates over the maturity of the bond and a term premium:

$$Y_t^{(n)} = \mathbf{E}[\tilde{Y}_{t,t+n}|I_t] + YTP_t^{(n)} \quad (1)$$

where $\mathbf{E}[\tilde{Y}_{t,t+n}|I_t]$ is the average short-term rate expected to prevail over the period t to

⁷Bernanke, Ben S. (19 November 2013) *Communication and Monetary Policy*. Retrieved from <https://www.federalreserve.gov/newsevents/speech/bernanke20131119a.htm>

$t + n$ (that is, the component of the yield that would drive yield variation if the expectations hypothesis were to hold exactly), and $YTP_t^{(n)}$ is a maturity-specific term premium. The term premium captures the additional required compensation for holding a long-term bond (duration risk), subsuming the price and amount of interest rate risk, inflation risk, and macroeconomic growth risk. In theory, conventional monetary policy operates chiefly via the expected path of short-term interest rates, as compensation for maturity risk shrinks to zero with the maturity of the bond (Hamilton 2009; Sims and Wu 2020). However, unconventional monetary policy influences both terms of (1), either by signaling the central bank's intention to keep interest rates low, thereby reducing $E[\tilde{Y}_{t,t+n}|I_t]$, or by removing duration risk from the market (decreasing $YTP_t^{(n)}$).

Focusing on the first term of (1), forward guidance can lower the expected path of interest rates by communicating the central bank's intention to keep interest rates low (or to pursue ongoing asset purchases), committing often to a specific time horizon or level of fundamentals. However, large-scale asset purchases themselves also contribute to the force of forward guidance by acting as a commitment mechanism. Growing and maintaining the balance sheet signals low future interest rates in the sense that a central bank that has purchased a large quantity of long-dated assets when interest rates are low stands to see the value of its portfolio decline when interest rates begin to climb (Fawley and Neely 2013). Similarly, forward guidance and large-scale asset purchases have the potential to lower term premia by decreasing the volatility of expected interest rates.

However, as the maturity of an asset increases, the expected path of short interest rates explains less of the return. For this reason, monetary policy at the zero lower bound also explicitly aims at decreasing the term premium. To target longer-term interest rates, central banks purchase long duration assets, reducing the effective supply of such assets and thereby raising their prices, lowering their yields, and decreasing the duration risk associated with holding them. As investors rebalance their portfolios in response to quantitative easing, the prices of the assets they acquire rise as well, decreasing their respective yields through the term premium and potentially prompting further rebalancing. "Restricted" or preferred habitat investors at home and abroad can amplify this portfolio balancing channel by purchasing additional long-dated assets, even as their prices rise in order to balance long-dated obligations on their balance sheets or to search for yield.⁸ Thus, an expansionary monetary policy shock with strong portfolio balance effects has the potential to decrease international term premia.

Financial center monetary policy can also generate changes in international term premia by revealing information about the state of the economy, thereby altering the amount of perceived (duration) risk in the market. Central banks release information purposefully through forward guidance, but policy actions also contain information regarding policy makers' level of confidence in economic fundamentals. For example, while an episode like the

⁸Shin (2017) provides an illuminating example of long-term bond yield amplification through the duration balancing activities of German insurance firms.

“Taper Tantrum” of 2013 may increase yields by signaling an increase in the path of US interest rates, it also suggests optimism on the part of the FOMC regarding the state of the US economy. This might, in turn, be expected to benefit the global economic outlook, raising yields via projected future growth and, in turn, expected real interest rates. Thus, unconventional monetary policy may affect international term premia through a “confidence” channel.

However, the overlapping but asynchronous nature of unconventional monetary policy suggests the potential expansion of (perceived) interaction of policy between central banks. As mentioned above, on the domestic front, quantitative easing serves as a signal to markets regarding the future path of interest rate policy. How might this operate internationally?

In practice, central bank policy rates can be correlated internationally for various reasons, especially among countries with close economic ties. These can emerge through trade flows, or they can comprise information flows that manifest through business cycle comovement (see, for example, Kose et al. (2003) and Baxter and Kouparitsas (2005)). For instance, as long as the UK and the Euro area maintain tight financial and trade linkages, their policy rates may be expected to move together due to synchronous demand conditions. That is, foreign monetary policy reveals information on the state of the global economy to which the marginal investor expects the domestic central bank to react. Such informational spillovers can manifest through the expected path of short rates (average path) as well as term premia (volatility).

Conversely, central banks increasingly act on a mandate to safeguard financial stability.⁹ Central banks in countries facing expansionary financial spillovers may therefore be expected by the marginal investor to *withdraw* stimulus in the face of increased liquidity from abroad. We would expect the same reaction by central banks if expansionary monetary conditions abroad generally engender expansionary domestic demand conditions through a trade channel.

Through these additional channels, in contrast to conventional monetary policy, unconventional monetary policy stands to generate larger financial spillovers due to its focus on long-term interest rates, meaning that asynchronous normalization of monetary policy has the potential to shape the term structure of normalizing and non-normalizing economies. However, before I can estimate the channels through which unconventional monetary policy operates, I need first to identify it. The next section discusses challenges inherent to identifying cross-country spillovers from unconventional monetary policy, while Section 4 presents solutions for identification.

3 Stylized Facts: Inference via Heteroskedasticity

In the baseline analysis, I utilize daily data on bond yields and interest rate futures to jointly estimate the spillover effects of monetary policy surprises among the four central banks, controlling for macroeconomic news surprises. Daily data is not only more accessible, but it also

⁹*Financial Stability: The Role of the Federal Reserve System*. Retrieved from <https://www.newyorkfed.org/newsevents/speeches/2013/bax131120>

possesses some advantages over intraday data. First, using intraday data increases the risk of excluding information through leaks that limit the “firmness” of the announcement time, particularly in international contexts. Similarly, intraday windows cut off slow market reactions without guaranteeing sole influence from the announcement of interest. Similarly, futures markets retain a higher risk of “dead quotes” for windows wherein the assets of interest do not turn over often due to lack of liquidity. This issue is particularly acute in international contexts.

However, the choice of daily data also poses challenges for identification. To expand on this and to motivate my approach, I examine monetary policy spillovers in an assumption-light fashion, testing for the *presence* of spillovers between the US, the UK, the Euro area, and Japan with an inference via heteroskedasticity-type exercise in the spirit of Rigobon (2003), Rigobon and Sack (2003), and Rigobon and Sack (2004). These straightforward estimates suggest some tentative conclusions about the presence of spillovers and highlights the importance of considering them jointly. In particular, these results underline some challenges of the event study approach for uniquely identifying monetary policy from the Bank of England and ECB using daily data due to an abundance of concurrent monetary policy surprises. Given the size of the ECB’s program of QE, this represents a non-trivial barrier to identification.

3.1 Methodology

In a regression framework, one can express an asset price’s relationship to monetary policy as

$$\Delta y_{i,t} = \begin{cases} \alpha_i + \beta MP_t^j + \epsilon_{i,t} & t = \text{Announcement day} \\ \alpha_i + \epsilon_{i,t} & t = \text{Non-announcement day}, \end{cases}$$

where $\Delta y_{i,t}$ is the change in the asset return in question for market i at time t , and MP_t^j is the monetary policy surprise originating from country j at time t (or in the case of a domestic monetary policy surprise, $i = j$). This setup requires only that returns during announcement windows would have the same distribution as those during non-announcement windows in the absence of central bank announcements. Taking the variance of returns on announcement and non-announcement days separately, we see that the following holds:

$$\Delta y_{i,t}^{(a)} = \alpha_i + \beta MP_t^j + \epsilon_{i,t} \tag{2}$$

$$\text{var}(\Delta y_{i,t}^{(a)}) = \beta^2 \text{var}(MP_t^j) + \text{var}(\epsilon_{i,t})$$

$$\Delta y_{i,t}^{(n)} = \alpha_i + \epsilon_{i,t} \tag{3}$$

$$\text{var}(\Delta y_{i,t}^{(n)}) = \text{var}(\epsilon_{i,t})$$

In order to test the null hypothesis that $\beta = 0$, I need only test whether the variance of returns on announcement days equals that on non-announcement days:

$$\begin{aligned} \text{var}(\Delta y_{i,t}^{(a)}) &= \beta^2 \text{var}(MP_t^j) + \text{var}(\Delta y_{i,t}^{(n)}) \\ \text{var}(\Delta y_{i,t}^{(a)}) > \text{var}(\Delta y_{i,t}^{(n)}) &\implies \beta \neq 0 \end{aligned} \tag{4}$$

Note that the above holds regardless of the sign of β . To test the equality of return variances on announcement versus non-announcement days, I use the Brown-Forsythe test, comprising the F-statistic from an analysis of variance on absolute deviations from the median. As opposed to a test of mean squared deviations (such as an F-test), the Brown-Forsythe test is robust to non-normal data such as financial returns. Testing the difference in variances provides an initial picture of monetary policy spillovers without leaning heavily on many assumptions.

3.2 Data, Announcements and Timing Conventions

The sample of returns consists of daily data from September 4, 2004, to December 15, 2017.¹⁰ For this exercise, I collect data on government bond yields at maturities of one, five, and ten years for each country from each of the central banks.

Because responses to the Global Financial Crisis (GFC) and turbulence surrounding the euro often elicited unscheduled policy decisions from all central banks in the sample, announcement days include both scheduled and unscheduled events. Central bank websites supply the majority of announcement dates; I take additional unscheduled dates from Rogers et al. (2014) and Chari et al. (2018).

In the current framework, identification requires the exclusion of announcement days with overlapping meetings or macroeconomic news events. While announcements from the ECB, the Bank of England, and the Bank of Japan seldom overlap with those from the Federal Reserve, important exceptions occur, especially in the period during which central banks responded to the GFC (see Table 1a).¹¹ Moreover, ECB and Bank of England dates overlap frequently throughout the sample. To highlight the informational content of these concurrent announcement dates, I test the response of asset returns to shared ECB/Bank of England dates separately from those with a single central bank announcement. In such concurrent instances, I define an announcement date as one on which *both* the Bank of England and the ECB release a monetary policy announcement.

Due to the geographic dispersion of these markets, I adjust the timing ascribed to each announcement to reflect trading hours and the time difference between source and recipient

¹⁰The sample dates match those used in the baseline, which reflects the availability of zero coupon bond yield data from the ECB.

¹¹For example, on March 18, 2009, the FOMC and Bank of Japan both announced asset purchase programs. On this date, the US 10-year bond yield exhibited the largest single day drop from 1987 to the time of this writing.

countries. For example, an FOMC announcement concluded at 2:45pm on date t may not affect Japanese bond yields until trading begins at 8:45am (GMT+9) on day $t + 1$. For this reason, I measure announcement effects from the US to other countries in the sample as the daily difference in yields from t to $t + 1$, whereas the impact of the ECB, Bank of England, and Bank of Japan on the US are measured as the daily difference of US yields from $t - 1$ to t . Table 1b provides a summary of timing conventions between the four markets.

3.3 Results

Table 2 displays the results. Statistically significant results (≤ 10 percent) are expressed as the ratio of standard deviations on announcement days to those on non-announcement days:

$$\frac{\sigma_i^{a_j}}{\sigma_i^n} - 1, \quad (5)$$

where j is the central bank generating a monetary policy announcement and i is the recipient market. Blank cells represent results insignificant at the 10 percent level. Finally, cells with red text denote spillovers from combined ECB/Bank of England dates that do not exhibit spillovers from either Bank of England or ECB announcements individually.

Several patterns stand out. First, these central banks influence their own yield curves at every maturity. In terms of spillovers, the UK and Euro area's monetary policies exhibit the most consistent connection, impacting each other's term structure at every maturity. In line with much of the extant literature, the results in Table 2 suggest that the FOMC generates spillovers to the Euro area and the UK, while no central bank in the sample generates unilateral spillovers to the US. This result aligns with some of the current literature addressing cross-country spillovers to the United States from other central banks (Ehrmann and Fratzscher 2005; Rogers et al. 2014; Shah 2018; Mueller et al. 2017; Brusa et al. 2017). Unique within the sample, the Bank of Japan does not appear to generate spillovers to the bond yields of any of the other markets in the sample, nor does Japan appear to receive detectable spillovers.

Notably, however, when I consider dates that contain both an ECB and a Bank of England announcement, these concurrent events increase the volatility of medium and longer-dated US yields. In this case, Bank of England and ECB monetary policies are not separately identified, but the receptiveness of US yields to these concurrent shocks suggest a shortcoming in measuring unilateral spillovers from the ECB or Bank of England using daily data in a univariate event study framework.

Beyond the preliminary and intuitive documentation of spillovers among these advanced economy central banks, this stylized fact from the data suggests that shared dates among these central banks matter for identification, especially in the case of the ECB and the Bank of England. The conservative approach embodied in this exercise leaves important information underutilized, and thus the impact of some central banks in the sample appears less well identified. These concerns motivate the main approach of the paper, to which I turn next.

4 Baseline Analysis

The previous section highlighted some potential pitfalls of identifying monetary policy surprises using daily data.¹² In this section, the baseline analysis displays a number of characteristics intended to capture the full impact of monetary policy surprises while addressing these obstacles in analyzing the influence of asynchronous monetary policy normalization on spillovers.

4.1 Monetary Policy Surprises

This paper follows the high frequency identification (HFI) literature pioneered by Cook and Hahn (1989), Kuttner (2001), Cochrane and Piazzesi (2002), Gürkaynak et al. (2005), and others. This literature often defines a monetary policy surprise (in the United States) as the daily difference in the implied yield on a Fed Funds futures contract on a date with some Federal Reserve activity and zero on all other dates. This approach requires some adjustments, however, in international applications and at the zero lower bound.

First, aside from case of the Federal Reserve, no futures market instruments track the other central banks' policy rates directly. Each of these markets does, however, have an active interbank lending market with its own Interbank Offered Rate. One year ahead futures contracts on the three-month Euro Interbank Offered Rate (Euribor), Sterling London Interbank Offered Rate (Sterling Libor), and Euroyen Tokyo Interbank Offered Rate (Euroyen Tibor) are all traded continuously throughout the sample and maintain variation at the ZLB (see Figure 1). Because these interbank rates are strongly influenced by current expectations of future policy rates, overnight futures contracts can act as close substitutes for a contract based explicitly on the policy.¹³

Further complicating identification, variation in the price of Fed Funds futures contracts decreased considerably at the zero lower bound. From December 2008 until December of 2015, the FOMC announced no changes to the target Fed Funds rate, and in much of that period, the FOMC worked to maintain the message that the policy rate would continue near zero. To account for this issue, I follow Gertler and Karadi (2015) in using the one year ahead, three-month Eurodollar futures contract instead of Fed Funds futures, which alleviates the issue of attenuation apparent in the Fed Funds Futures data. The use of Eurodollar futures also brings the monetary policy measure for the FOMC in line with measures for the other central banks. Thus, I use the daily change in the yields implied by these overnight interbank interest rate futures prices (Eurodollar, Euribor, Euroyen and Short Sterling) as my measure of the surprise element contained in announcements by each respective central bank. The majority of included central bank announcement dates in the sample come from central bank websites. However, as in the previous exercise, I also include additional unscheduled dates.

¹²See Nakamura and Steinsson (2015) and Curcuru et al. (2018a) for more work in this area.

¹³Bernoth and Von Hagen (2004), for example, find that the three month Euribor futures rate is an unbiased predictor of Euro area policy rate changes.

Although attenuation does not appear to pose a problem in the sample period for the chosen contracts, time varying volatility of any short term interest rate into and away from the zero lower bound may still be a concern (see Figures 1a - 1d). To this end, and in recognition of quantitative easing's explicit goal of influencing longer-term interest rates, I also measure the surprise as the daily change in the two-year zero coupon bond yield as a robustness check, following Gilchrist et al. (2014).¹⁴ While these assets do not possess the desirable quality of serving as insurance against future interest rate changes, one may still reasonably attribute changes in the price of these assets on announcement days primarily to reactions to monetary policy surprises.

Tables 3a and 3b show summary statistics of the measured monetary policy surprises. For ease of interpretation and to make comparisons between central banks more germane, I normalize monetary policy surprises to a one standard deviation loosening in basis points.

4.2 Yield Curve Measures

In the baseline regressions and to estimate the shadow rate term structure model, I use zero coupon bond yield data gathered from central banks. The Federal Reserve publishes daily data on US zero coupon bond yields from Gürkaynak, Sack, and Wright (2007).¹⁵ The Bank of England and ECB websites publish UK and Euro area zero coupon bond yields, respectively.¹⁶ For Japan, zero coupon curve smoothing parameters are produced from JGB coupon bonds using the Nelson-Siegel-Svensson method, as described in Gürkaynak, Sack, and Wright (2007). All zero coupon curves comprise AAA-rated sovereign bonds.¹⁷ To give a more complete picture of term structure adjustments, I estimate the impact of monetary policy surprises on yields with maturities of 1, 3, 5, 7, and 10 years. As in the previous section, the sample spans September 4, 2004, to December 13, 2017. The availability of zero coupon bond yields from the Euro area determines the start date of the sample.

To extract the term premium and expected path of short rates from the term structure, I estimate the shadow rate term structure model of Wu and Xia (2016). Many papers in the literature on monetary policy spillovers utilize Gaussian affine term structure models (GATSM) to estimate term premia. However, because these models assume the short rate to be linear in Gaussian factors, GATSMs place a positive probability on negative nominal interest rates and therefore face challenges in periods of a binding effective lower bound. By contrast, the

¹⁴A suitable futures contract on a medium duration bond is not available for all sample countries. Contracts for Japan and the UK (5-year JGB futures and Medium Gilt futures) do not have an adequately long trading history, and no futures contract exists for a generic European bond yield. In the case of Japan, trade in 5-year JGB futures ceased entirely from June of 2002 to January of 2008, while in the case of the UK, Medium Gilt Futures did not launch until November of 2009.

¹⁵<https://www.federalreserve.gov/pubs/feds/2006/200628/200628abs.html>

¹⁶<http://sdw.ecb.europa.eu/browse.do?node=9691417>

<https://www.bankofengland.co.uk/statistics/yield-curves>

¹⁷Note that the ECB also publishes a series using all Euro area central government bonds (including AAA-rated), but this collection of bonds is less likely to be considered free of default risk. Nevertheless, repeating the exercise with parameters estimated using all Euro area sovereign bonds yields similar results.

SRTSM used here is a latent factor model where the state variables have Gaussian dynamics but the short rate has a shadow rate interpretation. Following Black (1995), the shadow rate class of term structure models represents the policy rate as the maximum of the effective lower bound and a shadow interest rate reflecting the value of the short rate if it could move freely below zero:

$$r_t = \max\{\underline{r}, s_t\} \quad (6)$$

The nonlinearity introduced by this representation makes such models difficult to estimate beyond one factor. However, Wu and Xia (2016) propose an analytical representation for the forward rate that makes a nonlinear term structure model tractable in empirical estimation for multiple factors. Having estimated the expected path of short rates for each of the US, the UK, the Euro area and Japan, I calculate the term premium as a residual in accordance with Eqn.

1. Summary statistics on yields, expected short rates, and term premia for each of the four markets can be found in Tables 4a and 4b.

4.3 Control variables

As mentioned above, this paper uses daily data to identify a monetary policy surprise in order to capture as much of the asset price's reaction as possible. In measuring the informational impact of monetary policy surprises, too narrow a window may miss part of the monetary policy surprise, but too wide a window risks the inclusion of non-monetary news. To retain the information of the announcement while reducing noise from other concurrent events, I control for macroeconomic news surprises from systemic economies using the Citigroup Economic Surprise Index (CESI) for Japan, the Euro area, the UK, and the US, in addition to controlling for concurrent monetary policy announcements. The CESI tracks how economic data compare to expectations; the indices rise when economic data exceed economists' consensus forecasts and falls when data come in below forecast estimates.¹⁸ In order to ensure that monetary policy surprises enter the regressions only through the futures-implied measures, I orthogonalize these news shocks to the monetary policy surprise measures. Finally, the lagged bilateral nominal exchange rate in local currency per unit of foreign currency controls for the influence of currency-based arbitrage, and a Friday dummy captures day-of-the-week effects.

4.4 Empirical Approach

Given my interest in what might be considered different global monetary policy phases, I partition the sample by count of central banks engaged in QE. The first subsample, ranging from

¹⁸Indices are defined as weighted historical standard deviations of data surprises (actual releases vs. Bloomberg survey median) and are calculated daily in a rolling three-month window. The weights of economic indicators are derived from relative high-frequency spot FX impacts of one standard deviation data surprises. The indices also employ a time decay function to replicate the limited memory of markets.

September 4, 2004, to September 15, 2008 (the collapse of Lehman Brothers), encompasses the pre-crisis period and constitutes broadly the period of conventional monetary policy (with the periodic exception of Japan). The period of initial quantitative easing (December 1, 2008 - May 21, 2013) comprises the introduction of multiple large-scale asset purchase programs, including LSAPs from the Federal Reserve, the Bank of England, and the Bank of Japan. Although the Bank of England and Bank of Japan began their asset purchase programs after the Federal Reserve (in March 2009 and October 2010, respectively), I group their entry with that of the United States as initial reactions to the deepening financial crisis that meet the definition of quantitative easing outlined previously.¹⁹

Beginning the period of asynchronous monetary policy normalization, the next subsample begins with the “Taper Tantrum” of May 22, 2013, when then-Chair Ben Bernanke first suggested the FOMC’s intention to taper US large-scale asset purchases. From this point on, I consider the United States to have begun normalizing monetary policy. Thus, from May 22, 2013, to January 21, 2015, only the Bank of Japan and Bank of England actively pursued quantitative easing. Throughout the text, I refer to this period as the “intra-QE” period, although there are still two quantitative easing programs in place. Finally, I partition the period from the start of the ECB’s program of quantitative easing to the end of the sample and refer to this as the EAPP period. During this last subsample, the Bank of Japan also intensified its unconventional monetary stimulus, instating policy frameworks such as “Quantitative and Qualitative Easing (QQE) with Negative Interest Rates” and “QQE with Yield Curve Control”. I refer to this latter period with the “EAPP” label throughout the text.

I consider each major QE entry or exit as a potential “critical juncture” and run piecewise regressions of the following form:

$$\Delta y_{it}^{(n)} = \alpha + \beta \Delta y_{it-1}^{(n)} + \sum_k \psi_k D_k MP_t^i + \sum_j \sum_k \gamma_k^j D_k MP_t^j + \theta_1^i S_t^i + \sum_j \theta_j S_t^j + \sum_j \phi_j \Delta e_{t-1}^{ij} + \delta Fri + \epsilon_{it} \quad (7)$$

$$MP_t^j = \begin{cases} Y_{j,t} - Y_{j,t-1} & t = \text{Announcement}_j \\ 0 & \text{Otherwise,} \end{cases}$$

where $y_{it}^{(n)}$ is either the zero coupon yield on an n -year bond in country i , the average expected path of short rates in country i from t to $t + n$ ($E[\tilde{Y}_{t,t+n}|I_t]$), or the term premium ($YTP_t^{(n)}$) on an n -year bond for country i at time t . To match asset reactions to markets, the timing conventions in Table 1b apply to this exercise as well. D_k refers to dummy variables equal to one in each of the aforementioned policy phases ($k = \{\text{pre-crisis, US QE, intra-QE,}$

¹⁹I contrast here entry in response to the GFC with the ECB’s initiation of quantitative easing in response to the deterioration of real economic conditions in the Euro area after the initial recovery of financial markets from the GFC.

EAPP}}, while MP_t^i is the domestic monetary policy surprise from country i 's central bank, and MP_t^j is the monetary policy surprise emanating from foreign central banks ($j \neq i$). In calculating the monetary policy surprise, $Y_{j,t}$ is the implied yield on the short futures contract in use for central bank j (or the yield on the 2-year zero coupon bond in market j). Δe_{t-1}^{ij} is the lagged daily change in the exchange rate (LC/FC), and S_t^{JP} , S_t^{US} , S_t^{EU} , and S_t^{UK} are the orthogonalized CESI for Japan, the US, the Euro area, and the UK, respectively. Finally, I include a Friday dummy to capture day-of-the-week effects.

To account for some of the unique characteristics of financial data, such as excess kurtosis, negative skewness, and serial correlation, I include an AR(1) term in the regressions and utilize HAC standard errors, where the bandwidth for the Parzen kernel is selected using Newey and West's (1994) procedure. Chow breakpoint tests support the chosen partition dates.

4.5 Results

Tables 5 - 7d display the main results.²⁰ In these tables I provide parameter estimates at 1-, 3-, 5-, 7-, and 10-year maturities; however, I largely limit discussion in the text to maturities of 1, 5, and 10 years for ease of exposition. Before turning to the baseline (piecewise) regressions and to provide a useful contrast, I document first the broad patterns in the full sample (Table 5).

Domestic monetary policy surprises pass through to domestic interest rates in a manner roughly similar across economies. These domestic monetary policy surprises elicit a statistically significant reaction along the yield curve in every market; in particular, point estimates suggest that an expansionary monetary policy surprise decreases the zero coupon bond yield at each maturity. In each case, this domestic effect dominates the size of spillovers from foreign central banks by a factor of roughly 1.5 to 8. In general, domestic surprises generate changes in a hump-shaped pattern (increasing and then decreasing with maturity) that peaks at the 3-year bond for the UK and the Euro area, the 5-year bond for the US, and the 7-year bond for Japan. For example, taking point estimates from Table 5 and standard deviations from Table 3a, a one standard deviation (8.66 basis point) loosening surprise in the full sample induces statistically significant decreases in US zero coupon bond yields of 1-, 5-, and 10-year duration, amounting to 3.7, 5.9, and 4.5 basis points, respectively. For the UK (Euro area), these point estimates are 3.3 (3.0), 3.7 (3.2), and 2.6 (1.6) basis points on 1-, 5-, and 10-year bond yields, respectively.²¹ For Japan, the domestic pass-through from a one standard deviation (2.29 basis point) monetary policy surprise to 1-, 5- and, 10-year bond yields are 0.4, 1.9, and 1.8 basis points, respectively.

Turning to cross-border spillovers in the full sample, the Euro area, the UK, the US, and Japan vary in the degree to which they generate spillovers to one another. Surprisingly, these

²⁰Full results, including estimates for control variables, can be found in the Internet Appendix.

²¹In the full sample, a one standard deviation surprise in the UK is 7.23 basis points, while for the Euro area it is 6.27 basis points.

central banks generate spillovers in the full sample of similar magnitude regardless of the source. That is, while the Federal Reserve exhibits the most consistent statistically significant spillovers in the sense that it influences every other yield curve, its point estimates do not stand out in terms of magnitude compared to other central banks. The ECB generates the second-most consistent set of spillovers, eliciting term structure adjustments in the UK and the US. In the full sample, only the ECB plays this role vis-à-vis the US. This latter pattern maps partially onto the results noted in Section 3, wherein only concurrent ECB/BoE monetary policy announcements appear to elicit a US yield response. The Bank of England, by contrast, has a statistically significant effect only on the long end of the Euro area yield curve, while the Bank of Japan generates modest spillovers to medium duration European bond yields.

Breaking the data into subsamples based on entry into and exit from QE, some additional nuance emerges. Tables 6 - 7d condense the results of the baseline regressions to allow for easier comparison between the sources of monetary policy surprises and between the channels of transmission. To show how the size, dispersion and maturity structure of spillovers has changed for time, Figures 13a - 13l plot statistically significant point estimates of domestic and international passthrough, adjusted to reflect the sample-specific standard deviation. For ease of exposition, the remainder of this section treats domestic effects by market (Table 6) and discusses spillovers by central bank (Tables 7a - 7d).

4.5.1 Domestic Transmission of Monetary Policy: Piecewise Baseline

Table 6 summarizes the estimated impact of domestic monetary policy surprises on yields, expected short rates, and term premia. As in the full sample, domestic effects dominate those of spillovers in all subsamples (i.e., $\gamma_k^j < \psi_k$ for all j). However, the loading of monetary policy surprises by maturity differs by subsample for both domestic monetary policy effects and spillover effects, reflecting changing channels of transmission. To compare subsample coefficients statistically, Tables 8a - 8d display Wald tests for equality of coefficients for each market.

In each market, expansionary monetary policy surprises decrease yields all along the domestic yield curve, but the “shape” of the loading pattern differs at and away from the zero lower bound, consistent with results from Rogers et al. (2014). In the pre-crisis period, the impact of monetary policy decreases with the maturity of the bond, in line with the conduct of conventional monetary policy. In this subsample, an expansionary monetary policy surprise decreases the 1-year zero coupon bond yield at a rate two to three times that of the 10-year yield. Among the four central banks, the Federal Reserve exhibits the highest domestic pass-through to the 10-year bond yield at 2.6 basis points, similar to point estimates from Gürkaynak et al. (2005).²²

²²Gürkaynak et al. (2005) find that a 25 basis point expansionary monetary policy surprise caused 10-year yields to fall about 10 basis points. Similarly, my results suggests US domestic pass-through to the 10-year bond yield of 8.7 basis points from a 25 basis point monetary policy surprise.

Related to decreasing pass-through by maturity, this period also exhibits a dominant domestic role for the expected path of short rates, which decreases monotonically with maturity. In fact, in line with results from Nakamura and Steinsson (2015), the term premium does not appear to strongly influence domestic bond yields at any maturity in the pre-crisis period. What small effect the term premium does have on bond yields runs counter to the force exerted by the expected path of short rates. That is, an expansionary monetary policy surprise increases the term premium, indicating that market participants anticipate future growth, inflation or interest rate volatility, or a combination thereof.

These patterns begin to diverge, however, after the onset of the GFC. Starting with the US, domestic patterns of interest rate pass-through shift with the onset of US QE. During this initial period of quantitative easing, the effect of US monetary policy increases with the maturity of the bond (although pass-through begins to decrease at a maturity of ten years), which aligns with the stated goals of the FOMC's unconventional monetary policy and fits with other results observed in the literature (Christensen and Rudebusch (2012); Shah (2018); Rogers et al. (2018); Georgiadis and Gräb (2015); and Neely (2015), for example). During this period, a 8.66 basis point loosening surprise induced a 5.4 basis point change in the 10-year US bond yield on average.²³ The domestic impact of FOMC monetary policy peaks along the yield curve at the 7-year bond yield in the initial period of quantitative easing, compared to the 5-year yield in the intra-QE period and the 3-year yield in the EAPP period. In the context of interest rate normalization, this implies that monetary policy exerts decreasing influence over domestic long-term bond yields as the Federal Reserve normalizes US monetary policy. We observe this in the transition from dominant term premium effects to dominant expected short rate effects over the US QE, intra-QE and EAPP periods in sequence.

The Euro area and the UK exhibit several shared patterns, accompanied by important divergences. Similar to results for the United States, domestic monetary policy shocks load more heavily onto their respective short-term bond yields in the pre-crisis period and generate a larger effect on medium- and long-term bond yields during and after the Global Financial Crisis. For the Euro area, this transition takes place in the period following the US tapering announcement, coinciding with Mario Draghi's renewed intent to support the euro "whatever it takes".²⁴ In terms of transmission channels within the Euro area, the expected path of interest rates dominates the term premium in explaining domestic yield changes in every subsample until the announcement of the ECB's policy of quantitative easing. However, the transition toward term premium dominance relative to the path of expected short rates begins in the period before the announcement of the EAPP, reflecting the increasing bind

²³To provide some context, the announcement of QE1 on November 25, 2008, was associated with a 26.5 basis point drop in the implied yield on the three month ahead Eurodollar futures contract and a 19.2 basis point drop in the implied yield from the 5-year Treasury bond futures contract. Across the three FOMC announcement dates from November 25 to December 16, 2008, the cumulative drop in these implied yields was 55 basis points and 53.3 basis points, respectively.

²⁴Draghi, Mario. (2012 July 26). Remarks to Global Investment Conference in London. Retrieved from <https://www.ecb.europa.eu/press/key/date/2012/html/sp120726.en.html>

of the effective lower bound.

In the UK, the transition from short- to long-term bond yield transmission corresponds to the beginning of its own QE program shortly after the Federal Reserve in March 2009. Domestic results from the UK diverge from those of the US and Euro area in the sense that, although the Bank of England pursued unconventional monetary policies throughout the GFC and post-GFC subsamples, the expected path of short rates drives the majority of bond yield responses to monetary policy surprises, with a comparatively smaller role for term premia. This indicates that Bank of England unconventional monetary policy operated to a substantial degree through forward guidance and balance sheet-based commitment. These results counter those found by Joyce et al. (2012), who find a dominant role for the term premium from individual QE announcements from the Bank of England. However, periods following US tapering indicate that monetary policy increasingly reduced term premia as well. Still, signaling appears to have played a larger role in the UK's domestic monetary policy transmission compared to domestic transmission from other central banks with policies of quantitative easing.

Domestic monetary policy surprises from the Bank of Japan generate the smallest impact among the central banks considered. However, considering the size of the measured surprises (see Table 3a), its degree of passthrough is similar to other central banks. In the pre-crisis period, monetary policy surprises load onto the yield curve in a hump-shaped fashion, peaking between the 3- and 5-year yield. However, in the periods following the collapse of Lehman Brothers, the Bank of Japan consistently generates pass-through to its medium- and long-term bonds. In these subsamples, domestic monetary policy acts entirely through the term premium. Overall, pass-through is largest in the last subsample, which contains the introduction of the Bank of Japan's QQE with Japan's Negative Interest Rates and QQE with Yield Curve Control programs.

The results depicting spillovers suggest fewer commonalities between markets. Thus, for the sake of exposition, I organize the discussion of these results by central bank, rather than by recipient market (Tables 7a - 7d).

4.5.2 Spillovers from the Federal Reserve

My discussion of spillovers begins with the Federal Reserve (Table 7a), as it generates the most consistent spillovers in the full sample and is the focus of much of the literature on the international effects of unconventional monetary policy. Curiously, in the pre-crisis period, the FOMC exhibits negligible pass-through to the UK and the Euro area (Panels A and B), which operates through contrasting channels cancelling one another out. In this period, an expansionary surprise brings down the path of short rates, but increases the term premium, generating an undetectable net effect. The sign of the term premium indicates that expansionary Fed policy generated upside growth and inflation risk. In each of the subsamples following the GFC, spillovers increase in the maturity of the bond and reflect a mix of signaling and

changes to the term premium. Counter to emphasis in the literature on US quantitative easing, the largest FOMC spillovers occur not during its implementation of QE, but during the periods of asynchronous monetary policy normalization.

The largest FOMC spillovers accrue to UK bond yields. From a subsample perspective, spillovers reach their peak during the years following the FOMC's tapering announcement and remain elevated for the remainder of the sample (Table 7a, Panel A). In addition to the overall size of spillovers to the UK, this sender-recipient pairing stands apart from the others in the strength of the signaling channel. Also unlike other pairings, the signaling channel from the FOMC to the UK increases in strength relative to changes in term premia during periods of heaviest global quantitative easing. These results imply that, to some extent, the Federal Reserve "heralded" the Bank of England in expectation in these latter subsamples.

On the other hand, the term premia explain the majority of spillovers received from the FOMC following the announcement of tapering and before the instatement of the EAPP, suggesting that contractionary monetary policy in the US also generated perceived growth or inflation risk, and may reflect portfolio rebalancing toward the United States in this initial normalization period. Disentangling these forces remains a challenge. However, an international confidence channel can be inferred by the absence of domestic term premium effects, since a decrease in the domestic term premium is a logical pre-condition to international portfolio effects. If domestic term premia do not decrease, then there has not been a change in the relative supply of assets sufficient to change domestic asset prices, and thus to incentivize substitution into other assets. It is not feasible, however, to positively and independently identify the presence of an international portfolio balancing channel because the *presence* of domestic term premium effects can arise through either confidence or portfolio balancing. Thus, that US monetary policy surprises in this subsample increase expected domestic interest rates at longer horizons offers corroborating evidence for an FOMC confidence channel to UK bond yields. These two observations (term premium spillovers and domestic impact on expected short rates in the US) together offer evidence that term premium spillovers in these later subsamples emanate from expected growth and interest rate volatility rather than pure portfolio balance effects.

Turning to the Euro area (Table 7a, Panel B), the Federal Reserve generated its strongest spillovers to the European yield curve during the intra-QE period, although the channels of transmission are not well-identified using the preferred monetary policy indicator. Point estimates in the baseline, though insignificant, suggest that the signaling channel strengthened during this period, indicating that market participants on average expected the Euro area to move toward normalization in the face of contractionary US monetary policy surprises. In the Online Appendix, results obtained using the two-year yield as the monetary policy measure corroborate the evidence from futures.

By contrast, periods of US and Euro area QE (the initial QE and EAPP periods) display smaller spillovers from the Federal Reserve to the Euro area. The term premium drives the modest spillovers observed in these subsamples. The importance of the term premium for de-

termining US domestic pass-through in the initial QE period suggests that FOMC-induced European term premium changes in that era could result from either portfolio balancing or expected growth. However, since the domestic effect of monetary policy from the FOMC indicates that portfolio balancing does not have a large impact on US yields in the period of Euro area quantitative easing, spillovers to the Euro area during the EAPP appear to manifest through changes in expected macroeconomic growth (i.e., a contractionary monetary policy shock from the US raises expected future growth and inflation risk) by revealing good news about market conditions.

As in previous exercises, results suggest that spillovers to Japan are smaller and less consistent (Table 7a, Panel C). This (non)result could represent an issue of identification, but may also reflect a level of disconnect between financial conditions in Japan and those in other advanced economies. To wit, the covariances between JGB bond yields and the sovereign bond yields of the other three markets hover near zero throughout the sample at every maturity. Regardless, point estimates suggest passthrough in the periods marked by numerous QE programs (the initial QE and EAPP periods), which operate through the term premium.

4.5.3 Spillovers from the European Central Bank

The decomposition of ECB spillovers to the US (Table 7b, Panel A) reveals a marked departure from the magnitudes estimated in the full sample. In particular, ECB spillovers to the US during and after the GFC increase substantially. Moreover, the periods of heaviest QE activity exhibit spillovers to the United States that mirror transmission channels from the FOMC to the Euro area in each of the subsamples (Panel B). That is, the signaling channel drives (modest) spillovers in the pre-crisis period, whereas the term premium takes on additional importance for spillovers in the periods of US and Euro area quantitative easing. In the periods of quantitative easing, spillovers from ECB monetary policy announcements to US long-term bond yields in particular increase.

Again, I appeal to the domestic effects of QE in the Euro area as a guide and suggest that portfolio balance effects dominate spillovers in the EAPP period and that the confidence channel played a comparatively larger role during the period of initial quantitative easing. In this subsample, ECB monetary policy surprises influenced domestic interest rates almost entirely through the expected path of short rates, implying that loosening monetary policy in the Euro area during that period lowered term premia in the US by generating expectations of lower economic growth or interest rate volatility. This pattern is consistent with a flight to safety. Given, however, that domestic monetary policy influenced Euro area yields primarily through term premia during the EAPP, portfolio balancing remains a candidate explanation in this last subsample.

Among sender-recipient pairings in the pre-crisis period, spillovers from the ECB to the UK rank largest in magnitude (Table 7b, Panel A). These pre-crisis spillovers operate almost exclusively through the term premium, suggesting a confidence channel without a strong sig-

naling component. However, the instances of high UMP activity in particular suggest that market participants expect the Bank of England to act in the same direction as the ECB in the context of unconventional monetary policy, reflecting a comparatively high degree of inter-connection between these markets. In the EAPP subsample, additional monetary stimulus from the ECB generates a substantial decrease in the path of expected interest rates in the UK, suggesting that expansionary ECB monetary policy pushes back expected normalization by the Bank of England. Interestingly, it appears that this signaling channel operates asymmetrically; spillovers from the ECB act through the UK's expected path of short rates near the zero lower bound, while spillovers from the Bank of England influence Euro area yields to a much lower degree (Table 7c, Panel A).

4.5.4 Bank of England Spillovers

Spillovers from the Bank of England (Table 7c) appear roughly on par with those from the ECB. In the case of spillovers to the US (Panel B), a Bank of England monetary policy surprise exhibits a statistically significant effect in the periods of asynchronous normalization, which increases with maturity and acts primarily through the term premium. Coefficients from the EAPP subsample suggest that the reduction in spillovers observed from the previous subsample result almost entirely from a reduced impact on term premia, consistent with moves toward normalization in each of those markets. The dominance of the expected path of short rates over the Bank of England's domestic transmission suggests that these term premium spillovers result from confidence effects more than portfolio balancing in these subsamples.

The Bank of England generates spillovers of similar magnitude to the Euro area (Panel A). These increasingly act through European term premia from one subsample to the next. Here again, domestic UK surprises drive changes in the expected path of domestic short rates at long horizons in the EAPP period, suggesting portfolio balancing plays a smaller role in spillovers to these maturities compared to confidence effects.

4.5.5 Bank of Japan Spillovers

Spillovers from Bank of Japan (Table 7d) generally lack statistical significance or else are vanishingly small, reflecting low co-movement with the other economies in general. The exception is the intra-QE period, during which expansionary monetary policy surprises from the Bank of Japan increase US yields substantially. Given the Japanese yen's role as a dominant carry trade funding currency, it could be that these coefficients reflect changes in carry trade activity. Although the influence of monetary policy on carry trade activity lies beyond the scope of this paper, it is reasonable to posit that expansionary Japanese monetary policy might increase the attractiveness of yen relative to other currencies, decreasing the price and increasing the yield of other safe assets.

4.5.6 Control variables

Turning to the effect of control variables, a number of consistent patterns emerge across markets (Tables 9a - 9d). For all countries in the sample, “expectations-beating” economic news in the US, the UK, and the Euro area triggers increased bond yields at most maturities for all countries, but especially at longer maturities. Second, most daily changes in the yield exhibit modest but statistically significant persistence, suggesting that bond prices exhibit some autocorrelation even in first differences. These prices, then, tend to go on brief “runs”.

While point estimates from the baseline provide valuable information regarding the immediate effect of monetary policy on asset prices, the economic significance of monetary policy surprises emerges in part from their persistence, to which I turn next.

Lagged exchange rates are insignificant in many of the baseline regressions, with some notable exceptions. In particular, previous day appreciation of the euro against the pound or yen is associated with increased yields in the Euro area, while an appreciation of the euro against the dollar is associated with lower euro area yields. Similarly, previous day appreciation of the pound against the yen is associated with decreasing UK bond yields. Finally, a depreciation of the yen against the dollar is associated with an increase in the Japanese yield. These exchange rate effects tend to increase slightly in maturity of the bond.

4.6 Persistence of Monetary Policy Surprises

To characterize the persistence of spillovers, I extend my baseline estimations using local projection methods (Jordà 2005; Stock and Watson 2018). While it is common in the literature on monetary policy transmission to use vector autoregression to document the persistence of shocks, these models have a number of drawbacks for the identification of cross-border monetary policy surprises.²⁵ Local projection methods allow the inclusion of multiple monetary policy surprises and macroeconomic news shocks without raising concerns of parameter proliferation and without imposing additional assumptions over the baseline model.²⁶ Specifically, I estimate the following:

$$\Delta y_{i,t+h}^{(10)} = \alpha + \beta_{i,h} \Delta y_{i,t-1}^{(10)} + \psi_{i,h} MP_{i,t} + \sum_j \gamma_{j,h} MP_{j,t} + \sum_{k=0}^K \theta_{i,h,k} x_{t-k} + \sum_{l=1}^L \sum_j \phi_{j,l} \Delta e_{t-l}^{i,j} + \delta Fri + \epsilon_{it}, \quad (8)$$

where $h = 0, \dots, H$ is the estimation horizon and x_{t-k} represents the vector of news con-

²⁵See, for example, Rogers et al. (2014); Rogers et al. (2018); Gertler and Karadi (2015); and Bluwstein and Canova (2016)

²⁶I favor local projection over external instrument vector autoregression in this context primarily due to the exigencies of daily data. Parameter proliferation in a VAR renders controlling for concurrent monetary and macroeconomic surprises intractable. Moreover, a principal components analysis suggests that these variables are not easily explained by one or two factors, meaning that a factor augmented VAR would not be appropriate.

trols. I plot impulse responses to a horizon of 25 days to reflect the average observed number of business days between announcements among the four central banks (23.75 days). $\psi_{i,h}$ and $\gamma_{j,h}$ represent the average monetary policy pass-through to the ten year bond yield in market i from domestic shocks (j) and spillovers from central bank j , respectively. As suggested by the Bayes Information Criterion (BIC), I include one lag of the dependent variable, one lag ($K = 1$) of the macro news controls x_t , and one lag over the baseline of the bilateral exchange rate $\Delta e_{t-1}^{i,j}$ (two lags total, $L = 2$).

Although local projection methods offer a number of improvements over vector autoregression in the current context, they tend to produce jagged impulse responses that can be difficult to interpret. To smooth excess variability of the estimator, I apply a compound moving median smoother to the estimated series $\hat{\beta}_i = \{\hat{\beta}_{i,0} \dots \hat{\beta}_{i,H}\}$ for the domestic impact and $\hat{\beta}_j = \{\hat{\beta}_{j,0} \dots \hat{\beta}_{j,H}\}$ for spillovers from central bank j .²⁷

Due to the unique role long-term bond yields play in the conduct of unconventional monetary policy, I limit my discussion to the persistence of monetary policy pass-through to 10-year zero coupon bond yields in each market. In terms of subsample periods, I contrast here the full sample results to those from the EAPP period, as this latter period exhibits the largest spillovers in static estimates. Figures 3 - 4 depict the persistence of domestic monetary policy surprises, plotting the smoothed path of the parameter estimates with smoothed 90% and 95% confidence bands. As in the baseline, monetary policy surprises are normalized to a one standard deviation loosening. Figures 5 - 8 depict the persistence of spillover effects.

Figures 3 and 4 indicate that, for each central bank, domestic monetary policy generates persistent pass-through to 10-year zero coupon bond yields lasting at least 25 days at the 10% level in both the full sample and the EAPP subsample period. Spillover persistence, on the other hand, varies by central bank/recipient pair. Overall, while the *magnitudes* of spillovers increase in the EAPP subsample period compared to the full sample, their persistence does not change drastically.

Nevertheless, interesting distinctions do arise in comparing the central bank/recipient pairs to one another in terms of persistence. Spillovers to the US from the ECB (Figures 6a, 6b) and Bank of England (Figures 7c, 7d), while larger in the EAPP subsample, generally last just under a week before becoming statistically insignificant.²⁸ On the other hand, spillovers from the Federal Reserve to the UK and Euro area persist to the end of the estimation horizon, in agreement with literature suggesting the centrality of the Federal Reserve in producing spillovers (Figures 5a - 5d). Interestingly, spillovers to the Euro area from the Bank of England persist past the 25 day estimation horizon, while ECB pass-through to Gilt yields dissipate in less than a week. As in the static estimates, spillovers to and from Japan are not significant (Figure 8).

²⁷In particular, I first apply a 3-spline moving median smoother with repetition to convergence, followed by a Hanning linear binomial smoother.

²⁸It is worth noting, however, that although the parameter estimates become statistically insignificant, the path of the point values does not generally converge toward zero in the 25-day horizon.

4.7 Policy Decomposition

Another strand of the literature supports the notion that a multidimensional monetary policy surprise more fully explains asset price movements. Therefore, following the work of Gürkaynak, Sack, and Swanson (2005), Swanson (2018) and Rogers et al (2018), and in explicit recognition of the changing mechanisms of monetary policy over time, I also consider three separate measures of monetary policy surprises constructed as follows.

First, I extract the surprise component of the decision about the target rate based on the change in yield on the one-month ahead OIS futures contracts on the dates of monetary policy announcements, which I label the “target surprise”. Next, I take the residual from a regression of the announcement day change in the 2-year bond zero coupon bond yield onto the target surprise and label this the “forward guidance surprise”. Finally, I take the residual from a regression of the announcement day change in the 7-year zero coupon bond yield onto the target and forward guidance surprises.²⁹ This “LSAP surprise” measures changes in long-term interest rates that are associated with announcements related to large-scale asset purchases. As large scale purchases begin after November 2008 for each case except for Japan, I restrict this monetary policy surprise measure to equal zero before then as in Swanson (2018) and Rogers et al. (2018). Figure 14 displays the decomposition for each central bank over time, and Table 10 displays summary statistics. As in the baseline, surprises are normalized to a one-standard deviation loosening.

This multidimensional surprise presents a small drawback in the current context. That the measure draws from changes in the yields themselves means that the dependent variable comprises, in part, the explanatory variable.³⁰ Nevertheless, with a small adjustment this exercise provides insights over the policies underlying spillovers. To limit the influence of the aforementioned “yield-on-yield” issue, I conduct the analysis on foreign announcement days only, keeping domestic announcements only when they coincide with foreign ones. For example, in the case of spillovers to US yields, I include in the sample announcement dates only from the schedules of the ECB, the Bank of England, and the Bank of Japan. For reference, I also include amongst the results the domestic coefficients estimated with all event days included. This exercise expands the baseline in the following manner:

²⁹While Swanson (2018) suggests the ten year bond to measure the LSAP shock, I use the seven year bond because I am interested in measuring the response of ten year bonds to the shock.

³⁰To see this, consider the yield decomposition presented in Equation 1. The yield on the 7 year bond has the following representation:

$$Y_t^{(7)} = \mathbf{E}[\tilde{Y}_{t,t+7}|I_t] + YTP_t^{(7)} \quad (9)$$

The 10 year bond shares the expected path of short rates and $YTP_t^{(10)}$ is a function of $YTP_t^{(7)}$:

$$Y_t^{(10)} = \mathbf{E}[\tilde{Y}_{t,t+7}|I_t] + \mathbf{E}[\tilde{Y}_{t+7,t+10}|I_t] + f(YTP_t^{(7)}) \quad (10)$$

$$\Delta y_{it}^{(n)} = \alpha + \rho \Delta y_{it-1}^{(n)} + \beta_1 target_t^i + \beta_2 fg_t^i + \beta_3 lsap_t^i + \dots \\ \dots + \sum_j \gamma_1^j target_t^j + \sum_j \gamma_2^j fg_t^j + \sum_j \gamma_3^j D_k lsap_t^j + X_t' \theta_i + \epsilon_{it} \quad (11)$$

Where X_t is a transposed vector of controls identical to the baseline and t is indexed to foreign central bank announcement days. In the interest of brevity, I limit my discussion to estimated spillovers to one- and ten-year yields.

Given the multidimensional nature of the monetary policy surprise, the results provide a map between the domestic passthrough and spillovers (Tables 11a - 11d). We see in the domestic results in Tables 7a - 7d and Figures 13a - 13l that the decomposition reflects changes in the maturity structure of domestic passthrough. LSAP spillovers generate the largest international spillovers, and passthrough of the unidimensional monetary policy shock to domestic 10-year yield peaks, in most cases, in the EAPP period. Thus, even with the relatively short maturity of the instrument underlying the unidimensional monetary policy measure, it captures announcement day comovement in long duration yields. These spillovers arise exclusively through term premia, mapping onto the baseline as well.

Interestingly, forward guidance surprises load onto international 10 year yields at nearly the same rate as LSAP surprises. Appealing to the domestic baseline results, in contrast to the domestic impact on 10 year yields mid-curve monetary policy passthrough rises in the initial crisis phase and remain roughly consistent through the post-Lehman period. Thus, the extra impulse to long term spillovers generating subsample changes in the baseline emanate from surprises that reach the long end of the domestic curve. These forward guidance surprises show up primarily, although not exclusively, in term premia. Spillovers influence the expected path of short rates from the FOMC and to the UK and from the Bank of England to the Euro Area.

Target shocks, unsurprisingly, do not strongly spill over into ten-year yields, and are more prevalent in the pre-crisis period, explaining the dearth of observed monetary policy spillovers in the pre-crisis baseline. These manifest almost exclusively through the path of expected short rates.

Taken together, these results suggest that controlling for news from other large markets and taking into account the cross-country nature of unconventional monetary policy through the lens of time varying regimes provides a more nuanced image of international spillovers, but also of domestic pass-through. Spillovers from unconventional monetary policy appear to change with both the domestic response and the comparative policy stance of other markets. While spillovers increase during periods of heavy multilateral quantitative easing, asynchronous normalization has engendered the largest cross-country spillovers from monetary policy.

5 Extensions and Robustness

5.1 Monetary Policy News Channels

Given the provenance of monetary policy cycles in differing macroeconomic, financial and political conditions over time, we might surmise that changes in spillovers result from changes in sentiment regarding global economic conditions. Recent literature on the information channel of monetary policy transmission argues that central banks affect asset prices via agents' beliefs not only about policy, but about the path of the economy (Leombroni et al. 2018; Nakamura and Steinsson 2018; Melosi et al. 2016; Jarocinski and Karadi 2018). This information falls into two broad categories. First, central banks can produce "Odyssean" forward guidance in the form of information about the path of policy. In the baseline analysis, results obtained using the expected path of short rates provides evidence regarding the (limited) importance of this transmission channel for international spillovers. However, as mentioned previously in reference to the confidence channel of monetary policy transmission, the central bank also generates "Delphic" information, wherein the announcement reveals news about the state of the economy. If, for example, the central bank enacts a more aggressive rate cut than expected or communicates a longer cycle than expected, agents may infer that the central bank possesses better information on downside growth risks and update their beliefs accordingly.³¹

Standard theory predicts that an expansionary announcement characterized only by information about the path of policy (without Delphic effects) should lead to a stock price rally through discount and dividend channels; that is, we would expect negative co-movement of surprises and equity returns (as in Bernanke and Kuttner 2005). In turn, if market participants extract information suggesting a weaker outlook for economic or financial conditions, stock prices would rise less or even fall on reduced expectations of cash flows or of higher risk. Thus, looser monetary policy that is accompanied by an decrease in stock returns (positive co-movement) indicates diminished economic or financial conditions. Thus, the sign of high-frequency co-movement of stocks and the implied yields on futures contracts can help disentangle events with strong risk premium implications versus no (or weak) risk premium implications.

In the context of spillovers, Delphic news shocks can propagate via two potential channels. The first mirrors that for domestic asset prices, but is two-fold. That is, bad news gleaned from monetary policy decreases yields through downward revisions to growth expectations. These revisions, in turn, should drive a lower path of expected future interest rates. On the other hand, downside risk to economic growth should increase risk premia, so to the (albeit modest) extent that these sovereign bonds are subject to a risk premium, this would increase yields on expansionary events if the information effect dominates. The second channel reflects flight to safety—increased risk revealed from monetary policy should induce capital to

³¹See Leombroni et al. 2018 for an in-depth discussion of the mechanism.

flow toward other safe assets, compressing their yields.

To test for the presence of risk-induced effects I separate surprises with positive equity return co-movement using the dummy variable *RPday*. For each market, I use Fama/French excess returns ($R_m - R_f$) and test interaction effects one pair at a time to economize on parameters. Regressions take two separate forms to account for spillovers. In the first set of specifications, *RPday* takes a value of 1 on announcement days characterized by positive equity return co-movement in the same country as the monetary policy surprise in question. For example, when considering risk premium effects from the ECB, I look for positive co-movement with the equity return in the Euro area.

$$\Delta y_{it}^{(10)} = \alpha + \rho \Delta y_{it-1}^{(10)} + \beta_0 MP_t^i + \beta_1 RPday_t^j + \beta_2 MP_t^j + \beta_3 RPday_t^j * MP_t^j + \sum_k \gamma_k MP_t^k + X_t' \theta_i + \epsilon_{it} \quad (12)$$

Where $y_{it}^{(10)}$ is either the yield on the 10 year sovereign bond or the expected path of short rates over a ten year horizon. In this and the next specification, X_t is a transposed vector of controls identical to the baseline. In this exercise, i is the domestic market/central bank, j is the foreign central bank of interest, and k indexes the other two central banks in the sample. When estimating domestic risk premium effects, k indexes all three foreign central banks. Thus, the expression for the domestic specification becomes:

$$\Delta y_{it}^{(10)} = \alpha + \rho \Delta y_{it-1}^{(10)} + \beta_0 MP_t^i + \beta_1 RPday_t^i + \beta_2 RPday_t^i * MP_t^i + \sum_k \gamma_k MP_t^k + X_t' \theta_i + \epsilon_{it} \quad (13)$$

In the second set of specification, *RPday* takes a value of 1 on announcement days characterized by positive equity return co-movement in the same country as the sovereign bond of interest. Thus, when considering risk premium effects on the US 10 year yield from the ECB, I look for positive co-movement between the ECB surprise and the equity return in the United States.

$$\Delta y_{it}^{(10)} = \alpha + \rho \Delta y_{it-1}^{(10)} + \beta_1 RPday_t^{i,j} + \beta_2 MP_t^j + \beta_3 RPday_t^{i,j} * MP_t^j + \sum_k \gamma_k MP_t^k + X_t' \theta_i + \epsilon_{it} \quad (14)$$

Tables 12 and 13 display the results. Ten-year Treasuries evince the most consistent pattern of the exercise; that is, spillovers from the ECB, the Bank of England and the Bank of Japan exhibit a statistically significant risk component. The sign of the impact indicates announcements containing a risk premium component exert larger spillovers to 10 year yields compared to those without, indicating that these announcements generate larger downward revisions of growth and interest rates and/or flight to safety flows. Some of the impact (about 21%, 26% and 59% for the Bank of England, ECB and Bank of Japan, respectively, based on Panels 10B and 11B) results from changes to the expected path of short rates and thus from

revisions to the expected path of policy and mean growth. I attribute the other roughly 41 - 75% to term premia. Interestingly, the Federal Reserve also appears to exert this type of risk premium effect on the the Euro area, albeit at a rate about on third of that observed in the opposite direction. Somewhat curiously, when measured using domestic equity market co-movement, risk premium days in Japan are associated with a dampening of spillovers to US yields—that is, when the BoJ generates bad news for the Japanese equity market, yields in the US rise abstracting from discount effects.

In the context of the current study, the question naturally arises as to whether these risk shocks contribute to increased spillovers in periods of unconventional monetary policy.³² To comment on the time variation in risk-based spillovers, I plot measured monetary policy surprises against changes in the Fama/French returns in each of the baseline subsamples (See Figures 9 - 12). In the interest of space, I plot only the pairings associated with statistically significant interactions. If risk-based spillovers drive increased spillovers to ten year yields in general, we should expect more of these types of surprises in later subsamples compared to the pre-crisis period.

Put differently, if monetary policy surprises with a strong risk component dominate the latter subsamples, the plots in Figures 9 - 11 should show increased pairings in the first and third quadrants, with a fit line nearer a slope of one compared to other periods. In fact, we observe just the opposite in most cases (the exceptions being the ECB's interaction with Japanese Equity returns). Thus, while spillovers in some country pairings rise in the presence of news effects, an increased incidence of risk-surprises does not appear to explain increased spillovers in the period of asynchronous monetary policy normalization.

5.2 Asymmetric Responses: Contractionary Versus Expansionary Surprises

Another candidate explanation arises from the distribution of contractionary versus expansionary surprises in the various subsamples. That is, if expansionary surprises generate larger spillovers than contractionary ones, we should expect periods marked by a prevalence of expansionary surprises to evince larger spillovers. To test for these asymmetric effects, I run the following specification, testing one interaction at a time:

$$\Delta y_{it}^{(10)} = \alpha + \rho \Delta y_{it-1}^{(10)} + \beta_1 MP_t^j + \beta_2 \mathbb{1}[MP_t^j < 0] + \beta_3 \mathbb{1}[MP_t^j < 0] * MP_t^j + \sum_k \gamma_k MP_t^k + \theta_1^i S_t^i + \sum_j \theta_j S_t^j + \sum_j \phi_j \Delta e_{t-1}^{ij} + \delta Fri + \epsilon_{it} \quad (15)$$

Where $\mathbb{1}[MP_t^j < 0]$ is an indicator function equal to one where the monetary policy surprise takes a negative value (i.e., an expansionary surprise). As in the previous exercise, i indicates the domestic market/central bank, j is the foreign central bank of interest, and k in-

³²For example, Leombroni et al. (2018) find that risk premium shocks in the Euro area rise in importance in the context of the European debt crisis.

dexes the other two central banks in the sample. When estimating domestic risk premium effects, k indexes all three foreign central banks.

Table 14 shows that yields do not in general react differently to expansionary monetary policy surprises compared to contractionary ones from the Bank of England or the Bank of Japan. On the other hand, yields in the US and the UK do appear to react more to expansionary surprises from the Federal Reserve, while these same yields react more to ECB contractionary surprises than to expansionary ones. Although the responses to expansionary versus contractionary shocks differ, shocks do not appear to be overwhelmingly contractionary or expansionary in any of the subsamples for the FOMC or the ECB. In Table 15, I show that the mean of the absolute value of expansionary shocks does not differ from that of contractionary shocks in any of the chosen subsamples in the case of the FOMC or the ECB. Only the Bank of England evinces shocks leaning in one direction—in the last subsample (EAPP) contractionary monetary policy shocks dominate expansionary shocks in size. Thus, it appears that the asymmetric reactions do not drive the baseline results.

5.3 Compound Monetary Policy Surprise Measure

While I have chosen futures contracts for their insurance characteristics and comparability across markets, my monetary policy measure differs from some of the recent literature in monetary policy shock identification in that it does not extract changes in the cross-section of maturities (Kiley 2014; Rogers et al. 2014; Rogers et al. 2018; Shah 2018). Monetary policy surprises derived from the cross-section of yields have the advantage of subsuming policies aimed at different maturities in the yield curve. Such compound measures summarize the overall stance of monetary policy both at and away from the zero lower bound.

In the present context, this compound measure has two shortcomings. First, the futures-based measures provide a more concrete interpretation over the magnitude of the effect. Second, and perhaps more importantly, the domestic monetary policy surprise MP_i comprises movements in the yields I am interested in measuring. For each market, the daily change in the first principal component of the yield curve correlates closely with the underlying individual bonds, as one might expect. As a consequence, we should expect domestic point estimates to change less between subsamples. Additionally, in interpreting the impact of foreign monetary policy surprises, the compound monetary policy surprise controls for movements in the interest rate of concern. Nevertheless, as a robustness check, I repeat the exercise described in Equation 7 with the terms MP_i and MP_j now comprising the announcement-day change in the first principal component of 2-month ahead OIS futures and 1-, 3-, 5-, 7-, and 10-year yields in the respective central banks' markets, normalized to a one standard deviation loosening.

Tables 16a - 16d display the results, which Figure 13 summarizes. While the patterns for the term premium and the expected path of short rates adhere reasonably closely with the baseline, the compound monetary policy measure compresses the differences between

post-2008 subsamples compared to the baseline. However, the pattern of medium- to long-duration spillovers becoming larger between periods of intense QE programs remains (Panels 13e - 13f versus 13k - 13l), as does the pattern of increasing ubiquity of spillovers between subsamples. In contrast to the baseline, which shows some waning in spillovers during the Intra-QE period by virtue of statistical insignificance, this exercise suggests spillovers rise in that subsample relative to the initial UMP period, and then FOMC and BoE spillovers fall somewhat in the last subsample, remaining still above the level observed during initial UMP. As in the baseline, ECB spillovers peak in the EAPP period.

5.4 Yield-based Measure of Monetary Policy Surprises

I also measure the surprise as the daily change in the two-year zero coupon bond yield as a robustness check, following Gilchrist et al. (2014). While these zero coupon bond yields again lack the desirable quality of serving as insurance against future interest rate changes, one may still reasonably attribute changes in these yields on announcement days primarily to monetary policy surprises. Although the point estimates from this exercise differ from the baseline, the broad patterns remain. Spillovers increase in periods of unconventional monetary policy and transmit primarily through term premia. In the interest of space, the results are displayed in the supplemental appendix.

6 Concluding Remarks and Directions for Future Research

In this paper, I utilize high frequency identification, a shadow rate term structure model, piecewise regressions, and local projection methods to identify the effect of monetary policy spillovers to and from advanced economies engaged in unconventional monetary policy across the yield curve over time. I provide evidence for the existence of heightened spillovers between the US, the UK, Japan, and the Euro area during the period of asynchronous monetary policy normalization, with the most persistent spillovers emanating from the Federal Reserve.

However, I also find evidence of surprisingly strong spillovers from the ECB and Bank of England to the US and to each other's markets. Results suggest that these central banks' programs of unconventional monetary policy compressed long-term bond yields in each other's markets primarily through the term premium, indicating the dominance of portfolio balance and confidence channels of transmission over signaling. However, results from the Federal Reserve suggest that large term premium spillovers may also arise through interest rate-based monetary policy and the expectation of quantitative tightening, as evinced by spillovers in the period of asynchronous monetary policy normalization. During this latter period, the Federal Reserve returned to interest rate-based monetary policy and yet still appears to drive spillovers at longer maturities, highlighting the continued influence of balance sheet-based measures and expectations thereof.

The mechanisms of unconventional monetary policy that distinguish it from conventional monetary policy imply unique challenges to the withdrawal of monetary stimulus, particularly in the presence of spillovers. Long-term bond yields compressed during the period of unconventional monetary policy may be less upwardly sensitive to conventional policy given the role of term premia in determining long-term interest rates. In the face of ongoing quantitative easing in other systemic, advanced economies, this implies that normalizing central banks conduct monetary policy primarily by exerting pressure on the expected path of short-rates (which is diminishing in maturity) compared to periods of quantitative easing, while international spillovers have the potential to exert force in the opposite direction on the term premium (which increases with maturity) (Hamilton 2009).

Asynchronicity of unconventional monetary policy in these systemically important markets makes the cross-country spillovers that I document particularly salient. For example, the evidence presented here suggests that US monetary policy normalization preceding the COVID-19 crisis effectively exerted contractionary monetary policy on European bond yields. This implies that the ECB would have needed to withdraw its stimulus more slowly (or even increase it) in order to keep credit conditions from tightening more than intended when it ultimately halts its asset purchases. From another angle, in the absence of international portfolio balance effects, domestic long-term bond yields would be more responsive to quantitative easing.

Once again, as of writing, these countries find themselves at the effective lower bound in shared macroeconomic or financial circumstances. For that reason, central banks do well to acknowledge the impact of spillovers on the shape of the sovereign yield curve, which makes monetary policy more or less effective.

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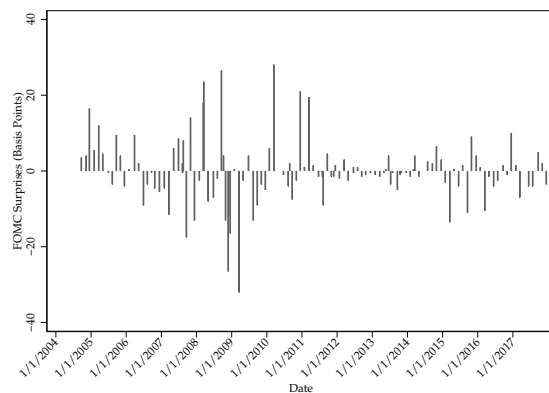
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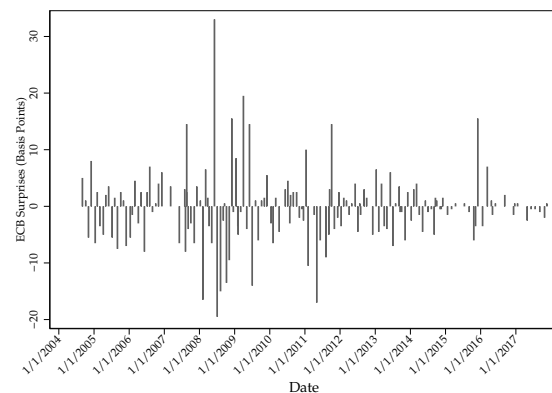
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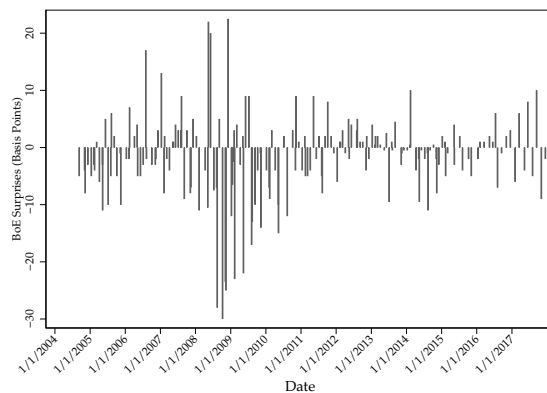
7 Appendix A: Figures



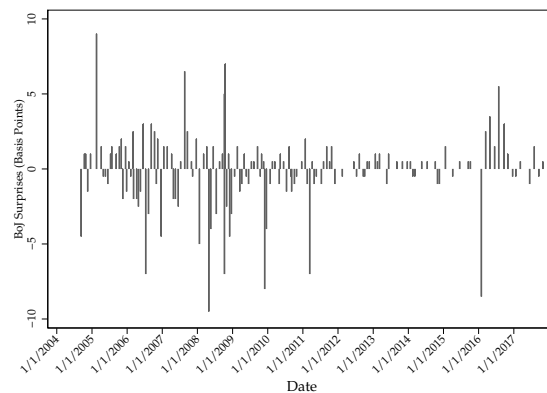
(a) FOMC



(b) ECB



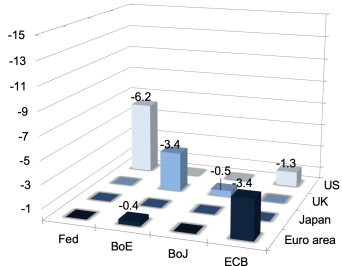
(c) Bank of England



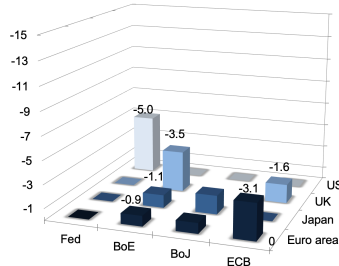
(d) Bank of Japan

Figure 1: Monetary Policy Surprises Measured with Interbank Futures

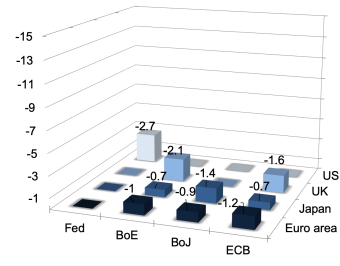
Figure 1 shows the open to close change in the implied yield on the one-year ahead futures contract based on the three-month (1a) Eurodollar on FOMC announcement days, (1b) Euribor on ECB announcement days, (1c) Short Sterling on BoE announcement days, and (1d) Euroyen Tibor on BoJ announcement days.



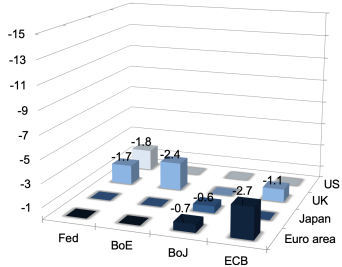
(a) 1 Year Yield: Pre-crisis



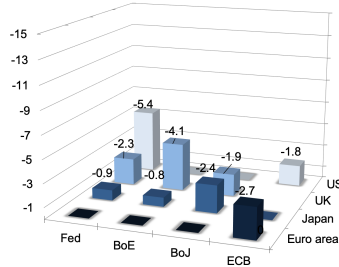
(b) 5 Year Yield: Pre-crisis



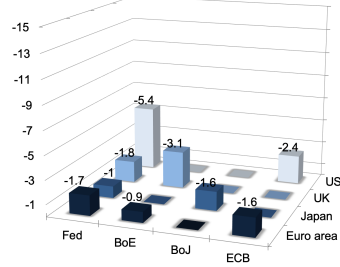
(c) 10 Year Yield: Pre-crisis



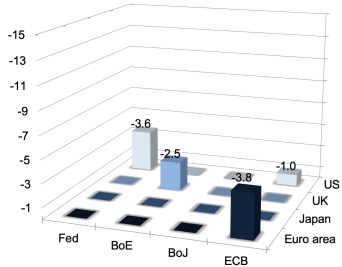
(d) 1 Year Yield: Initial QE



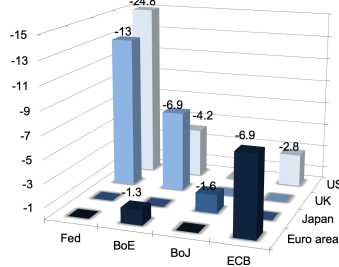
(e) 5 Year Yield: Initial QE



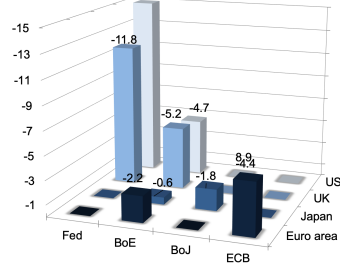
(f) 10 Year Yield: Initial QE



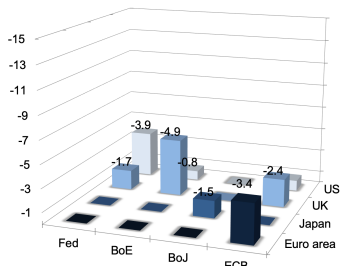
(g) 1 Year Yield: Intra-QE



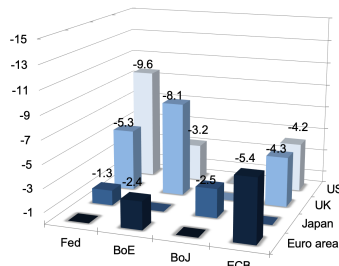
(h) 5 Year Yield: Intra-QE



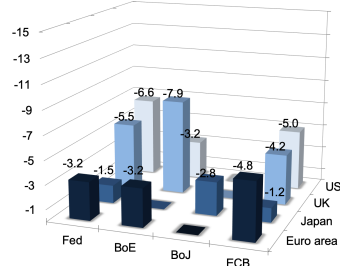
(i) 10 Year Yield: Intra-QE



(j) 1 Year Yield



(k) 5 Year Yield



(l) 10 Year Yield

Figure 2: Effect of a One Standard Deviation Monetary Policy Loosening Surprise on Yields

Figures 13a - 13l summarize the results of daily piecewise regressions where the dependent variable is the change in zero coupon bond yields for maturities of 1, 5, and 10 years. The monetary policy shock is the daily change in the implied yield for the year-ahead futures contract on the Eurodollar (Fed), Euribor (ECB), Short Sterling (BoE) and Euroyen Tibor (BoJ) on monetary policy meeting days of the respective central banks. Monetary policy measures are normalized to be a one standard deviation loosening, where standard deviations are calculated by sub-sample. All control variables from the baseline are included in the regression and their point estimates are available on request. All bars represent parameter estimates that are statistically significant at the 10% level or better.

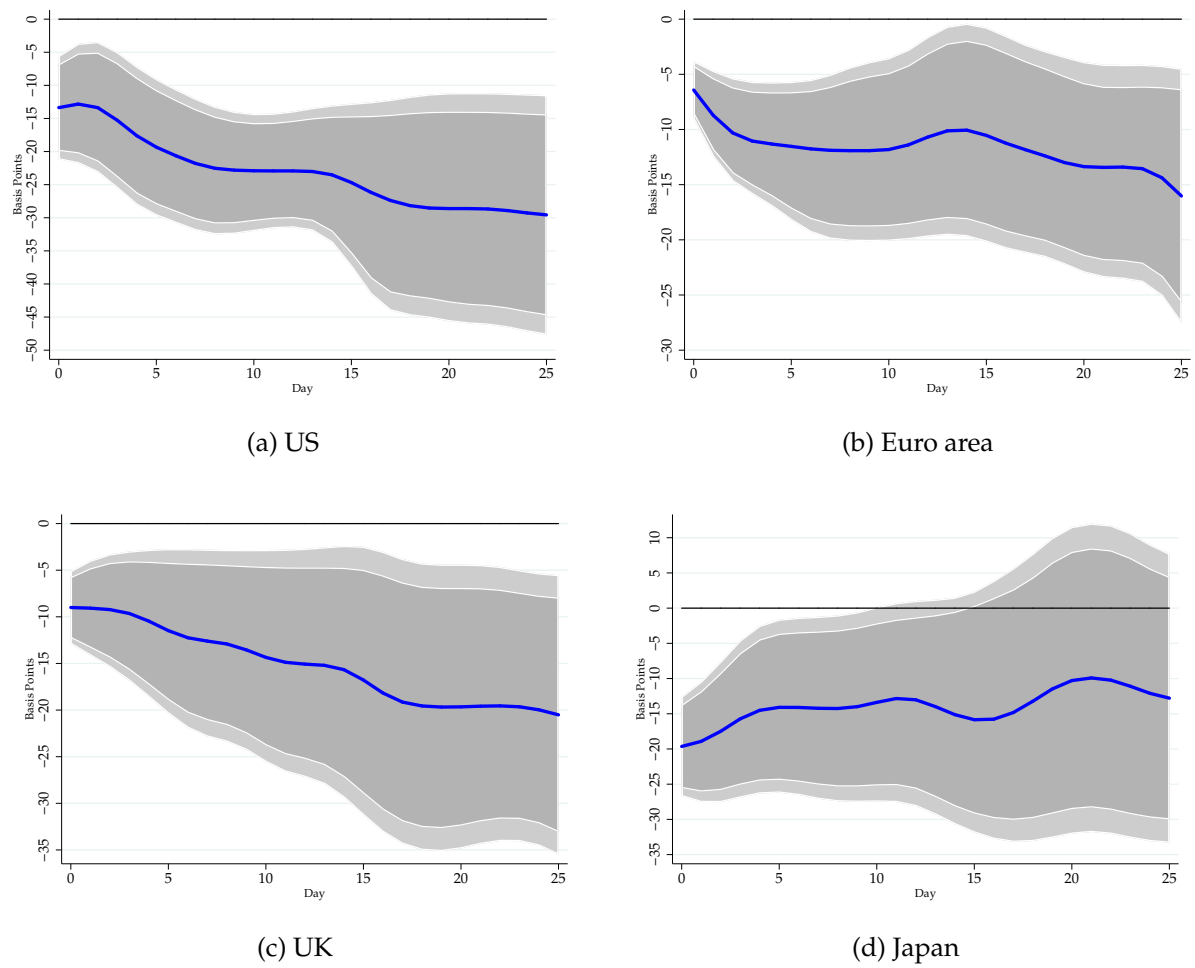


Figure 3: Effect of a One Standard Deviation Expansionary Surprise on Domestic 10 Year Bond, Full Sample

Figure 3 summarizes the results of daily local projections in the full sample where the dependent variable is the change in the domestic 10 year zero coupon bond from 0 to 25 days after the date of a domestic monetary policy announcement. The impulse variable is the daily change in the implied yield for the year-ahead futures contract on the (a.) Eurodollar (Fed), (b.) Euribor (ECB), (c.) Short Sterling (BoE) and (d.) Euroyen Tibor (BoJ) on monetary policy meeting days of the respective central banks. Monetary policy measures are normalized to be a one standard deviation loosening. Red lines show the unsmoothed estimates from local projections, $\hat{\beta}_{i,0}, \dots, \hat{\beta}_{i,25}$, where i indexes the source of the monetary policy surprise. Thick blue lines show the path of the smoothed estimate for the path of $\hat{\beta}_i$ using a compound moving median smoother. The dark and light gray areas indicate smoothed confidence intervals at 95% and 90% confidence intervals, respectively.

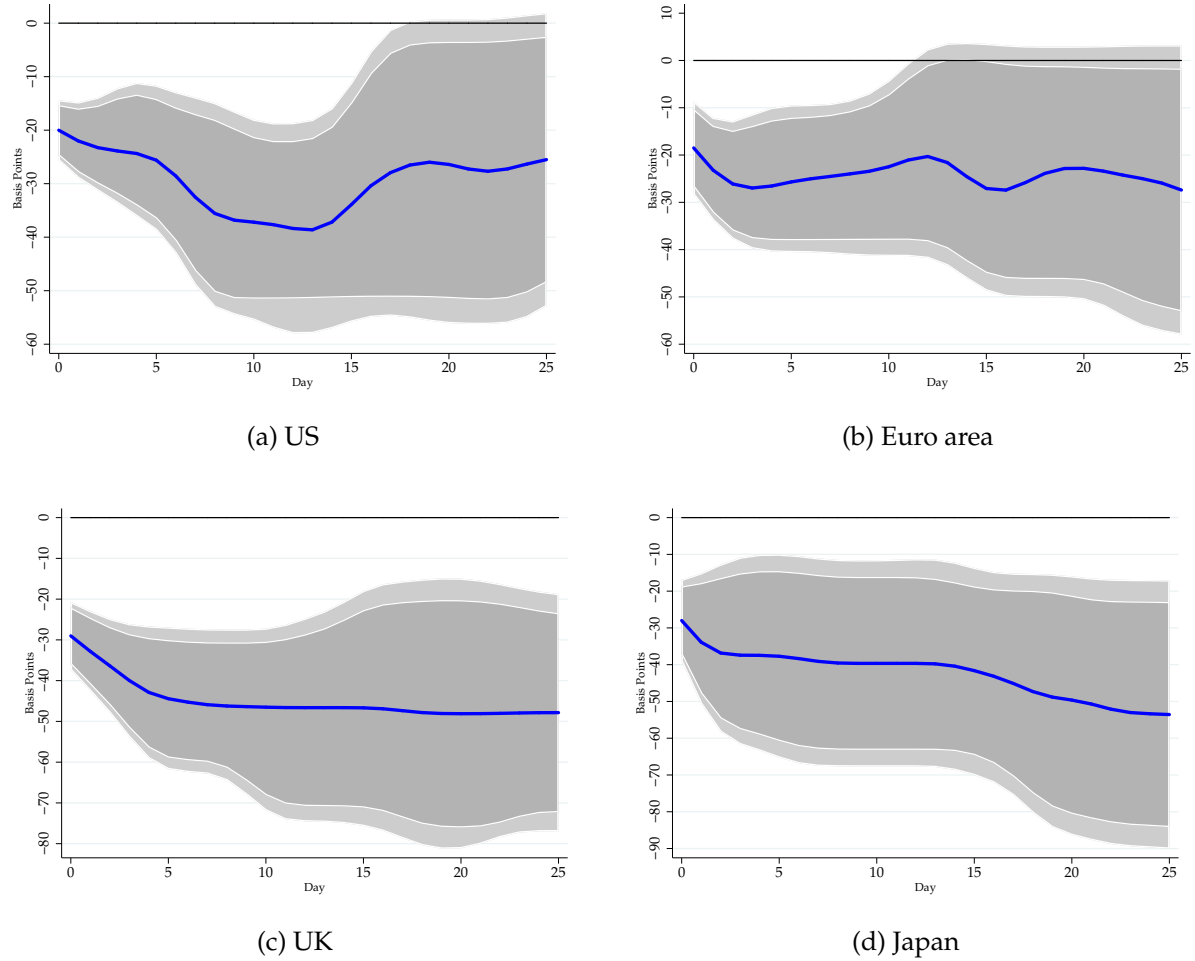


Figure 4: Effect of a One Standard Deviation Expansionary Surprise on Domestic 10 Year Bond, EAPP

Figure 4 summarizes the results of daily local projections in the EAPP subsample period, where the dependent variable is the change in the domestic 10 year zero coupon bond from 0 to 25 days after the date of a domestic monetary policy announcement. The impulse variable is the daily change in the implied yield for the year-ahead futures contract on the (a.) Eurodollar (Fed), (b.) Euribor (ECB), (c.) Short Sterling (BoE) and (d.) Euroyen Tibor (BoJ) on monetary policy meeting days of the respective central banks. Monetary policy measures are normalized to be a one standard deviation loosening. Red lines show the unsmoothed estimates from local projections, $\hat{\beta}_{i,0}, \dots, \hat{\beta}_{i,25}$, where i indexes the source of the monetary policy surprise., where i indexes the source of the monetary policy surprise. Thick blue lines show the path of the smoothed estimate for the path of $\hat{\beta}_i$ using a compound moving median smoother. The dark and light gray areas indicate smoothed confidence intervals at 95% and 90% confidence intervals, respectively.

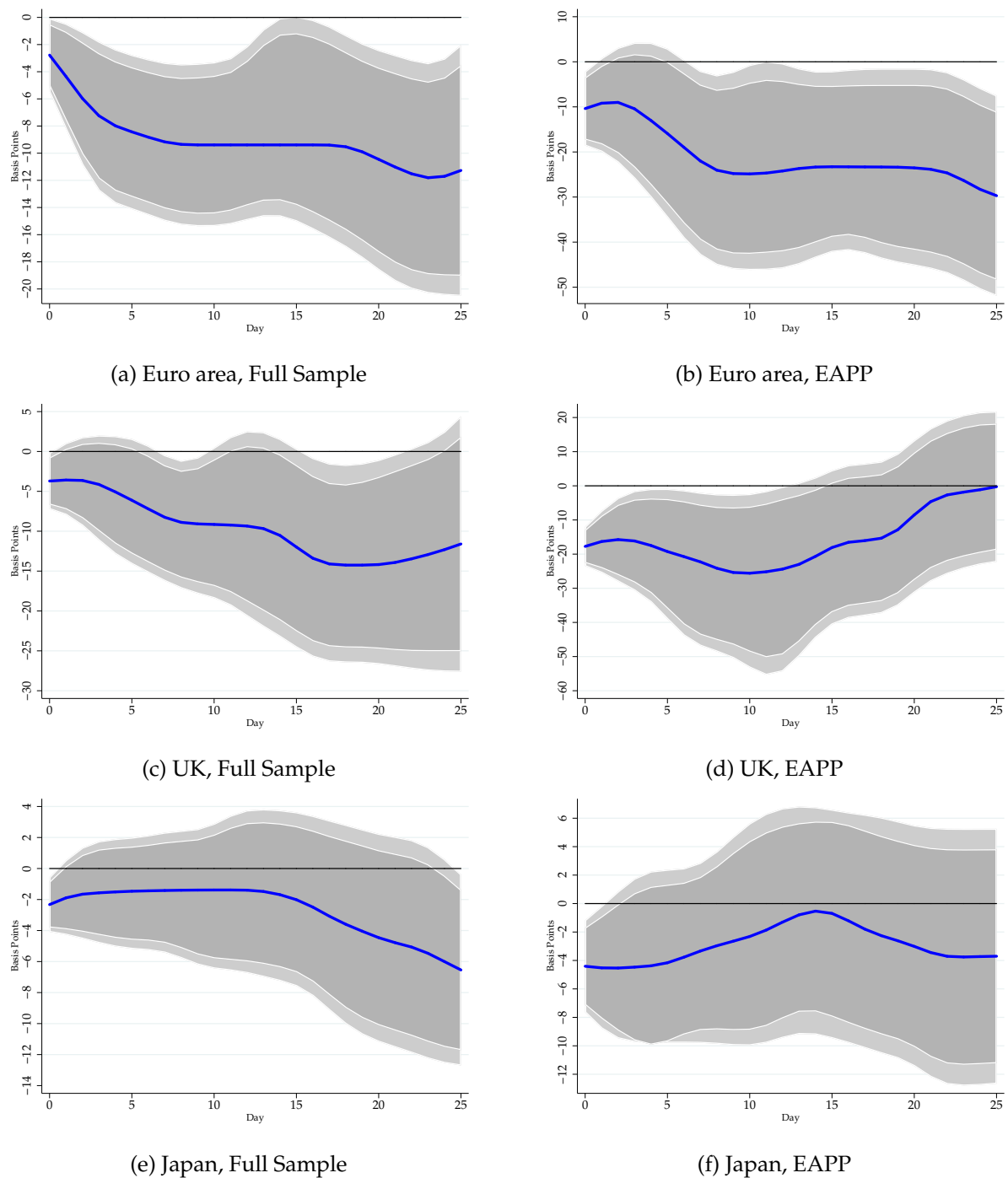


Figure 5: Effect of a One Standard Deviation Expansionary FOMC Surprise on 10 Year Bond Yields

Figure 5 summarizes the results of daily local projections, where the dependent variable is the change in 10-year zero coupon yields in the Euro area (Panels 5a, 5b), UK (Panels 5c, 5d), and Japan (Panels 5e, 5f) from 0 to 25 days after the date of a Fed monetary policy announcement. The impulse variable is the daily change in the implied yield for the year-ahead futures contract on the Eurodollar on FOMC announcement days. Monetary policy measures are normalized to be a one standard deviation loosening. Red lines show the unsmoothed estimates from local projections, $\hat{\beta}_{i,0}, \dots, \hat{\beta}_{i,25}$, where i indexes the source of the monetary policy surprise. Thick blue lines show the path of the smoothed estimate for the path of $\hat{\beta}_i$ using a compound moving median smoother. The dark and light gray areas indicate smoothed confidence intervals at 95% and 90% confidence intervals, respectively.

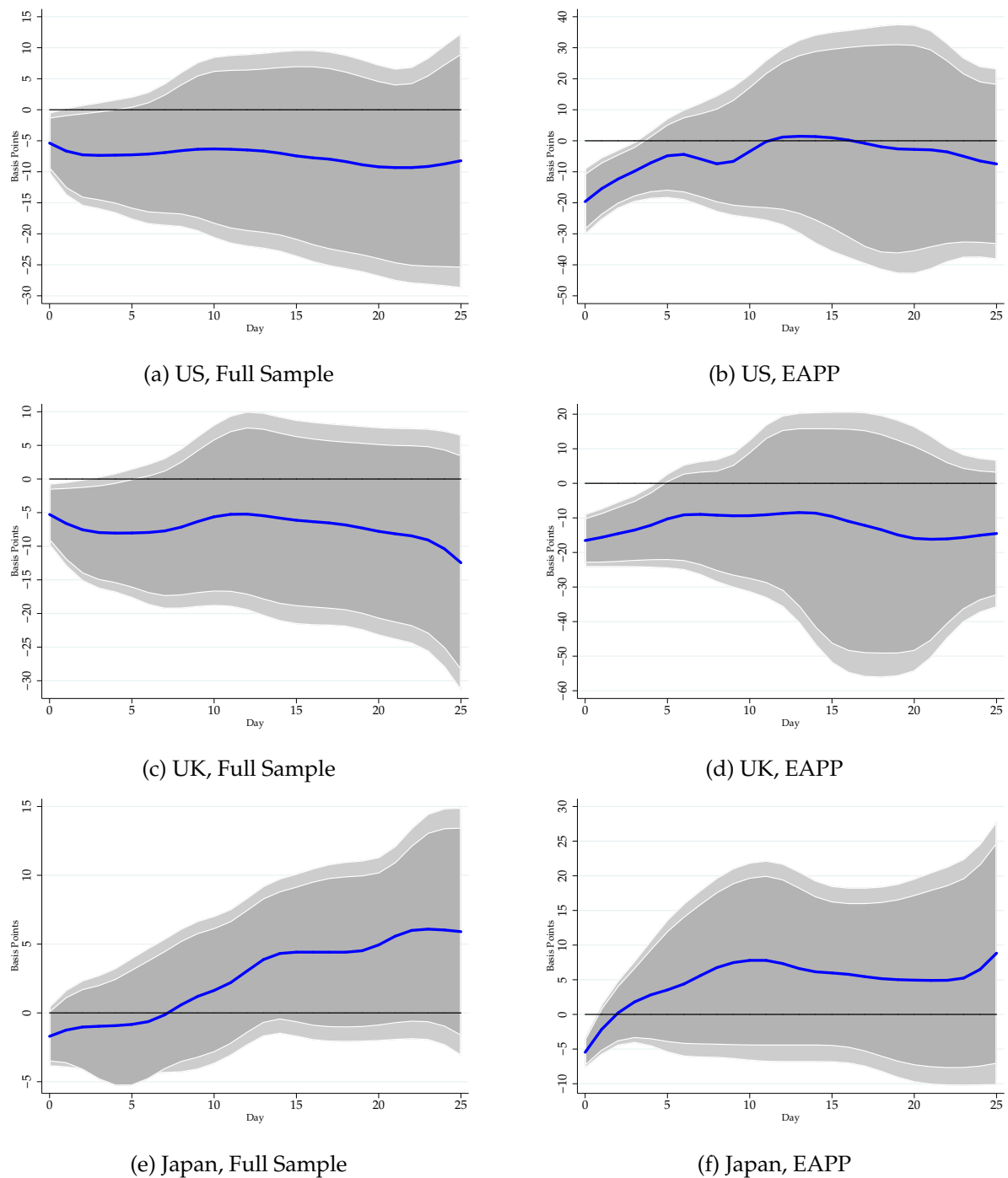


Figure 6: Effect of a One Standard Deviation Expansionary ECB Surprise on 10 Year Bond Yields

Figure 6 summarizes the results of daily local projections, where the dependent variable is the change in 10-year zero coupon yields in the US (Panels 6a, 6b), UK (Panels 6c, 6d), and Japan (Panels 6e, 6f) from 0 to 25 days after the date of an ECB monetary policy announcement. The impulse variable is the daily change in the implied yield for the year-ahead futures contract on the Euribor on ECB announcement days. Monetary policy measures are normalized to be a one standard deviation loosening. Red lines show the unsmoothed estimates from local projections, $\hat{\beta}_{i,0}, \dots, \hat{\beta}_{i,25}$, where i indexes the source of the monetary policy surprise. Thick blue lines show the path of the smoothed estimate for the path of $\hat{\beta}_i$ using a compound moving median smoother. The dark and light gray areas indicate smoothed confidence intervals at 95% and 90% confidence intervals, respectively.

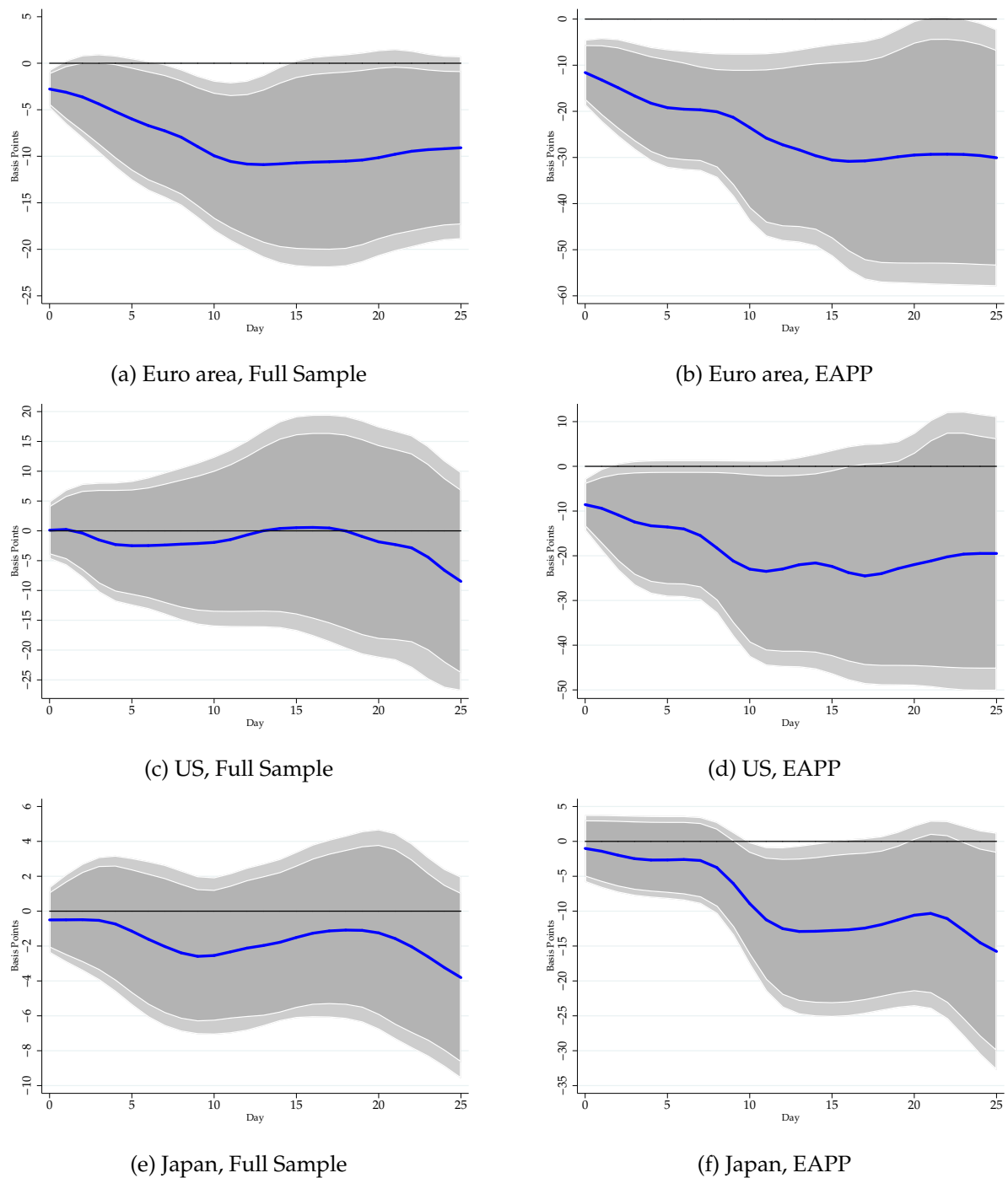


Figure 7: Effect of a One Standard Deviation Expansionary BoE Surprise on 10 Year Bond Yields

Figure 7 summarizes the results of daily local projections, where the dependent variable is the change in 10-year zero coupon yields in the Euro area (Panels 7a, 7b), US (Panels 7c, 7d), and Japan (Panels 7e, 7f) from 0 to 25 days after the date of a BoE monetary policy announcement. The impulse variable is the daily change in the implied yield for the year-ahead futures contract on the Short Sterling on BoE announcement days. Monetary policy measures are normalized to be a one standard deviation loosening. Red lines show the unsmoothed estimates from local projections, $\hat{\beta}_{i,0}, \dots, \hat{\beta}_{i,25}$, where i indexes the source of the monetary policy surprise. Thick blue lines show the path of the smoothed estimate for the path of $\hat{\beta}_i$ using a compound moving median smoother. The dark and light gray areas indicate smoothed confidence intervals at 95% and 90% confidence intervals, respectively.

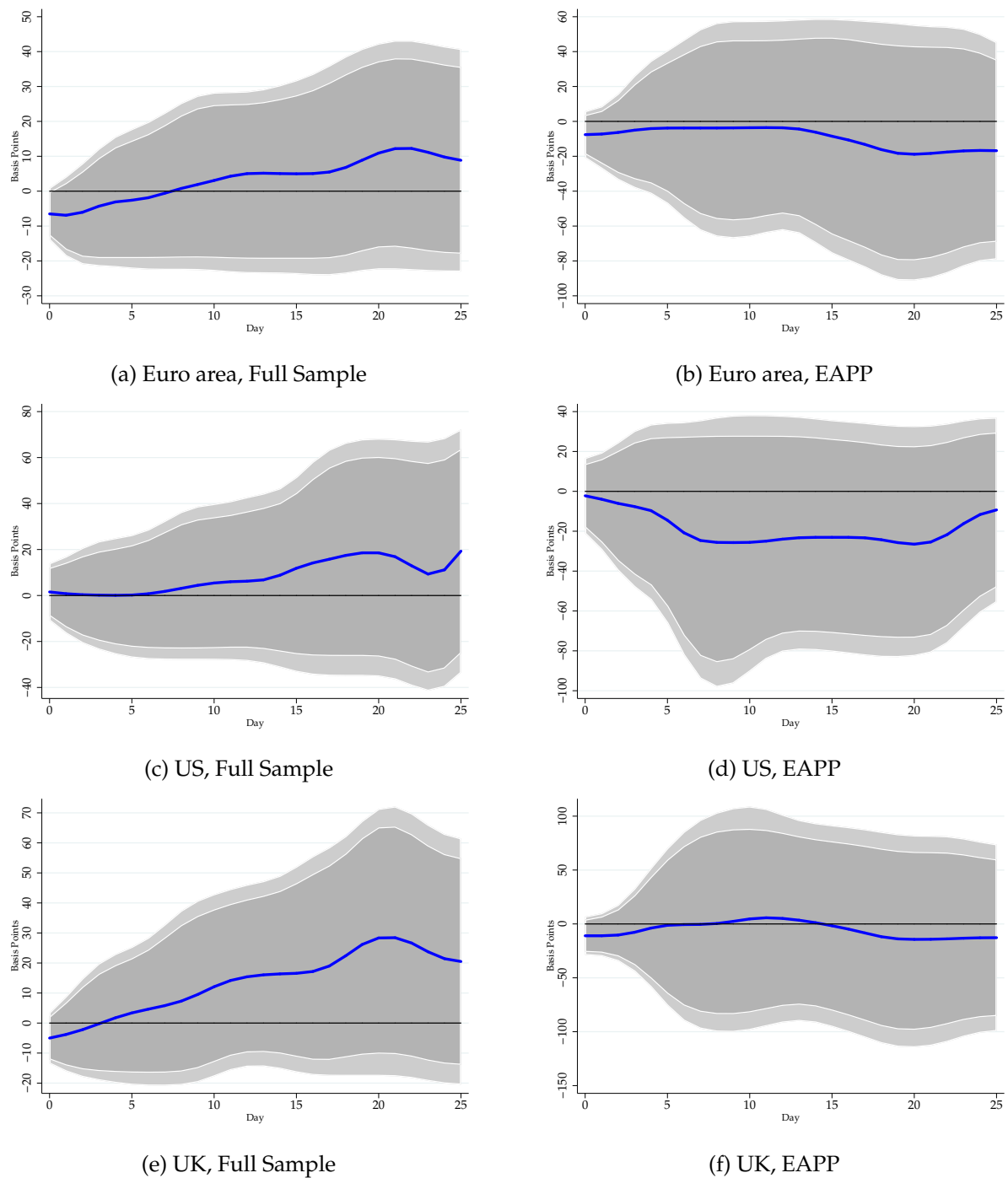
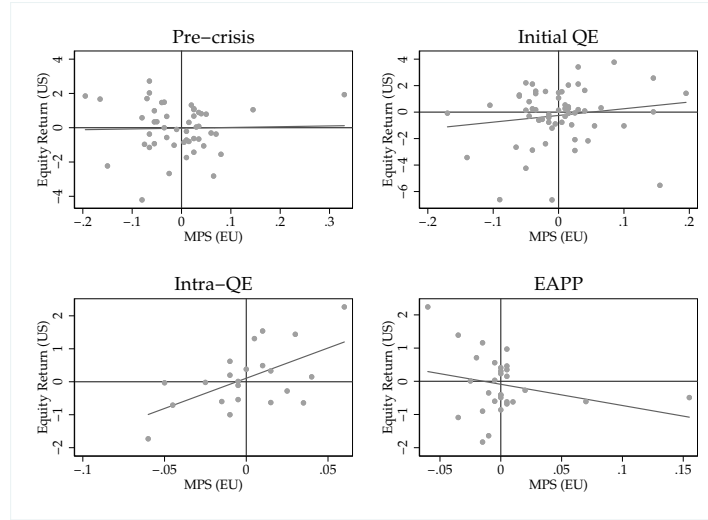
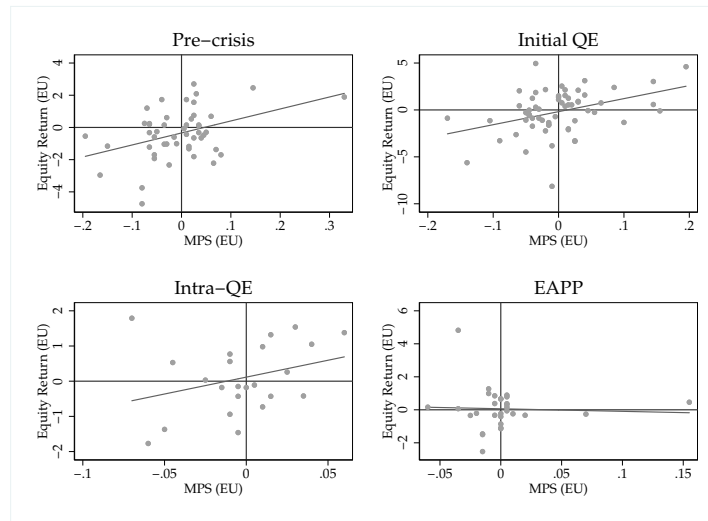


Figure 8: Effect of a One Standard Deviation Expansionary BoJ Surprise on 10 Year Bond Yields

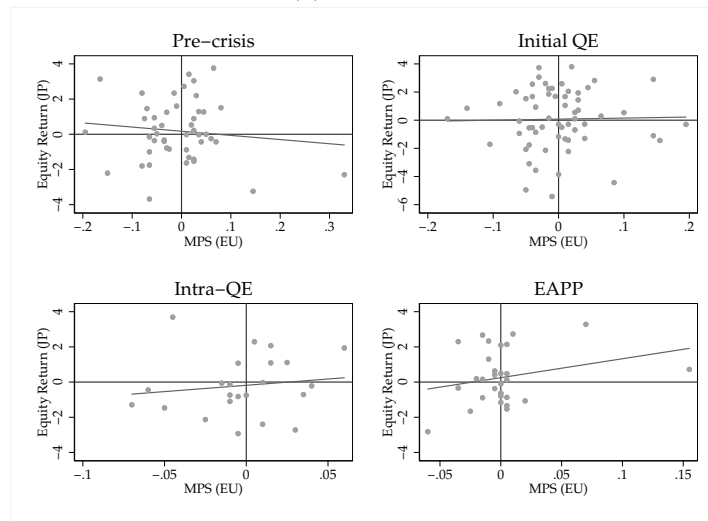
Figure 8 summarizes the results of daily local projections, where the dependent variable is the change in 10-year zero coupon yields in the Euro area (Panels 8a, 8b), US (Panels 8c, 8d), and UK (Panels 8e, 8f) from 0 to 25 days after the date of a BoJ monetary policy announcement. The impulse variable is the daily change in the implied yield for the year-ahead futures contract on the Euroyen Tiber on BoJ announcement days. Monetary policy measures are normalized to be a one standard deviation loosening. Red lines show the unsmoothed estimates from local projections, $\hat{\beta}_{i,0}, \dots, \hat{\beta}_{i,25}$, where i indexes the source of the monetary policy surprise. Thick blue lines show the path of the smoothed estimate for the path of $\hat{\beta}_i$ using a compound moving median smoother. The dark and light gray areas indicate smoothed confidence intervals at 95% and 90% confidence intervals, respectively.



(a) US



(b) Euro area



(c) Japan

Figure 9: Positive Co-movement Days, ECB Announcements against US, EU and JP Equity Returns

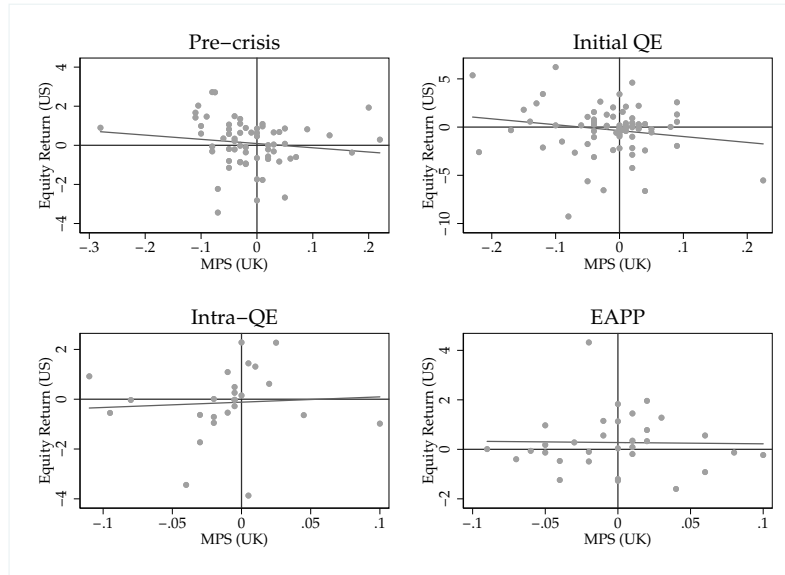


Figure 10: Positive Co-movement Days, BoE Announcements and US Equity Returns

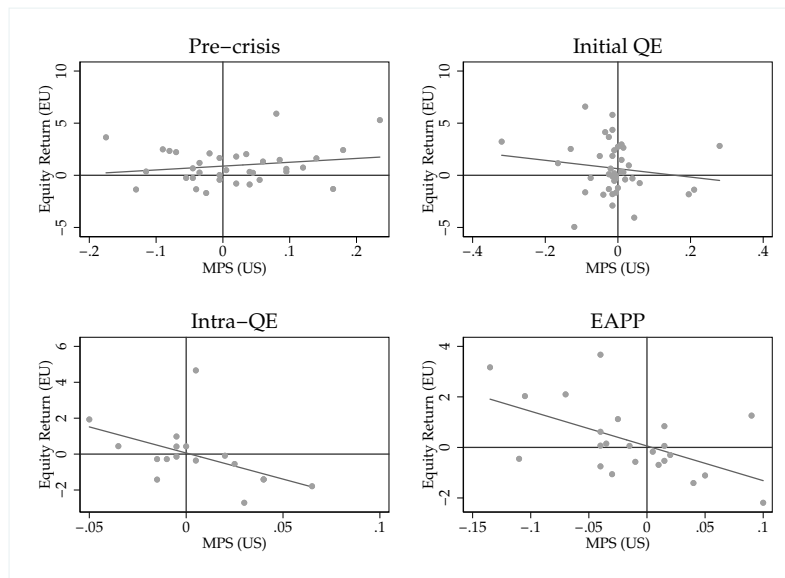
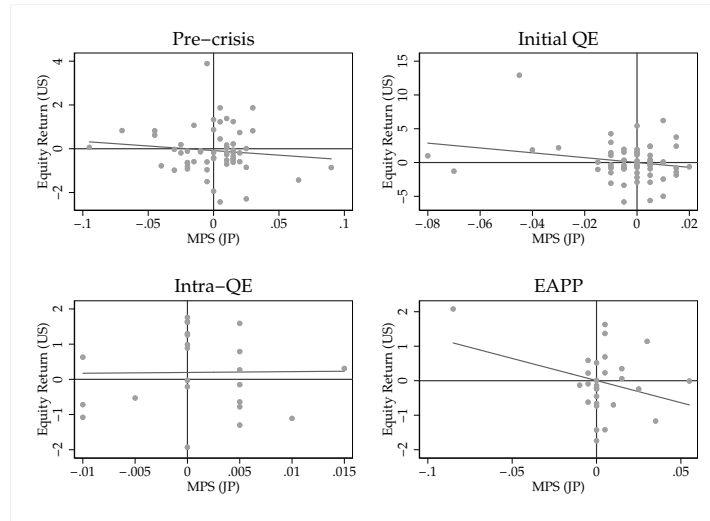
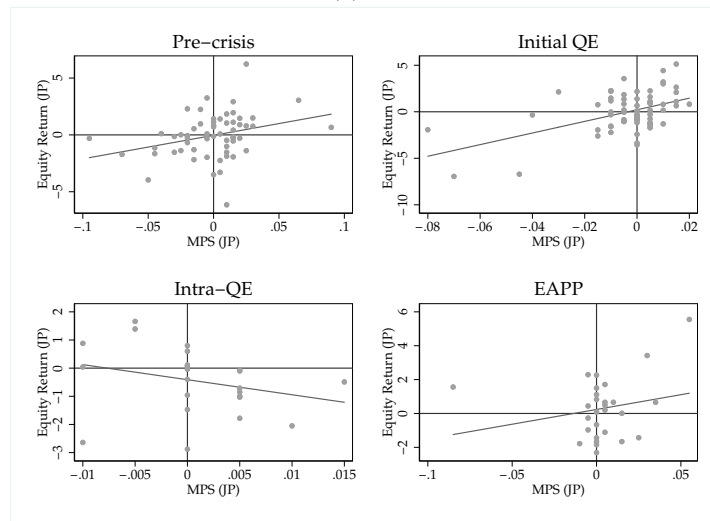


Figure 11: Positive Co-movement Days, FOMC Announcements and EU Equity Returns



(a) US



(b) Japan

Figure 12: Positive Co-movement Days, BoJ Announcements against US, JP Equity Returns

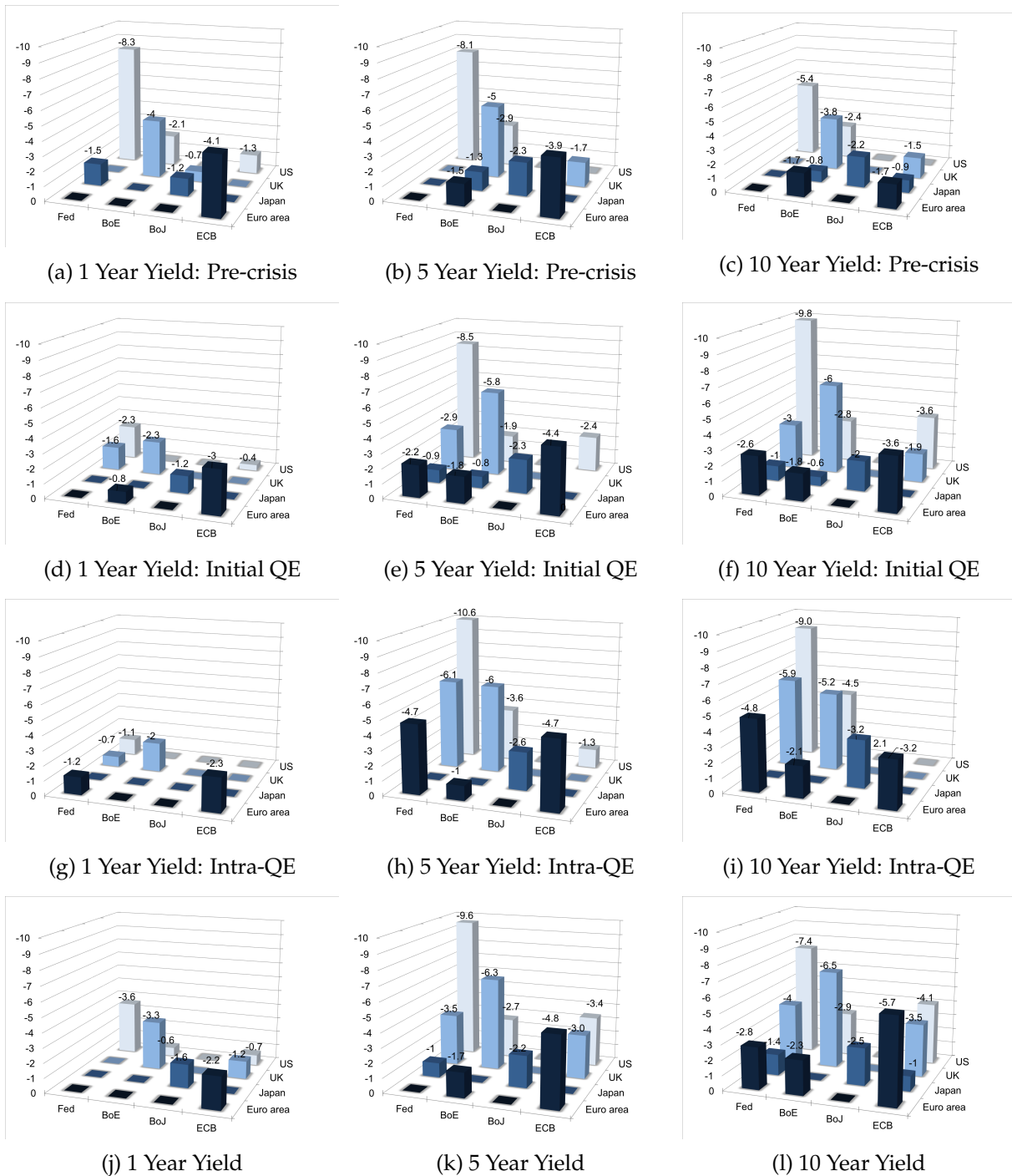
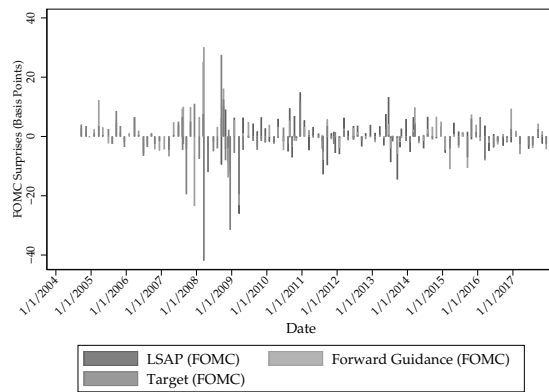
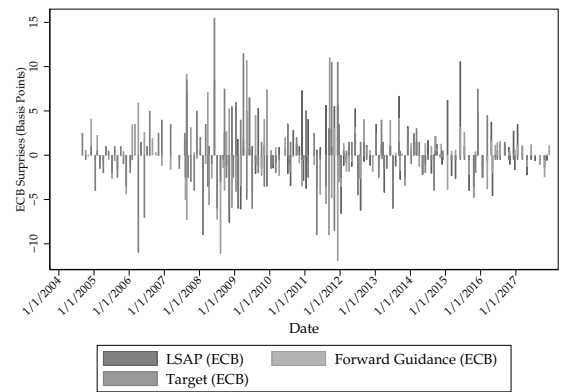


Figure 13: Effect of a One Standard Deviation Monetary Policy Loosening Surprise on Yields

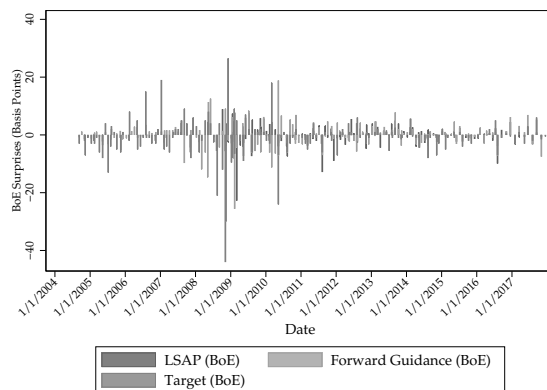
Figures 13a - 13l summarize the results of daily piecewise regressions where the dependent variable is the change in zero coupon bond yields for maturities of 1, 5, and 10 years. The monetary policy shock is the daily change in the first principal component of the 2-month ahead OIS futures and 1-, 3-, 5-, 7-, and 10-year yields in the respective central bank's markets on monetary policy meeting days. Monetary policy measures are normalized to be a one standard deviation loosening. All control variables from the baseline are included in the regression and their point estimates are available on request. All bars represent parameter estimates that are statistically significant at the 10% level or better.



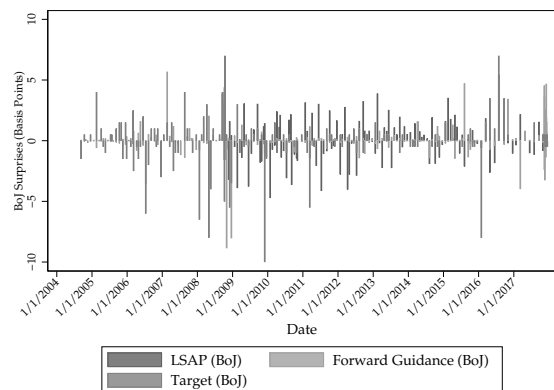
(a) FOMC



(b) ECB



(c) Bank of England



(d) Bank of Japan

Figure 14: Three-part Monetary Policy Surprise Measure

Figure 1 shows “Target”, “Forward Guidance” and “LSAP” shocks for the FOMC, ECB, Bank of England and Bank of Japan. For each central bank’s announcement day, target shocks comprise the surprise component of the decision about the target rate based on the change in yield on the one-month ahead OIS futures contracts. Forward guidance shocks contain the residual from a regression of the announcement day change in the 2-year bond zero coupon bond yield onto the target surprise. LSAP shocks comprise residual from a regression of the announcement day change in the 7-year zero coupon bond yield onto the target and forward guidance surprises.

8 Appendix B: Tables

Table 1: Monetary Policy Sample Counts and Market Timing Conventions

Central Bank	Full Sample	Pre-crisis	US QE	Post-Taper	EU QE
FOMC	162	86	42	40	23
ECB	244	116	60	53	30
BoE	275	135	74	58	32
BoJ	259	125	67	52	28
ECB or BoE	406	198	100	94	60
ECB and BoE	113	60	34	17	2

(a) Count of Announcement Days

Source	Recipient Market			
	US	UK	Euro area	Japan
FOMC	$t - 1, t$	$t, t + 1$	$t, t + 1$	$t, t + 1$
BoE	$t - 1, t$	$t - 1, t$	$t - 1, t$	$t, t + 1$
ECB	$t - 1, t$	$t - 1, t$	$t - 1, t$	$t, t + 1$
BoJ	$t - 1, t$	$t - 1, t$	$t - 1, t$	$t - 1, t$

(b) Timing of Asset Price Changes

Table 2: Inference via Heteroskedasticity

Panel A: 1 Year Yields

	EUR	JPY	UK	US
ECB	0.421***		0.134*	
BOJ		0.249*		
BOE			0.352***	
FOMC	0.448***		0.188**	0.36***
BOE & ECB	0.769***		0.526***	

Panel B: 5 Year Yields

	EUR	JPY	UK	US
ECB	0.36***		0.154**	
BOJ		0.116*		
BOE			0.32***	
FOMC	0.337***		0.479***	0.441***
BOE & ECB	0.429***		0.189**	0.154**

Panel C: 10 Year Yields

	EUR	JPY	UK	US
ECB	0.267***		0.184***	
BOJ		0.136*		
BOE	0.117*		0.333***	
FOMC	0.388***		0.402***	0.392***
BOE & ECB	0.187**			0.179**

Table 2 summarizes the results of a Brown-Forsythe test for equality of variance across the full sample of zero coupon bond yield changes for maturities of 1, 5, and 10 years on announcement days compared to non-announcement days. Columns represent the central bank generating potential surprises. Rows indicate recipient markets. Empty cells indicate results which are not significant at the 10% level (minimum). Cells with text in red indicate yields for which the ECB and BoE monetary policy surprise is not identified, but where joint days generate a statistically significant response. *, **, and *** denote statistical significance at the 10%, 5%, and 1% levels, respectively.

Table 3: Monetary Policy Surprise Summary Statistics by Subsample

(a) Summary Statistics: Interbank Interest Rate Futures Measure

Central Bank	Full Sample		Pre-crisis		Initial QE		Intra-QE		EAPP	
	Mean	St. Dev.	Mean	St. Dev.	Mean	St. Dev.	Mean	St. Dev.	Mean	St. Dev.
FOMC	-0.16	8.66	1.54	9.05	-0.95	9.35	0.53	2.88	-1.46	5.81
BoE	-1.58	7.23	-1.17	7.57	-1.55	7.19	-1.44	4.44	-0.28	4.29
ECB	-0.35	6.27	-0.58	8.11	-0.07	6.45	-0.28	3.21	0.10	3.60
BoJ	-0.08	2.29	-0.14	2.87	-0.34	1.71	0.08	0.60	0.34	2.24

(b) Summary Statistics: 2-Year Yield Measure

Central Bank	Full Sample		Pre-crisis		Initial QE		Intra-QE		EAPP	
	Mean	St. Dev.	Mean	St. Dev.	Mean	St. Dev.	Mean	St. Dev.	Mean	St. Dev.
FOMC	0.11	6.93	1.90	8.71	-1.09	5.58	1.02	4.16	-1.48	5.56
BoE	-1.19	5.51	-1.16	5.76	-1.14	5.66	-0.71	3.89	-0.46	4.01
ECB	-1.24	6.04	-0.41	5.66	-2.22	7.42	-0.56	5.09	-0.58	2.66
BoJ	-0.04	1.37	0.03	1.10	-0.20	1.16	0.06	0.51	0.13	1.54

Table 4a: Summary Statistics on Dependent Variables, US and UK

Panel A: US

Variable	Full Sample	Pre-crisis	Initial QE	Intra-QE	EAPP
$Y_{zc}^{(1)}(US)$	1.46 (1.69)	3.79 (1.13)	0.31 (0.14)	0.15 (0.04)	0.75 (0.37)
$Y_{zc}^{(5)}(US)$	2.35 (1.26)	4.05 (0.65)	1.57 (0.68)	1.58 (0.18)	1.62 (0.29)
$Y_{zc}^{(10)}(US)$	3.24 (1.08)	4.53 (0.34)	2.92 (0.87)	2.68 (0.27)	2.17 (0.29)
$Y_{tp}^{(1)}(US)$	-0.24 (0.4)	-0.21 (0.17)	0.03 (0.1)	-0.11 (0.03)	-0.82 (0.43)
$Y_{tp}^{(5)}(US)$	0.72 (0.67)	0.68 (0.33)	1.14 (0.57)	1.09 (0.23)	-0.14 (0.47)
$Y_{tp}^{(10)}(US)$	1.58 (0.88)	1.62 (0.42)	2.13 (0.76)	1.84 (0.43)	0.39 (0.43)
$Y_{eh}^{(1)}(US)$	1.70 (1.76)	4.00 (1.19)	0.29 (0.08)	0.26 (0.04)	1.58 (0.73)
$Y_{eh}^{(5)}(US)$	1.63 (1.38)	3.37 (0.91)	0.43 (0.15)	0.49 (0.21)	1.76 (0.5)
$Y_{eh}^{(10)}(US)$	1.66 (0.99)	2.91 (0.64)	0.79 (0.15)	0.84 (0.19)	1.78 (0.34)

Panel B: UK

Variable	Full Sample	Pre-crisis	Initial QE	Intra-QE	EAPP
$Y_{zc}^{(1)}(UK)$	1.82 (2.04)	4.81 (0.46)	0.58 (0.22)	0.39 (0.09)	0.26 (0.15)
$Y_{zc}^{(5)}(UK)$	2.51 (1.6)	4.64 (0.38)	1.92 (0.84)	1.64 (0.27)	0.83 (0.38)
$Y_{zc}^{(10)}(UK)$	3.17 (1.28)	4.61 (0.3)	3.08 (0.86)	2.62 (0.35)	1.48 (0.39)
$Y_{tp}^{(1)}(UK)$	0.04 (0.15)	-0.04 (0.07)	0.13 (0.17)	0.10 (0.04)	-0.03 (0.16)
$Y_{tp}^{(5)}(UK)$	0.79 (0.58)	0.46 (0.13)	1.28 (0.61)	1.07 (0.3)	0.31 (0.25)
$Y_{tp}^{(10)}(UK)$	1.39 (0.78)	1.01 (0.24)	2.13 (0.68)	1.66 (0.51)	0.56 (0.25)
$Y_{eh}^{(1)}(UK)$	1.77 (2.08)	4.84 (0.47)	0.45 (0.22)	0.29 (0.07)	0.29 (0.13)
$Y_{eh}^{(5)}(UK)$	1.72 (1.68)	4.18 (0.38)	0.64 (0.3)	0.58 (0.24)	0.52 (0.23)
$Y_{eh}^{(10)}(UK)$	1.78 (1.25)	3.60 (0.28)	0.95 (0.28)	0.96 (0.24)	0.92 (0.27)

Table 4b: Summary Statistics on Dependent Variables, Euro area and Japan

Panel A: Euro area					
Variable	Full Sample	Pre-crisis	Initial QE	Intra-QE	EAPP
$Y_{zc}^{(1)}(EA)$	1.11 (1.59)	3.21 (0.8)	0.59 (0.48)	0.03 (0.07)	-0.55 (0.21)
$Y_{zc}^{(5)}(EA)$	1.81 (1.54)	3.54 (0.54)	1.91 (0.77)	0.64 (0.32)	-0.23 (0.22)
$Y_{zc}^{(10)}(EA)$	2.55 (1.43)	3.90 (0.41)	2.98 (0.73)	1.62 (0.49)	0.41 (0.27)
$Y_{tp}^{(1)}(EA)$	-0.34 (0.27)	-0.47 (0.19)	-0.19 (0.16)	-0.02 (0.1)	-0.59 (0.22)
$Y_{tp}^{(5)}(EA)$	0.46 (0.55)	0.38 (0.26)	0.99 (0.35)	0.49 (0.26)	-0.30 (0.19)
$Y_{tp}^{(10)}(EA)$	1.13 (0.73)	1.12 (0.32)	1.82 (0.41)	1.07 (0.44)	0.07 (0.21)
$Y_{eh}^{(1)}(EA)$	1.45 (1.65)	3.68 (0.81)	0.79 (0.59)	0.04 (0.08)	0.04 (0.17)
$Y_{eh}^{(5)}(EA)$	1.35 (1.37)	3.17 (0.62)	0.92 (0.56)	0.15 (0.12)	0.07 (0.18)
$Y_{eh}^{(10)}(EA)$	1.42 (1.04)	2.77 (0.44)	1.17 (0.44)	0.55 (0.12)	0.34 (0.22)
Panel B: Japan					
Variable	Full Sample	Pre-crisis	Initial QE	Intra-QE	EAPP
$Y_{zc}^{(1)}(JP)$	0.16 (0.26)	0.38 (0.29)	0.16 (0.08)	0.07 (0.03)	-0.11 (0.11)
$Y_{zc}^{(5)}(JP)$	0.48 (0.45)	1.00 (0.31)	0.45 (0.19)	0.22 (0.09)	-0.07 (0.13)
$Y_{zc}^{(10)}(JP)$	0.99 (0.58)	1.59 (0.2)	1.12 (0.24)	0.63 (0.14)	0.14 (0.2)
$Y_{tp}^{(1)}(JP)$	-0.23 (0.39)	-0.46 (0.45)	0.11 (0.15)	-0.52 (0.11)	-0.33 (0.23)
$Y_{tp}^{(5)}(JP)$	0.29 (0.36)	0.57 (0.24)	0.43 (0.2)	-0.04 (0.11)	-0.17 (0.09)
$Y_{tp}^{(10)}(JP)$	0.88 (0.53)	1.34 (0.18)	1.10 (0.25)	0.48 (0.16)	0.08 (0.15)
$Y_{eh}^{(1)}(JP)$	0.40 (0.5)	0.84 (0.6)	0.05 (0.14)	0.59 (0.11)	0.21 (0.27)
$Y_{eh}^{(5)}(JP)$	0.19 (0.26)	0.42 (0.33)	0.02 (0.06)	0.25 (0.05)	0.09 (0.12)
$Y_{eh}^{(10)}(JP)$	0.11 (0.15)	0.25 (0.19)	0.01 (0.04)	0.15 (0.03)	0.05 (0.07)

Table 5: Response of Yield Changes to a One Standard Deviation Monetary Policy Surprise (Benchmark Specification), Full Sample

Monetary Policy Surprises		(1)	(2)	(3)	(4)	(5)
US		Y1 (US)	Y3 (US)	Y5 (US)	Y7 (US)	Y10 (US)
Domestic Pass-through	MPS, Full Sample, FOMC	-3.7*** (0.663)	-5.7*** (0.920)	-5.9*** (1.120)	-5.5*** (1.267)	-4.6*** (1.297)
Spillovers by Central Bank	MPS, Full Sample, ECB	-0.9*** (0.314)	-1.2*** (0.430)	-1.3** (0.551)	-1.3** (0.603)	-1.3** (0.635)
	MPS, Full Sample, BoE	0.2 (0.390)	-0.1 (0.564)	-0.1 (0.715)	-0.1 (0.772)	-0.1 (0.764)
	MPS, Full Sample, BoJ	0.1 (0.341)	0.1 (0.539)	0.1 (0.646)	0.2 (0.653)	0.2 (0.606)
UK		Y1 (UK)	Y3 (UK)	Y5 (UK)	Y7 (UK)	Y10 (UK)
Domestic Pass-through	MPS, Full Sample, BoE	-3.2*** (0.359)	-4.2*** (0.546)	-3.6*** (0.591)	-3.1*** (0.599)	-2.6*** (0.592)
Spillovers by Central Bank	MPS, Full Sample, ECB	-0.8** (0.358)	-1.4** (0.562)	-1.4** (0.577)	-1.4** (0.590)	-1.4** (0.605)
	MPS, Full Sample, BoJ	-0.6*** (0.182)	-0.7** (0.371)	-0.7* (0.397)	-0.6 (0.402)	-0.5 (0.392)
	MPS, Full Sample, FOMC	-1.3*** (0.346)	-1.7*** (0.534)	-1.6*** (0.532)	-1.4** (0.569)	-1.1* (0.595)
Euro area		Y1 (EU)	Y3 (EU)	Y5 (EU)	Y7 (EU)	Y10 (EU)
Domestic Pass-through	MPS, Full Sample, ECB	-3.0*** (0.286)	-4.0*** (0.325)	-3.2*** (0.348)	-2.4*** (0.345)	-1.6*** (0.350)
Spillovers by Central Bank	MPS, Full Sample, BoE	-0.7 (0.456)	-0.5 (0.438)	-0.7 (0.412)	-0.8** (0.355)	-0.9*** (0.310)
	MPS, Full Sample, BoJ	0.0 (0.312)	-0.8*** (0.229)	-0.9*** (0.248)	-0.7** (0.292)	-0.6* (0.358)
	MPS, Full Sample, FOMC	-0.8** (0.331)	-1.0* (0.492)	-1.1** (0.477)	-1.1** (0.467)	-1.1** (0.499)
Japan		Y1 (JP)	Y3 (JP)	Y5 (JP)	Y7 (JP)	Y10 (JP)
Domestic Pass-through	MPS, Full Sample, BoJ	-0.4 (0.439)	-1.5*** (0.305)	-1.9*** (0.286)	-2.0*** (0.304)	-1.8*** (0.334)
Spillovers by Central Bank	MPS, Full Sample, ECB	0.6 (0.687)	-0.1 (0.221)	-0.2 (0.276)	-0.4 (0.296)	-0.5* (0.275)
	MPS, Full Sample, BoE	-0.1 (0.292)	-0.4** (0.160)	-0.5* (0.272)	-0.4 (0.312)	-0.2 (0.276)
	MPS, Full Sample, FOMC	0.2 (0.618)	-0.5** (0.222)	-0.9*** (0.312)	-1.1*** (0.326)	-0.9*** (0.316)

Table 5 summarizes the results of daily regressions where the dependent variable is the change in zero coupon bond yields for maturities of 1, 3, 5, 7 and 10 years. MPS is the daily change in the implied yield for the year-ahead futures contract on the Eurodollar (Fed), Euribor (ECB), Short Sterling (BoE) and Euroyen Tibor (BoJ) on monetary policy meeting days of the respective central banks. Monetary policy measures are normalized to be a one standard deviation loosening (in basis points). Full results, including control variables, are shown in the Internet Appendix. Standard errors are shown in parentheses. *, **, and *** denote statistical significance at the 10%, 5%, and 1% levels, respectively.

Table 6: The Impact of a Domestic One Standard Deviation Monetary Policy Surprise on Yields, Expected Short Rates and Term Premia (Benchmark Specification)

		(1)	(2)	(3)	(4)	(5)
Panel A: US Domestic Passthrough	Dep. Var.	Y1 (US)	Y3 (US)	Y5 (US)	Y7 (US)	Y10 (US)
MPS (Interbank Futures), Pre-crisis, FOMC	Yield	-6.2***	-6.3***	-5.0***	-3.8***	-2.7***
	E(Short rate)	-7.5***	-7.1***	-6.3***	-5.5***	-4.5***
	Term premium	1.3**	0.8	1.3**	1.7**	2.0***
MPS (Interbank Futures), US QE, FOMC	Yield	-1.8*	-4.0**	-5.4**	-5.8**	-5.4*
	E(Short rate)	-0.8	-1.2*	-1.6**	-1.7***	-1.6***
	Term premium	-1.0*	-2.9**	-3.8*	-4.1*	-3.7
MPS (Interbank Futures), TT to EAPP, FOMC	Yield	-3.6***	-18.4***	-24.8***	-23.8***	-18.6***
	E(Short rate)	-0.2	-5.8**	-10.5***	-11.5***	-10.9***
	Term premium	-3.3***	-12.7***	-14.4**	-12.4*	-7.7
MPS (Interbank Futures), EAPP, FOMC	Yield	-3.9***	-9.7***	-9.6***	-8.3***	-6.6***
	E(Short rate)	-7.4***	-9.1***	-8.7***	-7.9***	-6.7***
	Term premium	3.4***	-0.6	-0.8	-0.3	0.3
Panel B: Euro Area Domestic Passthrough	Dep. Var.	Y1 (EU)	Y3 (EU)	Y5 (EU)	Y7 (EU)	Y10 (EU)
MPS (Interbank Futures), Pre-crisis, ECB	Yield	-3.4***	-4.2***	-3.1***	-2.1***	-1.2***
	E(Short rate)	-4.5***	-4.5***	-4.0***	-3.6***	-2.9***
	Term premium	0.9***	-0.1	0.5**	1.1***	1.5***
MPS (Interbank Futures), US QE, ECB	Yield	-2.7***	-3.5***	-2.7***	-2.1***	-1.6***
	E(Short rate)	-3.2***	-3.2***	-2.9***	-2.6***	-2.2***
	Term premium	0.5	-0.2	0.3	0.6	0.6
MPS (Interbank Futures), TT to EAPP, ECB	Yield	-3.8***	-6.7***	-6.9***	-6.0***	-4.4***
	E(Short rate)	-1.5*	-1.7*	-3.6***	-4.0***	-3.8***
	Term premium	-2.2**	-5.0***	-3.4***	-2.2**	-0.7
MPS (Interbank Futures), EAPP, ECB	Yield	-3.4***	-5.2***	-5.4***	-5.3***	-4.8***
	E(Short rate)	-0.0	-0.1	-0.6	-1.6***	-2.1***
	Term premium	-3.4***	-5.1***	-4.9***	-3.6***	-2.7***
Panel C: UK Domestic Passthrough	Dep. Var.	Y1 (UK)	Y3 (UK)	Y5 (UK)	Y7 (UK)	Y10 (UK)
MPS (Interbank Futures), Pre-crisis, BoE	Yield	-3.4***	-4.3***	-3.5***	-2.8***	-2.1***
	E(Short rate)	-4.0***	-3.8***	-3.4***	-3.1***	-2.6***
	Term premium	0.5***	-0.4	0.1	0.5	0.7
MPS (Interbank Futures), US QE, BoE	Yield	-2.4***	-4.5***	-4.1***	-3.6***	-3.1***
	E(Short rate)	-3.0**	-3.3***	-3.2***	-2.9***	-2.4***
	Term premium	0.6	-1.3*	-1.0	-0.7	-0.6
MPS (Interbank Futures), TT to EAPP, BoE	Yield	-2.5***	-6.4***	-6.9***	-6.2***	-5.2***
	E(Short rate)	-1.7	-2.8***	-3.7***	-3.7***	-3.3***
	Term premium	-0.8	-3.5***	-3.1**	-2.4*	-1.7
MPS (Interbank Futures), EAPP, BoE	Yield	-4.9***	-7.4***	-8.1***	-8.3***	-7.9***
	E(Short rate)	-1.7	-3.2***	-4.8***	-6.4***	-6.7***
	Term premium	-3.1***	-4.1***	-3.5*	-2.1	-1.5
Panel D: Japan Domestic Passthrough	Dep. Var.	Y1 (JP)	Y3 (JP)	Y5 (JP)	Y7 (JP)	Y10 (JP)
MPS (Interbank Futures), Pre-crisis, BoJ	Yield	-0.0	-1.6***	-1.6***	-1.5***	-1.4***
	E(Short rate)	-0.6*	-0.7*	-0.5*	-0.4*	-0.3*
	Term premium	0.7	-0.8*	-1.0**	-1.1**	-1.1**
MPS (Interbank Futures), US QE, BoJ	Yield	-0.6**	-1.7***	-2.4***	-2.3***	-1.6***
	E(Short rate)	-0.1	-0.1	-0.1	-0.0	-0.0
	Term premium	-0.4	-1.6***	-2.4***	-2.2***	-1.5***
MPS (Interbank Futures), TT to EAPP, BoJ	Yield	0.0	-1.2	-1.6**	-1.6*	-1.8*
	E(Short rate)	0.6	0.4	0.3	0.2	0.2
	Term premium	-1.3	-1.9*	-2.0	-2.0	-2.2
MPS (Interbank Futures), EAPP, BoJ	Yield	-1.5***	-2.0***	-2.5***	-2.8***	-2.8***
	E(Short rate)	0.2	0.1	0.1	0.1	0.1
	Term premium	-1.7***	-2.1***	-2.5***	-2.8***	-2.8***

Table 6 summarizes the results of daily piecewise regressions where the dependent variable is the change in domestic (i) zero coupon bond yields for maturities of 1, 3, 5, 7 and 10 years, (ii) the path of the expected short rate over the life of the bond, and (iii) the term premium relevant for each maturity. Measures of the expected short rate and the term premium are estimated using a shadow rate term structure model from Wu and Xia (2016). The independent variable of interest is the daily change in the implied yield for the year-ahead futures contract on the Eurodollar (Fed), Euribor (ECB), Short Sterling (BoE) and Euroyen Tabor (BoJ) on monetary policy meeting days of the respective central banks. Monetary policy measures are normalized to be a one standard deviation loosening (in basis points). *, **, and *** denote statistical significance at the 10%, 5%, and 1% levels, respectively.

Table 7a: The Impact of a One Standard Deviation FOMC Monetary Policy Surprise on Yields, Expected Short Rates and Term Premia (Benchmark Specification)

		(1)	(2)	(3)	(4)	(5)
Panel A: UK yields	Dep. Var.	Y1 (UK)	Y3 (UK)	Y5 (UK)	Y7 (UK)	Y10 (UK)
MPS (Interbank Futures), Pre-crisis, FOMC	Yield	-0.9	-0.5	-0.0	0.4	0.7
	E(Short rate)	-1.5*	-1.3*	-1.2*	-1.1*	-0.9*
	Term premium	0.6	0.9**	1.2**	1.5**	1.7***
MPS (Interbank Futures), US QE, FOMC	Yield	-1.7**	-2.4**	-2.3**	-2.1**	-1.8*
	E(Short rate)	-1.5*	-1.6**	-1.5**	-1.3**	-1.1**
	Term premium	-0.2	-0.7	-0.7	-0.7	-0.7
MPS (Interbank Futures), TT to EAPP, FOMC	Yield	-1.5	-9.9**	-13.0**	-13.1**	-11.8*
	E(Short rate)	0.4	-2.4	-3.7**	-3.9**	-3.6**
	Term premium	-1.9	-7.5*	-9.3*	-9.2	-8.2
MPS (Interbank Futures), EAPP, FOMC	Yield	-1.7**	-4.4***	-5.3***	-5.5***	-5.5***
	E(Short rate)	-0.5	-2.5**	-3.1***	-3.1***	-2.8***
	Term premium	-1.3**	-1.8**	-1.9**	-1.9**	-2.2**
Panel B: Euro area yields	Dep. Var.	Y1 (EU)	Y3 (EU)	Y5 (EU)	Y7 (EU)	Y10 (EU)
MPS (Interbank Futures), Pre-crisis, FOMC	Yield	-0.4	-0.7	-0.4	0.0	0.5
	E(Short rate)	-1.2**	-1.2*	-1.2*	-1.0*	-0.9*
	Term premium	0.9*	0.9**	1.0**	1.2**	1.5**
MPS (Interbank Futures), US QE, FOMC	Yield	-0.8	-1.1	-1.4	-1.6*	-1.7*
	E(Short rate)	-0.3	-0.3	-0.3	-0.3	-0.3
	Term premium	-0.6	-0.8**	-1.1**	-1.3**	-1.4*
MPS (Interbank Futures), TT to EAPP, FOMC	Yield	-2.4	-6.9	-8.9	-9.4	-8.8
	E(Short rate)	-4.0	-5.9	-6.7	-6.7	-6.0
	Term premium	1.6	-1.1	-2.3	-2.8	-2.7
MPS (Interbank Futures), EAPP, FOMC	Yield	-0.1	-0.6	-1.6	-2.4**	-3.2**
	E(Short rate)	1.3	1.0	0.6	0.1	-0.2
	Term premium	-1.2	-1.2	-1.6**	-2.0**	-2.5**
Panel C: Japan yields	Dep. Var.	Y1 (JP)	Y3 (JP)	Y5 (JP)	Y7 (JP)	Y10 (JP)
MPS (Interbank Futures), Pre-crisis, FOMC	Yield	1.2	-1.0**	-0.6	-0.7	-0.5
	E(Short rate)	-0.2	0.0	0.0	0.0	0.0
	Term premium	1.8	-0.4	-0.2	-0.4	-0.3
MPS (Interbank Futures), US QE, FOMC	Yield	-0.3	-0.5	-0.9**	-1.0***	-1.0***
	E(Short rate)	0.1	0.1	0.1	0.1	0.0
	Term premium	-0.2	-0.6	-0.9**	-1.1***	-1.1***
MPS (Interbank Futures), TT to EAPP, FOMC	Yield	1.2	0.4	-1.0	-1.6*	-1.4
	E(Short rate)	-0.0	0.3	0.3	0.2	0.2
	Term premium	2.5*	0.5	-1.0	-1.6	-1.3
MPS (Interbank Futures), EAPP, FOMC	Yield	0.3	-0.5	-1.3***	-1.4***	-1.5**
	E(Short rate)	1.6	1.0	0.8	0.6	0.4
	Term premium	-0.8	-1.3*	-1.8***	-1.8***	-1.8***

Table 7a summarizes the results of daily piecewise regressions where the dependent variable is the change in (i) zero coupon bond yields for maturities of 1, 3, 5, 7 and 10 years, (ii) the path of the expected short rate over the life of the bond, and (iii) the term premium relevant for each maturity in the UK, Euro area and Japan. Measures of the expected short rate and the term premium are estimated using a shadow rate term structure model from Wu and Xia (2016). The independent variable of interest is the daily change in the implied yield for the year-ahead futures contract on the Eurodollar on monetary policy FOMC meeting days. Monetary policy measures are normalized to be a one standard deviation loosening (in basis points). *, **, and *** denote statistical significance at the 10%, 5%, and 1% levels, respectively.

Table 7b: The Impact of a One Standard Deviation ECB Monetary Policy Surprise on Yields, Expected Short Rates and Term Premia (Benchmark Specification)

		(1)	(2)	(3)	(4)	(5)
Panel A: UK yields	Dep. Var.	Y1 (UK)	Y3 (UK)	Y5 (UK)	Y7 (UK)	Y10 (UK)
MPS (Interbank Futures), Pre-crisis, ECB	Yield	-0.4	-1.4**	-1.6***	-1.6***	-1.6***
	E(Short rate)	0.0	-0.2	-0.2	-0.1	-0.1
	Term premium	-0.4***	-1.2***	-1.5***	-1.7***	-1.7***
MPS (Interbank Futures), US QE, ECB	Yield	-1.1*	-1.7	-1.5	-1.5	-1.4
	E(Short rate)	-2.1	-1.8	-1.6*	-1.5*	-1.3**
	Term premium	1.0	-0.0	-0.1	-0.1	-0.2
MPS (Interbank Futures), TT to EAPP, ECB	Yield	-0.4	-1.1	-1.3	-1.4	-1.4
	E(Short rate)	0.8	1.2*	0.1	-0.3	-0.5
	Term premium	-1.1*	-2.3**	-1.7	-1.3	-1.0
MPS (Interbank Futures), EAPP, ECB	Yield	-2.4***	-4.0***	-4.3***	-4.3***	-4.2***
	E(Short rate)	-0.9***	-2.8***	-3.0***	-3.0***	-2.7***
	Term premium	-1.6***	-1.2***	-1.0	-1.1	-1.2
Panel B: US yields	Dep. Var.	Y1 (US)	Y3 (US)	Y5 (US)	Y7 (US)	Y10 (US)
MPS (Interbank Futures), Pre-crisis, ECB	Yield	-1.3**	-1.0	-0.7	-0.6	-0.4
	E(Short rate)	-1.3*	-1.1	-0.9	-0.8	-0.6
	Term premium	-0.0	0.1	0.2	0.2	0.2
MPS (Interbank Futures), US QE, ECB	Yield	-0.3	-1.2**	-1.8**	-2.2**	-2.4**
	E(Short rate)	-0.3	-0.5	-0.5	-0.5	-0.5
	Term premium	-0.0	-0.8	-1.3*	-1.7*	-1.9*
MPS (Interbank Futures), TT to EAPP, ECB	Yield	-1.0*	-2.2**	-2.8*	-2.6	-1.6
	E(Short rate)	-0.3	-0.8**	-1.3**	-1.4**	-1.3**
	Term premium	-0.7	-1.3	-1.5	-1.2	-0.4
MPS (Interbank Futures), EAPP, ECB	Yield	-0.9**	-2.7***	-4.2***	-4.8***	-5.0***
	E(Short rate)	0.4	0.2	0.1	-0.0	-0.1
	Term premium	-1.3	-2.9*	-4.2**	-4.8**	-4.9**
Panel C: Japan yields	Dep. Var.	Y1 (JP)	Y3 (JP)	Y5 (JP)	Y7 (JP)	Y10 (JP)
MPS (Interbank Futures), Pre-crisis, ECB	Yield	1.1	-0.4	-0.5	-0.8**	-0.7**
	E(Short rate)	-0.3	-0.1	-0.1	-0.1	-0.0
	Term premium	1.5	-0.4	-0.5	-0.8*	-0.7**
MPS (Interbank Futures), US QE, ECB	Yield	0.1	0.0	-0.0	-0.1	-0.3
	E(Short rate)	0.0	0.0	0.0	0.0	0.0
	Term premium	0.1	0.1	-0.1	-0.2	-0.3
MPS (Interbank Futures), TT to EAPP, ECB	Yield	-0.0	0.2	-0.3	-0.6	-0.5
	E(Short rate)	-0.7	-0.5	-0.3	-0.3	-0.2
	Term premium	0.4	0.7	0.0	-0.4	-0.4
MPS (Interbank Futures), EAPP, ECB	Yield	-0.2	-0.1	-0.2	-0.7***	-1.2***
	E(Short rate)	1.0***	0.5***	0.4**	0.3**	0.2**
	Term premium	-1.7***	-0.8	-0.8**	-1.2***	-1.6***

Table 7b summarizes the results of daily piecewise regressions where the dependent variable is the change in (i) zero coupon bond yields for maturities of 1, 3, 5, 7 and 10 years, (ii) the path of the expected short rate over the life of the bond, and (iii) the term premium relevant for each maturity in the US, UK and Japan. Measures of the expected short rate and the term premium are estimated using a shadow rate term structure model from Wu and Xia (2016). The independent variable of interest is the daily change in the implied yield for the year-ahead futures contract on the Euribor (ECB) on ECB meeting days. Monetary policy measures are normalized to be a one standard deviation loosening (in basis points). *, **, and *** denote statistical significance at the 10%, 5%, and 1% levels, respectively.

Table 7c: The Impact of a One Standard Deviation BoE Monetary Policy Surprise on Yields, Expected Short Rates and Term Premia (Benchmark Specification)

		(1)	(2)	(3)	(4)	(5)
Panel A: Euro area yields		Y1 (EU)	Y3 (EU)	Y5 (EU)	Y7 (EU)	Y10 (EU)
MPS (Interbank Futures), Pre-crisis, BoE	Yield	-0.4*	-0.8**	-0.9**	-1.0**	-1.0**
	E(Short rate)	-0.2	-0.2	-0.2	-0.2	-0.2
	Term premium	-0.2	-0.4	-0.5	-0.6	-0.7
MPS (Interbank Futures), US QE, BoE	Yield	-0.3	-0.8	-0.7	-0.8	-0.9*
	E(Short rate)	-0.1	-0.2	-0.2	-0.2	-0.2
	Term premium	-0.1	-0.5	-0.4	-0.5	-0.7
MPS (Interbank Futures), TT to EAPP, BoE	Yield	0.0	-0.6	-1.3*	-1.8**	-2.2**
	E(Short rate)	-0.9	-1.1	-1.1**	-1.0**	-0.9**
	Term premium	0.9	0.6	0.0	-0.5	-1.1
MPS (Interbank Futures), EAPP, BoE	Yield	-0.8	-1.7**	-2.4***	-2.8***	-3.2***
	E(Short rate)	0.5*	0.4*	0.3	-0.1	-0.9**
	Term premium	-1.3	-2.0***	-2.6***	-2.7***	-2.2***
Panel B: US yields		Y1 (US)	Y3 (US)	Y5 (US)	Y7 (US)	Y10 (US)
MPS (Interbank Futures), Pre-crisis, BoE	Yield	-0.8	-1.2	-1.1	-0.9	-0.7
	E(Short rate)	-0.7	-0.7	-0.6	-0.6	-0.5
	Term premium	-0.0	-0.4	-0.3	-0.3	-0.2
MPS (Interbank Futures), US QE, BoE	Yield	0.7*	0.1	-0.1	-0.3	-0.3
	E(Short rate)	0.2	0.3	0.2	0.1	0.1
	Term premium	0.5	-0.1	-0.2	-0.3	-0.4
MPS (Interbank Futures), TT to EAPP, BoE	Yield	-0.1	-2.8***	-4.2***	-4.5***	-4.7***
	E(Short rate)	0.4	0.2	-0.4	-0.6	-0.6
	Term premium	-0.5	-2.9***	-3.7***	-3.9***	-4.2***
MPS (Interbank Futures), EAPP, BoE	Yield	-0.8**	-2.4***	-3.2***	-3.4***	-3.2***
	E(Short rate)	-0.1	-0.5	-0.6	-0.6	-0.6
	Term premium	-0.7	-1.9**	-2.6**	-2.8**	-2.6*
Panel C: Japan yields		Y1 (JP)	Y3 (JP)	Y5 (JP)	Y7 (JP)	Y10 (JP)
MPS (Interbank Futures), Pre-crisis, BoE	Yield	-0.5	-0.8***	-1.1***	-0.9***	-0.7***
	E(Short rate)	0.3	0.3	0.2	0.2	0.1
	Term premium	-1.4	-1.1**	-1.3***	-1.2***	-0.9***
MPS (Interbank Futures), US QE, BoE	Yield	-0.1	-0.4**	-0.8***	-0.8**	-0.5
	E(Short rate)	-0.2	-0.1	-0.1	-0.1	-0.0
	Term premium	-0.0	-0.4*	-0.7***	-0.7**	-0.5
MPS (Interbank Futures), TT to EAPP, BoE	Yield	-0.5	-0.1	-0.3	-0.4	-0.6*
	E(Short rate)	0.1	0.1	0.0	0.0	0.0
	Term premium	-0.5	-0.2	-0.3	-0.4	-0.6
MPS (Interbank Futures), EAPP, BoE	Yield	0.3	-0.1	-0.6	-0.6	-0.3
	E(Short rate)	-1.0	-0.7	-0.5	-0.4	-0.3
	Term premium	1.1	0.5	-0.2	-0.3	-0.1

Table 7c summarizes the results of daily piecewise regressions where the dependent variable is the change in (i) zero coupon bond yields for maturities of 1, 3, 5, 7 and 10 years, (ii) the path of the expected short rate over the life of the bond, and (iii) the term premium relevant for each maturity in the US, Euro area and Japan. Measures of the expected short rate and the term premium are estimated using a shadow rate term structure model from Wu and Xia (2016). The independent variable of interest is the daily change in the implied yield for the year-ahead futures contract on the Short Sterling (BoE) on Bank of England meeting days. Monetary policy measures are normalized to be a one standard deviation loosening (in basis points). *, **, and *** denote statistical significance at the 10%, 5%, and 1% levels, respectively.

Table 7d: The Impact of a One Standard Deviation BoJ Policy Surprise on Yields, Expected Short Rates and Term Premia (Benchmark Specification)

		(1)	(2)	(3)	(4)	(5)
Panel A: US yields	Dep. Var.	Y1 (US)	Y3 (US)	Y5 (US)	Y7 (US)	Y10 (US)
MPS (Interbank Futures), Pre-crisis, BoJ	Yield	-0.4	-0.4	-0.5	-0.6	-0.5
	E(Short rate)	-0.1	-0.1	-0.0	-0.0	-0.0
	Term premium	-0.2	-0.2	-0.4	-0.5	-0.5
MPS (Interbank Futures), US QE, BoJ	Yield	-0.2	-0.8	-1.0	-0.9	-0.7
	E(Short rate)	-0.2	-0.3*	-0.4	-0.4	-0.3
	Term premium	0.0	-0.4	-0.5	-0.5	-0.4
MPS (Interbank Futures), TT to EAPP, BoJ	Yield	-0.0	1.5	4.2*	6.7**	8.9***
	E(Short rate)	0.1	-0.4	-0.3	-0.3	-0.2
	Term premium	-0.2	2.1	4.8***	7.2***	9.3***
MPS (Interbank Futures), EAPP, BoJ	Yield	-0.1	-0.4	-0.4	-0.3	-0.1
	E(Short rate)	-0.6	-0.6	-0.6	-0.5	-0.4
	Term premium	0.5	0.2	0.2	0.2	0.3
Panel B: UK yields	Dep. Var.	Y1 (UK)	Y3 (UK)	Y5 (UK)	Y7 (UK)	Y10 (UK)
MPS (Interbank Futures), Pre-crisis, BoJ	Yield	-0.5**	-0.5	-0.4	-0.4	-0.3
	E(Short rate)	-0.5**	-0.5**	-0.4**	-0.4**	-0.3**
	Term premium	0.0	0.0	0.0	0.1	0.1
MPS (Interbank Futures), US QE, BoJ	Yield	-0.5	-1.7**	-1.9**	-1.9**	-1.8
	E(Short rate)	0.0	-0.2	-0.3	-0.2	-0.2
	Term premium	-0.5	-1.2**	-1.4	-1.5	-1.5
MPS (Interbank Futures), TT to EAPP, BoJ	Yield	-0.8	-2.5	-2.9	-2.1	-0.9
	E(Short rate)	-0.4	-0.6	-1.8	-2.2	-2.2
	Term premium	-0.5	-2.3	-1.2	0.1	1.3
MPS (Interbank Futures), EAPP, BoJ	Yield	-0.5	-1.4*	-1.4	-1.3	-1.1
	E(Short rate)	-0.3	-0.7**	-1.1**	-1.1**	-1.0*
	Term premium	-0.2	-0.6	-0.2	-0.2	-0.1
Panel C: Euro area yields	Dep. Var.	Y1 (EU)	Y3 (EU)	Y5 (EU)	Y7 (EU)	Y10 (EU)
MPS (Interbank Futures), Pre-crisis, BoJ	Yield	-0.1	-0.6*	-0.9**	-0.9**	-0.9**
	E(Short rate)	0.1	-0.0	-0.1	-0.1	-0.1
	Term premium	-0.1	-0.5*	-0.8**	-0.8**	-0.8*
MPS (Interbank Futures), US QE, BoJ	Yield	-0.7*	-1.1*	-1.0	-0.8	-0.7
	E(Short rate)	-1.0	-0.9	-0.8	-0.7	-0.6
	Term premium	0.2	-0.1	-0.1	0.0	0.0
MPS (Interbank Futures), TT to EAPP, BoJ	Yield	2.7	-3.7	-4.5	-5.1	-4.7
	E(Short rate)	-1.8	-3.0	-3.0	-2.9	-2.6
	Term premium	4.5***	-0.5	-1.2	-1.9	-1.9
MPS (Interbank Futures), EAPP, BoJ	Yield	-0.3	-0.5	-0.7	-0.7	-0.7
	E(Short rate)	-0.0	-0.0	-0.0	-0.2**	-0.3*
	Term premium	-0.3	-0.4	-0.5	-0.4	-0.3

Table 7d summarizes the results of daily piecewise regressions where the dependent variable is the change in (i) zero coupon bond yields for maturities of 1, 3, 5, 7 and 10 years, (ii) the path of the expected short rate over the life of the bond, and (iii) the term premium relevant for each maturity in the US, UK and Euro area. Measures of the expected short rate and the term premium are estimated using a shadow rate term structure model from Wu and Xia (2016). The independent variable of interest is the daily change in the implied yield for the year-ahead futures contract on the Euroyen Tibor (BoJ) on monetary policy meeting days. Monetary policy measures are normalized to be a one standard deviation loosening (in basis points). *, **, and *** denote statistical significance at the 10%, 5%, and 1% levels, respectively.

Table 8a: Test for Equality of Coefficients between Break Points (US Yields)

Panel A: Piecewise Comparison	Y1 (US)	Y3 (US)	Y5 (US)	Y7 (US)	Y10 (US)
Pre-crisis = US QE, US	0.00***	0.31	0.91	0.52	0.36
US QE = Intra-QE, US	0.08*	0.00***	0.00***	0.00***	0.02*
Intra-QE = EAPP, US	0.85	0.00***	0.00***	0.01***	0.02*
Pre-crisis = US QE, EA	0.17	0.81	0.35	0.22	0.15
US QE = Intra-QE, EA	0.21	0.41	0.57	0.85	0.72
Intra-QE = EAPP, EA	0.82	0.62	0.38	0.23	0.13
Pre-crisis = US QE, UK	0.05*	0.17	0.42	0.63	0.8
US QE = Intra-QE, UK	0.12	0.00***	0.00***	0.01***	0.02*
Intra-QE = EAPP, UK	0.19	0.65	0.45	0.5	0.43
Pre-crisis = US QE, Japan	0.32	0.27	0.35	0.41	0.45
US QE = Intra-QE, Japan	0.03*	0.72	0.64	0.31	0.2
Intra-QE = EAPP, Japan	0.12	1	0.93	0.54	0.33
Panel B: Cumulative Comparison					
Pre-crisis = US QE, US	0.00***	0.31	0.91	0.52	0.36
Pre-crisis = US QE = Intra-QE, US	0.00***	0.00***	0.00***	0.00***	0.01***
Pre-crisis = US QE = Intra-QE = EAPP, US	0.01***	0.00***	0.00***	0.00***	0.00***
Pre-crisis = US QE, Euro area	0.17	0.81	0.35	0.22	0.15
Pre-crisis = US QE = Intra-QE, Euro area	0.25	0.63	0.45	0.39	0.35
Pre-crisis = US QE = Intra-QE = EAPP, Euro area	0.37	0.16	0.00***	0.01***	0.01***
Pre-crisis = US QE, UK	0.05*	0.17	0.42	0.63	0.8
Pre-crisis = US QE = Intra-QE, UK	0.10*	0.00***	0.00***	0.01***	0.02*
Pre-crisis = US QE = Intra-QE = EAPP, UK	0.04*	0.00***	0.00***	0.01***	0.02*
Pre-crisis = US QE, Japan	0.32	0.27	0.35	0.41	0.45
Pre-crisis = US QE = Intra-QE, Japan	0.08*	0.54	0.62	0.51	0.4
Pre-crisis = US QE = Intra-QE = EAPP, Japan	0.16	0.74	0.81	0.7	0.58

Table 8a shows the results from a two-way Wald test for equality of coefficients between sub-sample periods. *, **, and *** denote statistical significance at the 10%, 5%, and 1% levels, respectively.

Table 8b: Test for Equality of Coefficients between Break Points (Euro area Yields)

Panel A: Piecewise Comparison	Y1 (EU)	Y3 (EU)	Y5 (EU)	Y7 (EU)	Y10 (EU)
Pre-crisis = US QE, US	0.58	0.71	0.34	0.11	0.02*
US QE = Intra-QE, US	0.38	0.21	0.19	0.19	0.22
Intra-QE = EAPP, US	0.21	0.16	0.19	0.24	0.33
Pre-crisis = US QE, EA	0.15	0.35	0.57	0.95	0.48
US QE = Intra-QE, EA	0.09*	0.00***	0.00***	0.00***	0.02*
Intra-QE = EAPP, EA	0.55	0.21	0.33	0.62	0.8
Pre-crisis = US QE, UK	0.86	0.94	0.79	0.76	0.81
US QE = Intra-QE, UK	0.61	0.89	0.53	0.29	0.2
Intra-QE = EAPP, UK	0.28	0.25	0.36	0.43	0.51
Pre-crisis = US QE, Japan	0.91	0.39	0.51	0.73	0.85
US QE = Intra-QE, Japan	0.07*	0.81	0.61	0.4	0.37
Intra-QE = EAPP, Japan	0.06*	0.65	0.47	0.32	0.33
Panel B: Cumulative Comparison					
Pre-crisis = US QE, US	0.58	0.71	0.34	0.11	0.02*
Pre-crisis = US QE = Intra-QE, US	0.47	0.38	0.22	0.09*	0.03*
Pre-crisis = US QE = Intra-QE = EAPP, US	0.6	0.55	0.33	0.08*	0.01***
Pre-crisis = US QE, Euro area	0.15	0.35	0.57	0.95	0.48
Pre-crisis = US QE = Intra-QE, Euro area	0.19	0.00***	0.00***	0.00***	0.02*
Pre-crisis = US QE = Intra-QE = EAPP, Euro area	0.34	0.00***	0.00***	0.00***	0.00***
Pre-crisis = US QE, UK	0.86	0.94	0.79	0.76	0.81
Pre-crisis = US QE = Intra-QE, UK	0.6	0.95	0.8	0.55	0.43
Pre-crisis = US QE = Intra-QE = EAPP, UK	0.66	0.72	0.42	0.2	0.13
Pre-crisis = US QE, Japan	0.91	0.39	0.51	0.73	0.85
Pre-crisis = US QE = Intra-QE, Japan	0.19	0.64	0.66	0.63	0.67
Pre-crisis = US QE = Intra-QE = EAPP, Japan	0.22	0.81	0.81	0.78	0.8

Table 8b shows the results from a two-way Wald test for equality of coefficients between sub-sample periods. *, **, and *** denote statistical significance at the 10%, 5%, and 1% levels, respectively.

Table 8c: Test for Equality of Coefficients between Break Points (UK Yields)

Panel A: Piecewise Comparison	Y1 (UK)	Y3 (UK)	Y5 (UK)	Y7 (UK)	Y10 (UK)
Pre-crisis = US QE, US	0.45	0.18	0.09*	0.05*	0.05*
US QE = Intra-QE, US	0.45	0.15	0.09*	0.09*	0.10*
Intra-QE = EAPP, US	0.5	0.29	0.23	0.25	0.29
Pre-crisis = US QE, EA	0.36	0.69	0.94	0.96	0.93
US QE = Intra-QE, EA	0.47	0.75	1	0.93	0.94
Intra-QE = EAPP, EA	0.01***	0.05*	0.12	0.17	0.21
Pre-crisis = US QE, UK	0.16	0.91	0.57	0.48	0.43
US QE = Intra-QE, UK	0.9	0.09*	0.06*	0.14	0.31
Intra-QE = EAPP, UK	0.00***	0.12	0.09*	0.04*	0.02*
Pre-crisis = US QE, Japan	0.29	0.81	0.67	0.55	0.45
US QE = Intra-QE, Japan	0.05*	0.4	0.54	0.55	0.58
Intra-QE = EAPP, Japan	0.02*	0.29	0.41	0.43	0.45
Panel B: Cumulative Comparison					
Pre-crisis = US QE, US	0.45	0.18	0.09*	0.05*	0.05*
Pre-crisis = US QE = Intra-QE, US	0.69	0.08*	0.03*	0.02*	0.02*
Pre-crisis = US QE = Intra-QE = EAPP, US	0.78	0.02*	0.00***	0.00***	0.00***
Pre-crisis = US QE, Euro area	0.36	0.69	0.94	0.96	0.93
Pre-crisis = US QE = Intra-QE, Euro area	0.65	0.92	1	1	1
Pre-crisis = US QE = Intra-QE = EAPP, Euro area	0.00***	0.01***	0.03*	0.07*	0.17
Pre-crisis = US QE, UK	0.16	0.91	0.57	0.48	0.43
Pre-crisis = US QE = Intra-QE, UK	0.14	0.07*	0.04*	0.09*	0.23
Pre-crisis = US QE = Intra-QE = EAPP, UK	0.00***	0.00***	0.00***	0.00***	0.00***
Pre-crisis = US QE, Japan	0.29	0.81	0.67	0.55	0.45
Pre-crisis = US QE = Intra-QE, Japan	0.04*	0.66	0.74	0.68	0.61
Pre-crisis = US QE = Intra-QE = EAPP, Japan	0.09*	0.68	0.75	0.76	0.77

Table 8c shows the results from a two-way Wald test for equality of coefficients between sub-sample periods. *, **, and *** denote statistical significance at the 10%, 5%, and 1% levels, respectively.

Table 8d: Test for Equality of Coefficients between Break Points (Japan Yields)

Panel A: Piecewise Comparison	Y1 (JP)	Y3 (JP)	Y5 (JP)	Y7 (JP)	Y10 (JP)
Pre-crisis = US QE, US	0.43	0.52	0.57	0.57	0.43
US QE = Intra-QE, US	0.11	0.17	0.9	0.68	0.88
Intra-QE = EAPP, US	0.28	0.19	0.61	0.92	0.9
Pre-crisis = US QE, EA	0.54	0.23	0.26	0.19	0.37
US QE = Intra-QE, EA	0.81	0.65	0.62	0.39	0.76
Intra-QE = EAPP, EA	0.75	0.57	0.98	0.79	0.27
Pre-crisis = US QE, UK	0.61	0.28	0.57	0.82	0.71
US QE = Intra-QE, UK	0.5	0.44	0.21	0.45	0.75
Intra-QE = EAPP, UK	0.21	0.98	0.68	0.86	0.67
Pre-crisis = US QE, Japan	0.49	0.33	0.16	0.08*	0.07*
US QE = Intra-QE, Japan	0.4	0.24	0.73	0.91	0.78
Intra-QE = EAPP, Japan	0.10*	0.08*	0.21	0.47	0.69
Panel B: Cumulative Comparison					
Pre-crisis = US QE, US	0.43	0.52	0.57	0.57	0.43
Pre-crisis = US QE = Intra-QE, US	0.19	0.22	0.85	0.76	0.72
Pre-crisis = US QE = Intra-QE = EAPP, US	0.29	0.38	0.73	0.8	0.77
Pre-crisis = US QE, Euro area	0.54	0.23	0.26	0.19	0.37
Pre-crisis = US QE = Intra-QE, Euro area	0.75	0.31	0.54	0.41	0.66
Pre-crisis = US QE = Intra-QE = EAPP, Euro area	0.71	0.49	0.74	0.5	0.18
Pre-crisis = US QE, UK	0.61	0.28	0.57	0.82	0.71
Pre-crisis = US QE = Intra-QE, UK	0.74	0.3	0.2	0.52	0.93
Pre-crisis = US QE = Intra-QE = EAPP, UK	0.57	0.42	0.36	0.73	0.96
Pre-crisis = US QE, Japan	0.49	0.33	0.16	0.08*	0.07*
Pre-crisis = US QE = Intra-QE, Japan	0.61	0.38	0.38	0.2	0.19
Pre-crisis = US QE = Intra-QE = EAPP, Japan	0.17	0.22	0.15	0.05*	0.03*

Table 8d shows the results from a two-way Wald test for equality of coefficients between sub-sample periods. *, **, and *** denote statistical significance at the 10%, 5%, and 1% levels, respectively.

Table 9a: The Impact of Monetary Policy Surprises on US Yields
(Benchmark Specification: Interbank Futures, Full Sample)

VARIABLES	(1) Y1 (US)	(2) Y3 (US)	(3) Y5 (US)	(4) Y7 (US)	(5) Y10 (US)
MPS, Full Sample, FOMC	-3.7*** (0.663)	-5.7*** (0.920)	-5.9*** (1.120)	-5.5*** (1.267)	-4.6*** (1.297)
MPS, Full Sample, ECB	-0.9*** (0.314)	-1.2*** (0.430)	-1.3** (0.551)	-1.3** (0.603)	-1.3** (0.635)
MPS, Full Sample, BoE	0.2 (0.390)	-0.1 (0.564)	-0.1 (0.715)	-0.1 (0.772)	-0.1 (0.764)
MPS, Full Sample, BoJ	0.1 (0.341)	0.1 (0.539)	0.1 (0.646)	0.2 (0.653)	0.2 (0.606)
CESI US	0.6*** (0.108)	0.9*** (0.172)	0.9*** (0.205)	0.9*** (0.209)	0.8*** (0.201)
CESI Japan	0.0 (0.092)	0.0 (0.132)	-0.0 (0.163)	-0.1 (0.179)	-0.1 (0.187)
CESI Euro area	0.2 (0.149)	0.1 (0.216)	0.1 (0.262)	0.1 (0.259)	0.1 (0.237)
CESI UK	0.2* (0.103)	0.5*** (0.165)	0.7*** (0.214)	0.8*** (0.246)	0.8*** (0.258)
fri	1.2*** (0.326)	1.4*** (0.427)	1.2*** (0.469)	1.1** (0.486)	0.9* (0.494)
US/EU (t-1)	8.6 (19.048)	14.9 (25.632)	0.3 (29.269)	-15.0 (33.128)	-31.0 (37.663)
US/UK (t-1)	-26.7 (20.129)	-27.1 (24.979)	-21.0 (25.451)	-14.6 (26.253)	-8.1 (26.596)
US/JP (t-1)	16.6 (16.474)	-41.4* (24.453)	-61.6* (32.309)	-55.3 (37.143)	-36.1 (38.674)
AR(1)	-0.1* (0.045)	-0.1** (0.042)	-0.1 (0.050)	-0.0 (0.051)	-0.0 (0.050)
Constant	-0.3** (0.117)	-0.1 (0.178)	-0.1 (0.227)	-0.1 (0.258)	-0.0 (0.274)
Observations	948	948	948	948	948
R-squared	0.187	0.207	0.183	0.155	0.121

Table 9a summarizes the results of daily piecewise regressions where the dependent variable is the change in zero coupon bond yields for maturities of 1, 3, 5, 7 and 10 years. MPS is the daily change in the implied yield for the year-ahead futures contract on the Eurodollar (Fed), Euribor (ECB), Short Sterling (BoE) and Euroyen Tibor (BoJ) on monetary policy meeting days of the respective central banks. Monetary policy measures are normalized to be a one standard deviation loosening. Standard errors are shown in parentheses. *, **, and *** denote statistical significance at the 10%, 5%, and 1% levels, respectively.

Table 9b: The Impact of Monetary Policy Surprises on Euro Area Yields
(Benchmark Specification: Interbank Futures, Full Sample)

VARIABLES	(1) Y1 (EU)	(2) Y3 (EU)	(3) Y5 (EU)	(4) Y7 (EU)	(5) Y10 (EU)
MPS, Full Sample, ECB	-3.0*** (0.286)	-4.0*** (0.325)	-3.2*** (0.348)	-2.4*** (0.345)	-1.6*** (0.350)
MPS, Full Sample, BoE	-0.7 (0.456)	-0.5 (0.438)	-0.7 (0.412)	-0.8** (0.355)	-0.9*** (0.310)
MPS, Full Sample, BoJ	0.0 (0.312)	-0.8*** (0.229)	-0.9*** (0.248)	-0.7** (0.292)	-0.6* (0.358)
MPS, Full Sample, FOMC = L,	-0.8** (0.331)	-1.0* (0.492)	-1.1** (0.477)	-1.1** (0.467)	-1.1** (0.499)
CESI US	0.1* (0.078)	0.3** (0.127)	0.4*** (0.127)	0.4*** (0.124)	0.4*** (0.122)
CESI Japan	-0.0 (0.066)	-0.1 (0.104)	-0.1 (0.107)	-0.1 (0.105)	-0.1 (0.104)
CESI Euro area	0.2* (0.103)	0.4*** (0.140)	0.4*** (0.142)	0.4*** (0.136)	0.3** (0.132)
CESI UK	0.0 (0.063)	0.2* (0.093)	0.2** (0.100)	0.2** (0.101)	0.2** (0.100)
fri	0.2 (0.190)	-0.1 (0.262)	-0.2 (0.272)	-0.3 (0.282)	-0.5 (0.303)
EU/US (t-1)	12.0 (22.761)	14.5 (30.535)	10.6 (31.769)	13.8 (34.055)	19.4 (37.923)
EU/UK (t-1)	-16.3 (11.855)	-15.0 (18.102)	-21.4 (19.521)	-27.2 (19.971)	-31.0 (20.484)
EU/JP (t-1)	-37.2 (24.434)	-34.4 (23.376)	-37.1 (25.553)	-42.4 (25.924)	-43.6 (27.648)
AR(1)	0.2*** (0.047)	0.1 (0.043)	0.0 (0.043)	0.0 (0.043)	0.0 (0.042)
Constant	-0.2** (0.104)	-0.2 (0.147)	-0.2 (0.152)	-0.1 (0.156)	-0.0 (0.163)
Observations	983	983	983	983	983
R-squared	0.283	0.221	0.169	0.129	0.091

Table 9b summarizes the results of daily piecewise regressions where the dependent variable is the change in zero coupon bond yields for maturities of 1, 3, 5, 7 and 10 years. MPS is the daily change in the implied yield for the year-ahead futures contract on the Eurodollar (Fed), Euribor (ECB), Short Sterling (BoE) and Euroyen Tibor (BoJ) on monetary policy meeting days of the respective central banks. Monetary policy measures are normalized to be a one standard deviation loosening. Standard errors are shown in parentheses. *, **, and *** denote statistical significance at the 10%, 5%, and 1% levels, respectively.

Table 9c: The Impact of Monetary Policy Surprises on UK Yields (Benchmark Specification: Interbank Futures, Full Sample)

VARIABLES	(1) Y1 (UK)	(2) Y3 (UK)	(3) Y5 (UK)	(4) Y7 (UK)	(5) Y10 (UK)
MPS, Full Sample, BoE	-3.2*** (0.359)	-4.2*** (0.546)	-3.6*** (0.591)	-3.1*** (0.599)	-2.6*** (0.592)
MPS, Full Sample, ECB	-0.8** (0.358)	-1.4** (0.562)	-1.4** (0.577)	-1.4** (0.590)	-1.4** (0.605)
MPS, Full Sample, BoJ	-0.6*** (0.182)	-0.7** (0.371)	-0.7* (0.397)	-0.6 (0.402)	-0.5 (0.392)
MPS, Full Sample, FOMC = L,	-1.3*** (0.346)	-1.7*** (0.534)	-1.6*** (0.532)	-1.4** (0.569)	-1.1* (0.595)
CESI US	0.2** (0.077)	0.4*** (0.115)	0.5*** (0.129)	0.5*** (0.142)	0.5*** (0.149)
CESI Japan	-0.1 (0.114)	-0.1 (0.155)	-0.1 (0.151)	-0.0 (0.151)	-0.1 (0.152)
CESI Euro area	-0.0 (0.116)	0.2 (0.160)	0.3* (0.167)	0.3** (0.166)	0.3** (0.168)
CESI UK	0.2** (0.116)	0.4*** (0.137)	0.5*** (0.138)	0.5*** (0.149)	0.5*** (0.161)
fri	0.6** (0.248)	0.7** (0.317)	0.4 (0.328)	0.1 (0.348)	-0.1 (0.362)
UK/US (t-1)	11.7 (47.435)	48.5 (57.477)	80.8 (57.243)	109.2* (58.091)	125.9** (58.454)
UK/EU (t-1)	14.2 (26.005)	0.6 (40.163)	-0.9 (41.491)	-0.8 (42.194)	0.4 (42.009)
UK/JP (t-1)	-32.2 (30.289)	-41.5 (39.072)	-64.3* (38.839)	-78.7** (37.715)	-83.3** (36.854)
AR(1)	0.2*** (0.066)	0.1** (0.042)	0.1 (0.040)	0.1 (0.043)	0.1 (0.048)
Constant	-0.4*** (0.117)	-0.4** (0.164)	-0.2 (0.186)	-0.1 (0.200)	0.0 (0.207)
Observations	980	980	980	980	980
R-squared	0.330	0.256	0.197	0.156	0.123

Table 9c summarizes the results of daily piecewise regressions where the dependent variable is the change in zero coupon bond yields for maturities of 1, 3, 5, 7 and 10 years. MPS is the daily change in the implied yield for the year-ahead futures contract on the Eurodollar (Fed), Euribor (ECB), Short Sterling (BoE) and Euroyen Tibor (BoJ) on monetary policy meeting days of the respective central banks. Monetary policy measures are normalized to be a one standard deviation loosening. Standard errors are shown in parentheses. *, **, and *** denote statistical significance at the 10%, 5%, and 1% levels, respectively.

Table 9d: The Impact of Monetary Policy Surprises on Japan Yields
(Benchmark Specification: Interbank Futures, Full Sample)

VARIABLES	(1) Y1 (JP)	(2) Y3 (JP)	(3) Y5 (JP)	(4) Y7 (JP)	(5) Y10 (JP)
MPS, Full Sample, BoJ	-0.4 (0.439)	-1.5*** (0.305)	-1.9*** (0.286)	-2.0*** (0.304)	-1.8*** (0.334)
MPS, Full Sample, ECB = L,	0.6 (0.687)	-0.1 (0.221)	-0.2 (0.276)	-0.4 (0.296)	-0.5* (0.275)
MPS, Full Sample, BoE = L,	-0.1 (0.292)	-0.4** (0.160)	-0.5* (0.272)	-0.4 (0.312)	-0.2 (0.276)
MPS, Full Sample, FOMC = L,	0.2 (0.618)	-0.5** (0.222)	-0.9*** (0.312)	-1.1*** (0.326)	-0.9*** (0.316)
CESI US	-0.0 (0.081)	0.0 (0.055)	0.0 (0.075)	0.1 (0.073)	0.1 (0.064)
CESI Japan	-0.1 (0.099)	0.1 (0.060)	0.0 (0.083)	-0.0 (0.098)	-0.0 (0.094)
CESI Euro area	-0.0 (0.129)	0.1 (0.059)	0.1 (0.067)	0.0 (0.075)	0.0 (0.068)
CESI UK	-0.2 (0.122)	0.0 (0.060)	0.1 (0.069)	0.0 (0.071)	-0.1 (0.066)
fri	-0.4 (0.402)	0.1 (0.181)	0.1 (0.199)	0.1 (0.206)	0.1 (0.198)
JP/US (t-1)	-0.2 (0.274)	0.1 (0.160)	0.2 (0.185)	0.3 (0.209)	0.3 (0.200)
JP/UK (t-1)	0.0 (0.130)	-0.1 (0.111)	-0.1 (0.115)	-0.1 (0.119)	0.0 (0.127)
JP/EU (t-1)	0.1 (0.181)	0.1 (0.105)	0.3** (0.133)	0.3* (0.135)	0.2 (0.127)
AR(1)	-0.3*** (0.064)	-0.1*** (0.040)	-0.1*** (0.037)	-0.1*** (0.036)	-0.1** (0.037)
Constant	0.1 (0.121)	0.0 (0.077)	-0.1 (0.081)	-0.1* (0.082)	-0.1* (0.083)
Observations	1,002	1,002	1,002	1,002	1,002
R-squared	0.116	0.111	0.149	0.159	0.148

Table 9d summarizes the results of daily piecewise regressions where the dependent variable is the change in zero coupon bond yields for maturities of 1, 3, 5, 7 and 10 years. MPS is the daily change in the implied yield for the year-ahead futures contract on the Eurodollar (Fed), Euribor (ECB), Short Sterling (BoE) and Euroyen Tibor (BoJ) on monetary policy meeting days of the respective central banks. Monetary policy measures are normalized to be a one standard deviation loosening. Standard errors are shown in parentheses. *, **, and *** denote statistical significance at the 10%, 5%, and 1% levels, respectively.

Table 10: Summary Stats, Three-Part Monetary Policy Surprises

Period	MPS	FOMC	ECB	BoE	BoJ
Precrisis	Target	-1.45 (9.2)	-0.08 (4.33)	-0.59 (5.86)	-0.19 (2.16)
	Forward Guidance	2.05 (9.01)	-0.04 (3.75)	-0.30 (4)	0.08 (1.04)
Initial QE	Target	-1.72 (6.1)	0.32 (3.99)	-0.38 (5.86)	-0.28 (1.74)
	Forward Guidance	-1.21 (5.3)	-0.50 (4.03)	-0.40 (5.36)	-0.14 (1.07)
	LSAP	-0.40 (7)	0.25 (2.95)	-0.16 (4.58)	-0.17 (2.07)
Intra-QE	Target	0.06 (1.55)	-0.15 (2.11)	-1.04 (2.86)	-0.04 (0.51)
	Forward Guidance	0.91 (3.99)	0.56 (1.72)	0.41 (2.67)	0.08 (0.54)
	LSAP	0.61 (6.78)	0.20 (2.23)	0.46 (2.28)	0.41 (1.27)
EAPP	Target	-0.87 (3.39)	-0.05 (1.9)	-0.52 (2.55)	0.39 (2.29)
	Forward Guidance	-1.43 (5.09)	0.06 (2.05)	0.37 (3.01)	0.08 (1.48)
	LSAP	-0.90 (2.59)	0.23 (3.3)	-0.39 (2.54)	0.37 (1.77)
Full Sample	Target	-0.92 (6.96)	0.05 (3.62)	-0.98 (6.33)	-0.05 (2.01)
	Forward Guidance	0.17 (6.68)	-0.08 (3.39)	-0.10 (4.32)	-0.01 (1.32)
	LSAP	-0.14 (5.18)	0.12 (2.48)	-0.02 (3.17)	0.06 (1.57)

Table 10 provides summary statistics of three part monetary policy shocks suggested by Swanson (2018). For each central bank's announcement day, target shocks comprise the surprise component of the decision about the target rate based on the change in yield on the one-month ahead OIS futures contracts. Forward guidance shocks contain the residual from a regression of the announcement day change in the 2-year bond zero coupon bond yield onto the target surprise. LSAP shocks comprise residual from a regression of the announcement day change in the 7-year zero coupon bond yield onto the target and forward guidance surprises.

Table 11a: The Impact of a One St. Dev. Monetary Policy Surprise on US Yields, Expected Short Rates and Term Premia (Alt. Measure: Three-Part Surprise)

MPS		ECB		BoE		BoJ		FOMC	
		Y1 US	Y10 US	Y1 US	Y10 US	Y1 US	Y10 US	Y1 US	Y10 US
Target	Yield	-0.7**	-0.8	-0.3	0.4	0.3	-0.3	-3.7***	-0.8*
	Exp. Short Rate	-0.8**	-0.5**	-0.4*	-0.3*	0.5	0.2	-2.8***	0.6
	Term Premium	0.1	-0.3	0.1	0.7**	-0.1	-0.5	-0.8	-2.0
Forward Guidance	Yield	-0.6*	-1.2**	-0.3	-2.0***	-0.1	0.8***	-2.5***	-4.0***
	Exp. Short Rate	-0.4	-0.2	-0.2	-0.2	-0.2	0.1	-4.0***	-5.3***
	Term Premium	-0.2	-1.0**	-0.1	-1.8***	0.0	0.7	1.5	1.3
LSAP	Yield	-0.3*	-1.5***	-0.4**	-2.0***	0.3	-0.0	0.6*	-6.0***
	Exp. Short Rate	0.2	-0.2	-0.1	-0.1	0.3	0.2	2.5***	1.0*
	Term Premium	-0.5*	-1.3***	-0.3**	-1.8***	0.1	-0.1	-1.9***	-7.1***

Table 11a summarizes the results of daily piecewise regressions where the dependent variable is the change in (i) zero coupon bond yields for maturities of 1 and 10 years, (ii) the path of the expected short rate over the life of the bond, and (iii) the term premium relevant for the US. Measures of the expected short rate and the term premium are estimated using a shadow rate term structure model from Wu and Xia (2016). The independent variables of interest are target, forward guidance, and LSAP shocks from the the FOMC, BoE, BoJ and ECB. Monetary policy measures are normalized to be a one standard deviation loosening. *, **, and *** denote statistical significance at the 10%, 5%, and 1% levels, respectively.

Table 11b: The Impact of a One St. Dev. Monetary Policy Surprise on EU Yields, Expected Short Rates and Term Premia (Alt. Measure: Three-Part Surprise)

MPS		FOMC		BoE		BoJ		ECB	
		Y1 EU	Y10 EU	Y1 EU	Y10 EU	Y1 EU	Y10 EU	Y1 EU	Y10 EU
Target	Yield	-0.7	-1.0**	-1.0*	-0.3	-0.0	-0.6**	-2.8***	-0.8***
	Exp. Short Rate	-0.1	-0.1	-0.7	-0.3	-0.5	-0.5	-3.2***	-2.2***
	Term Premium	-0.6	-0.8	-0.3	0.1	0.4	-0.1	0.4*	1.4***
Forward Guidance	Yield	-0.2	-0.5	-0.5***	-1.3***	-0.2	0.4**	-2.0***	-2.1***
	Exp. Short Rate	-0.1	-0.2	-0.6**	-0.5***	-0.6*	-0.3	-2.3***	-1.9***
	Term Premium	-0.1	-0.1	0.1	-0.8***	0.4	0.8***	0.4*	-0.2
LSAP	Yield	-0.3	-1.9***	-0.3*	-0.7***	-0.0	-0.4	0.3*	-2.7***
	Exp. Short Rate	-0.2	-0.4	-0.3	-0.4	-0.5	-0.3	1.4***	0.3*
	Term Premium	-0.2	-1.5***	0.0	-0.3	0.5	-0.0	-1.2***	-2.9***

Table 11b summarizes the results of daily piecewise regressions where the dependent variable is the change in (i) zero coupon bond yields for maturities of 1 and 10 years, (ii) the path of the expected short rate over the life of the bond, and (iii) the term premium relevant for the Euro Area. Measures of the expected short rate and the term premium are estimated using a shadow rate term structure model from Wu and Xia (2016). The independent variables of interest are target, forward guidance, and LSAP shocks from the FOMC, BoE, BoJ and ECB. Monetary policy measures are normalized to be a one standard deviation loosening. *, **, and *** denote statistical significance at the 10%, 5%, and 1% levels, respectively.

Table 11c: The Impact of a One St. Dev. Monetary Policy Surprise on UK Yields, Expected Short Rates and Term Premia (Alt. Measure: Three-Part Surprise)

MPS		FOMC		ECB		BoJ		BoE	
		Y1 UK	Y10 UK	Y1 UK	Y10 UK	Y1 UK	Y10 UK	Y1 UK	Y10 UK
Target	Yield	-1.5***	-1.1**	-0.4	-0.7	-0.7***	-0.9**	-2.8***	-1.2***
	Exp. Short Rate	-1.7***	-1.1***	-0.6	-0.6*	-0.6	-0.5**	-3.5***	-2.4***
	Term Premium	0.1	0.1	0.1	-0.2	-0.1	-0.3	0.7***	1.2***
Forward Guidance	Yield	-0.9*	-0.1	-0.3	-0.9**	0.7**	0.4	-2.6***	-3.8***
	Exp. Short Rate	-1.3*	-1.0**	0.3	0.1	0.8*	0.2	-2.8***	-2.3***
	Term Premium	0.4	1.0**	-0.5	-0.9***	-0.0	0.2	0.2	-1.5***
LSAP	Yield	-0.1	-2.4***	-0.2	-1.3***	0.4**	-0.1	0.5***	-3.2***
	Exp. Short Rate	0.4	0.2	0.0	-0.0	0.3	0.2	2.3***	0.9***
	Term Premium	-0.4	-2.7***	-0.3	-1.2***	0.0	-0.3	-1.8***	-4.2***

Table 11c summarizes the results of daily piecewise regressions where the dependent variable is the change in (i) zero coupon bond yields for maturities of 1 and 10 years, (ii) the path of the expected short rate over the life of the bond, and (iii) the term premium relevant for the UK. Measures of the expected short rate and the term premium are estimated using a shadow rate term structure model from Wu and Xia (2016). The independent variables of interest are target, forward guidance, and LSAP shocks from the FOMC, BoE, BoJ and ECB. Monetary policy measures are normalized to be a one standard deviation loosening. *, **, and *** denote statistical significance at the 10%, 5%, and 1% levels, respectively.

Table 11d: The Impact of a One St. Dev. Monetary Policy Surprise on Japan Yields, Expected Short Rates and Term Premia (Alt. Measure: Three-Part Surprise)

MPS		FOMC		ECB		BoE		BoJ	
		Y1 JP	Y10 JP	Y1 JP	Y10 JP	Y1 JP	Y10 JP	Y1 JP	Y10 JP
Target	Yield	-0.5*	-0.8*	-0.0	-0.3	0.1	-0.1	-0.6**	-1.6***
	Exp. Short Rate	0.6**	0.2***	0.1	0.1	-0.1	0.0	-0.2	-0.1
	Term Premium	-1.1**	-1.0**	-0.2	-0.4**	0.3	-0.1	-0.3	-1.5***
Forward Guidance	Yield	-0.5**	-0.5	0.2	-0.5**	-0.2	-0.6***	-0.5***	-0.1
	Exp. Short Rate	0.5	0.2	0.3	0.1	-0.4**	-0.2*	-0.3	-0.1
	Term Premium	-0.7	-0.6	-0.1	-0.6***	0.1	-0.5***	-0.2	-0.1
LSAP	Yield	0.2	-0.5*	-0.1	-0.3	-0.1	0.0	0.3	-1.0***
	Exp. Short Rate	-0.5**	-0.1**	-0.0	-0.0	-0.1	-0.0	0.1	0.0
	Term Premium	0.6*	-0.4	0.0	-0.2	-0.1	0.0	0.3	-1.1***

Table 11d summarizes the results of daily piecewise regressions where the dependent variable is the change in (i) zero coupon bond yields for maturities of 1 and 10 years, (ii) the path of the expected short rate over the life of the bond, and (iii) the term premium relevant for Japan. Measures of the expected short rate and the term premium are estimated using a shadow rate term structure model from Wu and Xia (2016). The independent variables of interest are target, forward guidance, and LSAP shocks from the FOMC, BoE, BoJ and ECB. Monetary policy measures are normalized to be a one standard deviation loosening. *, **, and *** denote statistical significance at the 10%, 5%, and 1% levels, respectively.

Table 12: Risk Premium Days: 10-Year Bond Yields

(a) Own-Market Equity Return Co-movement Days

i. Federal Reserve					ii. ECB			
VARIABLES	(1) Y10 US	(2) Y10 UK	(3) Y10 EU	(4) Y10 JP	(5) Y10 US	(6) Y10 UK	(7) Y10 EU	(8) Y10 JP
$\text{Sign}(MP_i) = \text{Sign}(R_i)$	0.216 (1.112)	-0.420 (0.843)	-1.194* (0.687)	-0.029 (0.377)	1.164 (0.745)	-0.028 (0.639)	0.316 (0.427)	0.447 (0.323)
MP_i	-2.879** (1.277)	-1.655 (1.189)	-1.185 (0.843)	-1.126** (0.550)	0.521 (1.252)	0.018 (0.958)	-1.841*** (0.644)	-0.517** (0.246)
Interaction (MP on RP days)	-2.652 (2.245)	0.836 (1.299)	0.059 (1.029)	0.335 (0.646)	-2.298 (1.419)	-1.736 (1.157)	0.257 (0.720)	0.130 (0.513)

iii. Bank of England					iv. Bank of Japan			
VARIABLES	(9) Y10 US	(10) Y10 UK	(11) Y10 EU	(12) Y10 JP	(13) Y10 US	(14) Y10 UK	(15) Y10 EU	(16) Y10 JP
$\text{Sign}(MP_i) = \text{Sign}(R_i)$	1.298* (0.750)	0.033 (0.596)	-0.086 (0.412)	-0.372 (0.323)	0.506 (0.748)	1.665*** (0.625)	1.094** (0.492)	-0.305 (0.272)
MP_i	0.366 (0.942)	-2.765*** (0.707)	-0.806** (0.382)	-0.485* (0.282)	-1.859*** (0.666)	-1.291** (0.587)	-0.651 (0.607)	-2.354*** (0.434)
Interaction (MP on RP days)	-0.727 (1.381)	0.363 (1.048)	-0.129 (0.528)	0.604 (0.488)	2.672*** (0.944)	1.024 (0.790)	0.049 (0.627)	0.692 (0.564)

(b) Cross-Market Equity Return Co-movement Days

i. Federal Reserve					ii. ECB			
VARIABLES	(1) Y10 US	(2) Y10 UK	(3) Y10 EU	(4) Y10 JP	(5) Y10 US	(6) Y10 UK	(7) Y10 EU	(8) Y10 JP
$\text{Sign}(MP_i) = \text{Sign}(R_i)$	0.216 (1.112)	-2.690*** (0.803)	-1.222* (0.648)	-0.354 (0.338)	-0.453 (0.719)	0.090 (0.664)	0.316 (0.427)	-0.062 (0.291)
MP_i	-2.879** (1.277)	-1.126** (0.550)	0.227 (0.470)	-0.796 (0.592)	0.018 (0.958)	-2.557*** (0.593)	-1.841*** (0.644)	-0.118 (0.413)
Interaction (MP on RP days)	-2.652 (2.245)	-1.193 (1.130)	-2.166*** (0.754)	-0.167 (0.680)	-4.785*** (1.427)	-0.731 (1.153)	0.257 (0.720)	-0.865* (0.488)

iii. Bank of England					iv. Bank of Japan			
VARIABLES	(9) Y10 US	(10) Y10 UK	(11) Y10 EU	(12) Y10 JP	(13) Y10 US	(14) Y10 UK	(15) Y10 EU	(16) Y10 JP
$\text{Sign}(MP_i) = \text{Sign}(R_i)$	-0.032 (0.614)	0.033 (0.596)	-0.209 (0.381)	0.072 (0.291)	0.340 (0.804)	1.251* (0.657)	1.080** (0.532)	-0.305 (0.272)
MP_i	-1.205* (0.616)	-2.765*** (0.707)	-0.806** (0.374)	-0.147 (0.091)	0.860 (0.695)	-0.643 (0.515)	-0.421 (0.287)	-2.354*** (0.434)
Interaction (MP on RP days)	-3.985*** (1.154)	0.363 (1.048)	-0.114 (0.520)	-0.643 (0.545)	-2.662*** (1.021)	0.503 (0.907)	-0.297 (0.705)	0.692 (0.564)

Table 12 summarizes the results of daily piecewise regressions where the dependent variable is the change in 10 year zero coupon bond yields in the US, UK, Euro area and Japan. The independent variable of interest is the daily change in the implied yield for the year-ahead futures contract on the Eurodollar (Fed), Euribor (ECB), Short Sterling (BoE) and Euroyen Tíbor (BoJ) on monetary policy meeting days of respective central banks. The regression interacts these monetary policy surprises with an indicator variable equal to one on announcement dates on which interest rate futures markets and equity returns moved in the same direction. Panel A shows the results where the equity market is in the home economy (*i*), while Panel B shows results where the equity market is in the recipient country (*j*). Monetary policy measures are normalized to be a one standard deviation loosening (in basis points). *, **, and *** denote statistical significance at the 10%, 5%, and 1% levels, respectively.

Table 13: Risk Premium Days: Expected Path of Short-rates (Based on 10-Year Yield)

(a) Own-Market Equity Return Co-movement Days

VARIABLES	i. Federal Reserve				ii. ECB			
	(1) SR(10) US	(2) SR(10) UK	(3) SR(10) EU	(4) SR(10) JP	(5) SR(10) US	(6) SR(10) UK	(7) SR(10) EU	(8) SR(10) JP
$\text{Sign}(MP_i) = \text{Sign}(R_i)$	0.611 (0.497)	0.381 (0.399)	-0.321 (0.407)	-0.037 (0.124)	0.124 (0.280)	-0.203 (0.377)	-0.177 (0.218)	0.111 (0.156)
MP_i	-3.721*** (0.589)	-1.342*** (0.393)	-1.447** (0.594)	0.181 (0.181)	-0.709 (0.569)	-0.077 (0.553)	-1.711* (0.953)	0.011 (0.108)
Interaction (MP on RP days)	0.537 (1.007)	0.326 (0.517)	1.318* (0.790)	-0.167 (0.194)	0.190 (0.635)	-0.600 (0.641)	-0.994 (1.022)	-0.028 (0.268)

VARIABLES	iii. Bank of England				iv. Bank of Japan			
	(9) SR(10) US	(10) SR(10) UK	(11) SR(10) EU	(12) SR(10) JP	(13) SR(10) US	(14) SR(10) UK	(15) SR(10) EU	(16) SR(10) JP
$\text{Sign}(MP_i) = \text{Sign}(R_i)$	0.405 (0.287)	0.027 (0.253)	-0.176 (0.302)	0.225 (0.167)	-0.879** (0.375)	-0.073 (0.340)	0.661* (0.365)	-0.070 (0.136)
MP_i	-0.282 (0.253)	-3.200*** (0.505)	0.290 (0.423)	-0.038 (0.141)	-0.508 (0.551)	-0.678 (0.552)	-1.572* (0.946)	-0.153 (0.200)
Interaction (MP on RP days)	0.460 (0.462)	0.837 (0.558)	-0.951 (0.620)	0.063 (0.171)	0.784 (0.548)	0.349 (0.610)	1.369 (0.955)	0.046 (0.222)

(b) Cross-Market Equity Return Co-movement Days

VARIABLES	i. Federal Reserve				ii. ECB			
	(1) SR(10) US	(2) SR(10) UK	(3) SR(10) EU	(4) SR(10) JP	(5) SR(10) US	(6) SR(10) UK	(7) SR(10) EU	(8) SR(10) JP
$\text{Sign}(MP_i) = \text{Sign}(R_j)$	0.611 (0.497)	-0.214 (0.440)	-0.714* (0.370)	-0.133 (0.146)	-0.352 (0.260)	-0.235 (0.376)	-0.177 (0.218)	-0.179 (0.158)
MP_i	-3.721*** (0.589)	0.181 (0.181)	-0.384 (0.603)	0.072 (0.190)	-0.077 (0.553)	-2.762*** (0.356)	-1.711* (0.953)	0.090 (0.113)
Interaction (MP on RP days)	0.537 (1.007)	-0.850 (0.786)	-0.211 (0.695)	-0.011 (0.204)	-1.254** (0.570)	-0.250 (0.598)	-0.994 (1.022)	-0.165 (0.193)

VARIABLES	iii. Bank of England				iv. Bank of Japan			
	(9) SR(10) US	(10) SR(10) UK	(11) SR(10) EU	(12) SR(10) JP	(13) SR(10) US	(14) SR(10) UK	(15) SR(10) EU	(16) SR(10) JP
$\text{Sign}(MP_i) = \text{Sign}(R_i)$	0.313 (0.252)	0.027 (0.253)	-0.373 (0.280)	-0.084 (0.177)	-0.118 (0.317)	-0.246 (0.336)	0.841* (0.441)	-0.070 (0.136)
MP_i	-0.510* (0.282)	-3.200*** (0.505)	0.238 (0.436)	-0.028 (0.036)	0.434 (0.355)	-1.048*** (0.373)	-0.198 (0.259)	-0.153 (0.200)
Interaction (MP on RP days)	-0.840** (0.413)	0.837 (0.558)	-0.823 (0.618)	-0.021 (0.164)	-1.566*** (0.534)	1.317** (0.599)	-0.576 (0.401)	0.046 (0.222)

Table 13 summarizes the results of daily piecewise regressions where the dependent variable is the change in the path of the expected short rate over 10 years in the US, UK, Euro area and Japan. The independent variable of interest is the daily change in the implied yield for the year-ahead futures contract on the Eurodollar (Fed), Euribor (ECB), Short Sterling (BoE) and Euroyen Tibor (BoJ) on monetary policy meeting days of respective central banks. The regression interacts these monetary policy surprises with an indicator variable equal to one on announcement dates on which interest rate futures markets and equity returns moved in the same direction. Panel A shows the results where the equity market is in the home economy (*i*), while Panel B shows results where the equity market is in the recipient country (*j*). Monetary policy measures are normalized to be a one standard deviation loosening (in basis points). *, **, and *** denote statistical significance at the 10%, 5%, and 1% levels, respectively.

Table 14: Asymmetric Responses to Expansionary Monetary Policy Surprises

VARIABLES	(1) Y10 (US)	(2) Y10 (EU)	(3) Y10 (UK)	(4) Y10 (JP)
MPS, Full Sample, FOMC	-2.386** (1.101)	0.021 (0.540)	0.408 (0.503)	-0.544 (0.457)
MPS, Full Sample, ECB	-0.264 (0.955)	-0.984** (0.414)	-1.913** (0.864)	-0.185 (0.231)
MPS, Full Sample, BoE	-2.073*** (0.724)	-1.672*** (0.510)	-2.132** (0.981)	-0.869*** (0.265)
MPS, Full Sample, BoJ	-0.006 (0.416)	-0.491 (0.309)	-0.512 (0.430)	-0.243 (0.571)
1[MPS<0], FOMC	0.983 (1.242)	-1.181 (0.799)	-1.171 (0.887)	-0.459 (0.324)
1[MPS<0], BoE	-1.303 (0.926)	-1.023** (0.476)	-2.192*** (0.687)	-0.387 (0.389)
1[MPS<0], ECB	-2.338** (1.136)	-1.212* (0.691)	-1.768 (1.079)	0.117 (0.439)
1[MPS<0], BoJ	-1.355 (1.478)	0.893 (0.708)	0.360 (0.986)	-0.472 (0.508)
1[MPS<0]*MPS (FOMC)	-5.314** (2.534)	-1.543 (1.054)	-2.324** (1.122)	-0.462 (0.629)
1[MPS<0]*MPS (BoE)	1.313 (1.616)	0.622 (0.561)	0.048 (1.251)	0.263 (0.591)
1[MPS<0]*MPS (ECB)	3.699** (1.675)	1.156 (0.707)	3.011* (1.590)	0.726 (0.763)
1[MPS<0]*MPS (BoJ)	0.209 (1.213)	-0.010 (0.506)	0.157 (0.899)	-1.249* (0.731)
...				
Observations	944	976	975	997
R-squared	0.148	0.107	0.148	0.106

Robust standard errors in parentheses

Table 14 summarizes the results of daily piecewise regressions where the dependent variable is the change in 10 year zero coupon bond yields in the US, UK, Euro area and Japan. The independent variable of interest is the daily change in the implied yield for the year-ahead futures contract on the Eurodollar (Fed), Euribor (ECB), Short Sterling (BoE) and Euroyen Tibor (BoJ) on monetary policy meeting days of respective central banks. The regression interacts these monetary policy surprises with an indicator variable equal to one on announcement dates marked by expansionary surprises, $\mathbb{1}[MP_t^j < 0] * MP_t^j$. Monetary policy measures are normalized to be a one standard deviation loosening (in basis points). *, **, and *** denote statistical significance at the 10%, 5%, and 1% levels, respectively.

Table 15: Test of Period Means, Contractionary versus Expansionary Shocks

Central Bank	Period	Equality of Means Test (p-value)
FOMC	Pre-crisis	0.13
	Initial QE	0.71
	Intra-QE	0.16
	EAPP	0.86
ECB	Pre-crisis	0.58
	Initial QE	0.36
	Intra-QE	0.46
	EAPP	0.24
BoE	Pre-crisis	0.33
	Initial QE	0.49
	Intra-QE	0.44
	EAPP	0.05
BoJ	Pre-crisis	0.20
	Initial QE	0.95
	Intra-QE	0.81
	EAPP	0.36

Table 15 summarizes the results of a simple t-test for equality of means comparing the absolute value of contractionary monetary policy shocks ($\mathbb{1}[MP_t^j > 0] * MP_t^j$) to that of expansionary monetary policy shocks ($\mathbb{1}[MP_t^j < 0] * MP_t^j$) by subsample. Shaded cells indicate subsamples in which expansionary and contractionary shocks differ in size at the 5% level.

Table 16a: The Impact of a One St. Dev. FOMC Monetary Policy Surprise on Yields, Expected Short Rates and Term Premia (Alt. Measure: Yield Curve First Principal Component)

		(1)	(2)	(3)	(4)	(5)
Panel A: UK yields		Y1 (UK)	Y3 (UK)	Y5 (UK)	Y7 (UK)	Y10 (UK)
MPS (Interbank Futures), Pre-crisis, FOMC	Yield	-0.7	-0.1	0.3	0.6	0.8
	E(Short rate)	-1.4	-1.1	-0.9	-0.8	-0.7
	Term premium	0.7	1.1*	1.3*	1.5*	1.6*
MPS (Interbank Futures), US QE, FOMC	Yield	-1.6*	-2.7**	-2.9**	-3.0***	-3.0***
	E(Short rate)	-1.4	-1.3*	-1.1	-1.0	-0.8
	Term premium	-0.2	-1.3*	-1.7**	-2.0***	-2.2***
MPS (Interbank Futures), TT to EAPP, FOMC	Yield	-0.7**	-4.5***	-6.1***	-6.4***	-5.9***
	E(Short rate)	0.4	-0.6	-1.3**	-1.4**	-1.3**
	Term premium	-1.0***	-3.9***	-4.9***	-5.0***	-4.7***
MPS (Interbank Futures), EAPP, FOMC	Yield	-0.5	-2.7*	-3.5**	-3.8***	-4.0***
	E(Short rate)	-0.3	-1.7*	-1.9*	-1.6	-1.3
	Term premium	-0.4	-0.9	-1.3	-1.7*	-2.1**
Panel B: Euro area yields		Y1 (EU)	Y3 (EU)	Y5 (EU)	Y7 (EU)	Y10 (EU)
MPS (Interbank Futures), Pre-crisis, FOMC	Yield	-0.1	-0.5	-0.3	0.0	0.4
	E(Short rate)	-0.8	-0.9	-0.9	-0.8	-0.7
	Term premium	0.9	0.8*	0.9	1.1	1.2
MPS (Interbank Futures), US QE, FOMC	Yield	-1.1	-1.7**	-2.2***	-2.4***	-2.6***
	E(Short rate)	-0.4	-0.5	-0.5	-0.5	-0.5
	Term premium	-0.6	-1.1***	-1.6***	-1.8***	-2.0***
MPS (Interbank Futures), TT to EAPP, FOMC	Yield	-1.2***	-3.6***	-4.7***	-5.1***	-4.8***
	E(Short rate)	-1.8	-2.7*	-3.2**	-3.2**	-2.9***
	Term premium	0.6	-1.1	-1.7***	-1.9***	-2.0***
MPS (Interbank Futures), EAPP, FOMC	Yield	0.1	-0.4	-1.3	-2.1*	-2.8**
	E(Short rate)	0.8	0.4	0.0	-0.2	-0.3
	Term premium	-0.4	-0.4	-0.8	-1.4	-2.0*
Panel C: Japan yields		Y1 (JP)	Y3 (JP)	Y5 (JP)	Y7 (JP)	Y10 (JP)
MPS (Interbank Futures), Pre-crisis, FOMC	Yield	-1.5***	-1.2**	-1.4	-1.3	-0.8
	E(Short rate)	0.7	0.7	0.5	0.4	0.3
	Term premium	-1.7	-1.2	-1.4	-1.4	-0.9
MPS (Interbank Futures), US QE, FOMC	Yield	-0.3	-0.5*	-0.9***	-1.0***	-1.0***
	E(Short rate)	0.1	0.1	0.1	0.0	0.0
	Term premium	-0.2	-0.6	-0.9***	-1.0***	-1.0***
MPS (Interbank Futures), TT to EAPP, FOMC	Yield	0.4	0.0	-0.4	-0.5	-0.4
	E(Short rate)	-0.1	0.0	0.0	0.0	0.0
	Term premium	0.8	0.0	-0.4	-0.4	-0.3
MPS (Interbank Futures), EAPP, FOMC	Yield	0.4	-0.4	-1.0***	-1.2***	-1.4***
	E(Short rate)	1.5	0.9	0.7	0.5	0.4
	Term premium	-0.8	-1.3**	-1.6***	-1.6***	-1.7***

Table 16a summarizes the results of daily piecewise regressions where the dependent variable is the change in (i) zero coupon bond yields for maturities of 1, 3, 5, 7 and 10 years, (ii) the path of the expected short rate over the life of the bond, and (iii) the term premium relevant for each maturity in the UK, Euro area and Japan. Measures of the expected short rate and the term premium are estimated using a shadow rate term structure model from Wu and Xia (2016). The independent variable of interest is the period-specific daily change in the first principal component of US 2-month ahead OIS futures and 1-, 3-, 5-, 7-, and 10-year yields on FOMC meeting days. Monetary policy measures are normalized to be a one standard deviation loosening. *, **, and *** denote statistical significance at the 10%, 5%, and 1% levels, respectively.

Table 16b: The Impact of a One St. Dev. ECB Monetary Policy Surprise on Yields, Expected Short Rates and Term Premia (Alt. Measure: Yield Curve First Principal Component)

		(1)	(2)	(3)	(4)	(5)
Panel A: UK yields	Dep. Var.	Y1 (UK)	Y3 (UK)	Y5 (UK)	Y7 (UK)	Y10 (UK)
MPS (Interbank Futures), Pre-crisis, ECB	Yield	-0.6	-1.6**	-1.7***	-1.6***	-1.5***
	E(Short rate)	-0.2	-0.4	-0.4	-0.3	-0.2
	Term premium	-0.3***	-1.2***	-1.4***	-1.4***	-1.4***
MPS (Interbank Futures), US QE, ECB	Yield	-0.8	-1.6*	-1.8**	-1.9**	-1.9**
	E(Short rate)	-0.5	-0.5	-0.5	-0.6	-0.6
	Term premium	-0.2	-1.0*	-1.2*	-1.3*	-1.3
MPS (Interbank Futures), TT to EAPP, ECB	Yield	0.0	-0.3	-0.4	-0.4	-0.4
	E(Short rate)	0.5	0.9**	0.2	-0.1	-0.3
	Term premium	-0.5	-1.2**	-0.7	-0.4	-0.2
MPS (Interbank Futures), EAPP, ECB	Yield	-1.2***	-2.5***	-3.0***	-3.3***	-3.5***
	E(Short rate)	-0.6**	-1.3**	-1.3**	-1.3**	-1.1**
	Term premium	-0.7**	-1.1***	-1.5**	-1.8**	-2.2**
Panel B: US yields	Dep. Var.	Y1 (US)	Y3 (US)	Y5 (US)	Y7 (US)	Y10 (US)
MPS (Interbank Futures), Pre-crisis, ECB	Yield	-1.3*	-0.8	-0.5	-0.3	-0.2
	E(Short rate)	-1.3	-1.1	-0.9	-0.8	-0.6
	Term premium	0.0	0.2	0.4	0.5	0.5
MPS (Interbank Futures), US QE, ECB	Yield	-0.4*	-1.4***	-2.4***	-3.1***	-3.6***
	E(Short rate)	-0.1	-0.2	-0.2	-0.2	-0.2
	Term premium	-0.4	-1.2***	-2.2***	-2.9***	-3.4***
MPS (Interbank Futures), TT to EAPP, ECB	Yield	-0.5	-1.4***	-1.3**	-0.7	0.4
	E(Short rate)	-0.2	-0.8***	-1.2***	-1.3***	-1.2***
	Term premium	-0.3	-0.5	0.0	0.7	1.6
MPS (Interbank Futures), EAPP, ECB	Yield	-0.7*	-2.3***	-3.4***	-3.9***	-4.1***
	E(Short rate)	0.1	0.2	0.1	0.0	-0.0
	Term premium	-0.8	-2.4*	-3.4*	-3.9**	-4.0**
Panel C: Japan yields	Dep. Var.	Y1 (JP)	Y3 (JP)	Y5 (JP)	Y7 (JP)	Y10 (JP)
MPS (Interbank Futures), Pre-crisis, ECB	Yield	0.4	-0.3	-0.6	-0.9*	-0.9**
	E(Short rate)	0.6	1.0	0.8	0.6	0.4
	Term premium	-0.2	-1.5	-1.4**	-1.5***	-1.3***
MPS (Interbank Futures), US QE, ECB	Yield	-0.2	0.2	0.1	-0.2	-0.5
	E(Short rate)	0.1	0.1	0.1	0.1	0.0
	Term premium	-0.2	0.2	-0.0	-0.2	-0.6
MPS (Interbank Futures), TT to EAPP, ECB	Yield	-0.1	0.1	-0.3	-0.6*	-0.6
	E(Short rate)	-0.2	-0.1	-0.1	-0.1	-0.1
	Term premium	-0.3	0.2	-0.2	-0.5*	-0.6
MPS (Interbank Futures), EAPP, ECB	Yield	-0.1	-0.0	-0.2	-0.6**	-1.0***
	E(Short rate)	0.5	0.3*	0.2	0.2	0.1
	Term premium	-0.7*	-0.4	-0.5*	-0.8***	-1.1***

Table 16b summarizes the results of daily piecewise regressions where the dependent variable is the change in (i) zero coupon bond yields for maturities of 1, 3, 5, 7 and 10 years, (ii) the path of the expected short rate over the life of the bond, and (iii) the term premium relevant for each maturity in the UK, Euro area and Japan. Measures of the expected short rate and the term premium are estimated using a shadow rate term structure model from Wu and Xia (2016). The independent variable of interest is the period-specific daily change in the first principal component of European 2-month ahead OIS futures and 1-, 3-, 5-, 7-, and 10-year yields on ECB meeting days. Monetary policy measures are normalized to be a one standard deviation loosening. *, **, and *** denote statistical significance at the 10%, 5%, and 1% levels, respectively.

Table 16c: The Impact of a One St. Dev. BoE Monetary Policy Surprise on Yields, Expected Short Rates and Term Premia (Alt. Measure: Yield Curve First Principal Component)

		(1)	(2)	(3)	(4)	(5)
Panel A: Euro area yields	Dep. Var.	Y1 (EU)	Y3 (EU)	Y5 (EU)	Y7 (EU)	Y10 (EU)
MPS (Interbank Futures), Pre-crisis, BoE	Yield	-0.4	-1.2***	-1.5***	-1.6***	-1.7***
	E(Short rate)	-0.0	-0.1	-0.2	-0.2	-0.2
	Term premium	-0.3	-0.8***	-1.1***	-1.2***	-1.3***
MPS (Interbank Futures), US QE, BoE	Yield	-0.8***	-1.7***	-1.8***	-1.8***	-1.8***
	E(Short rate)	-0.8	-0.9	-0.9	-0.8	-0.7
	Term premium	-0.0	-0.8**	-0.9***	-1.0**	-1.1*
MPS (Interbank Futures), TT to EAPP, BoE	Yield	0.1	-0.3	-1.0*	-1.6**	-2.1***
	E(Short rate)	-0.4	-0.5	-0.5	-0.4	-0.3
	Term premium	0.6	0.3	-0.4	-1.0**	-1.6***
MPS (Interbank Futures), EAPP, BoE	Yield	-0.6	-1.2**	-1.7***	-2.0***	-2.3***
	E(Short rate)	0.0	-0.0	-0.0	-0.3	-0.8***
	Term premium	-0.6	-1.1**	-1.6***	-1.7***	-1.5***
Panel B: US yields	Dep. Var.	Y1 (US)	Y3 (US)	Y5 (US)	Y7 (US)	Y10 (US)
MPS (Interbank Futures), Pre-crisis, BoE	Yield	-2.1***	-2.9***	-2.9***	-2.7***	-2.4***
	E(Short rate)	-1.8**	-1.8**	-1.6***	-1.4***	-1.2***
	Term premium	-0.2	-1.1**	-1.2**	-1.2**	-1.2*
MPS (Interbank Futures), US QE, BoE	Yield	0.0	-1.0***	-1.9***	-2.4***	-2.8***
	E(Short rate)	0.2	0.2	0.1	0.0	-0.0
	Term premium	-0.1	-1.2***	-1.8***	-2.3***	-2.7***
MPS (Interbank Futures), TT to EAPP, BoE	Yield	-0.1	-2.3***	-3.6***	-4.2***	-4.5***
	E(Short rate)	0.3	0.2	-0.2	-0.3	-0.3
	Term premium	-0.4*	-2.4***	-3.4***	-3.8***	-4.2***
MPS (Interbank Futures), EAPP, BoE	Yield	-0.6**	-1.9***	-2.7***	-2.9***	-2.9***
	E(Short rate)	0.1	-0.2	-0.3	-0.3	-0.3
	Term premium	-0.7	-1.8***	-2.4***	-2.7***	-2.7***
Panel C: Japan yields	Dep. Var.	Y1 (JP)	Y3 (JP)	Y5 (JP)	Y7 (JP)	Y10 (JP)
MPS (Interbank Futures), Pre-crisis, BoE	Yield	-0.5	-0.9***	-1.3***	-1.1***	-0.8***
	E(Short rate)	-0.5	-0.5	-0.4	-0.3	-0.2
	Term premium	-0.2	-0.3	-0.8*	-0.8*	-0.6*
MPS (Interbank Futures), US QE, BoE	Yield	-0.0	-0.3*	-0.8***	-0.8***	-0.6**
	E(Short rate)	-0.1	-0.1	-0.0	-0.0	-0.0
	Term premium	-0.0	-0.3*	-0.8***	-0.8***	-0.6**
MPS (Interbank Futures), TT to EAPP, BoE	Yield	-0.3	-0.2	-0.2	-0.2	-0.4
	E(Short rate)	-0.4	-0.2	-0.2	-0.1	-0.1
	Term premium	0.3	0.0	-0.0	-0.1	-0.3
MPS (Interbank Futures), EAPP, BoE	Yield	0.2	-0.2	-0.5	-0.5	-0.4
	E(Short rate)	-1.6	-1.0	-0.7	-0.6	-0.4
	Term premium	1.3	0.6	0.1	-0.1	-0.0

Table 16c summarizes the results of daily piecewise regressions where the dependent variable is the change in (i) zero coupon bond yields for maturities of 1, 3, 5, 7 and 10 years, (ii) the path of the expected short rate over the life of the bond, and (iii) the term premium relevant for each maturity in the UK, Euro area and Japan. Measures of the expected short rate and the term premium are estimated using a shadow rate term structure model from Wu and Xia (2016). The independent variable of interest is the period-specific daily change in the first principal component of UK 2-month ahead OIS futures and 1-, 3-, 5-, 7-, and 10-year yields on BOE meeting days. Monetary policy measures are normalized to be a one standard deviation loosening. *, **, and *** denote statistical significance at the 10%, 5%, and 1% levels, respectively.

Table 16d: The Impact of a One St. Dev. BoJ Monetary Policy Surprise on Yields, Expected Short Rates and Term Premia (Alt. Measure: Yield Curve First Principal Component)

		(1)	(2)	(3)	(4)	(5)
Panel A: US yields	Dep. Var.	Y1 (US)	Y3 (US)	Y5 (US)	Y7 (US)	Y10 (US)
MPS (Interbank Futures), Pre-crisis, BoJ	Yield	-0.6	-0.5	-0.6	-0.6	-0.4
	E(Short rate)	-0.4	-0.3	-0.3	-0.2	-0.2
	Term premium	-0.2	-0.1	-0.3	-0.3	-0.2
MPS (Interbank Futures), US QE, BoJ	Yield	0.1	-0.1	-0.1	0.0	0.3
	E(Short rate)	0.1	0.1	0.1	0.0	0.0
	Term premium	0.0	-0.1	-0.1	0.0	0.3
MPS (Interbank Futures), TT to EAPP, BoJ	Yield	0.2	0.5	1.2	1.7	2.1*
	E(Short rate)	0.1	0.1	-0.2	-0.3	-0.3
	Term premium	0.1	0.3	1.4	2.0	2.5*
MPS (Interbank Futures), EAPP, BoJ	Yield	-0.2	-0.5	-0.5	-0.4	-0.3
	E(Short rate)	-0.5	-0.5	-0.5	-0.4	-0.4
	Term premium	0.3	0.0	-0.0	0.0	0.1
Panel B: UK yields	Dep. Var.	Y1 (UK)	Y3 (UK)	Y5 (UK)	Y7 (UK)	Y10 (UK)
MPS (Interbank Futures), Pre-crisis, BoJ	Yield	-0.7*	-0.9*	-0.8	-0.7	-0.5
	E(Short rate)	-0.7**	-0.7**	-0.6**	-0.5**	-0.4**
	Term premium	0.0	-0.1	-0.1	0.0	0.1
MPS (Interbank Futures), US QE, BoJ	Yield	0.2	-0.5	-0.6	-0.6	-0.4
	E(Short rate)	0.5	0.2	0.2	0.4	0.4
	Term premium	-0.3	-0.5	-0.6	-0.7	-0.7
MPS (Interbank Futures), TT to EAPP, BoJ	Yield	0.2	-2.4	-3.7	-3.6	-2.8
	E(Short rate)	0.6	-0.3	-1.0	-1.2	-1.1
	Term premium	-0.4	-2.2*	-2.7	-2.4	-1.5
MPS (Interbank Futures), EAPP, BoJ	Yield	-0.1	-0.7	-0.8	-0.8	-0.6
	E(Short rate)	-0.1	-0.3	-0.5	-0.5	-0.5
	Term premium	-0.0	-0.4	-0.2	-0.2	-0.1
Panel C: Euro area yields	Dep. Var.	Y1 (EU)	Y3 (EU)	Y5 (EU)	Y7 (EU)	Y10 (EU)
MPS (Interbank Futures), Pre-crisis, BoJ	Yield	0.1	-0.3	-0.6	-0.6	-0.6
	E(Short rate)	0.2	0.1	0.1	0.0	0.0
	Term premium	-0.1	-0.3	-0.5	-0.6	-0.6
MPS (Interbank Futures), US QE, BoJ	Yield	-0.4	-0.6	-0.4	-0.3	-0.2
	E(Short rate)	-0.6	-0.5	-0.4	-0.4	-0.3
	Term premium	0.2	-0.0	0.1	0.2	0.2
MPS (Interbank Futures), TT to EAPP, BoJ	Yield	2.2	-1.9	-2.8	-3.5	-3.8
	E(Short rate)	-2.4	-3.4	-2.8	-2.5	-2.1
	Term premium	4.7***	1.7	0.3	-0.7	-1.4
MPS (Interbank Futures), EAPP, BoJ	Yield	-0.2	-0.4	-0.6	-0.7	-0.7
	E(Short rate)	-0.1	-0.2	-0.2	-0.3	-0.4
	Term premium	0.0	-0.1	-0.2	-0.2	-0.3

Table 16d summarizes the results of daily piecewise regressions where the dependent variable is the change in (i) zero coupon bond yields for maturities of 1, 3, 5, 7 and 10 years, (ii) the path of the expected short rate over the life of the bond, and (iii) the term premium relevant for each maturity in the UK, Euro area and Japan. Measures of the expected short rate and the term premium are estimated using a shadow rate term structure model from Wu and Xia (2016). The independent variable of interest is the daily change in the first principal component of Japanese 2-month ahead OIS futures and 1-, 3-, 5-, 7-, and 10-year yields on BOJ meeting days. Monetary policy measures are normalized to be a one standard deviation loosening. *, **, and *** denote statistical significance at the 10%, 5%, and 1% levels, respectively.