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Abstract

Using monetary policy shocks for 7 advanced economy central banks, measured at high frequency, we document the strength and characteristics of interest rate spillovers to 47 advanced and emerging market economies. Our main goal is to assess different channels through which spillovers occur and why some economies' interest rates respond more than others. We find that there is no evidence that spillovers relate to real linkages, such as trade flows. There is some indication that exchange rate regimes influence the extent of spillovers. By far the strongest determinant of interest rate spillovers is financial openness. Economies that have stronger bilateral (and aggregate) financial links with the United States or euro area are susceptible to stronger interest rate spillovers. These effects are much more pronounced at the longer end of the yield curve, indicating that while economies retain policy rate independence, financial conditions are influenced by global yields.

JEL Classification Numbers: E44, F36, F42, F65

Keywords: monetary policy spillovers, high-frequency data, financial integration

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1. Introduction

It is well established that interest rates co-move across countries. The extent of this co-movement, and the underlying drivers, are more uncertain but are important for many reasons. The greater the co-movement of a country's interest rates with foreign rates that is unrelated to domestic conditions, the weaker the control by the central bank over domestic financial conditions, diminishing its ability to achieve its policy objectives. Interest rate co-movement is also an important channel through which financial shocks can propagate internationally. In addition, co-movement may diminish the diversification opportunities available to international investors in fixed income markets.

Concerns regarding co-movement have been particularly prominent surrounding quantitative easing (QE) and its reverse, as 'quantitative tightening' gathers momentum. The exceptionally large expansions in major central banks' balance sheets in the wake of the financial crisis and thereafter depressed domestic yield curves. QE policies are also commonly believed to have spilled over to very easy financial conditions and low yields in other countries, which may not have been warranted given domestic economic conditions in those economies. However, a pertinent policy question remains over whether major central banks' eventual balance sheet wind-down will spillover to other countries' yield curves in a symmetric manner as macroeconomic and financial conditions are very different now to when these policies were first implemented.

While many papers have documented some co-movement of interest rates internationally, extant work often struggles to cleanly identify whether the co-movement stems from spillovers in a causal sense or rather from common drivers. In this paper, we improve on the existing literature by using cleanly identified monetary policy shocks from high-frequency interest rate changes to precisely estimate the spillovers from one country's interest rates to others.[1]

We identify three components to a monetary policy shock: (i) a 'target' policy rate shock, (ii) a shock to the expected 'path' of policy, and (iii) a 'term premium' shock. This set-up encompasses the wide range of information contained in central bank announcements, and allows us to use a sample that covers both the period of 'normal' interest rate policies prior to the financial crisis and the period of 'zero' policy rates that followed in the QE period.

Our study uses a rich set of data in the time-series and cross-sectional dimensions. Using high-frequency data to measure the interest rate change to the originating economy's monetary policy announcement ensures exogeneity and thus enables us to pin down the direction of spillovers in a causal sense. We perform this analysis for monetary policy shocks originating from 7 advanced economies. We look beyond the 'matrix' of monetary policy spillovers among these 7 economies, to consider an even larger matrix of responses of 47 advanced and emerging market economies. We test for spillovers for short- and long-term interest rates. This approach provides more power for the analysis in the cross-sectional dimension, to better shed light on the nature and extent of interest rate spillovers.

Another key feature of our work is to thoroughly test through which channels interest rate spillovers occur. We propose three alternative channels: (i) domestic economic conditions (including economic linkages), (ii) FX regime, and (iii) the impact of bond risk premia (and financial factors more broadly).

1 Note that throughout this paper, we use the term 'spillovers' in a broad sense to encompass changes in an economy's interest rate that are in *direct* response to those in another economy's interest rate.

We use a comprehensive set of financial and economic data for our broad panel of economies, encompassing bilateral and aggregate economic and financial links as well as economy-specific factors. With these data at hand, we explore the economic and financial conditions that lead to stronger (or weaker) interest rate spillovers.

We find that there are strong spillovers originating from Federal Reserve monetary policy announcements, leading to a swift repricing of fixed income markets globally. Notably, however, the Fed is not the sole originator of spillovers. We also present evidence of significant spillovers from ECB policies, albeit to a lesser extent. However, spillovers from other advanced economy central banks, including from the Bank of Japan and the Bank of England, are mild.

The spillovers we document are much more prevalent for long-term interest rates, while short rates do not consistently respond to foreign monetary policy news. This suggests that central banks have been able to retain a significant degree of autonomy in their interest rate policies (consistent, for example, with Obstfeld (2015)), despite the forces of the global financial cycle.[2] One may argue, however, in line with Rey (2013) that it is particularly longer-term rates that determine financial conditions. Our results are thus consistent with the view that the independence of central banks to determine financial conditions is limited by the presence of spillover effects. And, somewhat surprisingly, we find that such spillover effects are larger to advanced economies (that are well-integrated in global capital markets) than they are to emerging markets.

We obtain a clear picture regarding the factors explaining different intensities of spillovers across economies. There is no empirical support for a macroeconomic channel in explaining the strength of spillovers. Neither trading linkages nor general economic openness are related to the sensitivity of interest rates to policy shocks in other currency areas. There is partial support for a channel related to exchange rates. In support of the bond risk premium spillover channel, financial openness unambiguously emerges as the strongest factor in explaining the extent of the sensitivity of an economy's interest rates to monetary policy shocks in major advanced economies. In explaining interest rate sensitivity, 'financial openness' is best captured by bilateral portfolio equity flows and the amount of the economy's debt denominated in the currency of the spillover originator economy, although the results are robust to using many alternative measures of financial openness.

The remainder of the paper is structured as follows. In Section 2 we outline the channels through which policy in one country can spill over (in the broad sense of the word) to other countries' interest rates and discuss the related literature. In Section 3 we provide a road map of our methodology for detecting spillovers and testing the different spillover channels. In Section 4 we outline the detailed data we use to first identify spillovers and then to test the channels. We then present our results on global spillovers and their main drivers in Sections 5 and 6, respectively. We then conclude.

2 Miranda-Agrippino and Rey (2015) suggest US monetary policy is a key driver of the global financial cycle. See, for example, Cerutti, Claessens and Rose (2017) for new evidence and a sceptical view regarding the existence of a global financial cycle, as conditions in the core do not explain a large share of global capital flows.

2. Why Do Monetary Policy Spillovers Occur?

2.1 Spillover Channels

Yield curves can be in influenced by a range of domestic and international factors.[3] In most financial systems, short-term market rates are dominated by central bank policy actions. Central banks' policy mandates and goals differ across countries, but most respond to macroeconomic conditions (in particular inflation, and often unemployment or the output gap) and, for some, exchange rate considerations matter as well. Central banks' control over long-term rates is usually significantly weaker under most monetary operating systems.[4] Long-term government bond yields reflect not only current and expected short-term rates, but also various risk premia (such as term premia and in some cases, for example emerging markets, also credit premia). Based on these broad macroeconomic and financial determinants of short and long interest rates, we identify *three potential channels* through which spillovers can occur from interest rates in an originator economy to those in the recipient economy.

2.1.1 Domestic macroeconomic conditions

Monetary policy announcements (in the originator country) may reveal new information on economic conditions in that country, as suggested by Campbell *et al* (2012) and Nakamura and Steinsson (2018). This may in turn lead investors to update their expectations of macro conditions in the recipient country due to the various economic linkages between the two economies. Such interlinkages can result from trade flows, or can encompass a range of business and information flows that manifest themselves through co-movements in business cycles (e.g. Kose, Otrok and Whiteman 2003; Baxter and Kouparitsas 2005) and/or inflation dynamics (e.g. Ciccarelli and Mojon 2010; Neely and Rapach 2011).

2.1.2 FX regime

Spillovers can occur via a foreign exchange (FX) channel if a country pegs its exchange rate to that of a larger economy, either formally or implicitly (including arrangements such as a managed or 'dirty' float). If it has an open capital account, then the country implementing the peg will need to maintain interest rates close to those of the larger economy in order to avoid exceptionally large capital flows (e.g. Shambaugh 2004).

Changes in interest rates in the larger economy will then be reflected almost mechanically in the yield curve of the smaller economy at least through expectations of the domestic policy interest rates, even if the recipient country's central bank does not respond immediately. In effect, the country pegging its exchange rate virtually 'outsources' its monetary policy to the larger economy. Not only will this lead to a co-movement in short-term policy rates, but if the peg is credible and expected to persist, interest rates at all maturities will co-move. Even some countries with notionally flexible exchange rate regimes may want to avoid large exchange rate adjustments against a major currency, for example for trade competitiveness or financial stability reasons, and hence their policy rates may shadow that of the larger economy. Alternatively, they may intervene in the FX market to

3 See Diebold, Piazzesi and Rudebusch (2005), Gürkaynak and Wright (2012), or Dahlquist and Hasseltoft (2013) for examples.

4 A notable exception is the Bank of Japan has been implementing a target for long-term bond yields since 2016 based on flexible asset purchases, labelled 'yield curve control'.

smooth the bilateral exchange rate. Even if such interventions are sterilised, local bond yields could still be affected through signalling and/or portfolio rebalancing effects.

2.1.3 Bond risk premia and financial conditions

With globally integrated capital markets, movements in term premia (and other possible risk premium components) in a large economy can drive those in other economies. This can occur, for instance, through the portfolio flows of international investors that are active in different countries' bond markets as they seek higher yielding assets, often described as a 'search for yield'.[5] Spillover effects can also arise due to the presence of global intermediaries and their relevant risk constraints (e.g. Bruno and Shin 2015; Malamud and Schrimpf 2018).

The intensity of these spillovers will depend on the degree of financial integration between the economies. This type of spillover, in particular if it operates independently of the exchange rate regime, also relates to the ongoing debate on the global financial cycle and the 'dilemma not trilemma' conjecture of Rey (2013, 2016). We return to this issue when we discuss the implications of our results.

2.2 Related Literature

This paper relates to several branches of the literature. Various papers examine how foreign asset prices respond to monetary policy shocks, although nearly all only consider interest rate changes by the largest central banks, the US Federal Reserve and/or ECB. Typically extant work also considers only a relatively narrow set of recipient countries (often emerging markets).[6] A number of papers have documented interest rate spillovers to foreign bonds, notably Gilchrist, Yue and Zakrajšek (2014) and Andersen *et al* (2007).[7] While most papers consider spillovers to (longer-term) bond yields, Edwards (2015) and Takáts and Vela (2014) find evidence of spillovers to short-term or policy rates although Devereux and Yetman (2010), Miyajima, Mohanty and Yetman (2014), and Obstfeld (2015) do not.[8] Others have looked at interest rate spillovers in a broader context, noting there are net economic spillovers, for example Fukuda *et al* (2013), Ammer *et al* (2016) and Georgiadis (2016).

Our paper is also related to the recent literature on the international impact of QE. Many papers have found spillovers from the Federal Reserve asset purchases, including Neely (2010), Wright (2012), Bauer and Neely (2014), Rogers, Scotti and Wright (2016) and Fratzscher, Lo Duca

5 This channel also relates to the risk-taking channel of monetary policy, as coined by Adrian and Shin (2010) and Borio and Zhu (2012). Bekaert, Hoerova and Lo Duca (2013) find that US monetary policy (measured via changes in policy rates) affects variance risk premiums based on the VIX, a common gauge for the global price of risk.

6 Some papers also look at the spillovers to exchange rates or foreign equities, such as Wongswan (2006, 2009), Kim and Nguyen (2009), Ammer, Vega and Wongswan (2010) and Brusa, Savor and Wilson (2018).

7 Other earlier contributions include Ehrmann and Fratzscher (2003), Forbes and Chinn (2004), Faust *et al* (2007), Craine and Martin (2008), and Ehrmann and Fratzscher (2009) for equity markets.

8 While most papers typically use daily (and sometimes intra data), some others have looked at spillovers to foreign interest rates, or other asset prices, with lower frequency VARs combining monthly or quarterly macro data. In some cases, these papers impose a Taylor rule to attempt to separate common shocks from spillovers, which makes strong assumptions about the suitability of the Taylor rule for identification of spillovers, see for example Bredin, Hyde and Reilly (2010), Fukuda *et al* (2013), Hofmann and Takáts (2015), Han and Wei (2016) and Dedola, Rivolta and Stracca (2017).

and Straub (2018).[9] In comparison with conventional monetary policies, Curcuru *et al* (2018) found that QE did not exert greater international spillovers. Other studies have also found that other major central banks' QE policies also triggered spillovers; Rogers, Scotti and Wright (2014) and Chen *et al* (2016) show that Fed, Bank of England and ECB unconventional policies affected foreign bond yields, although QE by the Bank of Japan did not. In contrast, Fratzscher, Lo Duca and Straub (2016) find that unconventional policies by the ECB had negligible effects on other countries' yields.

Some papers have gone beyond documenting international interest rate spillovers, and attempt to explain them. Two papers have a similar objective to ours. Hausman and Wongswan (2011) look at the effect of FOMC announcement surprises on short and long interest rates (for 20 countries). They use a fairly small number of explanatory variables to model the cross-section of responses, though, and study a sample period that ends before the financial crisis.[10] Bowman, Londono and Sapriza (2015) examine what variables relate to the intensity of US unconventional monetary policy spillovers to emerging market sovereign yields, but they do not consider spillovers to advanced economies and focus on QE.[11] The cross-section of responsiveness is modelled in a panel data framework with a broad set of country-specific controls. A number of other papers have found the intensity of spillovers to relate to various specific factors, including Shah (2018) (the level of interest rates), Aizenman, Chinn and Ito (2016) and MacDonald (2017) (degree of integration), Mishra *et al* (2014) and Ahmed, Coulibaly and Zlate (2017) (economic fundamentals for emerging market economies), Jotikasthira, Le and Lundblad (2015) (risk compensation) and Ehrmann and Fratzscher (2005) (monetary union).[12]

Our paper improves upon this existing work by precisely identifying interest rate spillovers from a broader set of central banks (seven major advanced economies), not just the Federal Reserve, for both short- and long-term interest rates. A key feature of our work is to consider the *full matrix of spillovers* to a plethora of advanced and emerging market economies. This approach is sensible given the dense network structure of financial claims connecting different economies highlighted in Shin (2017). Crucially, we then put some structure on the transmission of spillovers by using a comprehensive dataset covering bilateral and aggregate economic and financial linkages. The goal of these empirical tests is to assess through which channels spillovers occur.

3. Research Design: Detecting and Explaining Spillovers

This section provides a brief summary of the main features of the research design. Our empirical analysis of spillovers proceeds in two stages.

Detecting spillovers. First, we test which central banks' policy actions trigger spillovers to others, and which economies' interest rates are most receptive. Specifically, we start with separate

9 This literature builds on studies finding that QE compressed domestic long-term yields, for the United States see Gagnon *et al* (2011), Krishnamurthy and Vissing-Jorgensen (2011) and Swanson (2016), and also Christensen and Rudebusch (2012) for the United States and the United Kingdom, and Krishnamurthy, Nagel and Vissing-Jorgensen (2017) for the ECB.

10 The variables they consider are: trade/GDP, trade with US/GDP, exports to US/GDP, share of equities owned by US, share of equity foreigners can own, total stock of bank lending form US/GDP, exchange rate regime, size of equity market/GDP.

11 They find smaller spillovers for stock prices and exchange rates.

12 Other studies have examined how the spillovers to equities and exchange rates in emerging markets relate to economic fundamentals, such as Aizenman, Binici and Hutchison (2016).

regressions for each originator-recipient combination of economies to compare spillovers from shock-originating central banks to recipient economies for interest rates. The equation we estimate is given as

$$\Delta r_{i,t} = \alpha_{ij} + \beta'_{ij} MPS_{j,t} + \varepsilon_{i,j,t} \quad (1)$$

where $\Delta r_{i,t}$ is the change in interest rates in economy i and $MPS_{j,t}$ is our measure of monetary policy shocks from central bank j. We provide exact details on measurement in Section 4 below.

Explaining spillovers. Second, we aim to distinguish between the different spillover channels outlined above drawing on the richness of our data in the cross-section of economies. The three channels differ in the types of macro and financial conditions affecting the strengths of spillovers across economies. For the channel of domestic economic conditions, we expect that spillovers should positively relate to bilateral trade flows as well as macroeconomic interlinkages (e.g. as proxied by correlations of the business cycle and inflation across economies). The FX regime channel posits that, when an exchange rate is tied to that of a major currency, volatility in the corresponding exchange rate cross will be significantly muted. Hence, one would expect FX volatility and spillover strengths to be negatively correlated. As for the channel of bond risk premia and financial conditions, a key prediction is that economies that are more financially open should receive larger spillovers.

To shed light on the empirical relevance of the three channels as spillover determinants, we run the following regression with interaction terms

$$\Delta r_{i,t} = \alpha_j + \theta'_j Z_t + \left(\boldsymbol{\beta}'_j + \gamma'_j X_{i,t-1}\right) MPS_{j,t} + \varepsilon_{j,t} \quad (2)$$

where Z_t is a global control; $X_{i,t}$ is a recipient-specific conditioning variable; θ_j measures the sensitivity to global controls; $\boldsymbol{\beta}_j$ is a vector that measures the unconditional spillover from our three monetary policy shocks.[13] Our main object of interest here is γ_j, which measures the spillover *conditional* on (recipient) economy-specific controls.

Our conditioning variable $X_{i,t}$ either measures economic linkages, conditions governing the FX regime of the economy, or financial linkages between the originator and recipient economies. Another important dimension to differentiate our channels is the maturity of the interest rates that will be more affected by spillovers. The domestic economic channel will be more prevalent for short rates (or expectations of future short rates embedded in long-term rates). The FX regime channel, by contrast, will operate predominantly via short-term interest rates, but longer-term rates might also be affected to some extent. As for the risk premium channel, we expect mostly long-term rates to be subject to spillover effects. This is because yields at the longer end of the yield curve are more susceptible to risk premium fluctuations than yields at the shorter end. The latter will be driven to a larger extent by expectations about the path of future short rates. Table 1 summarises the different predictions of the three spillover channels and our empirical approach to differentiate among them.

13 For conditional variables, some of them measure bilateral relations. In that case, they are not only recipient-specific but also originator-specific.

Table 1: Distinguishing Spillover Channels

	Channel	Maturity of affected interest rates	Macrofinancial conditioning variables
(a)	Domestic macroeconomic conditions	Mainly short	Trade (+); commonality in growth and inflation (+)
(b)	FX regime	Both short and long	FX volatility (–)
(c)	Bond risk premia and financial conditions	Long	Financial openness (+)

Notes: The table summarises testable implications of the three spillover channels along two key dimensions: (i) maturity of the affected interest rates, and (ii) macroeconomic or financial conditioning variables determining whether spillovers might be stronger or weaker; the (+)/(–) sign in parentheses indicates whether the expected relationship between the conditioning variables and spillover strength is positive/negative

4. Data

A key feature of our work is to rely on high-frequency data on various interest rates to measure the surprise element of monetary policy announcements. This approach ensures exogeneity of the measured monetary policy shocks, and hence us allows to pin down the direction of spillovers in a causal sense.

4.1 High-frequency Monetary Policy Shocks

We construct monetary policy shocks from interest rate changes in a narrow window around monetary policy announcements. These include both scheduled monetary policy events such as the release of information on the outcomes of policy meetings, as well as non-scheduled events (e.g. key speeches or press releases) that reveal news about unconventional policies such as asset purchases or forward guidance.[14] We summarise the monetary policy shock from central bank j at time t by a three-dimensional vector to capture the different components of news included in the central bank announcement

$$MPS_{j,t} = \begin{bmatrix} \tilde{\Delta} r_{j,t}^{1\mathrm{m}\,OIS} \\ \tilde{\Delta} r_{j,t}^{2\mathrm{y}} \perp \tilde{\Delta} r_{j,t}^{1\mathrm{m}\,OIS} \\ \tilde{\Delta} r_{j,t}^{10\mathrm{y}} \perp \tilde{\Delta} r_{j,t}^{2\mathrm{y}} \end{bmatrix} \tag{3}$$

where $\tilde{\Delta} r$ represents the change in the interest rate in a narrow window of +/– 20 minutes around the announcement

$$\tilde{\Delta} r_t = \overline{r_{t+5min \to t+20min}} - \overline{r_{t-20min \to t-5min}}$$

Note that we use a 15-minute average before and after the event to reduce any noise in quoted interest rates. When computing the level shift in average interest rates before and after the event, we omit five minutes just before and after to account for the time the market takes to process the news and to be robust against any potential misalignment of timestamps.[15] Our source of (1-minute)

14 See Ferrari, Kearns and Schrimpf (2017) for a more detailed description of the dataset of monetary policy events.

15 For ECB monetary policy shocks, we make use of German government bond yields which are the common benchmark rates in the euro area. Moreover, we use a larger window of one hour in order to also cover market reactions to the ECB's press conference.

high-frequency data for the computation of monetary policy surprises by these seven central banks is Thomson Reuters (now Refinitiv) Tick History.

The first component of the monetary policy shock vector given in Equation (3) is the change in the interest rate on 1-month overnight indexed swaps (OIS).[16] We refer to this as the 'target' shock as it captures the repricing of market expectations of the short-term policy rate target. The second component is the change in the 2-year government bond yield that is orthogonal to the change in 1-month OIS rates. We refer to this as the 'path' shock, as it largely reflects revisions in investor expectations of the expected path of policy rates in the future. These two components originally proposed by Gürkaynak, Sack and Swanson (2005) have been commonly used in the literature.[17]

To broaden the channels through which monetary policy can have an impact, and in order to accommodate episodes of unconventional policies, we expand the monetary policy shock vector by a third component – a risk premium shock. We measure this shock as the change in the 10-year government bond yield that is orthogonal to the change in 2-year yields. This component is intended to capture the impact on risk premia induced by news about monetary policy, in particular for asset purchase programs which have been found to operate to a large extent via their impact on term premia. Gilchrist *et al* (2014) adopted a similar measure to assess the impact of US unconventional monetary policy.[18]

We consider monetary policy shocks from seven advanced economy central banks: Federal Reserve, European Central Bank, Bank of Japan, Bank of England, Bank of Canada, Reserve Bank of Australia, Swiss National Bank. An overview of the different central banks' monetary policy events is given in Table 2. It provides a summary of basic statistics for the shocks, including mean, standard deviation, time span and number of observations of these shocks. Target shocks close to zero on average for all the seven central banks, which ensures that our sample is not biased towards monetary policy easing or tightening regimes. The average for both path and premium shocks is zero by construction. Standard deviations for the three shocks are more or less of similar magnitudes, suggesting the necessity of including all these components to measure the monetary policy shock.

16 OIS contracts are OTC derivatives contracts allowing investors to hedge against (or speculate on) movements of the average level of the overnight rate over the maturity of the contract. Unlike futures contracts which refer to the overnight rate in a particular calendar month, the maturity in the OIS contract is fixed. Hence they allow investors to more finely calibrate their hedges. OIS contracts are widely traded in a broad array of currencies.

17 In fact, Gürkaynak *et al* (2005) find that most of the explanatory power of monetary policy news for US Treasury yields comes from their 'path' factor derived from short rates and interest rate futures.

18 Also see Swanson and Williams (2014) for an approach that is similar in spirit than ours.

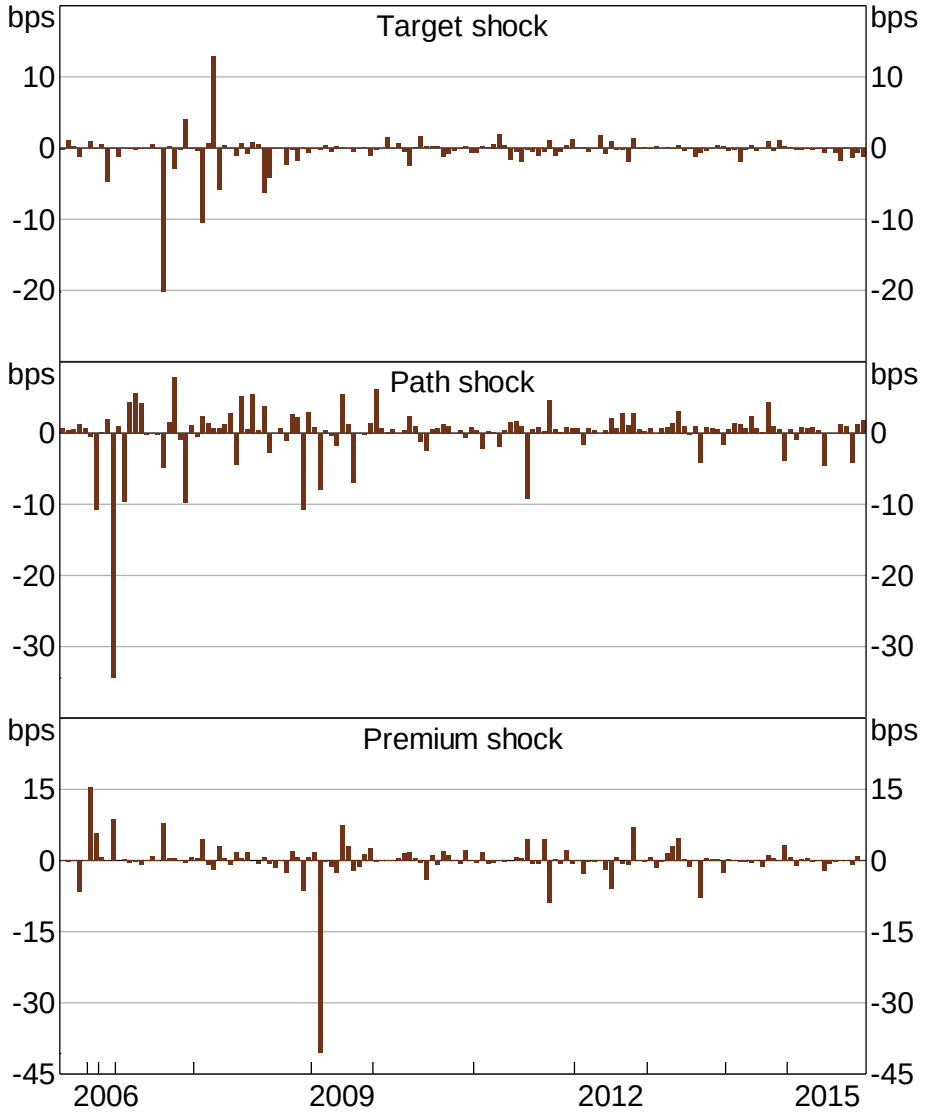
Table 2: Summary Statistics of Monetary Policy Shocks

	Mean (bps)			Standard deviation (bps)			Sample		Number of events
	Target	Path	Premium	Target	Path	Premium	Start	End	
Fed	–0.39	0	0	2.5	4.1	4.3	01/07/2004	28/10/2015	144
ECB	–0.09	0	0	2.8	3.1	2.1	04/05/2006	12/11/2015	143
BoJ	0.00	0	0	0.6	0.2	0.5	18/12/2009	24/12/2015	73
BoE	–0.19	0	0	6.1	2.5	1.6	06/09/2007	05/11/2015	202
BoC	–0.04	0	0	5.0	4.8	1.3	10/07/2007	02/12/2015	62
RBA	0.25	0	0	5.8	4.0	1.4	05/07/2006	14/12/2015	149
SNB	0.11	0	0	0.8	1.7	0.7	21/12/2010	17/09/2015	21

Notes: The table provides basic summary statistics of the monetary policy shocks used in our spillover analysis; target, path and premium shocks are computed as given by Equation (3); the originator central banks are the Federal Reserve Bank (Fed), European Central Bank (ECB), Bank of Japan (BoJ), Bank of Canada (BoC), Bank of England (BoE), Reserve Bank of Australia (RBA), and Swiss National Bank (SNB); besides basic statistics on the mean and the standard deviation of the shocks, the sample period and number of events in the sample is reported for each central bank

The time series of Fed monetary policy shocks, depicted in Figure 1, demonstrates the different phases of US monetary policy over our sample period. Fed target shocks were close to zero after 2009 as the Fed funds rate had been constrained by the effective lower bound (ELB). Path shocks were also much smaller after this date with the market mostly confident that ultra-low interest rates would persist. Risk premium shocks, by contrast, did not decline in magnitude. Key policy announcements also stand out for their large measured shocks. When the Fed revealed news on the first round of large-scale asset purchases in March 2009, the risk premium shock registered its most negative reading in the sample. The Fed's explicit forward guidance on maintaining policy rates low for long in August 2011 was captured by a large negative path shock. Shocks from other central banks, plotted in Figure A1 in the Online Appendix, similarly characterise the various phases of monetary policy as policy rates dipped to historical lows and some central banks resorted to asset purchase programs.

Figure 1: Fed Monetary Policy Shocks



Notes: The figure depicts monetary policy shocks by the Federal Reserve, computed based on the repricing of various interest rates on the release of monetary policy news; the top panel shows target shocks as estimated via the change in 1-month OIS rates in a (+/–) 20-minute window around Fed monetary policy announcements; the middle panel shows path shocks as the change in 2-year US Treasury bond yields orthogonalised against the change in 1-month OIS rates; the bottom panel shows premium shocks as the change in 10-year US Treasury bond yields orthogonalised against the change in 2-year bond yields

4.2 Gauging Spillovers to Recipient Economies

In this paper, we use a broad panel of 27 advanced and 20 emerging market economies as potential recipients of spillovers. The wide cross-section delivers more power to shed light on the different channels outlined above.[19] Each recipient economy's interest rate change is computed as the daily change from the closing yields preceding the monetary policy announcement to the subsequent daily closing yield (which will be after the policy announcement). These changes are calculated with careful adjustment of time zone difference and daylight saving time conventions. Our daily interest rate data are taken from Bloomberg.

19 Table A1 in the Online Appendix presents an overview of the spillover originator and recipient economies in our sample.

Note that, while the three monetary policy shock variables are constructed from the high-frequency data to precisely pin down monetary policy shocks, we opt for measuring the response with daily data for two reasons: first, as it allows us to use a much broader panel of economies (including EMEs), and second as it mitigates issues due to any time zone difference, which mean that some markets are closed (or less active) when our originator central banks unveil their policy decisions.

4.3 Conditioning Variables

We consider a broad range of macro and financial variables to explain cross-country differences in the strength of spillovers. Our tests of the domestic economic conditions channel rely on bilateral and aggregate imports, exports and variables commonly used in the trade literature explaining the volume of trade between countries. We also constructed measures of growth and inflation correlations from realised GDP and CPI to represent more amorphous economic links between economies. To gauge the impact of the FX regime for spillover effects, we compute a measure of realised FX volatility from squared daily changes of spot exchange rates (see, for example, De Grauwe and Schnabl (2008) for a similar approach to construct de facto measures of FX regimes). To assess the bond risk premium channel, we rely on proxies of financial openness. We consider both the overall financial openness of recipient economies and the bilateral financial openness between recipient economies and originator economies. We make use of a wide range of data to gauge financial openness, including bilateral and aggregate FDI, portfolio investments, and bank loans, as well as the currency of composition of foreign debt. Details on variable definitions and sources are provided in Table A2 in the Online Appendix.

5. Does Monetary Policy Spill Over to Other Economies?

We start with Equation (1) to test whether monetary policy shocks originating from the seven advanced economies spill over to the recipient economies under consideration. To measure the interest rate response, we consider rates of different maturities: 1-month and 6-month interest rates, and 2-year and 10-year government bond yields.[20] We define that a spillover from an originator central bank j to a recipient economy i is significant if the p-value from the F-test of joint significance of $\hat{\beta}_{ij}$ for the three monetary policy shocks coeffcients is less than 10 per cent.

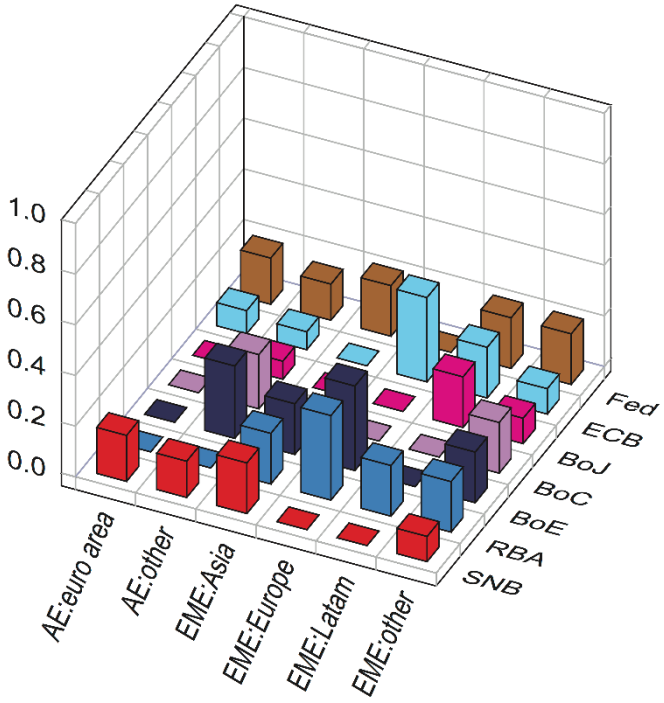
Figures 2 and 3 show the fraction of economies whose interest rates are significantly affected by the policy shocks originating from our seven major advanced economy central banks for short-term and long-term rates, respectively. To simplify the exposition, we show the strength of spillovers to recipient economies grouped by world regions and split into advanced economies and emerging market economies.

20 Depending on data availability, for 1-month or 6-month interest rates, we used OIS rates, government bill rates, interbank rates or deposit rates. Please see the Online Appendix for details.

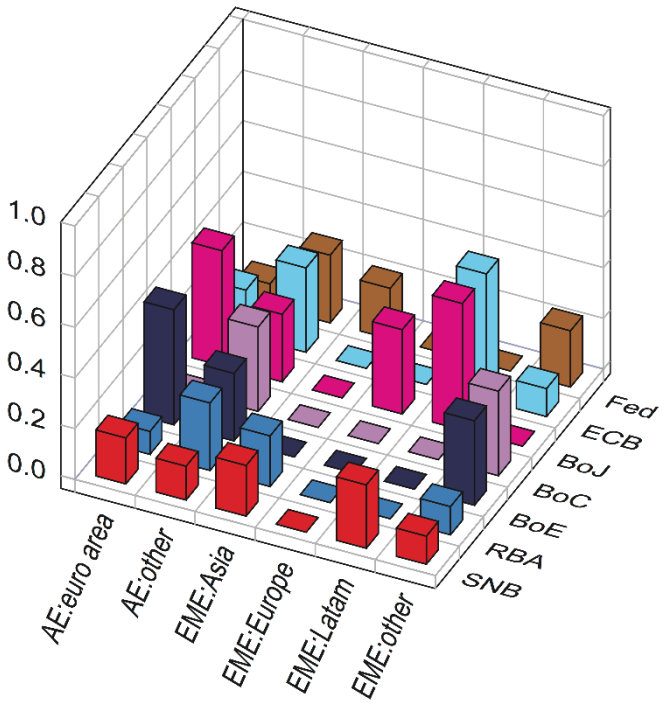
Figure 2: Global Spillover Matrix for Short Rates

2011–15 sample

1-month interest rates



6-month interest rates

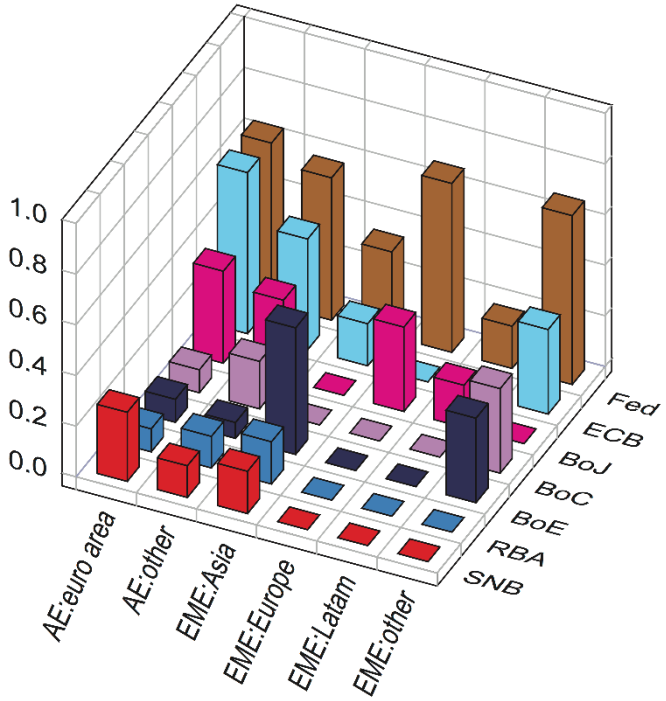


Notes: The figure plots the fraction of economies in each world region receiving a significant spillover from monetary policy shocks originating from 7 major central banks (summarising the regression results of Equation (1) for 47 recipient economies); the originator central banks are the Federal Reserve Bank (Fed), European Central Bank (ECB), Bank of Japan (BoJ), Bank of Canada (BoC), Bank of England (BoE), Reserve Bank of Australia (RBA), and Swiss National Bank (SNB); a spillover is counted as significant if the *p*-value from the *F*-test of joint significance of $\hat{\beta}_{ij}$ coefficients in Equation (1) is less than 10 per cent

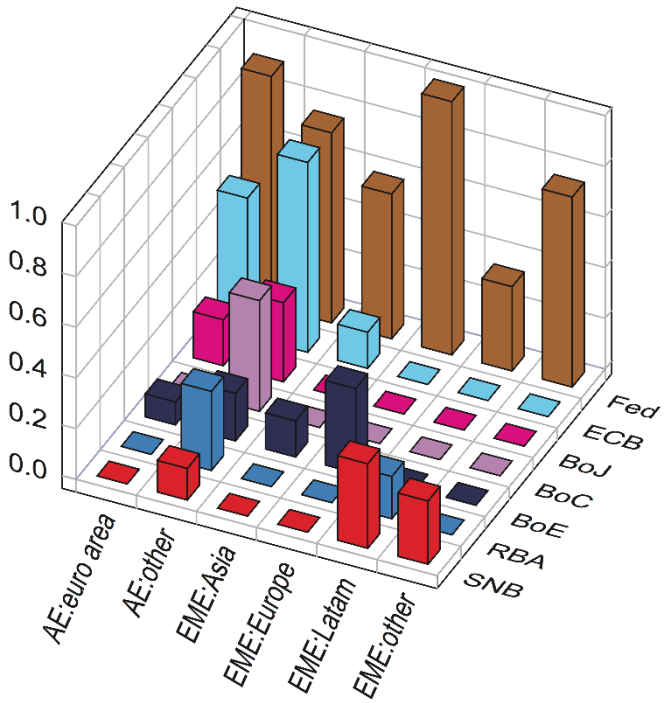
Figure 3: Global Spillover Matrix for Bond Yields

2011–15 sample

2-year government bond yields



10-year government bond yields



Notes: The figure plots the fraction of economies in each world region receiving a significant spillover from monetary policy shocks originating from 7 major central banks (summarising the regression results of Equation (1) for 47 recipient economies), see notes to Figure 2 for more details; a spillover is counted as significant if the *p*-value from the *F*-test of joint significance of $\hat{\beta}_{ij}$ coefficients in Equation (1) is less than 10 per cent

5.1 Spillovers to Short-term Interest Rates

A first key finding is that there are hardly any meaningful spillover effects to rates at the short-end of the yield curve. Spillovers to 1- and 6-month interest rates, Figure 2, display quite a bit of noise. While some of the estimated effects are intuitive, for example the ECB has the greatest spillover to emerging market Europe, others are not.[21] What is clear is that no central bank triggers widespread short-rate spillovers; for 1-month rates not even the Fed generates statistically significant spillovers to more than 20 per cent of economies in any given region. Furthermore, the pattern of measured spillovers to 6-month interest rates bears little resemblance to those to 1-month rates. Overall, for short-term interest rates it is diffcult to distinguish any economically significant spillovers from noise.

5.2 Spillovers to Long-term Interest Rates

The spillover matrices for bond yields show much clearer, and economically meaningful, patterns, as depicted in Figure 3. These are even clearer for 10-year yields than they are for the 2-year yields. There are more significant spillovers from monetary policy shocks originating from the Fed and the ECB. For most regions well over half of economies' 10-year yields have a significant response to Fed monetary policy news. Interestingly, there are significant spillovers from the ECB to three-quarters of advanced economies outside of Europe, but there are no significant spillovers to emerging market economies, including those in Europe.

It is also notable that there are also significant spillovers to the non-European *advanced economies* from the Bank of Japan and even the other four central banks for which we measure monetary spillovers (Reserve Bank of Australia, Bank of Canada, Bank of England and Swiss National Bank). In contrast, these central banks have little consistent impact on emerging market economies. A potential reason for the smaller spillovers from the ECB, Bank of Japan and Bank of England could be the smaller use of their currencies in trade invoicing, as argued by Zhang (2018).

Given that spillovers are much stronger and more consistent originating from the Fed and ECB, and to longer-term government bond yields, we focus on these in our following deeper analysis of spillover channels. Moreover, the observation that spillovers are more prevalent for long-term rates than short-term rates suggests a relatively minor role of the channel operating via domestic economic conditions, as this channel is likely to present through spillovers of short rates. That said, we explore the validity of this channel in more depth in Section 6 based on observable proxies.

5.3 Panel Regressions

We move from our originator-recipient specific regressions and adopt a panel regression specification to understand the drivers of spillovers to long-term rates.[22] The panel regression restricts the unconditional spillover strength to be the same across different economies. We first present the baseline regression with only using monetary policy shocks as regressors (top half of Table 3).

21 For instance, many short rates in Latin America respond to RBA announcements as they do to Fed announcements.

22 Given that strong and consistent spillovers only emerge from shocks originating from the Fed and ECB to long-term interest rates in recipient economies, all panel regressions focus on shocks from the Fed and ECB. The data sample spans from 2004 to 2015 for the Fed shocks, and from 2006 to 2015 for the ECB shocks.

Table 3: The Baseline Spillover Regression

	Target	Path	Premium	10-year US Treasury yield	VIX	R^2 (%)
ECB	–0.12	0.32	0.32			1.5
	(–1.29)	(4.03)	(2.61)			
Fed	0.32	0.28	0.36			2.8
	(2.24)	(3.44)	(4.67)			
ECB	–0.09	0.24	0.16	0.18	0.07	2.4
	(–1.00)	(3.06)	(1.29)	(4.26)	(2.23)	
Fed	0.32	0.27	0.38	0.30	0.10	5.5
	(2.57)	(3.73)	(5.50)	(6.73)	(2.83)	

Notes: The table rows report the results of panel regressions as given by Equation (2), which in turn serve as baseline specification for our analysis; the dependent variable is the daily change in 10-year bond yields in our set of 47 recipient economies; as regressors, besides the monetary shocks for the ECB and the Fed, some specifications also consider the daily change in the US Treasury yield and the VIX as global controls; the reported coefficients correspond to $\hat{\beta}_j$ and $\hat{\theta}_j$ in Equation (2); *t*-stat from panel-corrected standard errors (PCSE) are given in parentheses; cells coloured red (blue) indicate statistically significant positive (negative) coefficients at a 10 per cent level

The estimated coefficients and panel-corrected standard errors corroborate the existence of significant monetary spillover effects from both the Fed and ECB. The coefficients on monetary policy shocks are all significant, with the exception of the target shock from the ECB. We also add two global controls to the regression – the *daily* change in 10-year US Treasury yields and the VIX.[23] Both variables are significant for the Fed and ECB regressions. These global factors are intended to capture other drivers independent of monetary policy shocks that would drive co-movements of interest rates globally. Yet, also after controlling for these global factors, most monetary policy shocks remain significant. An exception is the risk premium shock from the ECB which loses its significance once the global controls are added to the regression. This specification including the two global variables serves as our baseline regression for the following analysis on the determinants of spillovers.

These effects are not only statistically, but also economically significant. Our results suggest that a 100 basis point 'target' shock from the Fed on (average) translates into around a 30 basis point change in 10-year government bond yields globally. At 38 basis points, Fed-induced bond risk premium shocks have the largest global effects, whereas path shocks still account for a sizable 27 basis point spillover effect. The pass-through is smaller for ECB shocks (also estimated with less statistical confidence), yet ECB shocks still account for an economically sizable 20 basis point global spillover effect on average.

23 The daily change in the 10-year US Treasury yield controls for any spillovers to global yields outside of our event window. For regressions with the shocks originating from the Fed, the daily change is orthogonalised relative to the shocks to avoid collinearity.

6. What Determines the Strength of Spillovers?

The primary goal of this section is to shed light on the different channels by examining which macro and financial variables determine the strength of spillover effects under the specification of Equation (2). The empirical results are reported in Tables 4–8. Our interpretation of the results presented below closely adheres to the framework of the three channels outlined above.

6.1 Domestic Economic Conditions

To test the domestic economic conditions channel, we interact monetary policy shocks with measures of economic linkages across economies. The main prediction of the domestic economic conditions channel is that economies with tighter economic linkages with shock originator economies should receive stronger spillovers. We first use trade variables to capture the direct economic linkages between economies. The trade-related variables we use are: bilateral export openness (exports from the recipient economy to the originator economy relative to GDP), bilateral import openness, as well as variables typically used in the trade gravity equation literature such as common language, weighted distance and time difference.

The results are presented in Table 4, pointing to a very limited explanatory power of the domestic economic conditions channel in determining spillover strength. Among all specifications, only the coefficient in front of the interaction term of bilateral trade with the ECB path shock is statistically significant. That said, this effect is no longer significant when removing euro area countries from the set of recipient economies, suggesting that among euro area countries trade openness may be a proxy for other factors. These results do not indicate there is a measurable role of the domestic economic conditions channel in determining spillovers.

Table 4: Spillovers and Bilateral Trade Linkages

		Target	Path	Premium	R^2 (%)
Exports	ECB	0.01	0.10	0.03	2.5
		(0.21)	(2.73)	(0.68)	
	ECB (excl EA)	–0.01	0.01	–0.01	3.0
		(–0.12)	(0.15)	(–0.27)	
	Fed	0.04	0.01	–0.01	5.0
		(0.47)	(0.22)	(–0.15)	
Imports	ECB	–0.03	0.08	0.00	2.4
		(–0.74)	(2.47)	(–0.02)	
	ECB (excl EA)	–0.01	0.02	–0.02	3.0
		(–0.29)	(0.49)	(–0.31)	
	Fed	0.01	0.01	0.00	5.0
		(0.20)	(0.52)	(0.02)	
Common language	Fed	0.08	0.05	–0.09	5.5
		(0.59)	(0.60)	(–1.18)	
Weighted distance	Fed	0.00	0.00	0.00	5.5
		(–0.50)	(0.55)	(0.09)	
Time difference	Fed	–0.03	–0.02	–0.02	5.5
		(–0.74)	(–1.02)	(–0.83)	

Notes: The table reports the results of panel regressions as given by Equation (2) with various recipient-specific conditional variables $X_{i,t-1}$ measuring bilateral trade linkages and other controls; the dependent variable is the daily change in 10-year bond yields in our set of 47 recipient economies; as regressors, besides the monetary shocks for the ECB and the Fed, some specifications also consider the daily change in the US Treasury yield and the VIX as global controls; the report coefficients correspond to $\hat{\gamma}_j$ in Equation (2); *t*-stat from PCSE are given in parentheses; cells coloured red (blue) indicate statistically significant positive (negative) coefficients at a 10 per cent confidence level; exports and imports (per cent of GDP) are measured in standard deviations from the mean

However, trade is only a small portion of the economic linkages between economies which also include the actions of multinational companies, information and investment flows and common global demand shocks. Hence, we also consider a measure of broader economic linkages, by looking at the commonality in macroeconomic conditions across economies. For this purpose we use long-term realised correlations in growth and inflation, without specifying the detailed mechanism underlying the correlation. Results using these measures as interaction terms are presented in Table 5.[24] None of the macro commonality measures robustly show up as significant when interacted with monetary policy shocks, however, further putting the validity of the domestic economic conditions channel in doubt.

24 We estimate the commonality in economies' business cycle and inflation with a 20-quarter rolling regression. The results are robust to sensible variations of this set-up.

Table 5: Spillovers and Commonality in Macro Conditions

		Target	Path	Premium	R^2 (%)
Inflation correlation	ECB	0.25	0.32	0.51	2.6
		(0.90)	(1.35)	(1.12)	
	ECB (excl EA)	0.47	–0.29	0.53	3.4
		(1.07)	(–0.77)	(0.87)	
	Fed	–0.05	–0.39	0.20	5.9
		(–0.12)	(–1.70)	(0.81)	
Growth correlation	ECB	–0.16	0.44	0.34	3.0
		(–0.86)	(2.68)	(1.00)	
	ECB (excl EA)	–0.04	0.18	0.39	5.4
		(–0.19)	(1.06)	(0.98)	
	Fed	0.02	0.28	0.50	5.5
		(0.05)	(1.00)	(1.68)	

Notes: The table reports the results of panel regressions as given by Equation (2) with various recipient-specific conditional variable $X_{i,t-1}$ measuring common macroeconomic conditions; the dependent variable is the daily change in 10-year bond yields in our set of 47 recipient economies; as regressors, besides the monetary shocks for the ECB and the Fed, specifications also include the daily change in the US Treasury yield and the VIX as global controls; the reported coefficients correspond to $\hat{\gamma}_j$ in Equation (2); *t*-stat from PCSE are given in parentheses; cells coloured red (blue) indicate statistically significant positive (negative) coefficients at a 10 per cent confidence level; inflation correlation and growth correlation are measured as a 20-year rolling correlation of realised CPI inflation and realised real GDP growth, respectively

6.2 FX Regime Channel

To test the FX regime channel, we interact monetary policy shocks with measures of FX regimes in our panel regression framework. The FX channel predicts that economies 'pegging' their currencies to those of the shock originator should experience stronger spillovers. Rather than rely on 'de jure' measures of FX regimes, we construct de facto measures as in De Grauwe and Schnabl (2008), which essentially boils down to the realised bilateral exchange rate volatility between the originator and recipient economies.[25]

The results reported in Table 6 indicate that the FX channel yields greater power than the domestic economic conditions channel in explaining variation in spillover strength across economies. In the case of ECB shocks, the coefficient in front of the interaction term of the FX regime measure and the path shock is negative and significant. The more dampened FX volatility is, for example due to an explicit or implicit currency peg, the larger the spillover of interest rate shocks. FX volatility remains a robust variable in explaining cross-country differences in spillover strengths also when removing the euro area from the set of recipient economies. In the case of Fed policy shocks, the coefficient in front of the interaction term of our FX regime measure and the risk premium shock is marginally significant. Overall, these results suggest that spillover strengths are to some extent related to FX regimes, consistent with recent findings in Han and Wei (2016).

25 FX volatility is calculated from the bilateral exchange rate between the originator and recipient economies.

Table 6: Spillovers and the FX Channel

		Target	Path	Premium	R^2 (%)
FX volatility	ECB	0.24	–0.49	–0.29	2.9
		(1.27)	(–2.82)	(–0.96)	
	ECB (excl EA)	–0.25	–0.48	–0.78	3.9
		(–1.18)	(–2.01)	(–1.87)	
	Fed	0.02	0.24	–0.22	5.6
		(0.04)	(0.86)	(–1.61)	

Notes: The table reports the results of panel regressions as given by Equation (2) with the recipient-specific conditional variable $X_{i,t-1}$ measuring FX volatility with respect to shock-originating economies; the dependent variable is the daily change in 10-year bond yields in our set of 47 recipient economies; as regressors, besides the monetary shocks for the ECB and the Fed, specifications also include the daily change in the US Treasury yield and the VIX as global controls; the reported coefficients correspond to $\hat{\gamma}_j$ in Equation (2); *t*-stat from PCSE are given in parentheses; cells coloured red (blue) indicate statistically significant positive (negative) coefficients at a 10 per cent confidence level; FX volatility is measured as a 1-year rolling realised volatility estimate, based on squared daily spot FX changes (%)

6.3 Risk Premium Channel

To assess the validity of the risk premium channel, we interact monetary policy shocks with measures of financial openness. The main idea is that the more financially open and interconnected an economy, the larger the impact of fluctuations in global risk appetite and financial conditions on bond yields. We explore a range of financial openness measures, including bilateral capital flows and the overall level of cross-border investments. Specifically, the bilateral variables used are: foreign currency debt denominated in the currency of the originator economy (i.e. either in US dollars or euro), and portfolio debt, portfolio equity, loans and FDI (all bilateral between the originator and recipient economies, assets and liabilities separately). We also use aggregate measures of financial openness: debt assets, portfolio assets, FDI assets and financial derivative assets (and separately, the equivalent liability measures) as well as the Chinn-Ito measure of financial openness.[26] Most of these variables are statistically significant in explaining the strengths of spillovers from the Fed and ECB.[27]

Given the correlation between these measures and to avoid any ensuing multicollinearity issues, we run separate regressions with each pair of these measures, checking which variables do not lose significance after controlling for other measures. This exercise helps us to determine which proxies are most powerful in capturing financial openness and in explaining spillover strengths. As can be gleaned from Table 7, two measures stand out, foreign currency debt and portfolio equity from originator economies.[28]

26 Ideally, we would like to have each economy's fixed income holdings in different currencies as a financial openness measure given its important role in portfolio choices of global fixed income investors. Unfortunately, such granular data does not exist for all economies we considered.

27 Comprehensive results are provided in Tables A3–A6 in the Online Appendix.

28 It is possible that recipient economies experiencing strong spillovers may take measures tightening financial openness to tame spillovers. This would result in negative relation between spillover strength and financial openness. The potential downward bias would actually make our evidence supporting the risk premium channel stronger.

Table 7: Spillovers and Financial Interconnectedness

	FX debt	Debt (from)	Equity (from)	Equity (to)	Portfolio assets	Portfolio liabilities	FDI assets	FDI liabilities
FX debt	na	yes	yes	yes	yes	yes	yes	yes
Debt (from)	no	na	yes	yes	yes	yes	yes	yes
Equity (from)	yes	yes	na	yes	yes	yes	yes	yes
Equity (to)	no	no	no	na	no	no	no	no
Portfolio assets	yes	yes	no	yes	na	yes	yes	yes
Portfolio liabilities	yes	no	no	yes	no	na	no	no
FDI assets	yes	yes	no	yes	no	no	na	no
FDI liabilities	yes	no	no	yes	yes	no	no	na

Notes: The table reports the results of regressions based on various financial openness indicators; it shows whether the row variable remains significant (*t*-stat > 1.69) after controlling for the column variable when both of them are included simultaneously in panel regression Equation (2); two variables, FX debt and equity investment from the originator economy remain significant even when included with all other controls

Our finding on the importance of financial openness in explaining spillovers is consistent with Rey (2013), as it points to important spillovers of major central banks' monetary policies to other countries' long-term rates and hence an impact on local financial conditions, regardless of whether the capital account is managed or not. To better differentiate between the risk premium and FX channel, we test whether FX regime and financial openness conditions present different channels. To this end, we include both FX volatility and our two financial openness measures as conditioning variables. Table 8 shows that FX volatility retains its significance in explaining cross-sectional variation in spillover strengths despite the addition of our financial openness measures. This result suggests that the FX regime represents a distinct and relevant channel, at least for explaining spillovers from ECB monetary policy shocks.

Table 8: Distinguishing FX and Financial Channels

	Foreign currency debt			**Portfolio equity from originator**			**FX volatility**		
	Target	Path	Premium	Target	Path	Premium	Target	Path	Premium
ECB	0.06	0.06	0.14	0.08	0.09	0.07	0.25	–0.39	–0.28
	(1.41)	(1.72)	(2.42)	(1.20)	(1.76)	(1.54)	(1.10)	(–1.92)	(–0.86)
ECB (excl EA)	–0.05	0.07	0.00	0.08	0.04	0.16	–0.44	–0.33	–0.92
	(–1.36)	(1.89)	(0.06)	(1.34)	(0.84)	(1.46)	(–1.82)	(–1.23)	(–1.91)
Fed	0.16	0.13	–0.06	–0.03	–0.07	0.15	0.20	0.36	–0.18
	(1.77)	(2.57)	(–1.80)	(–0.38)	(–1.20)	(2.25)	(0.29)	(1.10)	(–1.06)

Notes: The table reports the results of panel regressions as given by Equation (2) with recipient-specific conditional variable $X_{i,t-1}$ including foreign currency debt, portfolio equity from shock-originating economies and FX volatility with respect to currencies in shock-originating economies; the dependent variable is the daily change in 10-year bond yields in our set of 47 recipient economies; as regressors, besides the monetary shocks for the ECB and the Fed, specifications also include the daily change in the US Treasury yield and the VIX as global controls; the reported coefficients correspond to $\hat{\gamma}_j$ in Equation (2); *t*-stat from PCSE are given in parentheses; cells coloured red (blue) indicate statistically significant positive (negative) coefficients at a 10 per cent confidence level

7. Conclusion

While it's well established that interest rates co-move across countries, less is known about the economic and financial forces behind this co-movement. Using precisely identified monetary policy shocks for 7 advanced economy central banks, we accurately document the extent of interest rate spillovers to 47 advanced and emerging market economies. The use of high-frequency data is important as it enables us to identify spillovers in a causal sense. While the spillovers from the policy interest rates of the Fed, and even ECB, to other economies' long-term bond yields come less of a surprise, we demonstrate that their monetary policies do not consistently spill over to other economies' short-term interest rates. We also show that spillovers from other major central banks, including the Bank of Japan and Bank of England, are mild at best. Further, in contrast to much of the literature which has focused on spillovers to emerging market economies, we show that the spillovers are actually significantly larger to advanced economies.

To put some structure on why these spillovers occur and some countries' interest rates are more responsive than others we test three possible channels. We study the role of domestic economic conditions, FX regime and bond risk premia (and financial conditions). Using a rich set of bilateral and aggregate economic and financial data, we find that there is no evidence that interest rate spillovers relate to economic linkages across economies. There is some indication that exchange rate regimes influence the extent of spillovers, but by far the strongest determinant of interest rate spillovers is financial openness. Economies that have stronger bilateral (and aggregate) financial links with the United States or euro area are susceptible to stronger interest rate spillovers. These effects are much more pronounced at the longer end of the yield curve. While this result is robust across a range of indicators of financial openness, two variables stand out for best representing the financial integration that influences spillover intensity: foreign currency debt denominated in US dollars or euros, and bilateral portfolio equity flows from the United States or euro area.

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