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CHANNELS OF US MONETARY POLICY SPILLOVERS INTO INTERNATIONAL BOND MARKETS [*]

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Abstract

We document 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 changes are identified as the response of short-term US treasury yields within a narrow window of Federal Reserve meetings, and trace its consequences on domestic bond yields using panel data regressions. We decompose yields for each country into a risk neutral and a term premium component, using the methodology developed by Adrian et al. (2013). We emphasize three main results. First, spillovers to long-term rates in our sample of countries has increased substantially after the global financial crisis: a 100 bp increase in US short-term rates during monetary policy meetings is associated with increases between 70-80 bp on international bond yields. Second, these effects work through markedly different channels on different country groups: while the effects in developed economies work mostly through risk neutral rates -associated with signaling effects in the course of future monetary policy-, spillovers to emerging countries are concentrated predominantly on the term premium channel -associated with portfolio rebalancing effects. Third, these spillovers are large compared to the effects of other events, and at least as large as the effects of domestic MP in long-term rates after 2008.

Resumen

Este trabajo estudia la transmisión de la política monetaria de EE.UU. a mercados de bonos domésticos en una muestra de 24 países, considerando 12 economías desarrolladas y 12 economías emergentes. Nuestra metodología está basada en regresiones de panel con estudio de eventos, donde cambios en la política monetaria de EE.UU. son identificados como el movimiento de tasas de gobierno de corto plazo alrededor de días de reuniones de la Reserva Federal. Para cada país considerado, se descompone las tasas de interés en un componente de riesgo neutral y otro de premios por plazo utilizando la metodología de Adrian et al. (2013). Se resaltan tres resultados principales. Primero, la transmisión de la política monetaria de EE.UU. a tasas de largo plazo se ha incrementado sustancialmente después de la crisis financiera global: un aumento de 100 pb en la tasa de corto plazo de EE.UU. durante reuniones de política monetaria es asociado a incrementos entre 70 a 80 pb en tasas de bonos internacionales. Segundo, esos efectos se dan a través de diferentes canales en los diferentes grupos de países: mientras que para economías desarrolladas se realiza principalmente a través de tasas de riesgo neutral – asociados a efectos de señal respecto a trayectoria futura de la política monetaria -, la transmisión a economía emergentes son concentradas principalmente en el canal del premio por plazo – asociado a efectos de rebalanceo de portafolio. Tercero, la transmisión de la política monetaria de EE.UU. a tasas internacionales es alta comparada

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[*] The opinions and mistakes are of exclusive responsibility of the authors and do not necessarily represent the opinion of the Central Bank of Chile or its Board. We thank Alberto Naudon for valuable comments and discussions, and Tobias Adrian for sharing the code used in Adrian et al. (2013). Emails: ealbagli@bcentral.cl, lceballos@bcentral.cl, sclaro@bcentral.cl y dromero@bcentral.cl.

a efectos de otros eventos, y al menos tan alta como el efecto de la política monetaria doméstica en tasas de largo plazo después de 2008.

1 Introduction

The conduit of monetary policy (MP) in mayor advanced economies has changed in important ways since the global financial crisis. After reaching an effective zero lower bound, the focus has shifted towards influencing long term rates, with significant efforts made by central banks in communicating their intentions of keeping rates at zero for an extended period (forward guidance), and/or through outright large scale asset purchase programs (LSAP). The increased presence of the FED, the ECB, and other central banks in fixed income market has been reinforced by large portfolio flows from private investors.[1]

Such trends raise important issues for academics and policymakers. In particular, with increasingly integrated capital markets, it begs the question of whether the cost of funds in non-core economies can remain independent from developments in mayor financial centers, thus challenging the ability of central banks for setting appropriate monetary conditions given each country's economic realities. This discussion is well captured by several recent studies, including Rey (2015), Bruno and Shin (2015), and Obstfeld (2015), and has spurred a large number of recent empirical works trying to assess the spillover effects of monetary policy in the US and other large developed economies.

There are several challenges and open questions that remain to be settled in this line of inquiry. 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 monetary policy in large financial centers, or merely reflect common underlying economic forces. Second, there is relatively little evidence about spillover effects of lax monetary conditions on emerging market economies, mostly due to the lack of reliable and long-dated yield curve information. Third, to the extent that spillover effects are identified, there is little evidence about the particular channels at work. In particular, do movements in long term rates reflect the anticipation of future monetary policy, or do they result from changes in risk compensation due to portfolio rebalancing motives?

This paper contributes to the debate by presenting evidence of significant spillover effects of US monetary policy into a group of 12 developed countries (henceforth, DEV) and 12 emerging market economies (henceforth, EME). In order to identify a US monetary policy shock, we follow the approach in Hanson and Stein (2015), conducting an event study using as the main explanatory variable the movements in short term treasury yields (1-yr maturity in our baseline specification) around a narrow window centered at FED meetings. Our measure of spillovers is the effect of such movements on the local bond yields (denominated in domestic currencies) at short and long maturities (1 and 10 years). Because we wish to highlight the difference between DEV and EME, we run panel regressions for each group of countries, and

[1] See IMF (2014).

estimate a spillover effect for DEV and EME separately. We also split our sample up to and after Nov. 25th, 2008, as that day marks the first FED announcement about unconventional MP measures, serving as a natural break point for the change in regime due to the global financial crisis (see Gilchrist et al. (2014)).

To further understand the economic mechanisms behind such spillovers, we decompose bond yields for each country into a term premium and a risk neutral component, following the methodology proposed by Adrian et al. (2013), but correcting for small sample bias as suggested by Bauer et al. (2012). This allows us to determine whether US MP spillovers into other economies work through a signaling effect –by giving relevant info about future paths of short term rates in other economies–, or whether other mechanisms related to portfolio rebalancing/compensation for risk prevail. Moreover, to compare the economic magnitude of such effects, we also study the impact of individual countries own MP meetings, as well as other events such as US and individual countries releases of CPI, activity (industrial production), and unemployment.

We highlight three main results as a preview of what follows. First, we document a significant spillover effect of US MP on short and long term yields for both DEV and EME, in particular for the subsample starting in Nov. 2008. Indeed, during 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 in 73 and 85 bp, respectively, while effects prior to Nov. 2008 are in general not statistically significant.

Second, there are major differences in transmission mechanisms involved. We find that while movement in risk neutral rates account for around two thirds of the overall movement in long-term yields in the DEV sample (based on point estimates, of which only the risk neutral component is statistically significant), more than 85% of the spillover into EME works though changes in term premium (with non-significant effects on the risk neutral component). These results are robust to a number of alternative specifications, and are consistent with stylized facts about economic activity and portfolio flows post 2008. Indeed, while activity has been largely decoupled between EME and DEV –the latter following similar paths to the US–, portfolio flows into EME have shown high correlation with other countries. This suggests that while economic fundamentals probably warranted different MP courses between EME and DEV, the long end of the yield curve was affected similarly by US MP events due to movements in portfolio flows.

Third, our results suggest that spillover effects are economically important compared to other events, and at least as large as the impact of domestic MP actions on long-term yields on those countries post Nov. 2008. In particular, the point estimates of the effects of US MP on domestic long-term bond yields of DEV economies post Nov. 2008 are about 55% larger than the response to domestic MP meetings. For

EME, the point estimate of US MP spillovers is more than double the estimate of domestic MP.[2] In these domestic events, however, movements in the risk neutral component dominate the action in yields, with the term premium component explaining only a minor fraction for both DEV and EME.

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 et al. (2011), and Christensen and Rudebusch (2012), show evidence of rather large effects of LSAP announcements on US long term yields. Several papers have also documented the international spillover effects of conventional US MP[3] and more recently the transmission of LSAP announcements.[4]

More closely related to our paper are the recent works by Gilchrist et al. (2014), Hoffman and Takats (2015), and IMF (2015), who put special emphasis on spillover effects into emerging countries. The main difference with these papers is our focus on studying the different transmission mechanisms behind US MP spillovers, which we do by applying the yield curve decomposition into risk neutral and term premium components for each individual country in the sample. Indeed, we see as the main result of the paper the important distinction that US MP spillovers into DEV work mostly though a signaling channel by moving expectations of future short-term rates, while the effect in EME is predominantly concentrated in movements on the term premium. 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 in affecting yields. Another difference, particularly with Hoffman and Takats (2015) and IMF (2015), is our identification strategy. While they use monthly VAR's with recursive (Cholesky) ordering to tease out the spillover effects of autonomous shocks on US long term yields, we use event-study analysis by focusing on narrow event windows around FED meetings to identify MP shocks.

The remainder of the paper is structured as follows. In section 2, we describe the data and introduce our main econometric specification, discussing in detail the construction of US MP events and the decomposition of yield curve movements into risk neutral and term premium components. In section 3, we present the effects of US MP meetings on DEV and EME, before and after Nov. 2008, and estimate separately the effects of events defined specifically around LSAP announcements. We also present some stylized facts about economic fundamentals and international portfolio flows that can help put our results into perspective. In section 4, we report the effect on yields of own MP meetings, as well as economic news both in the US and in individual countries. Section 5 discusses our results under alternative specifications,

[2]More formally, the hypothesis that US MP spillover effects are equal to domestic MP effects after Nov. 2008 cannot be rejected at usual confidence levels.

[3]See Craine and Martin (2008); Hausman and Wongswan (2011); Georgiadis (2015).

[4]Bauer and Neely (2014); Bauer and Rudebusch (2014); Rogers et al. (2014).

as a way of evaluating the robustness of our findings. Section 6 concludes.

2 Data description and identification strategy

2.1 Econometric specification: panel data event-study

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

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

In equation (1), the main explanatory variable of interest is MPR_{t}^{US} , which corresponds to the change in observed 1-yr US yield at the closing of the business day after each FED meeting, and the closing of the business day before the announcement.[5] The rationale for this measure, proposed by Hanson and Stein (2015), is that actual MP rates display infrequent movements, and are often anticipated by the market.[6] Moreover, there could be significant information in each meeting about the future course of MP that could be highly relevant, and missed if one uses only actual rates. For these reasons, they propose using a relatively short-maturity treasury yield (two-years in their specification) for capturing changes in the stance of future MP that could arise form information released on each FED meeting.

The other variables in the right hand side of equation (1) include $MPR_{j,t}^{Own}$, defined as the change in country j's 1-yr yield around an analogously defined 2-day window centered at each of j's MP meetings; $S_{n,t}^{US}$, defined as the change in 1-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 1-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 be affecting yields, we try several specifications of fixed effects, and different ways of clustering standard errors. In our baseline specification, we include a year and a country-month fixed effect in each regression, denoted by α_{year}^{h} and $\alpha_{j,month}^{h}$ in equation (1). In section 5, we replicate the main results under different specifications to check the robustness of our results.

We now turn to the left hand side of equation (1). Because we are interested on the effect of US MP and other economic events on overall yields, as well as their decomposition, we use 3 different variables: the h-yr domestic bond yield (where the subscript h stands for maturity);[7] the portion of this yield identified as the

[5] For example, for the meeting that took place on Oct. 29, 2014, the change in US yields is the difference between the 1-yr treasury at the close of Oct. 30, and the close of Oct. 28.

[6] See Cochrane and Piazzesi (2002).

[7] In the case of yields we use on the left-hand side the model-implied yield rather than the observed interest rates. These two need not coincide due to measurement error in the affine model estimation. Table 12 in appendix B reports the results of

risk-neutral component (that is, the expectations of future short-term interest rates); and the remaining term premium component. Hence, for each specification, we run 3 regressions using the yield and both of its components separately. While we run regressions for several maturities, we only focus the discussion on 1-yr (short-term) and 10-yr (long-term) bonds due to space considerations. In all specifications, $\Delta y^h_{j,t}$ is defined as the change in yields (or their components) the business day after the FED's meeting, relative to the yield close the day before the FED meeting.[8]

Because we place special emphasis on the effects of US MP on EME and DEV, we run separate regressions for each class of economies. That is, we estimate the set of US MP spillover coefficients β^h separately for DEV and EME. Analogously, we estimate a separate set of coefficients for own MP (γ^h) and economic releases (δ^h_n for US, and θ^h_n for domestic) for EME and DEV. Finally, we follow Gilchrist et al. (2014) in splitting the sample into a conventional MP period, prior to and including the FED meeting up to November 24th 2008, and an unconventional period starting with the announcement of November 25th 2008.

2.2 Data sources

We consider 12 DEV economies, including Australia, Canada, Czech Republic, France, Germany, Italy, Japan, New Zealand, Norway, Sweden, Switzerland, and the United Kingdom. In the EME sample we include Chile, Colombia, Hungary, India, Indonesia, Israel, Korea, Mexico, Poland, South Africa, Taiwan, and Thailand. Some countries are excluded from the analysis due to lack of sufficient yield curve data, which is necessary for constructing the risk neutral and term premium components , as described momentarily.[9] Our panel data is balanced and built from January 2003 to March 2015.

using instead actual yields. Our mains results are reinforced under this alternative specification.

[8]Because of time zone differences, this means that for countries on time zones earlier than EST, the window is relatively longer before the FED announcement than after, while the opposite is true for countries with later time zones. However, it is always the case that the fed meeting is contained in within the window.

[9]This is the case, for example, of Brazil, for which reliable YC data exists only since 2007, and even then there is not enough cross-sectional information of yields at different maturities for decomposing yields according to the procedure described in section 2.4.

Table 1: Countries and Economic Releases

Code	Country	Classification	Number of Releases			
			MPM	CPI	Activity	Unemployment
US	United States	DEV	104	136	146	635
CAD	Canada	DEV	98	144	146	146
JPN	Japon	DEV	151	144	122	146
UK	United Kingdom	DEV	147	139	146	146
GER	Gemany	DEV	146	120	47	146
ITA	Italy	DEV	146	136	84	42
FR	France	DEV	146	144	146	26
AUD	Australia	DEV	87	47	48	146
NZ	New Zeland	DEV	97	49	48	49
CHK	Czeck Republic	DEV	116	144	146	0
NOR	Norway	DEV	96	146	113	144
SW	Sweden	DEV	79	145	127	86
SZ	Switzerland	DEV	46	147	44	147
KOR	Korea	EME	144	138	140	57
TW	Taiwan	EME	52	111	144	113
CL	Chile	EME	146	144	145	145
MX	Mexico	EME	92	169	146	113
HUN	Hungary	EME	139	120	124	90
SOA	SouthAfrica	EME	74	144	98	15
TH	Thailand	EME	65	98	44	0
ISR	Israel	EME	136	114	27	0
INDO	Indonesia	EME	116	146	47	0
IND	India	EME	51	24	39	0
POL	Poland	EME	129	144	146	145
COL	Colombia	EME	141	115	99	96

This table shows the economic releases considered, based on reported Bloomberg's Survey. The country classification is based on the criteria followed by the International Monetary Fund, United Nations, MSCI and DJI for all economies considered. Columns 4 to 6 show the number of monetary policy meetings (MPM), economic releases of inflation (CPI), economic activity (Activity), and unemployment (Unemployment). Zero reported values are due to lack of systematic coverage by Bloomberg.

We use different data sources. For DEV, we use yields mainly reported from Bloomberg and by central bank's websites. FED and individual MP meetings dates, as well as dates on economic releases are taken from central banks and Bloomberg respectively. Table 1 lists the countries considered and the number of each class of events that enter the sample. Table 9 in appendix A lists all data sources and time periods considered for each individual country.

In section 3 we make use of the subsample of FED meetings defined as corresponding to LSAP announcements. These dates are taken from other studies, such as Rogers et al. (2014), who identify relevant unconventional monetary policy announcements for several central banks including the Fed up to April 2014. We employ and extend the database up to March 2015.

2.3 Identification issues

Our identification strategy relies on two main premises. First, implicit in the use of MP calendar days is the notion that such events are relevant to the dynamics of interest rate movements in the US. Table 2 reports the moments of interest rate changes around different economic events, and shows that this is indeed the case: the st. dev. of 1-yr US yields is significantly larger around MP meetings than on non-meetings days, both pre and post Nov. 2008. The conclusion regarding other economic events is similar: CPI releases are associated with larger volatility than non-event days, and so are activity releases in the pre Nov. 2008 subsample.

In the case of DEV economies, interest rates on MP meetings days, and during unemployment release days, have significantly larger volatility than non-event days in both subsamples. The same is true for industrial production but only in the post Nov. 2008 sample. For EME, on the other hand, the pre Nov. 2008 sample displays similar volatility during economic releases compared to non-event days. However, MP meetings, inflation, and activity releases all display higher interest rate volatility than non-event days in the post Nov. 2008 sample.[10]

Table 2: Changes in One-year rates around events

	Pre Nov. 2008						Post Nov. 2008					
	US		DEV		EME		US		DEV		EME	
	mean	std	mean	std	mean	std	mean	std	mean	std	mean	std
MPM	-0.05	10.91***	-0.52	8.95***	-1.72	18.47	-1.58	5.26***	-1.39	10.04***	-2.57	15.71***
No news	0.44	6.51	0.01	6.05	0.29	19.31	-0.34	2.79	-0.28	7.52	-0.42	10.84
CPI	0.74	9.50***	0.35	6.12	0.42	19.24	-0.92	4.84***	-0.36	7.23	-1.43	12.65***
IP	-0.83	7.37*	-0.33	5.11	0.64	12.87	-0.41	2.15	-0.49	9.25***	-0.72	11.42**
UMP	-0.31	7.37***	0.27	6.81***	1.12	8.41	0.09	3.03**	-0.03	8.90***	-0.61	9.34

This table shows the mean and standard deviation of changes in 1-yr yields around domestic economic releases. *** p-value < 0.01, ** p-value < 0.05, and * p-value < 0.1, denote the probability that volatility is higher in the corresponding event that in non-event days.

[10]The higher volatility of rates on event days is not a necessary condition for the identification strategy to be valid, but it does provide support to the notion that FED meetings are important events for movements in the yield curve, and thus suitable episodes to test MP spillovers.

Second, for the event to correctly measure US MP as a causal force affecting international yields, it is desirable that such events are not often contaminated by other economic releases that might obscure the transmission mechanism from US MP. Table 3 shows that, indeed, the overlap between US MP meetings and other events is rather small. For instance, there are 104 US MP meetings between January 2003 and March 2015. In the panel regression of EME, this amounts to 12*104 = 1,248 country-days on the right hand side of the panel regression. We proceed to count the number of events that correspond to own MP on those same days, leading to 34 occasions (for example, 4 times in Chile, 5 times in Thailand, 2 times in Mexico, and so on). This means that of the 1,248 country-events defined by US MP meetings, the overlap of events amounts to 34/1,248 = 2.72%. This is the overlap frequency reported in line 1, column 1, of Table 3 in panel B. Analogously, the table reports the overlap frequency between different US and individual countrys events. Column 5 in the table reports the cumulative overlap of any event vis-à-vis US key dates.[11] In short, although FED meetings are not always the only event moving yields in a given day, this is the case much more often than not.[12]

Table 3: Economic releases overlap

Panel A: Developed economies					
	Monetary policy rate	Inflation	Activity	Unemployment	Total
US monetary policy	3.53	4.73	3.37	3.61	7.13
US inflation	2.57	5.51	1.35	2.45	6.68
US activity	2.13	4.43	1.49	2.59	5.92
US unemployment	0.84	3.47	3.85	3.30	5.59
Panel B: Emerging economies					
	Monetary policy rate	Inflation	Activity	Unemployment	Total
US monetary policy	2.72	2.72	3.04	2.80	7.61
US inflation	2.88	3.62	4.60	0.74	6.37
US activity	2.41	4.94	4.25	0.23	6.21
US unemployment	3.42	2.64	2.80	2.56	6.11

This 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, 3.53% in column 1, row 1, equals the number of own MPM summed across the 12 countries in the DEV sample which also occur during a US MPM window, divided by 104*12 country-episodes (where 104 is the number of US MPM, and 12 is the number of countries).

[11] Because some economic events also coincide on the same day the total column does not correspond to the sum of each column.

[12] An overlap with other events does not introduce bias, only noise in the estimation of the corresponding coefficients.

2.4 Decomposition of yields

To decompose interest rates into the risk neutral and term premium components, we rely on the affine model approach developed in Adrian et al. (2013). The standard affine model is characterized by the existence of K risk factors, summarized in vector X_t which follow a first-order VAR under the probability measure $\mathbb{P}$:

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

It is assumed that the short-term interest rate r_t is an affine linear function of the risk factors:

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

Finally, it is assumed that there exists an unique stochastic discount factor (SDF) that prices all assets under no arbitrage, which is affine as in Duffee (2002):

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

where the vector of risk prices (λ) are also affine to risk factors: $\lambda_t = \lambda_0 + \lambda_1 X_t$. Under the risk-neutral probability measure $\mathbb{Q}$, the price of an n-period zero coupon bond is determined by $P_t^n = E_t^{\mathbb{Q}}(\exp(-\sum_{h=0}^{n-1} r_{t+h}))$ and the risk factors under the risk neutral measure also follow a Gaussian VAR:

$$X_{t+1} = \mu^{\mathbb{Q}} + \Phi^{\mathbb{Q}} X_t + v_{t+1}^{\mathbb{Q}}$$

where $\mu^{\mathbb{Q}} = \mu - \Sigma\lambda_0$ and $\Phi^{\mathbb{Q}} = \Phi - \Sigma\lambda_1$. With this, the price of bonds at different maturities can be summarized into $P_t^n = \exp(\mathcal{A}_n + \mathcal{B}_n' X_t)$, where $\mathcal{A}_n$ and $\mathcal{B}_n$ follow the recursions:

$$\mathcal{A}_{n+1} = \mathcal{A}_n + \left(\mu^{\mathbb{Q}}\right)' \mathcal{B}_n + \frac{1}{2}\mathcal{B}_n' \Sigma\Sigma' \mathcal{B}_n - \delta_0 \tag{5}$$

$$\mathcal{B}_{n+1} = \left(\phi^{\mathbb{Q}}\right)' \mathcal{B}_n - \delta_1 \tag{6}$$

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 obtain if investors priced bonds under risk neutrality) corresponds to:

$$\tilde{y}_t^n = \tilde{A}_n + \tilde{B}_n' X_t \tag{7}$$

$$\tilde{\mathcal{A}}_{n+1} = \tilde{\mathcal{A}}_n + \mu' \tilde{\mathcal{B}}_n + \frac{1}{2}\tilde{\mathcal{B}}_n' \Sigma\Sigma' \tilde{\mathcal{B}}_n - \delta_0 \tag{8}$$

$$\tilde{\mathcal{B}}_{n+1} = \Phi' \tilde{\mathcal{B}}_n - \delta_1 \tag{9}$$

The risk-neutral yield denoted in (7) essentially reflects the expected path of the future monetary policy rate, and therefore, reflects the part of the interest rates that are driven by expectations. Furthermore, the derivation of the expected short rate allows us to identify the term premium component, which corresponds to the difference between the implied yield and the risk-neutral yield, as follows:

$$tp_t^n = y_t^n - \tilde{y}_t^n \tag{10}$$

To estimate the affine term structure model we follow the approach proposed by Adrian et al. (2013). This methodology exploits the log excess holding return predictability showed in empirical studies, such as Cochrane and Piazzesi (2005).[13] Based on that idea, Adrian et al. (2013) propose a simple methodology to construct market prices of risk into an affine model consistent with the predictability of excess bond returns. In appendix C we detail the step-by-step procedure to compute the affine model using the Adrian et al. (2013) approach.

Bias correction. One issue faced by standard affine methodologies estimation is that the short-term interest rate follows a VAR(1) process. This assumption is key because it affects the statistical process of the stochastic discount factor, and therefore the capacity of the model to fit yields properly and the computation of risk-neutral yields and term premium. Given the vector autoregressive nature of the model and the well-known small sample bias related to these models, it is important to take into account procedures that could alleviate this bias, in order to provide a proper identification of the parameters μ, Φ and Σ. If such bias is not corrected for, Bauer et al. (2012) shows that the OLS estimation generates artificially lower persistence than the true process, which is reflected in risk-neutral rates with too little volatility. In that case, most of the variability on interest rates is (incorrectly) attributed to term premium instead of risk-neutral rates.

To deal with this problem, we employ an indirect inference to correct the bias in the VAR process of equation (2). The idea of this method is to choose parameter values which yield a distribution of the OLS estimator with a mean equal to the OLS estimate in the actual data.[14]. In what follows, we estimate the affine model with the indirect inference bias correction procedure.[15]

[13]They show that a relevant fraction of excess returns on bonds can be captured with a small number of factors. In particular, a single factor helps to predict more than 44% of one-year returns. See Gürkaynak and Wright (2012) for a comprehensive revision of this literature.

[14]See the online Appendix of Bauer et al. (2012) for details.

[15]The Matlab code to apply bias correction are publicly available at `http://faculty.chicagobooth.edu/jing.wu/`.

3 International spillover of US MP: developed vs emerging market economies

3.1 Effect of regular FED meetings

Table 4 presents the main results of the paper. The upper panel contains the estimated elasticity between movements in US 1-yr yields on FED meeting days and yields on DEV economies, while the lower panel reports the coefficients for EME. The first two columns report the effects on 1-yr and 10-yr rates before Nov. 2008, while the third and fourth columns report the effects for the later part of the sample.

We begin the discussion of the effects of US MP on DEV economies (upper panel). Prior to Nov. 2008, spillovers are rather small. A movement of 100 bp in US 1-yr yields is associated with a statistically significant (at the 5% confidence), yet economically modest increase of 14 bp on 1-yr yields (column 1, first row). This movement is almost entirely due to changes in the risk neutral component (13 bp, in column 1, 2nd row), while the effect on term premium is virtually zero (column 1, 3rd row). However, the impact on long term yields (column 2) is insignificant, and associated with an increase in the risk neutral component of 15 bp (non significant) and a reduction of 7 bp in the term premium component (statistically significant at the 1% confidence). Hence, prior to Nov. 2008, an increase in US rates on FED meeting days is associated with a mild increase (and a slight flattening) of the yield curve among the DEV sample.

Things are markedly different after Nov. 2008 (third and fourth columns). Indeed, we now see that a 100 bp increase in US 1-yr rates is associated with a statistically significant increase of 43 bp in DEV 1-yr rates, dominated once again by a 39 bp increase in the risk neutral component (statistically significant), and only a 5 bp (non significant) increase in the term premium. More interestingly, the point estimate on 10-yr yields is more than 8 times larger than in the earlier sample, at 73 bp (significant at 10%). The effect is still dominated by movements in the risk neutral component, at 48 bp increase (statistically significant), and a non significant effect on the term premium of 26 bp. Hence, of the overall spillover effect on LT yields, the split is roughly 66-34% (based on the point estimate) tilted towards the signaling channel through risk neutral rates, vis-à-vis portfolio effects working through changes in the term premium.

Table 4: Effects of US monetary policy

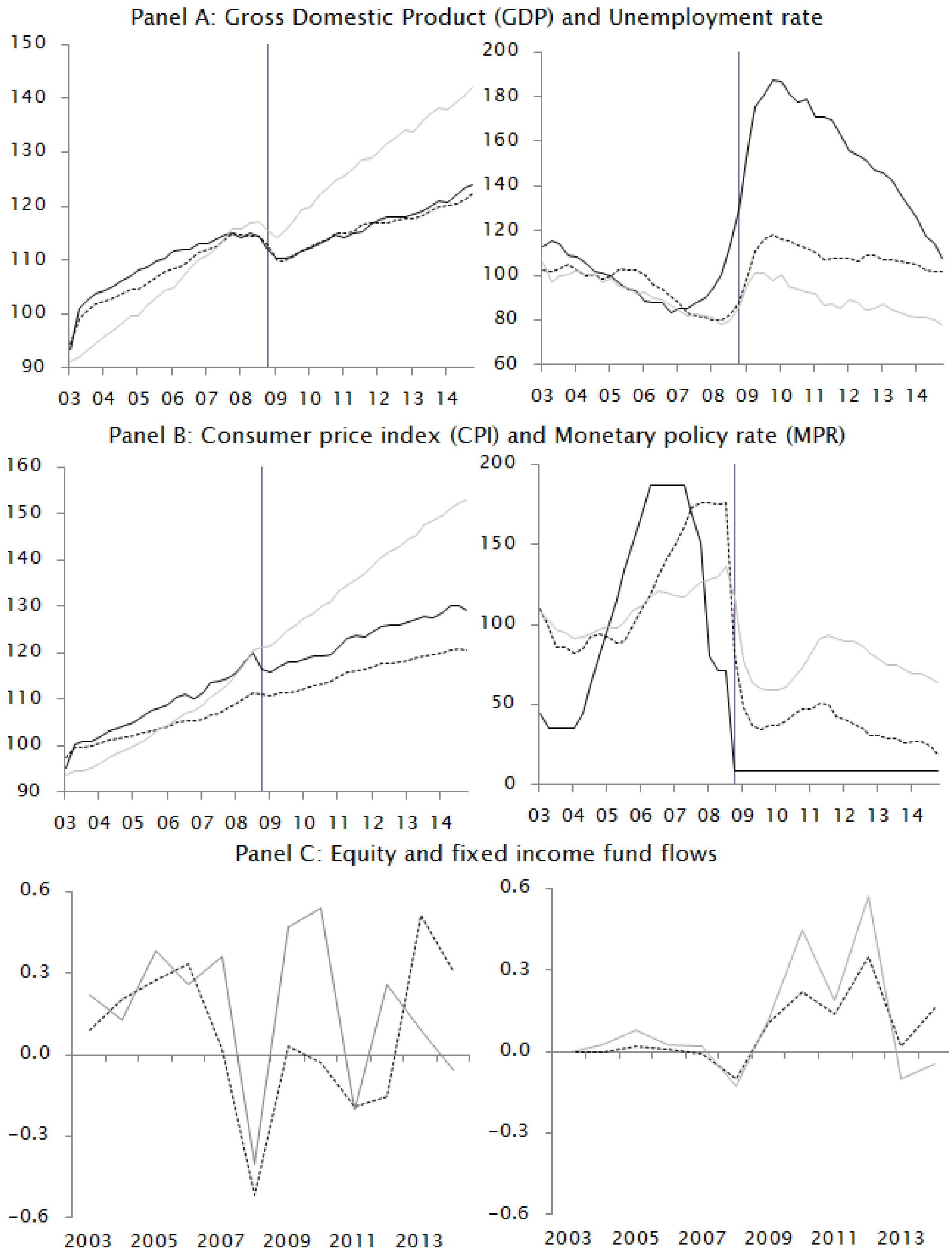
	Panel A: Developed economies			
	Pre Nov. 2008		Post Nov. 2008	
	One-year	Ten-year	One-year	Ten-year
yield	0.139*	0.085	0.433**	0.731*
	(0.065)	(0.104)	(0.149)	(0.345)
risk neutral	0.131*	0.154	0.386**	0.476**
	(0.063)	(0.106)	(0.132)	(0.172)
term premia	0.008	-0.069***	0.047	0.255
	(0.017)	(0.022)	(0.083)	(0.212)
	Panel B: Emerging economies			
	Pre Nov. 2008		Post Nov. 2008	
	One-year	Ten-year	One-year	Ten-year
yield	0.188	0.277	0.427	0.854**
	(0.125)	(0.190)	(0.239)	(0.321)
risk neutral	0.064	0.061	0.082	0.115
	(0.053)	(0.053)	(0.209)	(0.201)
term premia	0.124	0.215	0.344***	0.739**
	(0.077)	(0.186)	(0.070)	(0.270)

This table shows the estimated coefficients of US monetary policy events, as described in equation (1). The regression is estimated separately for each block: Developed (DEV) and Emerging economies (EME). In parentheses are reported standard errors. *** p-value < 0.01. ** p-value < 0.05 and * p-value < 0.1

We now turn to EME. Prior to Nov. 2008 (first and second columns), the point estimate of US MP on 1-yr yields 19 bp (but non significant). However, we see a marked difference on the composition of yield movements, which are now dominated by changes in the term premium (at 12 bp), with only a 6 bp increase in risk neutral rates (none of them significant, however). A similar pattern is observed for 10-yr yields: a non significant overall effect of 28 bp, explained by a 22 bp and a 6 bp increase in risk neutral rates.

After Nov. 2008 (third and fourth column), a 100 bp increase in 1-yr US yields is associated with a (non significant) 43 bp increase in 1-yr EME yields. The composition of this effect, however, is markedly different than for DEV countries, as now the spillover is heavily concentrated on the term premium component, with a highly statistically significant 34 bp increase, and a non significant 8 bp effect of risk neutral rates. For 10-yr yields, the overall spillover is a statistically significant 85 bp spillover, again heavily tilted towards a 74 bp (statistically significant) increase in the term premium, and a non significant increase of 12 bp in risk neutral rates. Hence, in the case of EME, the split is now only 14-86% (based on the point estimate) tilted towards risk neutral rates, with the bulk of US spillover working through the term premium channel.

FIGURE 1: Macroeconomic conditions



This figure reports changes in several macroeconomic variables for US (solid black line), developed economies (dashed black line) and emerging economies (grey solid line). All variables are expressed as index 2003-2006=100. Vertical line corresponds to 2008q3. Source: author's calculations.

What is the economic rationale behind these results? In figure 1 we plot some stylized facts about economic activity and portfolio flows to provide a plausible explanation. After 2008, there is a large disconnect in economic activity between these groups of countries. While many countries belonging to the DEV group had prolonged episodes of sluggish growth in line with activity in the US (Figure 1, panel a), EME had a quick recovery. Among the reasons often cited for this behavior are the relatively unharmed financial systems (where structured products had not yet developed), as well as the surge in commodity prices linked to the expansion of China. In the last two years these forces have subdued, while at the same time growth in DEV has picked up. Because of the strong correlation in economic activity between the US and the DEV sample, one would expect new information about future rates in the US released during FED meetings to also affect market expectations about future economic conditions in DEV countries (the signaling channel), and hence about expected short term rates captured by the risk neutral decomposition. On the other hand, the decoupling of activity between EME and the US would tend to suggest a mild, if any, correlation between MP paths. Indeed, panel b) of Figure 1 shows that inflation and MP rates in the DEV sample follow more closely the dynamics of these variables for the US, while EME have their own story to tell. This is confirmed by the low importance of the risk neutral channel in the spillovers from US MP into EME yields.

On the other hand, portfolio flows into EME and DEV have exhibited a larger correlation (Figure 1, panel c). This trend has been highlighted as a consequence of the extraordinary monetary conditions in the US and other major financial centers in several publications, such as the IMF (2014) and the BIS (2014). Indeed, as a fraction of GDP, these movements have been even stronger for EME. This pattern is consistent with a growing literature that documents the importance of global push factors such as US interest rates and global risk appetite as determinants of capital flows into EME.[16]. It is then natural to expect that monetary conditions in the US will have a causal impact on EME yields, by affecting risk taking and portfolio flows into emerging markets.

3.2 Effects of LSAP announcements

To complement our previous results, we now study a subset of events that have been identified in previous work as corresponding to LSAP announcements by the Federal Reserve.[17] As before, the explanatory variable is the change in 1-yr US treasury yields around the window centered at the day of the announcement, while the dependent variable is the changes in individual countries yields in each group of countries in our panel regressions.

Table 5 reports the estimated coefficients associated to these events. For DEV, we see that a 100 bp increase in the US 1-yr rate is associated with a 40 bp increase in 1-yr rates (significant at 5%), tilted more towards the term premium channel (although none of the components are individually significant). For 10-yr yields, there is a strong effect of 100 bp, split 40-60% between the risk neutral and term premium channels. Indeed, because one would expect LSAP programs to work mainly through the portfolio channel, it is not strange to see a dominance of the term premium component, as has been documented for DEV

[16]See Ahmed and Zlate (2014); Ananchotikul and Zhang (2014); Nier et al. (2014), Gosh et al. (2012)

[17]In particular we considerer LSAP announcements made by Rogers et al. (2014) which we extend to March 2015.

economies by many authors recently[18].

Table 5: Effects of US monetary policy during LSAP announcements

	Developed economies		Emerging economies	
	One-year	Ten-year	One-year	Ten-year
yield	0.391**	1.000**	0.469	0.699*
	(0.176)	(0.393)	(0.276)	(0.389)
risk neutral	0.281	0.394*	0.163	0.148
	(0.166)	(0.187)	(0.244)	(0.191)
term premia	0.110	0.606**	0.304***	0.551*
	(0.095)	(0.257)	(0.080)	(0.298)

This table shows the estimated coefficients of US monetary policy events, as described in equation (1). The regression is estimated separately for each block: Developed (DEV) and Emerging economies (EME). In parentheses are reported standard errors. *** p-value $<$ 0.01. ** p-value $<$ 0.05 and * p-value $<$ 0.1

Turning to the EME sample, at 1-yr horizon the only statistically significant effect is a 30 bp increase in the term premium component. At the 10-yr horizon, the 70 bp increase in yields is associated with a 55 bp increase in the term premium (both significant only at 10%), and a 15 bp increase in the risk neutral component (not statistically significant). Again, we see that for EME the effect is more tilted towards the portfolio rebalancing channel, with the signaling channel working through risk neutral rates having a minor, if any, effect on interest rates.

4 Spillover effects in perspective: a comparison with other economic events

4.1 Effect of own MP

To gain perspective into the quantitative importance of US MP spillovers, we now study the impact of own MP meetings in domestic yields. The explanatory variable here is defined as the movement in 1-yr domestic rates on a 2-day window centered at the business day corresponding to each countrys MP meetings. For this reason, we only present the results on 10-yr yields.

[18] For instance Bauer and Neely (2014), Bauer and Rudebusch (2014), Gagnon et al. (2011), Krishnamurthy and Vissing-Jorgensen (2011) and Rogers et al. (2014) study the channel for which LSAP announcement operates in developed economies identifying the risk neutral and term premia components as the signaling and portfolio balance channels that affects unconventional announcements.

The estimated coefficients are reported in Table 6. In the case of developed economies, we see that prior to Nov. 2008 (1st column) an increase of 100 bp is associated with an effect of 30 bp on long term yields. This corresponds to a highly significant increase of 53 bp in the risk neutral component, partly offset by a reduction in the term premium of 22 bp (significant only at 10%). In the post Nov. 2008 sample (2nd column), the magnitudes are larger, with an effect on overall yields of 47 bp corresponding of 96 bp increase in risk neutral rates, partly offset by a reduction in the term premium of 49 bp (both significant at 1%).

Table 6: Effects of Own monetary policy

	Developed		Emerging	
	Pre Nov. 2008	Post Nov. 2008	Pre Nov. 2008	Post Nov. 2008
Ten-year	0.304***	0.471***	0.256***	0.344**
	(0.066)	(0.038)	(0.070)	(0.123)
risk neutral	0.527***	0.957***	0.702***	0.430***
	(0.147)	(0.117)	(0.084)	(0.050)
term premia	-0.223*	-0.486***	-0.446***	-0.086
	(0.121)	(0.118)	(0.127)	(0.135)

This table shows the estimated coefficients of own monetary policy events, as described in equation (1). The regression is estimated separately for each block: Developed (DEV) and Emerging economies (EME). In parentheses are reported standard errors. *** p-value < 0.01. ** p-value < 0.05 and * p-value < 0.1.

A comparison of these magnitudes with the effect of US MP reveals that spillover mechanisms are actually larger after Nov. 2008 than the effects on domestic yields of each country's own MP (73 bp in table 4, vs just 47 bp in Table 6). It is also interesting to note that while the term premium component contributes positively to US MP spillovers, it plays a systematic offsetting effect when it comes to domestic MP actions.

For EME, the effect of domestic MP meetings on 10-yr yields is a highly statistically significant 26 bp increase pre Nov. 2008 and 34 bp increase after Nov. 2008 (significant at 5%). In both cases the pattern is similar than for DEV countries, with a high increase in the risk neutral component partly offset by a fall in the term premium. As was the case for DEV, we see that US MP has a much larger effect (more than double) on long term yields than domestic MP events after Nov. 2008 (85 bp in Table 4, vs 34 bp in Table 6). The mechanisms involved, however, are starkly different. While US spillover effects in EME work predominantly through a positive term premium component, in the case of domestic MP the largest effect is through risk neutral rates, with the term premium playing an offsetting (negative) role.

4.2 Effect of economic releases

We now study the impact of other economic events, namely releases of inflation (CPI), activity (industrial production) and unemployment. Table 7 reports the results from the panel regression for economic releases for the DEV sample. For space considerations and comparison purposes (with domestic macroeconomic events), we include only the effects on 10-yr yields. In the top panel we report the effects of US macroeconomic releases. Before Nov. 2008, we see no significant impact of CPI releases, but a strong and significant effect of activity (23 bp) and unemployment (37 bp) releases, working almost exclusively through changes in risk neutral rates. In the later part of the sample, there is an increase in the point estimate of US activity releases but the effect is not statistically significant, while the effects of US unemployment releases roughly maintain the economic and statistical significance, again concentrated on the risk neutral component of domestic yields.

In the lower panel of Table 7, we include the effects of domestic macroeconomic releases. We see that 1-yr yield movements around all economic releases have a significant impact on 10-yr yields, with inflation being the most dominant in the first half of the sample (39 bp), followed by unemployment (32 bp) and activity (29 bp). As was the case for domestic MP events, we see a strong positive impact on risk neutral rates, partly offset by a negative movement in term premia. For the second half of the sample, it is activity releases that have the largest effects on long term yields (at 47 bp), followed by CPI (31 bp) and unemployment (15 bp). Comparing the effects of domestic news vis-à-vis US macro releases, it is interesting to note that after Nov. 2008, the impact of US unemployment releases have larger point estimate than the corresponding domestic releases on long term yields, with the response due predominantly to the signaling channel associated with risk neutral rates.

Table 7: Response of DEV 10-year interest rates during economic releases

US	Pre Nov. 2008			Post Nov. 2008		
	Ten-year	risk-neutral	term premia	Ten-year	risk-neutral	term premia
Inflation	0.092	0.127	-0.035	-0.225	-0.118	-0.107
	(0.134)	(0.130)	(0.044)	(0.359)	(0.165)	(0.240)
Activity	0.225**	0.242**	-0.016	0.457	0.074	0.383
	(0.101)	(0.108)	(0.049)	(0.398)	(0.264)	(0.269)
Unemployment	0.367***	0.392***	-0.025	0.309***	0.415***	-0.106*
	(0.055)	(0.055)	(0.020)	(0.085)	(0.066)	(0.054)
Domestic	**Pre Nov. 2008**			**Post Nov. 2008**		
	Ten-year	risk-neutral	term premia	Ten-year	risk-neutral	term premia
Inflation	0.394***	0.702***	-0.308***	0.311***	0.716***	-0.406***
	(0.076)	(0.068)	(0.092)	(0.059)	(0.087)	(0.092)
Activity	0.291**	0.665***	-0.374***	0.473***	0.993***	-0.520***
	(0.110)	(0.068)	(0.058)	(0.071)	(0.078)	(0.143)
Unemployment	0.318***	0.468***	-0.150	0.147**	0.516***	-0.369***
	(0.076)	(0.125)	(0.118)	(0.056)	(0.117)	(0.100)

This table shows the estimated coefficients of US and domestic macroeconomic events, as described in equation (1). The regression is estimated for Developed economies (DEV). In parentheses are reported standard errors. *** p-value < 0.01. ** p-value < 0.05 and * p-value < 0.1.

We now turn to the EME sample, in Table 8. In the top panel we include the effects of US economic releases. Interestingly, in the case of EME the effects are in general not significant, both in the pre and post Nov. 2008 sample.[19] One hypothesis to rationalize these results that is consistent with our previous discussion that perhaps economic releases in the US spillover to other economies only to the extent that they signal future rate movements, which in turn follows from correlated economic fundamentals between the US and other advances economies. Because DEV countries display such a positive correlation in economic fundamentals, we find evidence of a significant spillover effect working predominantly through the risk neutral component. For EME, on the other hand, the decoupling of economic activity from US developments implies a weak or inexistent spillover through risk neutral rates. It seems that economic releases in the US are less associated with portfolio rebalancing forces that seem to affect the term premium component of EME yields around regular FED meetings.

[19] The exceptions are a statistically significant effect of US unemployment releases prior to Nov. 2008 on overall yields (13 bp), and a 59 bp effect of US activity releases on domestic term premium component in the post Nov. 2008 sample (significant at 10%).

Table 8: Response of EME 10-year interest rates during economic releases

US	Pre Nov. 2008			Post Nov. 2008		
	Ten-year	risk-neutral	term premia	Ten-year	risk-neutral	term premia
Inflation	-0.002	0.029	-0.031	-0.452	-0.008	-0.445
	(0.080)	(0.052)	(0.110)	(0.354)	(0.206)	(0.287)
Activity	0.008	0.061	-0.053	0.454	-0.134	0.588*
	(0.062)	(0.054)	(0.082)	(0.391)	(0.276)	(0.321)
Unemployment	0.125**	0.015	0.111	0.137	0.096	0.040
	(0.056)	(0.058)	(0.093)	(0.144)	(0.067)	(0.101)
Domestic	**Pre Nov. 2008**			**Post Nov. 2008**		
	Ten-year	risk-neutral	term premia	Ten-year	risk-neutral	term premia
Inflation	0.053	0.263***	-0.209***	0.262***	0.419***	-0.158**
	(0.038)	(0.061)	(0.063)	(0.068)	(0.052)	(0.065)
Activity	0.127	0.323***	-0.197*	0.350**	0.481***	-0.130**
	(0.107)	(0.036)	(0.099)	(0.117)	(0.104)	(0.058)
Unemployment	0.302	0.785***	-0.483	0.244**	0.741***	-0.497***
	(0.198)	(0.188)	(0.345)	(0.085)	(0.073)	(0.144)

This table shows the estimated coefficients of US and domestic macroeconomic events, as described in equation (1). The regression is estimated for Emerging economies (EME). In parentheses are reported standard errors. *** p-value < 0.01. ** p-value < 0.05 and * p-value < 0.1.

In the case of domestic economic releases (bottom panel of Table 8) the impact of economic releases on overall yields are non significant in the pre Nov. 2007 sample, although the effect in all cases composed of statistically significant increase in risk neutral rates, partly offset by a negative effect in the term premium component (as was the case with domestic MP releases). After Nov. 2008, the effects of all domestic economic releases are significant (at 5% or more level of confidence), again compose of an increase in risk neutral rates, and a reduction in term premium.

5 Robustness

We now briefly describe different robustness checks that we perform on our main specification. For space considerations, we report only the coefficients related to US MP spillovers (for overall 10-yr yields, and each of their components, as well as pre and post Nov. 2008). The main tables are included in Appendix B, and we limit our attention here to highlighting the main results.

Our first set of robustness checks are related to the choice of fixed effects in equation (1). We present four alternative fixed effects specifications, as detailed in the rows of the lower panel of Table 10. In this same exercise, we present the alternative p-values that result from choosing a different time frame for clustering errors (two last rows in the lower panel of the figure). We find that in most cases the point estimates of spillovers under alternative FE specifications are increased, and using alternative an clustering does not have a major impact on statistical significance.

A second set of robustness checks involve sample selection. We repeat all calculations but iteratively replacing one country from each group (for example, we run all the regressions for DEV without Japan, then put Japan back in and exclude Sweden, and so forth). This is to ensure that our main results are not driven by specific outliers. These results are reported in Table 11. The main conclusions remain intact, namely, while significant US MP spillover effects are present in the post Nov. 2008 data, the effect on DEV is much more tilted towards spillovers through risk neutral rates, while EME are predominantly affected though the term premium channel.

Finally, a third robustness check involves changing the specific interest rate variable used on the left hand side of equation (1) as is presented in Table 12. That is, instead of using fitted yields from the affine model estimation, we use the observed yields. This implies that while the effect on the risk neutral component and the term premium component are identical as in the baseline regression –since they are still the estimated components from the yield curve model–, they will not add up exactly to the effect on overall yields due to the existence of measurement error in the model specification. This modification does not qualitatively change our main results, as can be seen in the comparison between Table 4 and Table 12.

6 Conclusions

In this paper, 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 changes are identified as the response of short-term US treasury yields within a narrow window of Federal Reserve meetings, and trace its consequences on domestic bond yields using panel data regressions. Moreover, we decompose yields at each individual country level into a risk neutral component, which captures the expected evolution of short-term rates, and bond term premia.

We conclude that while the spillover effect to developed countries work predominantly through changes in the risk neutral component, the impact on our sample of emerging countries points to a transmission mechanism associated with compensation for risk. Our results are consistent with the strong correlation in activity, inflation, and monetary policy paths between the US and our developed economy sample, and the low correlation of the US along these dimensions with emerging countries. On the other hand, the evident correlation in fixed income fund flows to both groups of countries suggests that portfolio flows might affect emerging market economies irrespective of whether they share fundamentals with the US, providing a rationale for strong spillover mechanisms working through risk compensation. Indeed, such spillovers are even larger than the effect on long term yields of countries own monetary policies after 2008.

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Appendix A Economics indicators

Table 9 shows the economic indicator used to identify the days when economic releases are reported described in section 2.2. The three columns show the economic indicator used in CPI, Activity and Unemployment for all countries. The parentheses shows the frequency of each variable being (Q): quarterly, (M): monthly, (B): bi-weekly and (W): weekly. When the data is not available or unreported by the Bloomberg Surveys we refer as N/A.

Table 9: Economic releases description

	CPI	Activity	Unemployment
US	CPI Urban Consumers (M)	Industrial Production YoY (M)	Initial Jobless Claims SA (W)
CAD	CPI YoY (M)	GDP All industries (M)	Unemployment rate SA (M)
JPN	CPI Nationwide YoY (M)	Industrial Production YoY (M)	Unemployment rate SA (M)
UK	CPI EU Harmonized YoY (M)	Industrial Production YoY (M)	Claimant Count 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)
FR	CPI EU Harmonized YoY (M)	Industrial Production YoY (M)	Unemployment rate SA (M)
AUD	CPI All Groups Goods (Q)	GDP YoY (Q)	Unemployment rate SA (M)
NZ	CPI All Groups (Q)	GDP YoY (Q)	Unemployment rate SA (Q)
CHK	CPI YoY (M)	Industrial Production YoY (M)	N/A (N/A)
KOR	CPI YoY (M)	Industrial Production YoY (M)	Unemployment rate SA (M)
TW	CPI YoY (M)	Industrial Production YoY (M)	Unemployment rate SA (M)
NOR	CPI YoY (M)	Industrial Production YoY (M)	Unemployment rate SA (M)
SW	CPI Headline YoY (M)	Industrial Production YoY (M)	Unemployment rate SA (M)
SZ	CPI YoY (M)	GDP YoY (Q)	Unemployment rate SA (M)
CL	CPI YoY (M)	Monthly Economic Index (M)	Unemployment rate SA (M)
MX	Biweekly CPI (B)	Industrial Production YoY (M)	Unemployment rate SA (M)
HUN	CPI YoY (M)	Industrial Production YoY (M)	Unemployment rate SA (M)
SOA	CPI YoY (M)	Manufacturing Production (M)	Unemployment rate SA (Q)
TH	CPI YoY (M)	GDP YoY (Q)	N/A (N/A)
ISR	CPI YoY (M)	GDP YoY (Q)	N/A (N/A)
INDO	CPI YoY (M)	GDP YoY (Q)	N/A (N/A)
IND	CPI YoY (M)	GDP YoY (Q)	N/A (N/A)
POL	CPI YoY (M)	Industrial Goods & Services (M)	Unemployment rate SA (M)
COL	CPI YoY (M)	Industrial Production YoY (M)	Unemployment rate SA (M)

Appendix B Robustness estimation

This appendix reports the three robustness exercises described in section 5. Our first set of alternative specification deal with including different fixed effects, as well as considering different clusters for constructing standard errors.

In table 10 the first panel includes the results for US MP spillovers into DEV economies, while the second panel reports the results on EME. For ease of comparison, the third column of the table reproduces the spillovers effects on long term yields in the baseline regression. Columns 4 to 11 replicate the estimation considering different combination of fixed effects in the panel regression, as well as alternative clusters which have an effect only on the significance of point estimates. The different combinations consider for each specification are detail in the bottom panel of the table. For example, fourth column of the table considers as specification in which there are no fixed effects and error are clustered at daily frequency.

Table 10: Changes in Fixed effects and clusters

Sample	yields	Baseline	Panel A: Developed Economies							
Pre Nov. 2008	Ten-year	0.085	0.080	0.080	0.081	0.081	0.081	0.081	0.085	0.085
Pre Nov. 2008	risk neutral	0.154	0.158**	0.158	0.154**	0.154	0.154**	0.154	0.154**	0.154
Pre Nov. 2008	term premia	-0.069***	-0.078**	-0.078***	-0.073**	-0.073***	-0.073**	-0.073***	-0.069**	-0.069***
Post Nov. 2008	Ten-year	0.731*	0.807**	0.807*	0.764**	0.764**	0.763**	0.763**	0.731**	0.731*
Post Nov. 2008	risk neutral	0.476**	0.525***	0.525**	0.479***	0.479**	0.478***	0.478**	0.476***	0.476**
Post Nov. 2008	term premia	0.255	0.282	0.282	0.285	0.285	0.285	0.285	0.255	0.255
Sample	yields	Baseline	Panel B: Emerging Economies							
Pre Nov. 2008	Ten-year	0.277	0.258	0.258	0.273	0.273	0.273	0.273	0.277	0.277
Pre Nov. 2008	risk neutral	0.061	0.058	0.058	0.061	0.061	0.062	0.062	0.061	0.061
Pre Nov. 2008	term premia	0.215	0.200	0.200	0.212	0.212	0.212	0.212	0.215	0.215
Post Nov. 2008	Ten-year	0.854**	1.205***	1.205***	0.834***	0.834**	0.834***	0.834**	0.854***	0.854**
Post Nov. 2008	risk neutral	0.115	0.409	0.409	0.133	0.133	0.132	0.132	0.115	0.115
Post Nov. 2008	term premia	0.739**	0.796***	0.796***	0.701***	0.701**	0.701***	0.701**	0.739***	0.739**
Controls		Baseline	Fixed effects and clusters							
FE	Country	No	No	No	Yes	Yes	No	No	No	No
FE	Year	Yes	No	No	Yes	Yes	No	No	No	No
FE	Country-Year	No	No	No	No	No	Yes	Yes	No	No
FE	Country-Month	Yes	No	No	No	No	No	No	Yes	Yes
C	Day	No	Yes	No	Yes	No	Yes	No	Yes	No
C	Month	Yes	No	Yes	No	Yes	No	Yes	No	Yes

Source: author's calculations

The second robustness exercise entertains the possibility that our results may be due to outliers in either subsamples of countries. To rule out this hypothesis, we iteratively exclude a particular country (in each country group, DEV and EME), and estimate the baseline regression with the remainder 11 members. The first column in table 11 identifies the country that is excluded in each iteration.

Table 11: Effects of removing each-country of the sample

Country excluded	Panel A: Developed economies					
	Pre Nov. 2008			Post Nov. 2008		
	Ten-year	risk neutral	term premium	Ten-year	risk neutral	term premium
AUD	0.061	0.153	-0.092***	0.745*	0.507**	0.238
CAD	0.095	0.149	-0.054*	0.749*	0.482**	0.267
CHK	0.082	0.153	-0.071**	0.785*	0.483**	0.302
FR	0.086	0.144	-0.058**	0.691*	0.351**	0.340
GER	0.087	0.144	-0.058**	0.682*	0.410**	0.272
ITA	0.092	0.135	-0.043**	0.694*	0.489**	0.205
JPN	0.089	0.165	-0.076**	0.770*	0.517**	0.254
NOR	0.102	0.184	-0.082***	0.678*	0.542**	0.135
NZ	0.069	0.125	-0.056**	0.801*	0.628**	0.174
SW	0.086	0.164	-0.078***	0.708**	0.435**	0.273
SZ	0.091	0.173	-0.082***	0.724*	0.499**	0.225
UK	0.085	0.165	-0.080***	0.736**	0.359**	0.377
	Panel B: Emerging economies					
Country excluded	Pre Nov. 2008			Post Nov. 2008		
	Ten-year	risk neutral	term premium	Ten-year	risk neutral	term premium
CL	0.286	0.068	0.217	0.903**	0.121	0.781**
COL	0.257	0.125*	0.133	0.863**	0.160	0.703**
HUN	0.283	0.076	0.208	0.766**	0.058	0.708**
IND	0.289	0.056	0.233	0.879**	0.165	0.714**
INDO	0.217*	0.001	0.217	0.834***	-0.007	0.841***
ISR	0.313	0.053	0.260	0.827**	0.175	0.653**
KOR	0.295	0.067	0.229	0.905**	0.139	0.765**
MX	0.261	0.051	0.210	0.783**	0.097	0.685**
POL	0.290	0.048	0.242	0.914**	0.108	0.806***
SOA	0.281	0.079	0.202	0.813*	0.136	0.677**
THAI	0.271	0.060	0.211	0.842**	0.068	0.774**
TW	0.276	0.053	0.223	0.920**	0.164	0.757**

Source: author's calculations

Finally, Table 12 presents the results of estimating US MP spillovers on observed country yields rather than on the implied fitted value that arises from the affine model estimation. As discuss above this implies that the point estimate and significance of individual channels are identical as the baseline regression reported in Table 4.

Table 12: Effects of US monetary policy

	Panel A: Developed economies			
	Pre Nov. 2008		Post Nov. 2008	
	One-year	Ten-year	One-year	Ten-year
yield	0.163**	0.097	0.321**	0.717*
	(0.053)	(0.105)	(0.134)	(0.345)
risk neutral	0.131*	0.154	0.386**	0.476**
	(0.063)	(0.106)	(0.132)	(0.172)
term premia	0.008	-0.069***	0.047	0.255
	(0.017)	(0.022)	(0.083)	(0.212)

	Panel B: Emerging economies			
	Pre Nov. 2008		Post Nov. 2008	
	One-year	Ten-year	One-year	Ten-year
yield	0.124	0.263	0.439	0.814**
	(0.090)	(0.176)	(0.284)	(0.305)
risk neutral	0.064	0.061	0.082	0.115
	(0.053)	(0.053)	(0.209)	(0.201)
term premia	0.124	0.215	0.344***	0.739**
	(0.077)	(0.186)	(0.070)	(0.270)

This table shows the estimated coefficients of US monetary policy events, as described in equation (1). The regression is estimated separately for each block: Developed (DEV) and Emerging economies (EME). In parenthesis are reported standard errors. *** p-value < 0.01. ** p-value < 0.05 and * p-value < 0.1

Appendix C Affine Model estimation

As we mentioned earlier, the main differences proposed by Adrian et al. (2013) regards the way in which market prices of risk are constructed. To obtain those prices, the authors propose the following three steps 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:

$$rx_{t+1}^{n-1} = \log P_{t+1}^{n-1} - \log P_t^n - r_t, \qquad n = 2, ..., N \tag{11}$$

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

$$rx = \alpha\iota_T' + \beta'\hat{V} + cX_- + E \tag{12}$$

   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 et al. (2013) shows that the fundamental decomposition of these returns could be written as:[20]

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

   After running (12), 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 (12), compute the market prices of risk as:

$$\hat{\lambda}_0 = (\hat{\beta}\hat{\beta}')^{-1}\hat{\beta}[\hat{a} + \frac{1}{2}(\hat{B}^*\text{vec}(\hat{\Sigma}) + \hat{\sigma}^2)] \tag{13}$$

$$\hat{\lambda}_1 = (\hat{\beta}\hat{\beta}')^{-1}\hat{\beta}\hat{c} \tag{14}$$

[20] See that paper for details.

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, we are able to compute equations (2)-(10). The difference between fitted yields and risk-neutral yields corresponds to the risk or term premium.

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