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Channels of US Monetary Policy Spillovers to International Bond Markets *

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Abstract

We document significant US monetary policy (MP) spillovers to international bond markets. Our methodology identifies US MP shocks as the change in short-term treasury yields within a narrow window around FOMC meetings, and traces their effects on international bond yields using panel regressions. We emphasize three main results. First, US MP spillovers to long-term yields have increased substantially after the global financial crisis. Second, spillovers are large compared to the effects of other events, and at least as large as the effects of domestic MP after 2008. Third, spillovers work through different channels, concentrated in risk neutral rates (expectations of future MP rates) for developed countries, but predominantly on term premia in emerging markets. In interpreting these findings, we provide evidence consistent with an *exchange rate channel*, according to which foreign central banks face a tradeoff between narrowing MP rate differentials, or experiencing currency movements against the US dollar. Developed countries adjust in a manner consistent with freely floating regimes, responding partially with risk neutral rates, and partially through currency adjustments. Emerging countries display patterns consistent with FX interventions, which cushion the response of exchange rates but reinforce capital flows and their effects in bond yields through movements in term premia. Our results suggest that the endogenous effects of FXI on long-term yields should be added into the standard cost-benefit analysis of such policies.

JEL classification: E43, G12, G15.

Keywords: monetary policy spillovers, risk neutral rates, term premia.

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1 Introduction

The conduct of monetary policy (MP) in many developed economies has changed in important ways since the global financial crisis. After reaching an effective zero lower bound, the focus shifted towards influencing long term yields, with significant efforts made by central banks in communicating their intentions to keep rates at zero for an extended period (forward guidance), and through large scale asset purchase programs (LSAP). The increased presence of the Fed, the ECB, and other central banks in fixed income markets has been reinforced by large portfolio flows from private investors, further contributing to the fast expansion of the world bond market in the last decade. This growth in size has also coincided with an increased presence of foreign investors in domestic bond markets, a change most noticeable for emerging market economies.[1]

While increased financial integration has multiple benefits, it also poses important challenges. In particular, it raises the question of whether the cost of funds in non-core economies can remain independent from developments in advanced countries, possibly undermining the ability of central banks to set appropriate monetary conditions given their domestic macroeconomic stance. This discussion is well captured by several studies assessing the international spillover effects from MP in the US and other large developed economies, including Rey (2015), Bruno and Shin (2015), and Obstfeld (2015), among many others.

There are several open questions that remain to be settled in this literature. First, there is a non-trivial problem of identification that makes it hard to assess whether comovements in yield curves are driven by causal effects from MP in advanced countries, or merely reflect common underlying economic forces. Second, there are few studies that test spillover effects on emerging market economies, mostly due to the lack of reliable, long-dated yield curve information. Third, to the extent that spillover effects are identified, there is little evidence about the specific channels at work. In particular, do movements in domestic long-term yields reflect the anticipation of future short-term rates that tend to follow MP changes in core economies, or do they result from changes in risk compensation due to portfolio rebalancing/risk-taking motives?

This paper contributes to the debate by presenting evidence of significant spillover of US MP into international bond yields. Our data includes 12 developed countries (henceforth, DEV) and 12 emerging market economies (henceforth, EME). In order to identify US MP shocks, we use the change in short-term treasuries (2-yr maturity in our baseline specification) within a narrow window centered around FOMC meetings. This identification strategy has been followed by several studies, most recently by Hanson and Stein (2015) in a setting similar to ours, and by Savor and Wilson (2014) to explain stock returns during days of macroeconomic announcements, including Fed meetings.[2] We then test how shocks to US MP affect international bond yields at different maturities using panel data regressions. Because we wish to highlight the difference between DEV and EME, we run panel regressions for each group of countries separately. Our sample runs from January 2003 to December 2016, and we split it in October 2008 to mark the MP regime change due to the global financial crisis (see Gilchrist, Yue, and Zakrajsek, 2016).

To further understand spillover mechanisms, we decompose long-term yields for each country into a term premium (TP) and a risk neutral (RN) component, following the methodology of Adrian, Crump, and Moench (2013), but

[1] See IMF (2014), and BIS (2015).

[2] A similar event study is used in Gilchrist, Yue, and Zakrajsek (2016). Cochrane and Piazzesi (2002) and Bernanke and Kuttner (2005) use a related measure of US MP shocks, but focusing on shorter maturities –the 1-month eurodollar rate and Federal funds futures, respectively.

correcting for small sample bias as suggested by Bauer, Rudebusch, and Wu (2012). This allows us to determine whether US MP spillovers to other economies work by affecting market expectations of future domestic MP in those countries, or whether they reflect changes in risk compensation. Moreover, to put perspective on the economic magnitude of spillovers, we study the impact on yields of individual countries' domestic MP shocks, as well as other events including US and domestic releases of inflation, activity, and unemployment.

We highlight three main results. First, US MP spillovers are large for both DEV and EME, especially for the sub-sample after October 2008. Throughout this period, we estimate that a 100 bp increase in US short-term rates during MP meetings increases long-term rates in DEV and EME countries by 43 and 56 bp, respectively. In the earlier subsample, the elasticities are smaller in magnitude, particularly so for EME.

Second, spillovers are economically important compared to other events, and at least as large as the impact of domestic MP actions on long-term yields post October 2008. In particular, the point estimates of the effects of US MP on domestic long-term bond yields of DEV economies is roughly equivalent to the effect of domestic MP, but significantly larger than the effect of domestic MP in the case of EME in the second part of the sample. Moreover, US MP spillovers are comparable to the elasticity of long-term rates to 2-year yield changes around key domestic macroeconomic releases.

Third, there seem to be important differences in the mechanisms involved in the transmission of US MP when comparing different country groups. Based on the complete sample estimates, the contribution of the RN component (expectations of short-term rates) accounts for almost all the variation in yields for DEV economies, with a non-significant contribution of the TP component. For countries in the EME sample the effect is the opposite, with most of the variation in yields being driven by movements in TP. Digging deeper into the underlying mechanisms that could explain these patterns, we find little evidence of an *informational channel* –the notion that FOMC meetings could affect expected rates in other countries by communicating relevant information about the US macroeconomy, potentially correlated with conditions abroad. We argue that there are weak theoretical and empirical grounds for this view within our specific identification strategy.

We provide additional evidence that favors an *exchange rate channel*, according to which central banks face a tradeoff between narrowing interest differentials, or experiencing currency movements. Conceptually, the effects of US MP spillovers depend on the policy responses of central banks. As shown by Blanchard, Adler, and Carvalho Filho (2015), (sterilized) exchange rate interventions (FXI) dampen the exchange rate effects of capital inflows in reaction to US MP, but in doing so reinforce such inflows, compared to the alternative of adjusting domestic MP. In A, we extend their model to include long-term bonds and derive implications for exchange rates, capital flows, and long-term yields in response to US MP shocks under different policy reactions. Consistent with the theoretical predictions, our evidence suggests that central banks in DEV adjust in a manner consistent with freely floating regimes, absorbing shocks with both exchange rate and RN rate movements. EMEs, on the other hand, display patterns consistent with FXI, a behavior widely documented for the countries in our sample.[3] These include weaker exchange rate effects, stronger capital inflows, and a stronger reaction of term premia. In contrast to the standard Mundell-Fleming paradigm in which effective FXI can in principle stabilize both short-term rates and the domestic currency –and thus present no apparent policy tradeoff– our results suggest FXI deflect the burden of adjustment

[3] See Table 12 in B for numerous references.

into long term yields through changes in term premia, casting new light into their cost-benefit analysis.

There is a growing literature studying the effect of conventional and unconventional MP in the US post 2008. Hanson and Stein (2015) show that conventional Fed meetings have a significant impact on the long end of the US yield curve. Krishnamurthy and Vissing-Jorgensen (2011), Gagnon, Raskin, Remache, and Sack (2011), and Christensen and Rudebusch (2012), find large effects of unconventional MP announcements on US long-term yields. Several papers have also documented the international spillover effects of conventional US MP,[4] and, more recently, the transmission of LSAP announcements.[5]

More closely related to our paper are the recent papers by Gilchrist, Yue, and Zakrajsek (2016), Hoffman and Takáts (2015), and IMF (2015), who put special emphasis on US MP spillovers to emerging countries. The main difference with these papers is our focus on the transmission mechanisms behind US MP spillovers. Indeed, the fact that the cost of credit at longer maturities in emerging markets could be partially disconnected from the expected path of MP decisions poses important challenges for central banks in these economies, and warns about additional, unintended consequences of FX interventions. Furthermore, by presenting evidence about the impact of own MP and economic releases, our paper helps to put into perspective the economic importance of spillover channels relative to other domestic and foreign events. Another difference, particularly with Hoffman and Takáts (2015) and IMF (2015), is the identification strategy. While they use a VAR methodology with recursive restrictions at monthly frequency to identify autonomous shocks on US long-term yields, we use event-study analysis based on narrow windows around Fed meetings to identify MP shocks.

The remainder of the paper is structured as follows. Section 2 describes the data and the main econometric specification, including the construction of US MP events and the decomposition of yield curve movements into RN and TP components. In section 3, we quantify US MP spillovers to international bond yields and their components, and contrast their magnitude with other economic events. Section 4 provides further analysis and evidence in order to interpret our results and identify specific mechanisms underlying US MP spillovers. Section 5 presents additional tests to check the robustness of our results to plausible deviations in sample choice, construction of the event study, and other methodological issues. Section 6 concludes.

2 Data description and identification strategy

2.1 Econometric specification

To estimate the effect of US MP spillovers, we test the following panel specification:

$$\Delta y_{j,t}^{h} = \alpha_{year}^{h} + \alpha_{month}^{h} + \beta^{h} MPR_{t}^{US} + \gamma^{h} MPR_{j,t}^{Own} + \sum_{n=1}^{N} \delta_{n}^{h} S_{n,t}^{US} + \sum_{n=1}^{N} \theta_{n}^{h} S_{j,n,t}^{Own} + \varepsilon_{j,t}^{h} \tag{1}$$

In equation (1), the main explanatory variable of interest is MPR_{t}^{US}: the change in the 2-yr US treasury yield between the closing of the business day before and the day after each meeting.[6] The rationale for this measure,

[4]See Craine and Martin (2008), Hausman and Wongswan (2011), and Georgiadis (2015).

[5]See Bauer and Neely (2014), and Bauer and Rudebusch (2014).

[6]For example, for the meeting that ended on October 29, 2014, the MP shock is the difference between the 2-yr treasury at the close of October 30, and the close of October 28.

proposed by Hanson and Stein (2015), is that the actual Fed Funds Rate (FFR) changes are infrequent, and often anticipated by the market. Moreover, there could be relevant information at each meeting about the future course of MP that would be missed if one used only the contemporaneous FFR. For these reasons, they propose using a relatively short-maturity yield for capturing changes in the stance of future MP that could arise from information released during FOMC meetings. The other variables in the right hand side of equation (1) include $MPR_{j,t}^{Own}$: the change in country j's 2-yr yield around an analogously defined 2-day window centered at its corresponding MP meeting; $S_{n,t}^{US}$: the change in 2-yr US yield around a 2-day window centered at each US economic release n (with n=CPI, IP, and unemployment); and $S_{j,n,t}^{Own}$: the change in country j's 2-yr yield around a 2-day window centered at j's economic release n (also, n=CPI, IP, and unemployment).

To control for other common events that might affect yields, we try several fixed-effects specifications and criteria for clustering standard errors. In our baseline specification, we include year- and month-fixed effects in each regression (α_{year}^{h} and α_{month}^{h} in equation (1)). We discuss robustness considerations in more detail in section 5.

We now turn to the left-hand side of equation (1). Because we are interested in the effect of US MP and other economic events on yields and their components, we use 3 different variables: the h-yr domestic bond yield (where the superscript h stands for maturity);[7] the portion of this yield identified as the RN component (the expectations of future short-term interest rates); and the TP component. We focus the discussion below on 2-yr and 10-yr yields. In all specifications, $\Delta y_{j,t}^{h}$ is defined as the change in yields (or yield components) between the close of the business day after and the day before each meeting.[8] Because we place special emphasis on the effects of US MP on EME and DEV, we run separate regressions for each group of countries. We also highlight the change in US MP spillovers over time by splitting the sample in two, with the first sub-sample including the period January 2003 up to (and including) October 2008.

2.2 Data sources and Identification issues

Our DEV sample comprises 12 countries: Australia, Canada, Czech Republic, France, Germany, Italy, Japan, New Zealand, Norway, Sweden, Switzerland, and the United Kingdom. The EME sample also includes 12 countries: Chile, Colombia, Hungary, India, Indonesia, Israel, Korea, Mexico, Poland, South Africa, Taiwan, and Thailand. Sample choice is limited by the availability of sufficiently rich yield curve data, as computation of yield components requires observing several yields along the term structure at each point in time. The resulting balanced panel runs from January 2003 through December 2016. Tables 9 and 10 in B provide further details.

Our identification strategy relies on two main premises. First, implicit in the use of MP calendar days is the notion that such events are quantitatively relevant to the dynamics of interest rate movements in the US.[9] Table 1 reports moments of interest rate changes around different economic events. In the first sub-sample, the standard deviation of 2-yr US yields is larger around MP meetings than on non-meeting days, though the difference is marginally

[7] In the case of yields we use on the left-hand side the model-implied yield rather than the observed interest rates, which may not coincide due to measurement error in the affine model estimation. An estimation using actual yields changes only the coefficients associated to yields, but not their components. The differences are marginal (not reported).

[8] While specific countries will have longer/shorter windows before/after the announcement depending on time zone differences, it is always the case that the FOMC meeting is contained within the window.

[9] The higher volatility of rates on event days is not a necessary condition for the identification strategy to be valid, but it supports the notion that Fed meetings are relevant events in yield curve movements.

significant at 10% confidence levels. Post October 2008, the volatility of rates around meetings is significantly larger than non-event days (at 1% confidence). Similarly, macroeconomic releases are not associated with higher volatility in the earlier sample, but after 2008 unemployment releases, and to some extent CPI releases, exhibit significantly more rate volatility compared to non-event days. For DEV economies, interest rates on MP meeting days, and during CPI and unemployment releases, display significantly larger volatility than non-event days in both samples, and so do activity releases in the second part of the sample. For EME, volatility around economic releases is only significantly larger than non-event days post October 2008 for MP meetings, activity and unemployment releases. Second, for the event to correctly measure US MP as a causal force affecting international yields, it should not be contaminated by other economic releases. Table 11 in B shows that although Fed meetings are not always the only event moving yields on a given day, this is the case much more often than not: the overlap frequency between US MP meetings and all other country events is only about 7%.

Table 1: Changes in 2-yr yields around selected events

	Pre Oct. 2008						Post Oct. 2008					
	US		DEV		EME		US		DEV		EME	
	mean	std	mean	std	mean	std	mean	std	mean	std	mean	std
No news	0.07	8.94	0.04	6.43	0.29	19.31	0.05	4.35	-0.25	7.35	-0.31	10.01
MPM	-0.22	9.50*	-0.86	9.73***	-1.72	18.47*	-0.23	5.67***	-1.24	11.07***	-2.09	14.38***
Inflation	-1.28	9.04	0.33	6.87**	0.42	19.24	-0.32	4.87*	-0.25	6.37**	-0.97	11.53***
Activity	-1.86	9.04	-0.40	5.32***	0.64	12.87***	-0.19	4.51	-0.60	8.41***	-0.58	10.59**
Unemployment	0.10	9.33	0.27	7.52***	1.12	8.41***	-0.24	4.95***	-0.27	7.93***	-0.29	8.44***

The table shows the mean and the standard deviation of changes in 2-yr yields around economic releases. ***p-value < 1%, **p-value < 5%, and *p-value < 10%, denote the probability that volatility is higher in the corresponding event than in non-event days.

2.3 Decomposition of yields

To decompose interest rates into RN and TP components, we use the affine term-structure model of Adrian, Crump, and Moench (2013). We now briefly sketch their methodology (D provides further details). The model is characterized by the existence of K risk factors summarized in vector X_t, which follows a first-order VAR:

$$X_{t+1} = \mu + \Phi X_t + v_{t+1}, \qquad v_{t+1} \sim N(0, \Sigma). \tag{2}$$

It is further assumed that the short-term interest rate r_t is a linear function of the risk factors

$$r_t = \delta_0 + \delta_1' X_t, \tag{3}$$

and that there exists a unique stochastic discount factor given by

$$-\log M_{t+1} = r_t + \frac{1}{2}\lambda_t'\lambda_t + \lambda_t' v_{t+1}, \tag{4}$$

where the vector of risk prices (λ_t) is also linear in the risk factors: $\lambda_t = \lambda_0 + \lambda_1 X_t$. The risk factors also follow a Gaussian VAR under the risk-neutral probability measure $\mathbb{Q}$: $X_{t+1} = \mu^{\mathbb{Q}} + \Phi^{\mathbb{Q}} X_t + v_{t+1}^{\mathbb{Q}}$, where $\mu^{\mathbb{Q}} = \mu - \Sigma\lambda_0$

and $\Phi^{\mathbb{Q}} = \Phi - \Sigma\lambda_1$. Using this probability measure, the n-period zero coupon bond price corresponds to $P_t^n = E_t^{\mathbb{Q}}(\exp(-\sum_{h=0}^{n-1} r_{t+h}))$, and prices of bonds at different maturities can be written $P_t^n = \exp(\mathcal{A}_n + \mathcal{B}_n' X_t)$, where $\mathcal{A}_n$ and $\mathcal{B}_n$ are solved recursively. One can then compute model-implied yields as $y_t^n = -\frac{\log(P_t^n)}{n}$. By setting risk prices equal to zero, one can obtain the yields that would prevail under risk neutrality, $\tilde{y}_t^n$, a measure of pure expectations about future rates at different maturities –the risk-neutral (RN) component. The difference between model-implied yields and RN rates is defined as the term premium (TP) component, $tp_t^n \equiv y_t^n - \tilde{y}_t^n$.

To estimate the model, Adrian, Crump, and Moench (2013) exploit the predictability of excess bond returns found in earlier studies, such as Cochrane and Piazzesi (2005),[10] and propose a simple OLS procedure to estimate the market prices of risk, details of which are provided in D.

Bias correction A potential issue encountered in the estimation of affine models is the assumption that the short-term interest rate follows a VAR(1) process. Bauer, Rudebusch, and Wu (2012) show that, due to the small-sample bias present in this type of estimations, OLS generates artificially lower persistence than the true process, understating the volatility of RN rates (and hence overstating the volatility of TP). We follow their advice and employ an indirect inference procedure. The idea of this method is to choose parameter values that yield a distribution of the OLS estimator with a mean equal to the OLS estimate in the actual data.[11]

3 International US MP spillovers in perspective

This section presents the main results of the paper. Part 3.1 documents the impact of US MP shocks on international bond yields and their components. In order to put these magnitudes in perspective, parts 3.2 and 3.3 provide further evidence about the impact of domestic MP shocks and other domestic economic releases (inflation, unemployment, and activity) on these variables.

3.1 Effect of regular Fed meetings

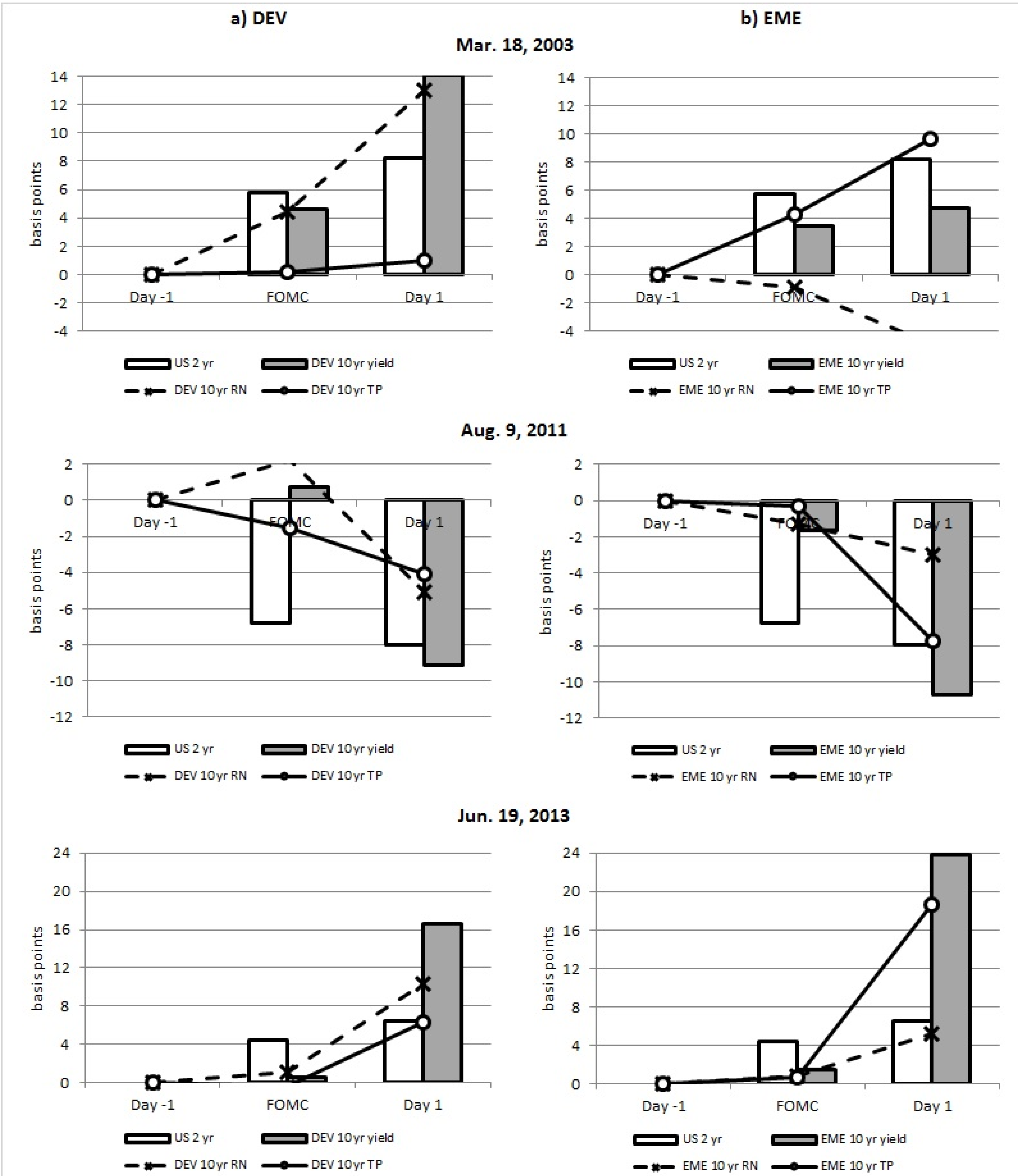
To build intuition about the regression design tested in equation (1), Figure 1 describes events during selected FOMC meetings. The plots include the change in US 2-yr yields (our measure of US MP shocks, depicted in white bars), as well as their impact on 10-yr yields (gray bars) and their components (dashed line: RN component; solid line: TP component). For each sub-sample of countries (DEV and EME), the series plotted correspond to simple averages across countries in each group.

The upper panel plots the reaction of these variables during the meeting of March 18, 2003. Our measure of US MP shock is a positive 8.2 bp move, associated with a change in DEV 10-yr yields of about 14 bp, 13 of which correspond to the RN component. In contrast, the average effect in EME 10-yr yields, at about 5 bp, is explained by an increase in the TP component close to 9 bp, with a counteracting movement in the RN component. A similar pattern emerges for the meeting of August 9, 2011, which led to a market revision in 2-yr US yields of -8 bp. Of the -9.2 bp reaction in DEV 10-yr yields, more than half is explained by movements in the RN component, although in

[10] See Gürkaynak and Wright (2012) for a comprehensive review of this literature.

[11] See the online Appendix of Bauer, Rudebusch, and Wu (2012) for details. The Matlab codes to apply the correction are available at `http://faculty.chicagobooth.edu/jing.wu/`.

Figure 1: US MP shocks and international bond yields during selected episodes



This figure plots the reaction of 10-yr yields (gray bars) and its components (RN component: dashed line; TP component: solid line) in response to changes in US 2-yr treasuries (white bars). The MP shock corresponds to the white bars at Day 1 (the difference between 2-yr yields at the closing of the day after and the day before the meeting). Panel a) and b) plot the average reaction across countries in the DEV and EME samples, respectively.

this episode the TP component does contribute a significant fraction. The slightly larger reaction in EME yields at -10.7 bp, on the other hand, is clearly dominated by the TP component. The third episode corresponds to the meeting of June 19, 2013, which increased US 2-yr rates in 6.5 bp. This shock had a comparably large effect of 16.7 bp in DEV 10-yr yields, of which more than 10 bp is accounted for by the RN component. The 24 bp effect in EME 10-yr yields is once again dominated by an increase in TP. While these are hand-picked cases, they capture the general pattern we document below: while overall yields in both groups of countries react similarly to US MP shocks, the action is dominated by the RN component for DEV, while TP is predominant for EME.

Table 2 presents the impact of US MP shocks in our baseline specification (the β^h coefficients in equation (1)), with panels a) and b) reporting the results for DEV and EME, respectively. The rows contain the effects on 2-yr yields, 10-yr yields, and the TP and RN components of 10-yr yields. The columns report the effects for the complete sample, the sub-sample ending in October 2008, and the sub-sample starting in December 2008.

Table 2: Effects of US monetary policy

	a) DEV			b) EME		
	Full sample	Pre Oct. 2008	Post Oct. 2008	Full sample	Pre Oct. 2008	Post Oct. 2008
2-yr yield	0.263***	0.318***	0.173***	0.160***	0.100*	0.287***
	(0.023)	(0.028)	(0.038)	(0.041)	(0.052)	(0.068)
10-yr yield	0.335***	0.297***	0.429***	0.293***	0.193***	0.557***
	(0.026)	(0.028)	(0.053)	(0.061)	(0.070)	(0.107)
RN (10-yr)	0.331***	0.390***	0.234***	0.054	0.019	0.136**
	(0.032)	(0.040)	(0.053)	(0.039)	(0.050)	(0.053)
TP (10-yr)	0.005	-0.092***	0.196***	0.239***	0.174**	0.421***
	(0.030)	(0.033)	(0.054)	(0.076)	(0.088)	(0.132)

The table shows the impact of US monetary policy events, corresponding to the β^h coefficient in equation (1). The regression is estimated separately for each group of countries: DEV and EME. Standard errors computed using Newey-West correction up to 40 lags (reported in parentheses). *** p-value $<$ 1%, ** p-value $<$ 5%, and * p-value $<$ 10%.

We begin the discussion of the effects of US MP on DEV economies. For the full sample, a 100 bp US MP shock increases 2-yr rates abroad by 26 bp. For the 10-yr maturity, the effect is 34 bp. Comparing the pre and post October 2008 periods, the effect of US MP shocks on 2-yr yields has decreased from 32 to 17 bp. Interestingly, the effect is the reverse for 10-yr rates, for which spillovers have increased from 30 to 43 bp. These differences are statistically significant at 5% (not reported).

Focusing now on the composition of US MP spillovers on 10-yr yields, we see that the action is concentrated predominantly on the RN component. For the complete sample, a 100 bp shock in US MP is associated with a 33 bp increase in the RN component (significant at the 1% confidence level), virtually the whole effect in yields, while the contribution of the TP component is not statistically different from zero. Comparing the first and second subsamples, we see that the TP component becomes statistically significant in the latter episode, although the RN component still explains more than half of the overall transmission of US MP to DEV yields.

For the EME group, a 100 bp US MP shock increases 2-yr rates about 16 bp in the full sample, an effect that increased from an insignificant 10 bp to a statistically significant 29 bp impact between the first and second estimation periods (a difference which is statistically significant at 1%). For the 10-yr maturity, the incremental effect across sub-periods is also noteworthy, growing from 19 bp to 56 bp per every 100 bp of US MP shocks (a difference also significant at 1%). Regarding the composition of US MP spillovers, these are now heavily tilted towards the TP component. For 10-yr yields, the full sample contribution of TP is 24 of the 29 bp total spillover effect (significant at 1%), while the 5 bp estimate for the RN component is not statistically significant. This dominance of the TP channel is evident in both sub-samples, although in the latter part the contribution of RN rates increases somewhat and is now marginally significant (at 5% confidence levels).

3.2 Effect of domestic MP

To gain perspective about the quantitative importance of US MP spillovers, Table 3 reports the impact of domestic MP meetings on yields (the γ^h coefficients in equation (1)), where the explanatory variable is the change in 2-yr domestic rates in a 2-day window centered at the business day corresponding to each country' s MP meetings (hence, we report only the elasticity of 10-yr domestic yields). For the DEV group in panel a), we see that an increase of 100 bp of the domestic 2-yr rate is associated with a 37 bp increase in 10-yr yields in the full sample. The effect is decomposed into a highly significant increase of 78 bp in the RN component, partly offset by a reduction in TP of 42 bp. These magnitudes are relatively similar across sub-periods, although the second sub-sample shows a somewhat larger effect on yields. Importantly, the point estimates of the effects of US MP shocks are almost identical to those corresponding to domestic MP shocks in both sub-periods (a non-significant 1 bp difference in favor of domestic shocks in the earlier sample, and a non-significant 1 bp difference in favor of US MP shocks in the latter period).

TABLE 3: Effects of domestic monetary policy

	a) DEV			b) EME		
	Full sample	Pre Oct. 2008	Post Oct. 2008	Full sample	Pre Oct. 2008	Post Oct. 2008
10-yr yield	0.371***	0.304***	0.418***	0.416***	0.518***	0.325**
	(0.060)	(0.098)	(0.070)	(0.116)	(0.068)	(0.164)
RN	0.782***	0.723***	0.825***	0.614***	0.677***	0.560***
	(0.070)	(0.093)	(0.092)	(0.081)	(0.130)	(0.112)
TP	-0.412***	-0.419***	-0.407***	-0.198	-0.159	-0.236
	(0.089)	(0.102)	(0.134)	(0.173)	(0.180)	(0.257)

The table shows the impact of domestic monetary policy events, corresponding to the γ^h coefficients of equation (1). The regression is estimated separately for each group of countries: DEV and EME. Standard errors computed using Newey-West correction up to 40 lags (reported in parentheses). *** p-value $<$ 1%, ** p-value $<$ 5%, and * p-value $<$ 10%.

For EME, per every 100 bp shock in domestic MP (2-yr domestic rates), 10-yr rates increase by 42 bp in the complete sample, again explained by a larger increase in the RN component (61 bp), counteracted by a compression in the TP (20 bp). The effect is more pronounced in the earlier sample, at 52 bp, statistically larger than the corresponding effect of US MP shocks. In the second part of the sample, however, the effect of domestic MP drops to 33 bp, now statistically smaller (at 1% confidence) than the effect of US MP documented in Table 2.

It is also interesting to point out that for both DEV and EME groups, domestic policy consistently raises RN rates by a larger amount than 10-yr yields, with the TP component playing a counteracting effect. One interpretation of this pattern could be related to the effects of domestic MP on inflation risk. Indeed, Abrahams, Adrian, Crump, and Moench (2017) decompose forward nominal and real yield curves for US treasuries and estimate the impact of conventional MP. They find that a tightening of US MP has a significant negative effect on inflation term premia. While our decomposition cannot make the finer distinction between real and nominal term premia due to lack of systematic TIPS data in our sample of countries, the results of Table 3 are in principle consistent with the argument that an unanticipated tightening in MP reduces inflation risk, and therefore the risk compensation demanded by investors for holding nominal bonds, in a broader sample of countries.

In short, the evidence suggest that US MP shocks affect the long end of the yield curve at least as much, and in some cases even more so, than domestic monetary policy events. The predominant role played by the Fed in affecting international asset prices documented here is complementary to the findings of Brusa, Savor, and Wilson (2016). They find that international stock markets consistently command a positive risk premium in days of scheduled FOMC announcements, but not during announcement days of central banks different from the Fed, including their own

Table 4: Effect of domestic economic releases

a) DEV	Full sample			Pre Oct. 2008			Post Oct. 2008		
	10-yr yield	RN	TP	10-yr yield	RN	TP	10-yr yield	RN	TP
Inflation	0.361***	0.662***	-0.301***	0.351***	0.812***	-0.461***	0.362***	0.561**	-0.199
	(0.085)	(0.170)	(0.096)	(0.055)	(0.053)	(0.049)	(0.135)	(0.247)	(0.126)
Activity	0.509***	0.819***	-0.310***	0.444***	0.796***	-0.353***	0.520***	0.820***	-0.300**
	(0.050)	(0.111)	(0.109)	(0.048)	(0.063)	(0.059)	(0.066)	(0.144)	(0.143)
Unempl.	0.487***	0.819***	-0.332***	0.485***	0.811***	-0.325***	0.480***	0.827***	-0.346***
	(0.046)	(0.042)	(0.063)	(0.047)	(0.048)	(0.064)	(0.071)	(0.063)	(0.097)
b) EME	**Full sample**			**Pre Oct. 2008**			**Post Oct. 2008**		
	10-yr yield	RN	TP	10-yr yield	RN	TP	10-yr yield	RN	TP
Inflation	0.394***	0.428***	-0.034	0.404***	0.424***	-0.020	0.369**	0.424***	-0.056
	(0.097)	(0.027)	(0.100)	(0.064)	(0.049)	(0.092)	(0.153)	(0.029)	(0.153)
Activity	0.341**	0.312***	0.030	0.135	0.253**	-0.118	0.640***	0.394***	0.246***
	(0.133)	(0.089)	(0.086)	(0.122)	(0.116)	(0.091)	(0.049)	(0.083)	(0.081)
Unempl.	0.400***	0.507***	-0.107	0.312*	0.530***	-0.218	0.422***	0.486***	-0.064
	(0.079)	(0.076)	(0.134)	(0.170)	(0.120)	(0.215)	(0.097)	(0.091)	(0.179)

The table shows the estimated impact of domestic economic releases, corresponding to the θ_n^h coefficients of equation (1). The regression is estimated separately for each group of countries: DEV and EME. Standard errors computed using Newey-West correction up to 40 lags (reported in parentheses). *** p-value $<$ 1%, ** p-value $<$ 5%, and * p-value $<$ 10%.

3.3 Effect of domestic economic releases

As an additional exercise to put US MP spillovers in perspective, Table 4 reports the elasticity of 10-yr yields to changes in 2-yr yields around a 2-day window centered on domestic macroeconomic announcements, including inflation (CPI), activity (industrial production) and unemployment –the θ_n^h coefficients in equation (1). Panel a) reports the results for the DEV group. In general, 2-yr yield movements around most economic releases have significant effects on 10-yr yields, with the transmission being larger in the case of unemployment and activity releases. In contrast, inflation releases in EME exhibit a larger comovement between short and long-term rates in the earlier sample, a pattern which is reversed in favor of activity and unemployment post October 2008.

All in all, the magnitudes of the effects are comparable to the impact of US MP on long-term yields, although their composition is different. As was the case for domestic MP events, we see a strong positive impact on RN rates, partly offset by a negative movement in TP.

4 Interpreting US MP spillover channels

Table 2 documents that, while the effects of US MP shocks to overall long-term yields is quantitatively similar across DEV and EME groups, the composition of yield changes differ, suggesting in principle different underlying spillover mechanisms. This section explores alternative explanations to account for these patterns.[12]

Two main hypotheses are generally mentioned as possible explanations for the comovement between US MP and international yields. According to the first, yield comovement during FOMC meetings could reflect an adjustment of financial markets to the revelation of US macroeconomic conditions, potentially correlated with those of other countries. Under this *information channel*, the reaction of foreign yields anticipates MP moves in these countries due to commonality in underlying conditions, and should therefore not be interpreted as a spillover in the causal sense.

A second mechanism, which we refer to as the *exchange rate channel*, points to a more causal effect of US MP on the decision of other central banks. Under this mechanism, MP abroad might partially follow the Fed to avoid currency movements arising from interest rate differentials. Such response could be motivated by inflationary pressures from exchange rate pass-through and/or trade balance considerations. Sections 4.1 and 4.2 investigate these two hypotheses and provide additional evidence to establish their relative merits as possible explanations behind our results. Section 4.3 discusses the connection of our results with the broader international finance literature.

4.1 The information channel

Economic fundamentals –inflation, activity and/or unemployment– may be correlated between the US and other countries. If, in addition, FOMC meeting are times where information about US fundamentals is revealed to the markets, then one could expect MP rates in other countries to be correlated with Fed decisions. If this mechanism, which we refer to as the *information channel*, dominates the international transmission of US MP documented above, then such transmission should not be regarded as a spillover in the causal sense, but merely as comovement reflecting common underlying economic trends. To investigate the relevance of this channel, one must document i) whether there is a significant degree of comovement between US and other countries' fundamentals, and ii) whether information about US fundamentals is indeed revealed at FOMC meetings.

The first condition has found support in the evidence. For much of the post financial crisis period, the US and other advanced economies –in particular the Eurozone, Japan, and the UK– displayed similar patterns of persistently low inflation and activity. More formally, Jotikasthira, Le, and Lundblad (2015) document that the observed comovement between yield curves in the US and other advanced countries' (Germany and the UK) depend on common underlying

[12] There is little evidence in the current literature to help narrow down the potential mechanisms behind the international transmission of interest rates. Bauer and Neely (2014) study the effects on foreign yields of LSAP's in the US, including a small sample of advanced economies and distinguishing between RN rates (which they dub the signaling channel), and TP. However, they do not investigate the economic mechanisms underlying their results.

factors. Specifically, interest rates depend on a set of macro variables, and those variables in Germany and the UK depend on both a global factor as well as a US factor, particularly so for inflation.

More problematic is to find support for the second condition –the revelation of fundamentals during FOMC meetings–, since we have chosen the event study around FOMC days precisely because these are days in which the main event is the meeting itself, having zero overlap with US economic releases and minimal overlap with events in other countries (see Table 11, B). It is not obvious therefore how an informational mechanism would play out within our particular identification strategy. One possibility is that the market learns something about the state of the economy from the FOMC minutes that could not be anticipated from the processing of publicly available economic releases accumulated up to that point. This interpretation relies on some form of superior analysis or insight in the way the Fed processes commonly known information.

Several papers have formally studied whether Fed forecasts of macroeconomic variables can beat the market in a consistent fashion. While there is some evidence of forecasting superiority by the Fed in older studies, more recent papers document a narrowing of this advantage post 2000.[13] One could still argue the FOMC minutes may provide relevant signals (in the Bayesian sense) that are incorporated in market expectations as long as they have some forecasting power –whether or not it beats market forecasts. We now present two pieces of evidence that tend to downplay the role of this particular channel.

The first evidence is based on comparing the elasticity of international yields to US short-term rates in days of FOMC announcement compared to other days. Hanson and Stein (2015) argue that non-FOMC days should have a comparably higher share of macro news, vis-à-vis Fed' s reaction-function news (what the Fed will do about the macro news in terms of policy). Conversely, while FOMC days could still reveal macro information, they should have a relatively larger share of reaction-function news. Therefore, if the elasticity of long-term rates to short-term rate movements around FOMC days is driven by macro news, this elasticity should be even stronger during non-FOMC days. They find the opposite.

Based on a similar idea, we calculate the elasticity of long-term rates abroad to changes in US 2-yr yields around specific US macroeconomic release dates, including inflation (CPI), activity (IP), and unemployment announcements –the δ_n^h coefficients in equation (1). Notice that this is an even starker comparison than the one documented by Hanson and Stein (2015), since we select specific US macroeconomic release dates as a benchmark for comparing the elasticities with respect to FOMC days, whereas they use all non-FOMC days as control. Table 5 shows the results. For DEV, all US macroeconomic release dates show a significant comovement between US 2-yr and foreign 10-yr yields (with the bulk of the effects acting through the RN component), but the point estimates are all below the corresponding effects of US MP shocks reported in Table 2. In fact, difference tests reveal that the transmission of US short-term rates to DEV long-term yields is in general significantly larger during FOMC meetings than during US macroeconomic releases. The only exceptions are unemployment releases in the first half of the sample, and activity in the second part of the sample, where the larger coefficient associated with US MP shocks is not statistically significant at 5% confidence levels.

[13]Romer and Romer (2000) document superior performance of Fed forecasts pre 1991, while Gavin and Mandal (2003), and Gamber and Smith (2009), find a deterioration in forecasting advantage when extending the sample up to the early 2000's. Similarly, D' Agostino and Whelan (2008) find that extending the sample leads to forecasting superiority by the Fed only on very short-term (within the quarter) projections of inflation, but not on other macroeconomic variables or forecast horizons.

Table 5: Response of 10-yr yields during US economic releases

a) DEV	Full sample			Pre Oct. 2008			Post Oct. 2008		
	10-yr yield	RN	TP	10-yr yield	RN	TP	10-yr yield	RN	TP
US Inflation	0.186***	0.129***	0.057	0.209***	0.173***	0.036	0.101**	0.031	0.069
	(0.028)	(0.035)	(0.036)	(0.033)	(0.044)	(0.044)	(0.049)	(0.050)	(0.054)
US Activity	0.227***	0.257***	-0.030	0.179***	0.231***	-0.052	0.335***	0.313***	0.022
	(0.024)	(0.036)	(0.038)	(0.027)	(0.042)	(0.039)	(0.060)	(0.069)	(0.093)
US Unempl.	0.305***	0.361***	-0.056***	0.307***	0.376***	-0.069***	0.307***	0.320***	-0.012
	(0.015)	(0.021)	(0.022)	(0.018)	(0.026)	(0.027)	(0.026)	(0.036)	(0.033)

b) EME	Full sample			Pre Oct. 2008			Post Oct. 2008		
	10-yr yield	RN	TP	10-yr yield	RN	TP	10-yr yield	RN	TP
US Inflation	-0.055	-0.011	-0.044	-0.027	-0.036	0.009	-0.174*	0.055	-0.230*
	(0.063)	(0.037)	(0.073)	(0.075)	(0.047)	(0.086)	(0.105)	(0.056)	(0.132)
US Activity	0.037	0.038	-0.001	0.006	0.056	-0.050	0.022	-0.045	0.067
	(0.054)	(0.049)	(0.064)	(0.064)	(0.062)	(0.078)	(0.100)	(0.063)	(0.104)
US Unempl.	0.051*	0.036*	0.015	0.042	0.046*	-0.004	0.085**	0.023	0.062
	(0.031)	(0.021)	(0.038)	(0.040)	(0.027)	(0.049)	(0.040)	(0.029)	(0.050)

The table shows the impact of US economic releases, corresponding to the δ_n^h coefficients of equation (1). The regression is estimated separately for each group of countries: DEV and EME. Standard errors computed using Newey-West correction up to 40 lags (reported in parentheses). *** p-value $<$ 1%, ** p-value $<$ 5%, and * p-value $<$ 10%.

For EME countries, the effect of changes in the US 2-yr treasury around macroeconomic releases is generally not significant, with a few exceptions where small effects are found. Not surprisingly, we find that the impact of US MP on foreign bond yields is significantly higher than the corresponding effect of US macroeconomic releases.

This evidence is thus not supportive of the informational channel. Following the argument in Hanson and Stein (2015), the fact that international yields comove less with US interest rates during US economic releases (days with a larger share of US macro news) than during FOMC meetings suggests that the main driving force between such comovement must be unrelated to the revelation of US macroeconomic fundamentals.

The second piece of evidence we present is based on testing directly whether yield changes during FOMC meetings affect macroeconomic variables in other countries.[14] Here it is important to recognize that, beyond a signaling channel of future macroeconomic conditions, US yield changes may also affect macroeconomic conditions in a causal manner through tighter policy. But notice that these channels are, a priori, associated with opposite signs: while the signaling channel suggests a positive correlation between US yield changes and future macro conditions (i.e., the Fed is tightening policy because it anticipates better macro performance in the US, in turn correlated with activity and inflation abroad), the causal effect predicts a negative relation –a tighter Fed policy, all else equal, is contractionary for other economies, as has been widely documented.[15]

To test this hypothesis we need to adjust to a monthly-frequency empirical strategy to fit in the frequency of macroeconomic releases. We compute the monthly change in the 2-yr US yield and separate it into two components: the change around the FOMC meeting of that respective month (the same measure of US MP shock as above), and the difference between the total change in the rate during the month and the FOMC component. The idea is that

[14] We thank the referee for suggesting this test.

[15] See Kim (2001), and Canova (2005), among others.

the first component captures the surprise component in Fed policy during the month, while the second component incorporates all other information that affected interest rates during the month.[16] That is, at each month t where there is an FOMC meeting, we have $\Delta US\ 2YR_t = FOMC_t + Rest_t$. We then regress different leads of activity and inflation in the countries included in each of our DEV and EME samples using monthly panel regressions. Specifically, we estimate the following model:

$$x_{j,t+h} = \alpha + \beta_1 * FOMC_t + \beta_2 * Rest_t + \gamma * x_{j,t} + \varepsilon_{j,t+h}, \tag{5}$$

where $x_{j,t+h}$ correspond to annual growth rates of realized macroeconomic variables at horizon $t+h$ for each country j (activity and inflation, depending on the regression). Table 6 summarizes the results. We find that increases in US 2-yr rates have a negative effect on future activity and inflation abroad, for both components of the overall change in yields. This suggests that the impact of higher US interest rates on foreign activity and inflation work predominantly through the standard channel –a higher interest rates in the US is contractionary for other countries, consistent with the literature on the international real spillovers of US MP.

Altogether, the evidence presented in this section suggests that, while impossible to completely rule out, the informational channel is unlikely to be the main driver behind the observed comovement between US 2-yr yields and international bond yields at longer maturities. We remark again that the evidence presented here should not be interpreted as against commonality in economic fundamentals between the US and other economies –well documented in other studies–, but merely against the interpretation that FOMC meetings are episodes where significant news about such fundamentals are revealed to the markets.

4.2 The exchange rate channel

By affecting the relative yield of dollar-denominated instruments, US MP drives changes in portfolio positions between US and international assets. In particular, an expansionary US MP shock will, for a given exchange rate, increase the demand for foreign bonds. Within the standard Mundell-Fleming paradigm, the equilibrium response in foreign yields and exchange rates will depend, in turn, on the reaction of foreign central banks. The more other central banks follow the Fed, the narrower the resulting yield differential and the more contained the appreciation of their currencies. We will refer to the effects of US MP shocks on foreign yields that result from this mechanism as the *exchange rate channel*.

As the evidence in section 3 suggests however, the adjustment not only takes place through changes in expected foreign MP (the RN channel), as there are relevant movements in bond term premia. Indeed, several recent papers have emphasized the "risk-taking" channel of US MP. According to this mechanism, an expansionary stance of US MP drives a search for yields in other assets, including longer-maturity US treasuries and higher risk securities (corporate bonds, MBS products), as well as foreign assets.[17] The addition of term premia as a margin of adjustment makes the underlying transmission mechanisms less straightforward than in the standard Mundell-Fleming model.

[16] A related approach is followed by Bernanke and Kuttner (2005), who study the dynamic effects of the surprise component of FFR changes on equity returns using a VAR approach at monthly frequency (see section II of their paper).

[17] See Hanson and Stein (2015), Krishnamurthy and Vissing-Jorgensen (2011), Bruno and Shin (2015), and Rey (2015). The risks being taken through larger international positions include currency risk (Gabaix and Maggiori, 2015) as well as default risk in the case of emerging countries.

Table 6: Response of international macroeconomic variables to US monetary policy

a) DEV

	Inflation				Activity			
	Pre Oct. 2008		Post Oct. 2008		Pre Oct. 2008		Post Oct. 2008	
h	FOMC	Rest	FOMC	Rest	FOMC	Rest	FOMC	Rest
1	-0.367**	0.236***	-0.046	0.100	-3.004**	0.219	3.353	-1.999
2	-0.062	0.170**	-0.083	0.350**	-2.274	1.349***	-2.901	0.465
3	0.094	0.083	-0.158	0.273	-5.219***	-0.505	0.603	1.830
4	-0.026	-0.107	-1.099	0.281	-3.682**	1.913***	0.455	0.145
5	-0.106	-0.192**	-0.453	0.209	-5.684***	0.301	0.096	1.867
6	-0.460**	-0.305***	-0.311	0.202	-4.750***	-0.654	8.753	3.771
7	-1.141***	-0.391***	-0.753	0.158	-4.988***	-0.223	1.181	-1.040
8	-2.143***	-0.427***	-0.538***	0.221	-4.967**	-2.338***	4.017	1.526
9	-1.649***	-0.252***	-0.440**	0.135	-5.171***	-1.904***	6.281	4.161
10	-0.516*	-0.078	-1.288**	0.283*	-3.677**	-1.151	1.643	2.021
11	0.140	-0.105	-1.290*	0.139	-1.407	-0.977*	-4.176	3.514*
12	-0.082	-0.031	-1.381*	-0.039	1.932	-0.041	-6.630	-1.564

b) EME

	Inflation				Activity			
	Pre Oct. 2008		Post Oct. 2008		Pre Oct. 2008		Post Oct. 2008	
h	FOMC	Rest	FOMC	Rest	FOMC	Rest	FOMC	Rest
1	-0.066	0.338***	1.031	-0.039	-4.509**	0.155	-14.099***	-2.041
2	-0.035	0.375***	1.629	0.782***	-2.249	2.384***	-7.534	-4.115***
3	-0.191	0.385**	1.063	0.757**	-6.189***	-0.911	-6.714*	-0.785
4	-0.661	0.126	1.074	0.519	-3.746**	2.061***	-14.261***	-3.400**
5	-1.256***	-0.124	1.091	0.605	-7.087***	0.458	-14.949***	-3.970***
6	-1.533***	-0.309	0.941	0.686	-0.076	-1.110*	-0.209	-0.815
7	-1.555***	-0.413*	0.132	0.148	-4.683**	-0.567	4.840	-1.473
8	-2.003***	-0.398*	0.989	0.397	-3.023	-3.129***	-2.076	-0.503
9	-2.209***	-0.357*	-0.037	0.466	-6.318***	-1.464**	-0.212	-1.357
10	-1.485**	-0.234	-2.900*	-0.042	-1.867	-0.813	12.929***	-0.817
11	-0.363	-0.004	-1.873	-0.108	2.743	0.043	-3.996	2.279**
12	-0.397	-0.021	-2.329	-0.194	7.329***	1.268*	3.340	0.235

The table reports the impact of changes in the components of the US 2-yr rates defined in equation (**??**) for a given month (in bp), in effective inflation and activity data h-months ahead (also in bp) –the β_1 and β_2 coefficients in equation (5). Standard errors computed using Newey-West correction up to 40 lags (reported in parentheses). *** p-value $<$ 1%, ** p-value $<$ 5%, and * p-value $<$ 10%.

In particular, it is not obvious whether the relevant interest rate differential behind exchange rate pressures are expected MP rates (the RN component) or overall yields, nor why the reaction in yields components differs across country groups.

To provide a coherent interpretation of the *exchange rate channel* in the context of our previous results, A presents a model about the international transmission of US MP that extends the framework developed in Blanchard, Adler, and Carvalho Filho (2015). In that paper, imperfect substitutability between international assets drives capital flows across countries in response to interest rate differentials. Their analysis stresses how two main tools used by central banks to confront flows –standard MP and (sterilized) exchange rate interventions (FXI henceforth)– have different effects on interest rates, exchange rates, and the resulting capital inflows in equilibrium. To illustrate, consider the case of a capital inflow into country-j (for example, as a response to an expansionary US MP shock). If the central bank remains inactive, capital inflows that respond to interest differentials will be large, and so will be the appreciation of the domestic currency. In contrast, a MP response that narrows the interest rate differential would contain inflows and exchange rate pressures. Yet the central bank could confront the same situation through direct FXI (buying USD in this case), and may in principle control both exchange rate and short-term interest rate movements –to the extent that sterilized interventions have meaningful effects on the exchange rate. However, the authors show that such policy response will increase the resulting capital inflows in equilibrium, as the market stabilization mechanism that would normally act through a currency appreciation (and the ensuing expected depreciation) is inhibited by the intervention.

Our model extends this framework by including a long-term bond market in each country. This allows us to study the effects of US MP shocks on interest rates at longer maturities, as well as their RN and TP components. In the US bond market, long-term yields are connected to short-term policy rates both through RN rates and term premia, where this last term is influenced by a risk-taking factor. This risk-taking factor is in turn a negative function of US MP. The model assumes that overall capital inflows to other countries depend endogenously on interest rate differentials against the US in both short and long-term bonds. In particular, there are foreign investors in the long-term bond market whose demand is a positive function of yield differentials against the US, net of the expected depreciation of the domestic currency. Implicit in this assumption is the notion that US and international assets are imperfect substitutes, and that lower yields in US bonds incentivize larger risk-taking in foreign bonds. Also, MP in the receiving country responds to the exchange rate (i.e., is reduced following a currency appreciation against the USD), which can be rationalized from inflationary pressures (exchange rate pass-through) or trade balance concerns. In addition, the central bank may choose to intervene the FX market by buying/selling USD against capital inflows/outflows. The equilibrium of the model is pinned down by a balance of payments equilibrium condition in which capital inflows net of FXI must finance the trade balance deficit. In the equilibrium, the main objects of interest in the model are linear functions of US MP shocks.

We now briefly summarize the main results of the model, their implications for interpreting the evidence presented in Section 3, and the additional testable predictions they deliver (which we test below). Following a negative US MP shock that increases the global risk-taking factor, capital flows into the US and country-j's long-term bond markets. The equilibrium level of capital inflows is a function of country-j's prevailing interest rate differentials in both short- and long-term securities. The effect on the main endogenous variables depends, in turn, on the reaction of policy in the receiving country, as summarized in propositions 1 and 2 in the model of A, which we reproduce here for convenience.

Proposition 1: *In reaction to an expansionary US MP shock, a higher sensibility of domestic MP to exchange rate fluctuations in country-j will imply a) a weaker appreciation of the currency against the USD; b) a weaker response of capital inflows; c) a stronger effect in the RN component of long-term yields, and d) an ambiguous effect in the TP component of long-term yields.*

The intuition for these results is as follows. In response to a more expansionary US MP, a central bank that reacts more to the ensuing appreciation of the currency by changing its own MP will tend to narrow interest rate differentials. This will contain capital inflows (part b) and reduce the resulting appreciation of the currency (part a). The effects on the long-term bond market are less obvious, however. Because foreign investors in the domestic bond market trade off positive interest rate differentials against an expected depreciation of the domestic currency going forward, the equilibrium response in long-term yields will be larger whenever the initial appreciation is contained by the action of domestic MP. Hence, overall yields fall by more. On the other hand, a stronger reaction of domestic MP mechanically implies a larger response of expected MP into the future, implying a larger elasticity of the RN component of long-term yields (part c). The effect on the TP component, which is the difference between yields and the RN component, is therefore ambiguous (part d).

Proposition 2: *In reaction to an expansionary US MP shock, a higher degree of central bank FXI in country-j will imply a) a weaker appreciation of the currency against the USD; b) a stronger response of capital inflows; c) a weaker effect on the RN component of long-term yields, and d) a stronger effect in the TP component.*

To understand this prediction, notice that if central banks intervene more, any given level of capital inflows will have a weaker effect on the domestic currency (part a). Since a currency appreciation (and the ensuing expected depreciation) in response to foreign inflows is a market force that tends to deter such flows, FXI strengthen flows precisely by dampening the corrective response played by exchange rates (part b). At the same time, a weaker impact on the exchange rate implies a more muted response of the standard MP tool (for a given value of the MP response parameter), reducing the sensitivity of the RN component (part c). But this implies that the adjustment in domestic long-term yields, which drop even more under FXI due to the surge in capital inflows, must be made to a larger extent by a compression of the TP component (part d).

The evidence presented in Section 3 documents only the reaction of yields and their components to US MP shocks, and thus allows at least two different interpretations in the context of the model. First, according to proposition 1, the relatively weak response of RN rates in EME might reflect a lower sensitivity of domestic MP to currency movements in these countries relative to DEV. However, such policy reaction would imply a stronger response of exchange rates to US MP shocks in EME. The alternative hypothesis is that central banks in EME are more prone to use FXI. According to proposition 2, this would also explain a weaker response of RN rates, but now as a result of lower effective currency movements and not from a lower sensitivity of domestic MP to exchange rate fluctuations. In addition, such response would amplify the response of capital inflows to EMEs, generating unambiguously larger movements in long-term yields concentrated in the TP component.

A priori, the predictions from proposition 2 seem to square better with the empirical evidence. Indeed, central bank interventions in FX markets have been widely documented for emerging economies, where managed floats are much more common than in developed countries. Table 12 in B includes a survey of the available evidence about FX intervention activity for all the countries in our sample, confirming this view. Moreover, recent literature shows that, once endogeneity issues are properly addressed (using high frequency intra-day data), interventions appear to be an effective exchange rate stabilizing tool, at least in the short term.[18] This prediction is also consistent with the evidence reported in Section 3, which shows a stronger response to US MP shocks in the TP component of yields for EME relative to DEV.

To further distinguish between these predictions, we now provide evidence of the two additional endogenous variables not addressed thus far, namely the reaction of exchange rates and capital flows around US MP events. Table 7 shows the impact of US MP shocks on exchange rates. The results are from a regression that replaces the interest rate variables of the left-hand-side of equation (1) with the cumulative NER response for each country over the same interval around the FOMC meeting. The NER is in units of foreign currency per USD, so an increase is a depreciation against the dollar. We find highly statistically significant effects of US MP shocks on exchange rates for the DEV sample. Specifically, a 10 bp US MP shock would depreciate the exchange rate in the DEV sample by about 75 bp in the full sample, an effect that has increased from 55 bp in the first half to 109 bp in the period post October 2008. For EME, we also find statistically significant effects, although of smaller magnitude. The full sample coefficient is just 33 bp, increasing from 16 to 66 bp when comparing both sub-periods. In short, exchange rates react in the anticipated direction in both groups of countries, although the effect is roughly half as large for EME. [19]

Table 7: US monetary policy and exchange rates

	Full sample	Pre Nov. 2008	Post Nov. 2008
DEV	7.50***	5.47***	10.92***
	(0.45)	(0.39)	(0.83)
EME	3.52***	1.93***	6.66**
	(0.44)	(0.49)	(0.77)

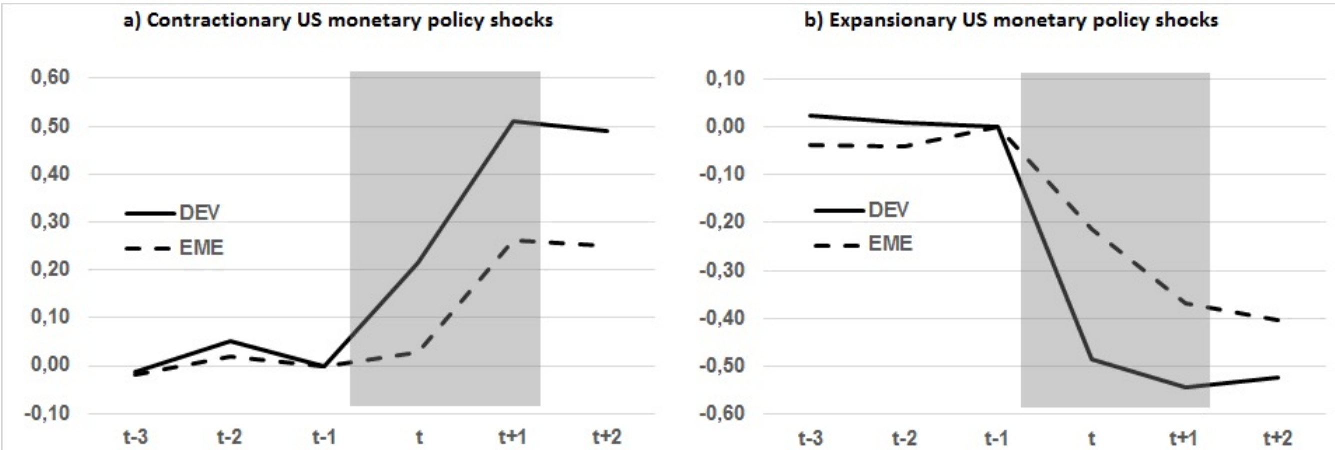
The table reports the impact of a 1 bp change in the US 2-yr rate on nominal exchange rate changes during the MP event window. The exhange rate is defined as units of the domestic currency per USD (an increase is a depreciation against the dollar). The coefficients are in bp. Standard errors computed using Newey-West correction up to 40 lags (reported in parentheses). *** p-value $< 1\%$, ** p-value $< 5\%$, and * p-value $< 10\%$.

One possible concern with this empirical strategy is that exchange rates could anticipate MP shocks. Previous research has pointed out that FFR futures tend to correctly anticipate most of Fed policy changes (Cochrane and Piazzesi, 2002). A recent paper by Karnaukh (2016) documents that, while the anticipation in FFR futures happen several days in advance, the exchange rate reacts only about 2 days prior to the actual change (when the Fed tightens policy, the USD appreciates, and vice-versa). If exchange rates react in anticipation of our MP events, our 2-day

[18] In fact, all but three countries in the DEV sample follow clean floating regimes, and within these exceptions, both the Czeck Republic and Switzerland have used the euro as a reference currency, making them clean floaters against the USD. For further evidence about FXI activity and its effectiveness in emerging markets see Sarno and Taylor (2001), Levy-Yeyati and Sturzenegger (2003), Husain, Mody, and Rogoff (2005), Menkhoff (2010), Ghosh, Ostry, and Chamon (2016), and Fratzscher, Gloede, Menkhoff, Sarno, and Stöhr (2017).

[19] Evidence of weaker exchange rate effects in emerging countries is also found in a recent paper by Hausman and Wongswan (2011), which use an event study methodology similar to ours but for an earlier time period. They find that, generally, the USD depreciates following a US MP easing, but significantly so only against developed currencies.

Figure 2: Exchange rate movements around US MP shocks



The figure plots the response (in percentage) of nominal exchange rates around FOMC meetings, measured as domestic currency per USD (an increase is an appreciation of the dollar). Values correspond to simple averages across all events in the complete sample within a country group, and are normalized to zero one day before the meeting (t-1). We split episodes into positive (panel a) and negative (panel b) US MP shocks.

window centered at the meeting could miss some of the action, and the results from the previous table would be misleading about the overall effects of US MP on foreign currencies.

To address this concern, Figure 2 plots the reaction of the USD against the currencies in each country group over a wider window range. Panel a) plots the average reaction over all episodes in which the US MP shock is positive, while panel b) presents the results for negative shocks (the effects on exchange rates are not normalized by the MP shock, so they should not be interpreted as elasticities, as in Table 7). Consistent with the coefficients in Table 7, the dollar appreciates for positive US MP shocks, and vice-versa. Crucial for our concern, the figure shows that prior to the beginning of the episode there is virtually no reaction in exchange rates. This is to be expected given the design of our event study, where MP shocks are defined as movements in short-term rates within the narrow window around FOMC meetings. Since this definition of MP shocks are, by construction, not anticipated by bond prices, they are not priced in by exchange rates either.[20]

Turning to flows, we run an event-study panel regression similar to the baseline exercise but using as dependent variable the net fund inflows into fixed-income securities for each country in the sample. We use EPFR data at weekly frequency, so the identification is less clean in this exercise than in the baseline regressions.[21] We define the US MP surprise as the change in 2-yr treasury yields around the week of the FOMC meeting and compute the net flows that occurs during the corresponding week. We use flows in levels, as well as normalized by nominal GDP and the value of bonds outstanding to control for the size of the corresponding fixed-income market.[22] Because systematic data on portfolio inflows is generally not available for the earlier sub-sample, we present results for the post October 2008 period only.

[20] We thank the anonymous referee for suggesting this test. To formalize the results presented in table 7, we run a similar regression but using a wider window of up to 2 days earlier than in the baseline regression, finding virtually identical cumulative effects on exchange rates. For space considerations we do not report this results here, but they are available upon request.

[21] The data covers all fixed-income flows, including government and corporate bonds, as well as other fixed-income securities.

[22] We use data on the stock of government debt denominated in domestic currency from the BIS: http://www.bis.org/statistics/totcredit.htm.

Table 8: US monetary policy and fixed-income flows

Units	Deflator	DEV	EME
MM USD	None	-154.971**	-92.682**
percent	GDP	-0.016**	-0.019*
percent	Government Debt	-0.041*	-0.057**

The table reports the impact of a 1 bp change in the US 2-yr yield in the week of each FOMC meeting, on net fixed income flows using weekly data from EPFR. The regressions include year-month fixed-effects. Standard errors computed using Newey-West correction up to 40 lags (reported in parentheses).*** p-value < 1%, ** p-value < 5%, and * p-value < 10%.

The main results of this exercise are shown in Table 8. The effect of US MP shocks on portfolio flow levels is significant for both groups of countries, and actually larger for DEV. However, flows normalized by either GDP or amount of bonds outstanding reveal that the relative effects on flows is larger for EME, in particular when using bonds outstanding as deflator.[23]

This additional evidence helps to draw a more coherent interpretation about the mechanisms underlying the joint behavior of exchange rates, capital flows, and long-term yield components in reaction to US MP shocks. Consistent with proposition 2, the stronger reaction of the RN component in DEV and the dominance of the TP component in EME in response to US MP shocks seem to reflect different policy responses. In particular, more pervasive FXI in EME imply a more muted response of the exchange rate but an amplified response of capital flows and the TP component of long-term yields in response to US MP shocks. In the case of DEV, the absence of FXI is consistent with a stronger effect on the exchange rate, a weaker effect on flows, and a reaction of long-term yields concentrated in the RN component.

A natural question that arises is why some countries find it desirable and/or feasible to choose FXI as a policy response, while other countries –mostly developed economies, as documented in table 12 in B– follow clean floats. Answers to this question can be found in several papers that study the predominance and effectiveness of FXI policies in different countries. Ghosh, Ostry, and Chamon (2016) conjecture that both the desirability and the feasibility of managing the exchange rate through sterilized interventions might differ between emerging and developed countries. Regarding their desirability, they note that exchange rate fluctuations tend to have larger macroeconomic effects in emerging countries for reasons that include more prevalent borrowing in foreign currency and financial markets with less scope for effective currency hedging. The resulting currency exposure of balance sheets in the financial and real sectors can prove highly disruptive in episodes of large exchange rate fluctuations. Besides from financial stability concerns, the evidence also generally documents a larger degree of exchange rate pass-through to domestic prices for emerging countries, suggesting currency interventions are used by central banks in these economies to help achieve their inflationary goals.[24] These arguments provide a rationale for the resistance to clean floating exhibited by many

[23] Ideally, flows should also be normalized by measures of bond market liquidity, which unfortunately are not available in a systematic manner for our sample. Arguably, adjusting for liquidity should reinforce the conclusions, to the extent that fixed-income markets in developed countries are generally viewed as more liquid.

[24] See Bussière, Delle Chiaie, and Peltonen (2014), and Carranza, Galdon-Sanchez, and Gomez-Biscarri (2009).

EMEs, explaining why they might be inclined to seek both MP independence and exchange rate stability through sterilized FXI.

With respect to its feasibility, Ghosh, Ostry, and Chamon (2016) argue that the size of central banks' foreign reserves, relative to normal currency transaction volumes, is typically much larger in emerging economies. This suggest that, using a relatively small fraction of their balance sheets, central banks in these countries can have a meaningful impact in the value of their currencies through direct FX interventions. For developed economies, in contrast, cross-border flows are likely to respond much more strongly to interest rate differentials against the US given the closer degree of asset substitutability. This implies that the size of interventions needed to make even a minor dent on the exchange rate may simply be too large to make it a viable option. This argument also features prominently in earlier papers such as Rogoff (1984) and Dominguez (1990), among others.

4.3 Discussion

We now relate our findings with two important strands of literature in international finance. The first is the relation with the Mundell-Fleming paradigm as a benchmark to understand the effects of changes in international interest rates on domestic nominal and real variables in the presence of imperfect capital mobility. We briefly highlight the main differences between the predictions of that model and our framework regarding the effects of policy choices by central banks in dealing with international MP shocks. The second is the literature documenting the failure of the UIP condition –the so called forward discount puzzle. We briefly review some of its main findings, emphasizing the consistency with our results and the implications for the spillover mechanisms in our model.

In its simplest form, the Mundell-Fleming model with imperfect capital mobility predicts that a contractionary MP shock in core economies will affect nominal and real variables in a particular country depending on the reaction of its monetary authority. If the domestic central bank moves the MP rate one-to-one, the model predicts a complete stabilization of the exchange rate, but at a rather high cost to domestic output. In contrast, a central bank that keeps the domestic interest rate constant, and absent any form of FX intervention, will induce a pressure on capital outflows that will depreciate the domestic currency. In equilibrium, this improves the trade surplus. Flexible exchange rates hence play a role in cushioning part the negative effect of higher foreign interest rates by enhancing external demand. While the model in A does not include aggregate demand, its predictions on exchange rates align well with the standard framework in this case –the flexible exchange rate case– suggesting they would play a similar absorption role in a general equilibrium framework with endogenous output. Naturally, since our model includes a long-term bond market and allows for adjustment in term premia, it will deliver somewhat richer predictions regarding the effect of different MP actions at different segments of the yield curve. In its core predictions however, the general message regarding the tradeoffs involved in setting interest rates in response to MP spillovers abroad would not markedly differ from the standard model.

Where our model does departs from this framework is regarding the implications of FXI policies. If the domestic Central Bank wants to keep MP unchanged and at the same time limit the exchange rate adjustment through FXI, it must fully compensate for the capital outflow consistent with a lower interest rate differential. Since in the standard model aggregate demand depends only on short-term interest rates and exchange rates, this combination of policies would appear to be effective in stabilizing both nominal and real variables. In our model, the inclusion of a long-term bond market opens an additional channel that breaks this result. As discussed above (prediction 2 in section 4.2), while FXI can achieve both a stabilization of the MP rate and the exchange rate, they cannot control long-term yields. Our model highlights that stabilizing the currency through FXI will indeed amplify the effect of yield differentials on capital flows, thus enhancing the endogenous response of term premia. To the extent that aggregate demand depends on the whole structure of interest rates, this policy reaction will not be able to isolate the real economy from the external shock. This is the key mechanism that arises in our model which is absent from the Mundell-Fleming paradigm. We believe this additional mechanism should be added an important consideration when evaluating the pros and cons of FXI policies.

Our results should also be contrasted with the literature documenting the forward discount puzzle, specifically regarding its implications for the validity of the underlying spillover mechanisms highlighted by our model. A large number of studies have investigated the dynamic effects of US MP shocks on exchange rates, including Clarida and Galí (1994), Eichenbaum and Evans (1995), Kim and Roubini (2000), and Scholl and Uhlig (2008), among others. All these studies focus on advanced countries, and differ in terms of the particular structural identification strategy chosen within vector autoregression models. Consistent with our results, these papers generally find that an expansionary US MP shock depreciates the USD, but their different identification strategies translate into varying results regarding the persistence of exchange rate dynamics –that is, whether the exchange rate exhibits immediate or delayed overshooting– , and thus into distinct predictions for the forward discount puzzle.

Regarding the implications of this evidence on the spillover mechanism highlighted by our model, it's important to stress that as long as an expansionary US MP shock results in an inflow of capital into other countries –and that such inflow in turn depends on the policy reaction by monetary authorities in that country–, our qualitative predictions regarding the impact on long-term yields would remain largely unchanged irrespective of whether the depreciation of the USD is sudden or gradual. This distinction is obviously important for whether or not MP shocks are associated with the forward discount puzzle, but as long as both scenarios imply a positive inflow into fixed-income markets to other countries, they both predict a narrowing of term premia abroad, thus explaining the spillover to long-term yields documented in section 3. In other words, our results do not hinge on whether the UIP condition holds in the data, but rather in whether fixed-income flows follow the direction of yield differentials in response to US MP shocks, and whether those flows are in turn affected by FXI.

A related literature focuses on the forward discount puzzle in more detail, but abstracting from the identification of MP shocks. Bansal and Dahlquist (2000) find evidence of the puzzle for developed economies, but not for their sample of emerging countries. Lustig, Roussanov, and Verdelhan (2014) show that a positive interest rate differential against the USD in a basket of advanced economies forecasts positive excess returns of these currencies. They propose an affine model in which high interest rates differentials against the USD take place when the US economy is hit by shocks which increase the volatility of the stochastic discount factor (SDF) relevant for US investors. In equilibrium, US investors require larger compensation for buying foreign bonds in these states of nature, which explains their higher returns. At face value, these studies do appear to be in tension with the mechanism of our model, since lower rates in the US are associated with higher, not lower, risk premia in foreign currencies.

The tension between these results and our findings can perhaps be resolved by noticing that a low interest rate environment in the US and an expansionary US MP *surprise* may well have different asset pricing implications.

In line with the argument in Lustig, Roussanov, and Verdelhan (2014), a low interest rate environment may be the consequence of a relatively weak US macroeconomy, one in which US investors must be compensated with higher excess returns in order to invest in foreign instruments. But within this environment, a MP decision and/or communiqué by the Fed that is perceived more expansionary than what could be anticipated from economic fundamentals –the notion of MP shocks captured by our methodology– may well incentivize investors at the margin to build up larger positions in foreign securities offering higher yields. This is consistent with a USD that depreciates on impact, in line with our results. The key distinction here is that that macroeconomic fundamentals, by pinning down the moments of the SDF, drive both interest rates in the US and international risk premia. On the other hand, *shocks* to US MP above and beyond fundamentals need not affect the SDF and therefore may well incentivize flows into foreign securities due to their higher relative yield. It should be stressed that this mechanism is not only consistent with our model and results, but also with the existing literature studying the "risk taking channel" of US MP cited above.

Supportive evidence in this regard is also provided in the aforementioned paper by Karnaukh (2016). She documents that the delayed reaction of the dollar vis-à-vis FFR futures in anticipation of rate changes actually goes "in the right direction" that is, the dollar depreciates when FFR futures are pricing in a rate cut. Moreover, she finds that during days when either no FOMC meetings take place, or during those meeting in which the rate is expected to be maintained, the results align closely with Lustig, Roussanov, and Verdelhan (2014); namely, higher rates against the USD forecast higher returns of holding foreign currencies – the forward discount puzzle. But in episodes in which futures are pricing in a change in the FFR, the evidence fails to reject the UIP condition.

While it is beyond the scope of this paper to provide a full-fledged analysis about the conditions under which the UIP relation is upheld or violated, it is interesting to note that the results of this paper, as well as those from related event studies focused on US MP shocks, suggests that the logic of interest rate arbitrage seems to square better with the evidence during days in which significant information about MP is reveled to markets. This interpretation is reminiscent of the results in Savor and Wilson (2014), who robustly document the success of standard asset pricing theories, such as the CAPM, during days in which important macroeconomic news are scheduled for announcement. Further inquiry into this issue seems an important topic for future research.

5 Robustness

We now briefly describe different robustness checks we perform to our baseline econometric specification. For space considerations, we focus mostly on the coefficients related to US MP spillovers for overall 10-yr yields and their components. The main tables are included in C.

A first robustness check involves sample selection. To ensure that our main results are not driven by outliers, we run equation (1) excluding iteratively one country from each group (for example, we run the regressions for DEV without Japan, then put Japan back in and exclude Sweden, and so forth). These results are reported in Table 13. The main conclusions remain unaltered, namely, US MP spillover effects are larger in the post October 2008 data, with similar point estimates for both DEV and EME samples. Moreover, these effects are much more tilted towards changes in the TP component in the case of EME.

The second set of robustness tests include different fixed effects in the panel regression of equation (1), as well as alternative windows for clustering standard errors (in this case, the differences arise only in the significance of point estimates). These results are reported in Table 14. For ease of comparison, the third column of the table reproduces the spillover effects on long-term yields in the baseline regression from Table 2. The point estimates from using alternative fixed-effects change only marginally. While the significance of the coefficients drop in some specifications, it is always the case that the impact of US MP shocks on long-term yields is significant at 5% confidence levels, and its point estimate larger in the post October 2008 period. In the DEV sample, the effect of US MP shocks on RN rates is always associated with a larger point estimate than the effect on TP, and the significance of the former effect is always larger than a 5% p-value, while in some specifications the significance on TP falls below the 5% threshold. For EME, the point estimate on TP is always larger than the effect on the RN component (both significant at 5% across specifications). Thus, our main conclusions are maintained in these exercises.

A third robustness exercise deals with the methodology for decomposing yields into their RN and TP components. In Table 15 we reproduce our main regression in Table 2 using the affine term-structure model of Joslin, Singleton, and Zhu (2011). Its main difference with the methodology of Adrian, Crump, and Moench (2013) is that the prices of risk associated with the factors driving the yield curve are estimated jointly with the parameters of the VAR in equation (2) using maximum likelihood.[25] Our main quantitative and qualitative results regarding the relative contribution of yield components for both the DEV and EME samples remain unaltered under this alternative decomposition methodology.

A fourth robustness check involves using a tighter window for defining the US MP shock. Indeed, the choice of the appropriate window involves non trivial tradeoffs: while shorter windows help identification by reducing overlap with other events, they also allow less time for the market to digest the relevant information that may be contained in FOMC minutes. Table 16 reports the regression results of Table 2, but defining the US MP shock as the change in the 2-yr US treasury between (the closing of) the day before and the same day of the FOMC meeting (as opposed to the day after the FOMC statement). Once again, the main qualitative results are maintained, with very minor differences in the point estimates.

As the final robustness exercise, we use alternative definitions of the interest rate chosen as a measure of US MP shocks. Table 17 replicates the main regression results of Table 2, but using the change of the 1-yr treasury around the FOMC meeting, as opposed to the 2-yr treasury used in the baseline specification. In general, the point estimates are larger, but the qualitative results from the baseline regression remain unaltered. Essentially, the 1-yr and 2-yr treasury yields have a very strong correlation (0.76 in the complete sample), but the standard deviation of the former is about 60% of the latter in the post October 2008 period, which explains the larger estimated elasticities when the 1-yr rate is used. We prefer to use the 2-yr rate in our baseline regressions as it is more likely to capture the stance of US MP in the medium term. This is especially relevant post October 2008, when changes in the tone of Fed policy often did not involve revisions in market expectations about the FFR in the coming 12 months.[26] Other

[25] For further discussion of the differences between methodologies, see Section 2.5 of Adrian, Crump, and Moench (2013).

[26] This is particularly the case in some FOMC statements associated with *forward guidance*. For example, in the FOMC meeting of Aug. 2011, the press release stated: "The Committee currently anticipates that economic conditions... are likely to warrant exceptionally low levels for the federal funds rate at least through mid-2013." At that meeting, the 1-yr rate fell only 3 bp, less than half the effect on the 2-yr rate. Furthermore, the 2-yr maturity is also used in other related studies, such as Hanson and Stein (2015) and Gilchrist, Yue, and Zakrajsek (2016), which makes results easier to compare.

authors have used changes in the short-term FFR futures (typically the next month contract) as an alternative measure of MP shocks, either directly (as in Bernanke and Kuttner, 2005), or indirectly as instruments (Gertler and Karadi, 2015). Table 18 contains the results from using 1 year-ahead FFR futures. Alternative 1 defines the MP shock as the change in the futures around the 2-day window, while Alt. 2 uses the change in futures as an instrument for the change in the 2-year yield. Results are quantitatively quite similar to the baseline regression.[27]

6 Conclusions

We document the presence of significant US monetary policy spillovers to domestic bond markets in a sample of 24 countries, including 12 developed and 12 emerging market economies. We rely on an event study methodology where US monetary policy shocks are identified with the response of short-term US treasury yields within a narrow window of FOMC meetings, and trace its consequences on international bond yields using panel regressions. We decompose yields for each individual country into a risk- neutral component, which captures the expected evolution of short-term rates, and bond term premia, in order to better understand the channels underlying such transmission. We find that US MP spillovers are statistically and economically significant for both developed and emerging market economies, and have become relatively larger after the global financial crisis. These spillovers are comparable in magnitude with the impact of other economic events that move international yield curves, including domestic monetary policy shocks and economic releases in each country.

While the size of spillovers is comparable across country groups, our results suggest they operate though different mechanisms, being concentrated in the risk-neutral component of yields (expected policy rates) in the case of developed economies, but predominantly on term premia for emerging countries. We test two alternative theories as possible explanations. The evidence presented is in general not supportive of an *information channel*, through which FOMC meetings reveal US economic fundamentals that might correlate with conditions abroad. We find more support for a *exchange rate channel*, according to which changes in Fed policy (as anticipated by the market) present a tradeoff to foreign central banks between narrowing interest rate differentials and experiencing exchange rate movements.

Importantly, the evidence suggests that developed and emerging countries react to this tradeoff with different tools. In particular, the patterns of relatively weak exchange rate movements, stronger sensitivity of capital inflows into domestic fixed-income markets, and a response of long-term yields tilted towards term premia, suggests emerging economies respond to US MP shocks and the ensuing capital flows by intervening the FX market, a behavior documented in numerous studies. Developed countries, on the other hand, display patterns associated with monetary policy responses under flexible exchange rate regimes –weaker capital flows, stronger exchange rate effects, and yield movements tilted towards risk-neutral rates. These results suggest that while FXI can be effective in stabilizing both short-term interest rates and exchange rates in some countries, they deflect the burden of adjustment into long term yields through endogenous changes in term premia.

With this evidence in hand, we conclude that bond markets around the globe are quite responsive to US monetary policy shocks. However, the evidence suggests that the effects on capital flows and domestic asset prices depend

[27] We prefer the use of the 1-year ahead FFR future due to the aforementioned reason that shorter maturity contracts (as used by Bernanke and Kuttner, 2005) are essentially flat for a considerable part of the post-2008 sample.

importantly on the set of tools through which foreign monetary authorities respond to these shocks, at least as expected by financial market participants. In particular, our results cast new light into the cost-benefit analysis behind the desirability of currency intervention policies.

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Appendix

A A model of US MP Spillovers

This appendix develops a model to understand the international transmission of US MP and guide the interpretation of the results documented in the main text. The building blocks of the model follow Blanchard, Adler, and Carvalho Filho (2015), who consider the effects of international capital flows on domestic exchange and interest rates as a function of country-specific policies, including MP and (sterilized) foreign exchange interventions (FXI).

We augment that model to capture the following key features. First, we assume that US MP affects investment flows into fixed income markets through to a *risk-taking channel*, modeled as a price-inelastic demand component for long-term bonds in the US. Second, in each country, fund flows are allocated both in the short-term money market (at the MP rate) and in the long-term bond market, depending on the yield differential relative to its US equal maturity bond, net of expected fluctuations in the value of the domestic currency. As in Blanchard, Adler, and Carvalho Filho (2015), central banks react to shocks with two policy choices: standard MP (equal to the interest rate of short-term, domestic bonds) and (sterilized) FXI. In equilibrium, the nominal exchange rate, as well as yields and their components, are pinned down by the balance of payments equilibrium condition. We now provide the details of the model.

US MP and long-term US yields

US MP follows an autoregressive process, normalized at a long-run mean of zero,

$$i_t^* = m_t^* \ , \qquad \text{with} \quad m_t^* = \rho \cdot m_{t-1}^* + \varepsilon_t^*. \tag{A.1}$$

US MP affects the evolution of a "risk-taking factor" z_t^* through

$$z_t^* = -i_t^*. \tag{A.2}$$

Besides from the short-term bond that yields the MP rate i_t^*, there is a long-term bond market composed of h-year zero coupon bonds (i.e., $h = 10$ years in our empirical setup). The demand for US h-yr zero-coupon bonds has an endogenous component that depends positively on the yield (negatively on the price), and a price-inelastic component given by z_t^*. For simplicity, we normalize bond supply to zero, leading to a bond-market equilibrium condition

$$0 = \beta^* y_t^{*(h)} + z_t^*. \tag{A.3}$$

The h-year yield in (A.3) and its decomposition into RN and TP components is then given by

$$y_t^{*(h)} = m_t^*/\beta^* = RN_t^{*(h)} + TP_t^{*(h)}, \quad \text{with} \quad RN_t^{*(h)} \equiv \frac{1}{h} E\left[\sum_{s=0}^{h-1} i_{t+s}^* | \Omega_t\right]. \tag{A.4}$$

Ω_t denotes the information set, common to all agents, which consists of all current state variables. Using equations

(A.1) through (A.4) we arrive at

$$RN_t^{*(h)} = m_t^* \left(\frac{1-\rho^h}{h(1-\rho)} \right), \text{ and} \tag{A.5}$$

$$TP_t^{*(h)} = m_t^* \left(\frac{1}{\beta^*} - \frac{1-\rho^h}{h(1-\rho)} \right). \tag{A.6}$$

Country-j block

The net private capital inflows (NPKI) into country j consist of foreign portfolio allocation into short-term (1-year) and long-term (h-year) bonds. Each flow is proportional to the bond yield differential with respect to its US equal-maturity counterpart, net of the expected depreciation rate of j' s currency over the corresponding horizon (we omit j-superscripts below for notational simplicity). Assuming the same elasticity of flows to yield differentials across maturities, the level of NPKI is given by

$$NPKI_t = \underbrace{\alpha \left(i_t - i_t^* - \left(e_t - E\left[e_{t+1} | \Omega_t \right] \right) \right)}_{\text{allocation into short-term bond}} + \underbrace{\alpha \left(y_t^{(h)} - y_t^{*(h)} - \left(e_t - E\left[e_{t+h} | \Omega_t \right] \right) \right)}_{\text{allocation into long-term bond}}, \tag{A.7}$$

where e_t is the (log of) value of one unit of domestic currency (an increase in e_t stands for an appreciation against the US dollar).

The interest rate of the 1-year bond is set by the central bank according to the rule

$$i_t = -d \cdot e_t + m_t \text{ ,with } m_t = \psi \cdot m_{t-1} + \varepsilon_t. \tag{A.8}$$

Equation (A.8) captures in a stylized manner the reaction function of domestic central banks to exchange rate movements. To stabilize the currency, central banks raise MP rates following a depreciation against the US dollar, and vice-versa. This stabilization motive, whose strength is captured by the parameter d, could reflect domestic MP reaction to inflationary pressures (due to exchange rate pass-through). It can also be rationalized as a direct exchange rate objective, due to trade balance and/or financial stability considerations.[28]

Besides traditional MP, the central bank in country j may choose to stabilize the currency by directly intervening the FX market in the opposite direction of the net private capital flows. Following Blanchard, Adler, and Carvalho Filho (2015), we assume an offset parameter ϕ, such that

$$FXI_t = -\phi \cdot NPKI_t, \tag{A.9}$$

and we assume that the trade balance depends negatively on the value of the domestic currency,

$$CA_t = -\gamma \cdot e_t. \tag{A.10}$$

[28]Implicitly, the central bank adjusts the supply of short-term bonds in order to reach the desired one-period rate.

We can now write the balance of payments equilibrium condition as

$$NPKI_t + FXI_t + CA_t = 0. \tag{A.11}$$

We close the model with the domestic long-term bond market. We assume that domestic investors respond positively to long-term yields with elasticity β, irrespective of exchange rate dynamics (for example, pension funds targeting returns in domestic currency). Foreign investors can also purchase domestic long-term bonds. In particular, their demand responds positively to yield differentials against US long-term bonds, net of the expected depreciation of the domestic currency, with elasticity α (i.e., the long-term component of NPKI in equation (A.7)). This gives the following bond market-clearing condition:

$$0 = \beta \cdot y_t^{(h)} + \alpha \left(y_t^{(h)} - y_t^{*(h)} - \left(e_t - E\left[e_{t+h}|\Omega_t\right]\right)\right). \tag{A.12}$$

Equation (A.12) states that an increase in the foreign demand for domestic bonds (due to a positive yield differentials against the h-year US bond) must be accommodated by a lower demand from domestic investors, inducing a fall in yields in equilibrium. This condition therefore links domestic yield movements with developments in the US long-term bond market.[29]

Equilibrium characterization

We now solve for the main objects of interest in our model, namely the exchange rate, long-term bond yields and their decomposition into RN and TP components, and the resulting equilibrium flows into fixed income markets as a function of the state variables. Because we are concerned only with the effects of US MP shocks, we focus on the special case where domestic MP shocks have zero variance. The relevant state variable in this case is thus only m_t^*.[30]

Using (A.12) and (A.8) in the capital market equilibrium condition (A.11), we can solve for the exchange rate by iterating forward the time $t+s$ expectation of future exchange rates as a function of m_t^*. Letting $a \equiv \alpha/(\alpha+\beta)$ and $b \equiv \beta/(\alpha+\beta)$ denote the relative demand elasticity of domestic and foreign investors, we obtain

$$e_t = -m_t^* \left(\frac{(1-\phi)\left(\alpha + a\frac{\beta}{\beta^*}\right)}{\gamma + \alpha(1-\phi)(1+d-\rho+b(1-\rho^h))} \right). \tag{A.13}$$

Intuitively, a tightening of US MP following an increase in m_t^* leads to a negative interest rate differential in both short- and long-term bonds. This leads to a retreat of flows which translates into a depreciation of the domestic currency (terms α and $a\beta/\beta^*$ in the numerator of the expression post-multiplying m_t^*).

[29] For simplicity, we have abstracted from local supply conditions as they are not at the core of the results we wish to highlight, although the model can be extended in this dimension with little extra complexity.

[30] An extension of the model with domestic MP shocks is available upon request.

We now use (A.13) in (A.11) to back out NPKI,

$$NPKI_t = -m_t^* \left(\frac{\gamma \left(\alpha + a\frac{\beta}{\beta^*}\right)}{\gamma + \alpha(1-\phi)(1+d-\rho+b(1-\rho^h))} \right). \tag{A.14}$$

NPKI follow the same logic described for the exchange rate. In particular, a tightening of US MP leads to negative foreign flows due to interest rate differentials. Indeed, the capital account equilibrium condition implies that NPKI must be equal to the exchange rate depreciation, multiplied by the ratio $\gamma/(1-\phi)$, which accounts for the impact of the exchange rate on the trade balance, net of central bank interventions.

The domestic long-term bond market is solved by iterating forward the h-period expectation of e_{t+h},

$$y_t^{(h)} = m_t^* \left(\frac{a}{\beta^*} - \frac{(1-\phi)(1-\rho^h)a\left(\alpha + a\frac{\beta}{\beta^*}\right)}{\gamma + \alpha(1-\phi)(1+d-\rho+b(1-\rho^h))} \right). \tag{A.15}$$

Expression (A.15) shows that a tightening of US MP affects domestic long-term yields through two separate forces. The first is the direct effect of US MP on US long-term yields, which increase due to the contraction in the global risk-taking factor. Domestic yields must also rise in response to the fall in foreign demand. The second term is the offset implied by the currency depreciation, which is thereafter expected to appreciate and provide a positive return, partly dampening the impact on yields of the first element.

To further understand the impact on yield components, we iterate forward the expectations of future exchange rates and domestic MP, which gives the RN component of h-year bond yields,

$$RN_t^{(h)} = m_t^* \left(\frac{d(1-\phi)\left(\alpha + a\frac{\beta}{\beta^*}\right)}{\gamma + \alpha(1-\phi)(1+d-\rho+b(1-\rho^h))} \frac{(1-\rho^h)}{h(1-\rho)} \right). \tag{A.16}$$

The logic behind expression (A.16) is as follows. An increase in m_t^* raises US MP, which depreciates the domestic currency due to the impact on foreign flows. Domestic policy reacts to the depreciation of the currency by increasing rates in a proportion d of the contemporaneous depreciation. The ratio $(1-\rho^h)/(h(1-\rho))$ is the expected average effect on the domestic MP rate from a contemporaneous increase in m_t of one unit in response to the shock m_t^*.

To solve for the TP component in long-term yields, we subtract the RN component from (A.16) into the yield expression (A.15) to get

$$TP_t^{(h)} \;=\; m_t^* \left(\frac{a}{\beta^*} - \frac{(1-\phi)(1-\rho^h)\left(\alpha + a\frac{\beta}{\beta^*}\right)}{\gamma + \alpha(1-\phi)(1+d-\rho+b(1-\rho^h))} \left(\frac{a(h(1-\rho)+d) + d \cdot b}{h(1-\rho)} \right) \right). \tag{A.17}$$

Expression (A.17) shows two terms post-multiplying m_t^*. The first comes from the direct effect of US MP on the US h-year yield, which increases due to the contraction in the risk-taking factor. All else equal, this leads to a retreat of foreign demand for domestic long-term bonds, raising domestic yields in a magnitude that depends on the relative elasticity of bond demand by foreign and domestic investors (parameter a). The second effect captures the response of expected domestic MP in reaction to the depreciation of the currency, acting as an offset to the increase in the term premium by raising the RN component in (A.16).

US MP spillovers: the role of country-specific characteristics

We now briefly describe how the main objects of interest in the model can be used to interpret the evidence presented in sections 3 and 4. In particular, inspection of equations (A.13) through (A.17) reveal several comparative statics regarding the impact of US MP shocks on endogenous model variables, as a function of country-specific characteristics.

While in principle all parameters of the country-specific bloc of the model can vary between economies, we will focus on the two parameters describing policy reaction: the response of traditional MP to exchange rate movements, d, and the degree of FXI, ϕ. The next two propositions highlight the comparative statics from varying these parameters, specifically how they affect the response of the main endogenous variables to US MP shocks.

Proposition 1: *In reaction to a more expansionary US MP, a higher sensibility of domestic MP to exchange rate fluctuations will imply a) a weaker appreciation of the domestic currency against the USD; b) a weaker response of capital inflows; c) a stronger effect in the RN component of domestic long-term yields, and d) a weaker effect in the TP component of yields whenever*

$$\frac{\gamma + \alpha(1-\phi)(1-\rho+b(1-\rho^h))}{\alpha(1-\phi)} > ah(1-\rho). \tag{A.18}$$

The proof is immediate by taking the corresponding derivatives of the terms multiplying m_t^* in equations (A.13) through (A.17) with respect to d, the parameter capturing the response of domestic MP to exchange rate movements. Following a more expansionary US MP, a central bank that reacts more to the ensuing appreciation of the currency will tend to narrow interest rate differentials, thus containing the movement in the exchange rate (part a), since lower interest differentials keep capital inflows more contained (part b). Also, and by construction, a stronger reaction of domestic MP implies a larger response of expected MP into the future, implying a larger elasticity of the RN component of long-term yields (part c). The effect on the TP component is ambiguous, however, since a more contained response of the exchange rate implies that a larger effect in long-term yields is needed to accommodate the surge in foreign bond demand. When the inequality in expression (A.18) holds, the first effect dominates (i.e., the reaction of RN rates is relatively large), leading to a weaker overall elasticity of the TP component to US MP shocks.

Proposition 2: *In reaction to a more expansionary US MP, a higher degree of central bank FXI in country-j will imply a) a milder appreciation of the domestic currency against the USD; b) a stronger response of capital inflows; c) a milder effect on the RN component of long-term yields (through expected changes in domestic MP); and d) a stronger effect in the TP component of long-term yields.*

The proof of this proposition is also immediate by taking the derivative of the terms multiplying m_t^* in equations (A.13) through (A.17) with respect to ϕ. Intuitively, if central banks intervene more, any given level of NPKI has a milder effect on the domestic currency (part a). Since a currency appreciation (and the ensuing expected depreciation) in response to foreign inflows is a market force that tends to deter such flows, FXI by central banks strengthen flows precisely by dampening the corrective response played by the exchange rate (part b). At the same time, a weaker impact on the exchange rate implies a more muted response of the standard MP tool (for a given MP response parameter d), reducing the sensitivity of the RN component (part c). But this implies that the adjustment in domestic long-term yields must be made to a larger extent by a compression of the TP component (part d).

B Economic indicators

This appendix provides further details on the construction of our dataset, and summarizes some basic descriptive statistics. Table 9 lists the countries considered and the number of events for each category.

Table 9: Countries and Economic Releases

Code	Country	Classification	Number of Releases			
			MPM	CPI	Activity	Ump
USA	United States	DEV	113	160	167	726
AUS	Australia	DEV	107	54	55	167
CAD	Canada	DEV	112	167	167	167
CZE	Czech Republic	DEV	131	167	167	0
FRA	France	DEV	165	167	167	33
GER	Germany	DEV	165	143	54	166
ITA	Italy	DEV	165	159	118	50
JPN	Japan	DEV	182	166	125	163
NZL	New Zealand	DEV	111	44	55	56
NOR	Norway	DEV	108	167	132	164
SWE	Sweden	DEV	91	167	147	108
SWI	Switzerland	DEV	48	167	50	167
UKG	United Kingdom	DEV	169	163	167	167
CHI	Chile	EME	167	164	164	165
COL	Colombia	EME	163	96	99	117
HUN	Hungary	EME	160	144	145	110
IND	India	EME	62	47	39	0
IDO	Indonesia	EME	133	150	49	0
ISR	Israel	EME	153	115	30	0
KOR	Korea	EME	166	126	142	79
MEX	Mexico	EME	108	217	167	134
POL	Poland	EME	148	167	167	166
SOA	South Africa	EME	85	167	120	23
TWN	Taiwan	EME	52	123	164	115
THA	Thailand	EME	80	95	43	0

This table shows the number of economic releases considered for each country, based on Bloomberg's Surveys. The country classification as developed/emerging economy is based on the criteria followed by the International Monetary Fund, United Nations, MSCI and DJI. Columns 4 to 6 show the number of monetary policy meetings (MPM), inflation releases (CPI), economic activity releases (Activity), and unemployment (Ump). A value of zero is reported when coverage by Bloomberg is not systematic.

Table 10 shows the economic indicators used to identify macroeconomic release days, as described in sub-section 2.2. The three columns show the sources for CPI, Activity, and Unemployment, for all countries, with the corresponding release frequency in parentheses. (Q): quarterly, (M): monthly, (B): bi-weekly and (W): weekly. N/A: not available.

Table 10: Economic releases description

	CPI	Activity	Unemployment
USA	CPI Urban Consumers (M)	Industrial Production YoY (M)	Initial Jobless Claims SA (W)
AUS	CPI All Groups Goods (Q)	GDP YoY (Q)	Unemployment rate SA (M)
CAD	CPI YoY (M)	GDP All industries (M)	Unemployment rate SA (M)
CZE	CPI YoY (M)	Industrial Production YoY (M)	N/A (N/A)
FRA	CPI EU Harmonized YoY (M)	Industrial Production YoY (M)	Unemployment rate SA (M)
GER	CPI EU Harmonized YoY (M)	GDP YoY (Q)	Unemployment rate SA (M)
ITA	CPI EU Harmonized YoY (M)	Industrial Production YoY (M)	Unemployment rate SA (M)
JPN	CPI Nationwide YoY (M)	Industrial Production YoY (M)	Unemployment rate SA (M)
NZL	CPI All Groups (Q)	GDP YoY (Q)	Unemployment rate SA (Q)
NOR	CPI YoY (M)	Industrial Production YoY (M)	Unemployment rate SA (M)
SWE	CPI Headline YoY (M)	Industrial Production YoY (M)	Unemployment rate SA (M)
SWI	CPI YoY (M)	GDP YoY (Q)	Unemployment rate SA (M)
UKG	CPI EU Harmonized YoY (M)	Industrial Production YoY (M)	Claimant Count Rate SA (M)
CHI	CPI YoY (M)	Monthly Economic Index (M)	Unemployment rate SA (M)
COL	CPI YoY (M)	Industrial Production YoY (M)	Unemployment rate SA (M)
HUN	CPI YoY (M)	Industrial Production YoY (M)	Unemployment rate SA (M)
IND	CPI YoY (M)	GDP YoY (Q)	N/A (N/A)
IDO	CPI YoY (M)	GDP YoY (Q)	N/A (N/A)
ISR	CPI YoY (M)	GDP YoY (Q)	N/A (N/A)
KOR	CPI YoY (M)	Industrial Production YoY (M)	Unemployment rate SA (M)
MEX	Biweekly CPI (B)	Industrial Production YoY (M)	Unemployment rate SA (M)
POL	CPI YoY (M)	Industrial Goods & Services (M)	Unemployment rate SA (M)
SOA	CPI YoY (M)	Manufacturing Production (M)	Unemployment rate SA (Q)
TWN	CPI YoY (M)	Industrial Production YoY (M)	Unemployment rate SA (M)
THA	CPI YoY (M)	GDP YoY (Q)	N/A (N/A)

Table 11 presents the overlap frequency of US MP meetings with other events in the sample.

Table 11: Economic releases overlap

	Domestic MP	Inflation	Activity	Unemployment	Total
a) DEV					
US MP	3.69	4.57	3.24	3.98	7.08
US inflation	2.74	5.38	1.42	2.69	6.75
US activity	2.30	4.59	1.65	3.04	5.99
US unemployment	0.78	3.59	4.05	3.51	5.74
b) EME	Domestic MP	Inflation	Activity	Unemployment	Total
US MP	2.65	2.88	2.36	2.73	7.30
US inflation	3.48	3.64	4.17	0.79	6.43
US activity	2.54	5.14	3.74	0.20	6.19
US unemployment	3.29	2.72	2.79	2.63	6.12

The table shows the overlap frequency (in percentage points) between the number of domestic releases of the variable in the column and the corresponding events in the US, in each row. For example, 3.69% in column 1, row 1, equals the number of own MP summed across the 12 countries in the DEV sample which also occur during a US MPM window, divided by 113*12 country-episodes (where 113 is the number of US MPM, and 12 is the number of countries in each group included in the panel regressions).

Table 12 presents different statistics to characterize the central bank FXI activity. Because many countries that actively intervene do not disclose information (Fratzscher et al., 2017), the statistics reported here will tend to underestimate the extent of FXI, particularly so for countries with managed floating regimes (classified here as "floating").

Table 12: Foreign exchange interventions

Country	FX regime (IMF)	Regular FXI	Public FXI	Recent episodes	References
DEV					
AUS	Free floating	No	No	November, 2008	(7), (9), (10)
CAD	Free floating	No	Yes	September, 1998	(7)
CZE	Stabilized arrangement	Yes	Yes		(7)
FRA	Free floating	No	No		
GER	Free floating	No	No		
ITA	Free floating	No	No		
JPN	Free floating	No	No	October, 2011	(5), (6), (9)
NZL	Floating	No	No	June, 2007	(3), (7)
NOR	Free floating	No	No	March, 2001	(2), (7)
SWE	Free floating	No	No		(7)
SWI	Floating	No	No		(5), (7)
UKG	Free floating	No	No	March, 2011	(7)
EME					
CHI	Free floating	No	Yes	January, 2011	(1), (3), (7), (8)
COL	Floating	No	Yes	October, 2015	(1), (3), (7), (8)
HUN	Floating	No	No	September, 2011	(3), (4)
IND	Floating	No	No	January, 2013	(4)
IDO	Floating	No	No	April, 2017	(3), (4)
ISR	Floating	No	Yes	December, 2015	(1), (3), (4), (7)
KOR	Floating	No	No	February, 2017	(3), (4), (5)
MEX	Free floating	No	Yes	February, 2017	(1), (3), (7), (8)
POL	Free floating	No	No	December 2011	(3), (4), (7)
SOA	Floating	Yes	Yes		(3), (4), (7)
TWN	Manage peg	No	No	February, 2017	(5)
THA	Floating	No	No	December, 2012	(3), (4)

References: (1) Adler and Tovar (2014); (2) Alstadheim (2016); (3) BIS (2005); (4) BIS (2013); (5) Department of Treasury (2017); (6) Fatum (2015); (7) Fratzscher, Gloede, Menkhoff, Sarno, and Stöhr (2017); (8) Fuentes, Pincheira, Julio, Rincon, Garcia, Zerecero, Vega, Lahura, and Moreno (2014); (9) Kearns and Rigobon (2005); (10) Newman, Potter, and Wright (2011)

Notes: FX regime corresponds to the International Monetary Fund arrangement (IMF, 2016). Regular FXI takes the value Yes if the country has an organized intervention schedule during the sample period, and No otherwise. Public FXI takes the value Yes if the country publishes information on actual interventions, and No otherwise. Recent episodes show information about FXI against the U.S. dollar only. CZE, SWE and SWI intervened during our sample period but against the euro.

C Robustness

This appendix presents the results from the robustness exercises discussed in Section 5.

TABLE 13: Effects of removing individual countries

a) DEV

Country excluded	Pre Oct. 2008			Post Oct. 2008		
	10-yr yield	RN	TP	10-yr yield	RN	TP
AUS	0.283***	0.403***	-0.121***	0.426***	0.230***	0.196***
CAD	0.296***	0.376***	-0.080**	0.391***	0.218***	0.172***
CZE	0.303***	0.419***	-0.116***	0.457***	0.260***	0.197***
FRA	0.291***	0.354***	-0.063*	0.428***	0.231***	0.197***
GER	0.294***	0.379***	-0.085**	0.414***	0.241***	0.174***
ITA	0.297***	0.381***	-0.084**	0.438***	0.259***	0.179***
JPN	0.319***	0.423***	-0.105***	0.456***	0.252***	0.204***
NZL	0.276***	0.345***	-0.069**	0.432***	0.203***	0.229***
NOR	0.304***	0.419***	-0.115***	0.439***	0.251***	0.188***
SWE	0.298***	0.404***	-0.107***	0.424***	0.210***	0.215***
SWI	0.311***	0.401***	-0.090**	0.430***	0.252***	0.178***
UKG	0.296***	0.372***	-0.076**	0.416***	0.194***	0.222***

b) EME

Country excluded	Pre Oct. 2008			Post Oct. 2008		
	10-yr yield	RN	TP	10-yr yield	RN	TP
CHI	0.189**	0.020	0.169*	0.591***	0.157***	0.434***
COL	0.141***	0.048	0.093	0.551***	0.148***	0.403***
HUN	0.217***	-0.007	0.223**	0.560***	0.114**	0.446***
IND	0.194**	0.013	0.181*	0.562***	0.123**	0.439***
IDO	0.203***	0.026	0.177*	0.484***	0.126**	0.358***
ISR	0.191***	0.021	0.170**	0.577***	0.147***	0.430***
KOR	0.193**	0.012	0.181*	0.573***	0.137**	0.437***
MEX	0.200***	0.016	0.184*	0.520***	0.122**	0.398***
POL	0.195**	0.009	0.186*	0.568***	0.173***	0.395***
SOA	0.200***	0.049	0.152*	0.571***	0.120**	0.451***
TWN	0.193**	0.004	0.189**	0.604***	0.139**	0.465***
THA	0.199***	0.018	0.181*	0.517***	0.121**	0.396***

The table estimates (1) using alternative samples that iteratively remove individual countries. Standard errors computed using Newey-West correction up to 40 lags. *** p-value $< 1\%$, ** p-value $< 5\%$, and * p-value $< 10\%$.

Table 14: Alternative fixed effects and clusters

Sample	yields	Baseline	a) DEV							
Pre Oct. 2008	10-yr yield	0.297***	0.291**	0.291***	0.294**	0.294***	0.294**	0.294***	0.297**	0.295***
Pre Oct. 2008	RN	0.390***	0.387***	0.387***	0.388***	0.388***	0.388***	0.388***	0.390***	0.390***
Pre Oct. 2008	TP	-0.092***	-0.097	-0.097**	-0.094	-0.094***	-0.094	-0.094***	-0.092	-0.090**
Post Oct. 2008	10-yr yield	0.429***	0.424**	0.424***	0.438**	0.438***	0.438**	0.438***	0.429**	0.429***
Post Oct. 2008	RN	0.234***	0.222**	0.222***	0.225***	0.225***	0.225***	0.225***	0.234***	0.231***
Post Oct. 2008	TP	0.196***	0.203*	0.203**	0.213*	0.213**	0.213*	0.213**	0.196*	0.198**
Sample	yields	Baseline	b) EME							
Pre Oct. 2008	10-yr yield	0.193***	0.182	0.182**	0.197	0.197***	0.197	0.197***	0.193	0.193**
Pre Oct. 2008	RN	0.019	0.015	0.015	0.019	0.019	0.019	0.019	0.019	0.019
Pre Oct. 2008	TP	0.174**	0.167	0.167*	0.178	0.178*	0.178	0.178*	0.174	0.174*
Post Oct. 2008	10-yr yield	0.557***	0.524***	0.524***	0.544***	0.544***	0.544***	0.544***	0.557**	0.556***
Post Oct. 2008	RN	0.136**	0.145***	0.145***	0.139***	0.139***	0.140***	0.140***	0.136***	0.135***
Post Oct. 2008	TP	0.421***	0.379**	0.379**	0.405**	0.405**	0.404**	0.404**	0.421**	0.421**
Controls		Baseline	Fixed effects and clusters							
FE	Country	N	N	N	Y	Y	N	N	N	N
FE	Year	Y	N	N	Y	Y	N	N	Y	Y
FE	Month	Y	N	N	N	N	N	N	N	N
FE	Country-Year	N	N	N	N	N	Y	Y	N	N
FE	Country-Month	N	N	N	N	N	N	N	Y	Y
Cluster	Year		Y	N	Y	N	Y	N	Y	N
Cluster	Month		N	Y	N	Y	N	Y	N	Y

The table estimates (1) using using alternative fixed effects and windows for clustering standard errors. *** p-value < 1%, ** p-value < 5%, and * p-value < 10%.

Table 15: Alternative term-structure decomposition

	a) DEV			b) EME		
	Full sample	Pre Oct. 2008	Post Oct. 2008	Full sample	Pre Oct. 2008	Post Oct. 2008
2-yr yield	0.254***	0.317***	0.150***	0.154***	0.102**	0.267***
	(0.024)	(0.029)	(0.037)	(0.040)	(0.051)	(0.068)
10-yr yield	0.322***	0.292***	0.399***	0.272***	0.163**	0.556***
	(0.025)	(0.027)	(0.051)	(0.058)	(0.066)	(0.102)
RN (10-yr)	0.345***	0.399***	0.261***	0.076**	0.045	0.145***
	(0.033)	(0.042)	(0.052)	(0.034)	(0.044)	(0.049)
TP (10-yr)	-0.023	-0.107***	0.138***	0.196***	0.118*	0.411***
	(0.029)	(0.034)	(0.050)	(0.065)	(0.070)	(0.120)

The table estimates (1) using the term-structure decomposition of Joslin et al. (2011) for computing yield components. Standard errors computed using Newey-West correction up to 40 lags (reported in parentheses).*** p-value < 1%, ** p-value < 5%, and * p-value < 10%.

Table 16: Alternative US MP shock: changes in 2-yr yields around a 1-day window

	a) DEV			b) EME		
	Full sample	Pre Oct. 2008	Post Oct. 2008	Full sample	Pre Oct. 2008	Post Oct. 2008
2-yr yield	0.219***	0.244***	0.186***	0.202***	0.135**	0.322***
	(0.024)	(0.030)	(0.038)	(0.041)	(0.053)	(0.071)
10-yr yield	0.248***	0.170***	0.445***	0.271***	0.142**	0.604***
	(0.028)	(0.029)	(0.052)	(0.064)	(0.070)	(0.123)
RN (10-yr)	0.246***	0.266***	0.229***	0.054	0.023	0.108*
	(0.034)	(0.043)	(0.052)	(0.041)	(0.051)	(0.063)
Tp (10-yr)	0.003	-0.095**	0.216***	0.216***	0.119	0.495***
	(0.034)	(0.040)	(0.052)	(0.078)	(0.084)	(0.155)

The table estimates (1) using an alternative window of a single day (the closing of the FOMC meeting day vs. the day before). Standard errors computed using Newey-West correction up to 40 lags (reported in parentheses). *** p-value < 1%, ** p-value < 5%, and * p-value < 10%.

Table 17: Alternative US MP shock: 1-yr yield changes

	a) DEV			b) EME		
	Full sample	Pre Oct. 2008	Post Oct. 2008	Full sample	Pre Oct. 2008	Post Oct. 2008
1-yr yield	0.145***	0.136***	0.222***	0.205**	0.204**	0.276***
	(0.024)	(0.025)	(0.057)	(0.082)	(0.092)	(0.093)
10-yr yield	0.148***	0.078**	0.788***	0.338***	0.287***	0.995***
	(0.035)	(0.031)	(0.089)	(0.097)	(0.101)	(0.192)
RN (10-yr)	0.207***	0.181***	0.440***	0.059	0.046	0.266***
	(0.040)	(0.041)	(0.096)	(0.063)	(0.068)	(0.102)
TP (10-yr)	-0.059*	-0.103***	0.348***	0.279***	0.241***	0.728***
	(0.033)	(0.033)	(0.100)	(0.091)	(0.093)	(0.234)

The table estimates (1) using the change in the 1-yr US treasury yield around FOMC meetings (2-day window) as a measure of US MP shocks. Standard errors computed using Newey-West correction up to 40 lags (reported in parentheses). *** p-value < 1%, ** p-value < 5%, and * p-value < 10%.

Table 18: Alternative US monetary policy shock: 1-year ahead FFR futures

	a) DEV			b) EME		
	Full sample	Pre Oct. 2008	Post Oct. 2008	Full sample	Pre Oct. 2008	Post Oct. 2008
2-yr yield						
baseline	0.263***	0.318***	0.173***	0.160***	0.100*	0.287***
Alt. 1	0.249***	0.244***	0.282***	0.196***	0.136***	0.327***
Alt. 2	0.262***	0.317***	0.174***	0.160***	0.099	0.287***
10-yr yield						
baseline	0.335***	0.297***	0.429***	0.293***	0.193***	0.557***
Alt. 1	0.259***	0.196***	0.435***	0.237***	0.127**	0.558***
Alt. 2	0.334***	0.295***	0.435***	0.293***	0.193***	0.558***
RN (10-yr)						
baseline	0.331***	0.390***	0.234***	0.054	0.019	0.136**
Alt. 1	0.284***	0.272***	0.331***	0.048	0.028	0.091*
Alt. 2	0.331***	0.389***	0.239***	0.054	0.019	0.135**
TP (10-yr)						
baseline	0.005	-0.092***	0.196***	0.239***	0.174**	0.421***
Alt. 1	-0.025	-0.076**	0.104**	0.189***	0.099	0.467***
Alt. 2	0.003	-0.094***	0.196***	0.239***	0.174	0.424***

The table estimates (1) using alternative specifications of the US monetary policy shock. Alt. 1 replaces changes in the US 2-yr by changes in the 1-yr FFR future. Alt. 2 instruments changes in the US 2-yr rate with changes in the 1-yr FFR future. Each panel shows results for different dependent variables. The regression is estimated separately for each group of countries: DEV and EME. Standard errors reported in parentheses. *** p-value $< 1\%$, ** p-value $< 5\%$, and * p-value $< 10\%$.

D Affine Model estimation

Using equations (2) through (4), it can be shown that the coefficients in the term-structure recursion satisfy

$$\mathcal{A}_{n+1} = \mathcal{A}_n + \left(\mu^{\mathbb{Q}}\right)^{'} \mathcal{B}_n + \frac{1}{2}\mathcal{B}_n^{'}\Sigma\Sigma^{'}\mathcal{B}_n - \delta_0 \tag{D.1}$$

$$\mathcal{B}_{n+1} = \left(\phi^{\mathbb{Q}}\right)^{'} \mathcal{B}_n - \delta_1 \tag{D.2}$$

with initial values $\mathcal{A}_0 = \mathcal{B}_0 = 0$. Thus, the model-implied yields are $y_t^n = -\frac{\log(P_t^n)}{n} = A_n + B_n^{'}X_t$, with $A_n = \frac{\mathcal{A}_n}{n}$ and $B_n = \frac{\mathcal{B}_n}{n}$. On the other hand, the risk-neutral yield (the yields that would be obtained if investors priced bonds under risk neutrality) corresponds to:

$$\tilde{y}_t^n = \tilde{A}_n + \tilde{B}_n^{'}X_t \tag{D.3}$$

$$\tilde{\mathcal{A}}_{n+1} = \tilde{\mathcal{A}}_n + \mu^{'}\tilde{\mathcal{B}}_n + \frac{1}{2}\tilde{\mathcal{B}}_n^{'}\Sigma\Sigma^{'}\tilde{\mathcal{B}}_n - \delta_0 \tag{D.4}$$

$$\tilde{\mathcal{B}}_{n+1} = \Phi^{'}\tilde{\mathcal{B}}_n - \delta_1 \tag{D.5}$$

The risk-neutral yield denoted in (D.3) essentially reflects the expected path of the future monetary policy rate, and the difference between model-implied yields and risk neutral rates gives the term premium component, at each corresponding maturity.

One of the innovations proposed by Adrian, Crump, and Moench (2013) regards the way in which market prices of risk are calculated. To obtain those prices, the authors propose the following three-step procedure:

1. Estimate the VAR(1) process for the observable state variables given by (2). With these estimates, collect residuals in vector $\hat{V}$ and compute its variance-covariance matrix ($\hat{\Sigma} = \hat{V}\hat{V}'/T$).

2. Construct the log excess holding return of a bond maturing in n periods as:

$$rx_{t+1}^{n-1} = \log P_{t+1}^{n-1} - \log P_t^n - r_t, \qquad n = 2, ..., N \tag{D.6}$$

   where P_t^n is the price of an n period bond, r_t is the risk-free rate, and N is the maximum maturity considered. In this regard, the main difference between Adrian, Crump, and Moench (2013) and Cochrane and Piazzesi (2005) is that the latter work with one-year excess return while the former uses one-month excess returns. Stacking the system across the N maturities and T time periods we can construct the vector rx and run the following regression:

$$rx = \alpha\iota_T' + \beta'\hat{V} + cX_- + E \tag{D.7}$$

   where ι_T is T vector of ones and X_- is the lagged value of factors. The idea of this regression is to recover the fundamental components of the data generating process of the log excess holding return. Adrian, Crump, and

Moench (2013) shows that the decomposition of these returns can be written as:

$$rx = \text{Expected return} + \text{Priced return innovation} + \text{Return pricing error}$$

After running (D.7), collect residuals in the $N \times T$ matrix $\hat{E}$ and estimate the return pricing error variance as $\hat{\sigma}^2 = \text{tr}(\hat{E}\hat{E}')/NT$.

3. Using the estimated parameters in (D.7), compute the market prices of risk as:

$$\hat{\lambda}_0 = (\hat{\beta}\hat{\beta}')^{-1}\hat{\beta}[\hat{a} + \frac{1}{2}(\hat{B}^* \text{vec}(\hat{\Sigma}) + \hat{\sigma}^2)] \tag{D.8}$$

$$\hat{\lambda}_1 = (\hat{\beta}\hat{\beta}')^{-1}\hat{\beta}\hat{c} \tag{D.9}$$

where $\hat{B}^* = [\text{vec}(\beta^1\beta^{1'}), ..., \text{vec}(\beta^N\beta^{N'})]'$ and β^i is the covariance between log excess holding return at maturity n and the VAR innovations.

With this procedure, we are able to solve equations (D.1) through (D.5). The difference between fitted yields and risk-neutral yields corresponds to the term premium component.

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