The Policy Trilemma and the Global Financial Cycle: Evidence from the International Transmission of Unconventional Monetary Policy*

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Abstract

We assess the international spillovers stemming from identified US conventional and unconventional monetary policy shocks by estimating a global VAR model which exploits panel variation on several macroeconomic and financial indicators for a set of advanced and emerging economies. We find that US monetary policy significantly drives equity prices worldwide and, when working via unconventional measures, it also leads to a generalized comovement in short- and long-term rates across countries. Both macroeconomic and financial spillovers are sizable, and in some instances even larger than the effects on the U.S. economy. Countries whose currency is anchored to the US Dollar feature larger spillovers, but this relationship is weak due to the high uncertainty surrounding the estimated effects.

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1 Introduction

The literature on the international transmission of monetary policy has emphasized that those economies which are able to exploit a flexible exchange rate are more insulated than those which devote their monetary policy to fixing the rate, a reflection of the classical Mundellian Trilemma according to which a country can attain just two of three objectives among exchange rate stability, free capital mobility, and independent monetary policy (Mundell, 1963; Obstfeld et al. 2005). The Trilemma's view has been recently challenged by Rey (2013), according to which countries are currently subject to a a *Global Financial Cycle*: an extraordinarily high degree of comovement in risky asset prices, credit growth, leverage and financial aggregates. In such a globalized world, domestic monetary policy may affect other countries' monetary conditions via several and complex channels, and flexible exchange rates are not sufficient to guarantee monetary autonomy.

Determining which view better characterizes the international transmission of monetary policy still remains an open question. In this paper we contribute to this debate by estimating a global VAR (GVAR) model for the world economy, a multi-country model which exploits panel variation on several macroeconomic and financial indicators for a set of advanced and emerging economies which altogether account for more than 90% of world GDP. We assess the international spillovers stemming from identified US conventional and unconventional monetary policy shocks, and study whether the exchange rate arrangement of the receiver country makes a difference. We find that US monetary policy significantly drives equity prices worldwide and, when working via unconventional measures, it also leads to a generalized comovement in short- and long-term rates across countries. Both macroeconomic and financial spillovers are sizable, and in some instances even larger than the effects on the U.S. economy. Finally, we provide evidence that countries whose currency is anchored to the US Dollar feature larger spillovers, but this relationship is weak due to the high uncertainty surrounding the estimated effects.

This paper links to the strand of the literature which examines whether floating exchange rates insulate the economy from foreign monetary policy shocks. Several works referenced in Obstfeld et al. 2017 have shown that countries with flexible exchange rates feature short-term interest rates which correlate less with the base country interest rates. In this respect, Di Giovanni and Shambaugh (2008) show that output spillovers stemming from foreign interest rate shocks are larger in those countries with fixed exchange rate. However, most of these papers do not identify the monetary policy component of the foreign interest rate. Conversely, Miniane and Rogers (2007) employ small bilateral VARs to identify US monetary policy shocks via exclusion restrictions and show that fixed and floaters are similarly affected in terms of output and inflation. Dedola et al. (2017) employ a large Bayesian VAR including US and global variables and theory-based sign restrictions to identify a US monetary policy shock, then regress country-level variables on the estimated shock and do not find a clear link between spillovers and the exchange rate flexibility. Conversely, Georgiadis (2016) employs a multi-country GVAR model that allows US monetary policy in one hand to affect a given economy not just directly but also indirectly via cross-country interactions, and in the other hand to be endogenous to the rest of the world via spillback effects. Within this framework US monetary policy shocks are identified via sign restrictions and results show sizable spillovers on output, and even larger than domestic effects for many countries, and economies with a floating exchange rate feature smaller spillovers. Similarly to Georgiadis (2016) we employ a GVAR which, by allowing for third-country and spillback effects, allows for a proper assessment of the international spillovers of US monetary policy shocks. However we extend the analysis in two dimensions. First, we provide a comprehensive picture of the recent US monetary policy by considering both conventional and unconventional monetary policy (CMP and UMP), the latter intended as a large variety of measures and announcements aimed at compressing the long-term bond yield spread. Specifically, we identify exogenous CMP and UMP shocks by means of a combination of zero and sign restrictions on impulse responses following the recently developed approach of Baumeister and Benati (2013). And second, our model considers a wider set of financial variables, namely equity prices and both short- and long-term interest rates, to allow for a proper modeling of the Rey's (2013) Global Financial Cycle. We show that such ingredient is essential to determine which view — the Trilemma or the Global Financial Cycle — better characterizes the international transmission of US monetary policy.

The structure of the paper is as follows. Section 2 describes the empirical analysis: the GVAR model, the data and the specification of the model, the identification strategy, and the estimation. Section 3 presents the results of the analysis. Section 4 concludes.

2 Empirical Methodology

2.1 The GVAR model

The analysis is based on a GVAR modeling framework as firstly developed in Pesaran et al. (2004) and further extended in Dées et al. (2007). The GVAR model is a system of national VAR models in which cross-country interactions are explicitly taken into account. Being a multi-country model, the GVAR deals with country heterogeneities in a simple and effective way, thus allowing for assessing asymmetries in the international transmission of monetary policy shocks. Specifically, each national economy i is modeled as a VARX(p_i,q_i),

$$Y_{it} = c_i + \sum_{j=1}^{p_i} A_{ij} Y_{i,t-j} + \sum_{j=0}^{q_i} B_{ij} Y^*_{i,t-j} + \sum_{j=0}^{q_i} C_{ij} X_{t-j} + u_{it} \tag{1}$$

where c_i is a vector of intercepts; A_{ij}, B_{ij}, and C_{ij} are matrices of coefficients; and u_{it} is a vector of idiosyncratic country-specific shocks which are assumed to be serially uncorrelated zero-mean processes with full variance-covariance matrix Σ_{ii}. The vector Y_{it} includes *domestic variables* which represent the domestic macro-financial conditions of the economy. The vector Y^*_{it} contains *foreign-specific variables*, which represent the influence of the main economic partners of a given economy and capture the relative spillovers. These variables are calculated as weighted averages of the corresponding domestic variables of the other countries,

$$Y^*_{it} = \sum_{j \neq i} w_{ij} Y_{jt} \qquad \text{with} \qquad \sum_{j \neq i} w_{ij} = 1 \tag{2}$$

where weights w_{ij} are generally based on bilateral trade flows or alternatively on bilateral measures of financial exposure.[1] The vector X_t includes *global variables* which affect all

[1] Weights are fixed over time in estimation, but this assumption can be relaxed by considering an alternative version of the model with time-varying weights.

countries at the same time, such as commodity prices. Common variables follow the process

$$X_t = c_x + \sum_{j=1}^{p_x} D_j X_{t-j} + \sum_{j=0}^{q_x} F_j \tilde{Y}_{t-j} + u_{xt} \tag{3}$$

where c_x is a vector of intercepts; D_j and F_j are matrices of coefficients; and u_{xt} is a vector of reduced form residuals which are assumed to be serially uncorrelated zero-mean processes with full variance-covariance matrix Σ_{xx}. The vector $\tilde{Y}_t$ is composed by weighted averages of all countries' domestic variables, where weights are based on the relative importance of each country in the world economy (GDP shares), and capture the feedback effects from all countries to the global variables.[2] In this setting, the sets of foreign-specific and global variables capture the external dimension of each economy and its corresponding effects on the domestic macro-financial conditions.

The GVAR model allows for interactions across economies through three distinct channels: (*i*) cross-country linkages, captured by the foreign-specific variables; (*ii*) the role of global factors; and (*iii*) a non-zero contemporaneous dependence of shocks in country i on the shocks in country j, as captured by the cross-country covariances Σ_{ij},

$$\Sigma_{ij} = cov(u_{it}, u_{jt}) = E(u_{it} u'_{jt}) \qquad \text{for} \quad i \neq j \tag{4}$$

where a typical element of Σ_{ij}, denoted by $\sigma_{ij,ls}$, measures the covariance of the lth variable in country i with the sth variable in country j. Hence country-specific shocks are allowed to be cross-sectionally correlated due to spatial or contagion effects that are not totally eliminated by the common and foreign-specific variables. Nonetheless, residual cross-sectional correlation should be weak, a condition that can be checked after estimating the model.

In order to obtain the final representation of the GVAR, we can exploit the fact that foreign-specific variables are linear combinations of the endogenous variables, $Y^*_{it} = W_i Y_t$, where W_i are country-specific matrices which capture interconnections across countries.

[2]Like in the case of the weights for the foreign variables, GDP-based weights are fixed over the estimation sample. This assumption can be relaxed by allowing for feedback variables which are constructed using time-varying weights.

Hence we can write each country-specific model as

$$G_{i0}Y_{it} = c_i + \sum_{j=1}^{p_i} G_{ij}Y_{i,t-j} + \sum_{j=0}^{q_i} C_{ij}X_{t-j} + u_{it} \tag{5}$$

where $G_{i0} = (I - B_{i0}W_i)$ and $G_{ij} = (A_{ij} + B_{ij}W_i)$. We can then stack all country-specific models to obtain

$$G_0Y_t = c + \sum_{j=1}^{p} G_jY_{t-j} + \sum_{j=0}^{q} C_jX_{t-j} + u_t \tag{6}$$

where $Y_t = (Y'_{1t}, \ldots, Y'_{Nt})'$, $u_t = (u'_{1t}, \ldots, u'_{Nt})'$, $G_0 = (G'_{10}, \ldots, G'_{N0})'$, $c = (c'_1, \ldots, c'_N)'$, $G_j = (G'_{1j}, \ldots, G'_{Nj})'$, $C_j = (C'_{1j}, \ldots, C'_{Nj})'$, $p = max(p_i)$, and $q = max(q_i)$.

Moreover, given that the feedback variables are weighted averages of the country-specific variables, $\tilde{Y}_t = \tilde{W}Y_t$, where $\tilde{W}$ is a matrix defined by the GDP-based weights, we can write the GVAR as

$$H_0Z_t = h_0 + \sum_{j=1}^{p} H_jZ_{t-j} + e_t \tag{7}$$

where the vector $Z_t = (Y'_t, X'_t)'$ includes all country-specific and common variables, and

$$H_0 = \begin{bmatrix} G_0 & -C_0 \\ -F_0\tilde{W} & I \end{bmatrix}, \qquad h_0 = \begin{bmatrix} c \\ c_x \end{bmatrix}, \qquad H_j = \begin{bmatrix} G_j & C_j \\ F_j\tilde{W} & D_j \end{bmatrix}, \qquad e_t = \begin{bmatrix} u_t \\ u_{xt} \end{bmatrix}.$$

The vector $e_t = (u'_t, u'_{xt})'$ collects all residuals, with variance-covariance matrix Σ, defined by,

$$\Sigma = \begin{bmatrix} \Sigma_{11} & \Sigma_{12} & \cdots & \Sigma_{1N} & \Sigma_{1x} \\ \Sigma_{21} & \Sigma_{22} & \cdots & \Sigma_{2N} & \Sigma_{2x} \\ \vdots & \vdots & \ddots & \vdots & \vdots \\ \Sigma_{N1} & \Sigma_{N2} & \cdots & \Sigma_{NN} & \Sigma_{Nx} \\ \Sigma_{x1} & \Sigma_{x2} & \cdots & \Sigma_{xN} & \Sigma_{xx} \end{bmatrix}$$

Provided that the H_0 matrix is invertible, we can obtain the GVAR(p) in its reduced form,

$$Z_t = k_0 + \sum_{j=1}^{p} K_jZ_{t-j} + v_t \tag{8}$$

where $k_0 = H_0^{-1}h_0$, $K_j = H_0^{-1}H_j$, and $v_t = H_0^{-1}e_t$ are reduced form shocks with zero mean and full variance-covariance matrix $\Omega = H_0^{-1}\Sigma(H_0^{-1})'$.

The dynamic properties of the global model are now determined by the Z_t process, including impulse response functions. In this respect, we can express the reduced form shocks as a linear combination of structural shocks ε_t so that $V\varepsilon_t = v_t$, where structural shocks are normalized to have unit variance $I = E(\varepsilon_t \varepsilon_t')$. This implies the restriction that $VV' = \Omega$. In practice, we are interested in identifying two specific columns of V which characterize the impact effects of unexpected conventional and unconventional monetary policy shocks from the United States. To do so, we employ a combination of sign and zero restrictions as detailed in section 2.3.

2.2 Data and specification of the model

We consider a panel dataset of quarterly data, whose sample period spans from 1994Q1 to 2016Q4, for 33 countries which altogether account for more than 90% of world GDP. The countries are listed in Table 1.

Table 1: Countries and Regions in the GVAR

United States	**Euro Area**	**Latin America**
China	Germany	Brazil
Japan	France	Mexico
United Kingdom	Italy	Argentina
Canada	Spain	Chile
Australia	Netherlands	Peru
New Zealand	Belgium	
	Austria	
	Finland	
Rest of Asia	**Rest of Western Europe**	**Rest of the World**
Korea	Sweden	India
Indonesia	Switzerland	South Africa
Thailand	Norway	Turkey
Philippines		Saudi Arabia
Malaysia		
Singapore		

Regarding the domestic variables, we employ data on real GDP growth, CPI inflation, short-term interest rate at annual rate, real equity prices, the nominal effective exchange rate, and the spread between the long- and short-term interest rates. The term spread is a relevant variable in order to identify exogenous unconventional monetary policy shocks, as discussed in next section. As in Dées et al. (2007), we model the Eurozone as a single

VAR model, by aggregating data of member countries using their relative GDP shares. Due to data limitations, some country VAR models do not include some specific variables. Table 4 in Appendix reports the data availability for each country model. Data come from the recent version of the GVAR Quarterly Database of Mohaddes and Raissi (2018), which we complement with data from the OECD Main Economic Indicators database for equity prices in Brazil, Mexico, and Turkey.

With respect to the foreign-specific variables which capture potential interactions across countries, we consider country-specific weighted averages of trade partners' real GDP growth, CPI inflation, short-term interest rate, real equity prices, and term spread. Weights are computed using cross-country bilateral trade flows averaged over the period 1994-2016, where data come from the GVAR Quarterly Database of Mohaddes and Raissi (2018). We include oil prices as common variable in X_t, which endogenously respond to developments of the world economy by including as feedback variables $\tilde{Y}_t$ the weighted averages of country-level output growth and inflation, where weights are based on GDP shares averaged over the period 1994-2016.

2.3 Identification

In the following we describe the procedure to separately identify exogenous US (conventional and unconventional) monetary policy shocks. The approach amounts to impose a combination of sign and zero restrictions on impulse responses of all US variables, while leaving completely unrestricted the responses of all variables in the rest of the world (similarly to Dedola et al. 2017). In this way, while we condition the responses of US variables according to standard monetary theory, we remain agnostic on the sign and magnitude of international spillovers.

We intend unconventional monetary policy as a large variety of measures aimed at compressing the long-term bond yield spread when the policy rate is close to its zero lower bound, as in Baumeister and Benati (2013). In this sense, an expansionary unconventional monetary policy shock which reduces the domestic term spread should increase domestic output growth, inflation, equity prices, should lead to a depreciation of the US Dollar, while at the same time the short-term interest rate should not respond on impact to the shock.[3]

At the same time, we require that a local expansionary conventional monetary policy shock which reduces the U.S. short-term interest rate should increase the domestic output growth, inflation, the term spread, real equity prices, and should lead to a depreciation of the Dollar vis-a-vis the other currencies. Requiring a steepening of the yield curve can be justified by an imperfect pass-through from short- to long-term rates due to the fact that the shock is transitory, as in Baumeister and Benati (2013).

Table 2: Identification of US monetary policy shocks

	Conventional MP shock	**Unconventional MP shock**
Responses of US variables:		
Short-term interest rate	-	0
Term spread	+	-
Inflation	+	+
Output growth	+	+
Real equity prices	+	+
NEER	-	-

Notes: restrictions are imposed on impact and one period after the shock. The responses of all variables in the rest of the countries are left unrestricted.

As shown in Table 2, these restrictions are sufficient to separate the two types of monetary policy shocks, thus achieving identification. Sign restrictions on US variables are imposed on impact and one month after the shock. The responses of all variables in the rest of the countries are left unrestricted. The implementation of the sign and zero restrictions is based on the algorithm developed in Arias et al. (2018).

[3]The requirement that equity prices should increase is reminiscent of the identification strategy in Weale and Wieladek (2016) in the context of exogenous expansions of the central bank's balance sheet.

2.4 Estimation

Estimation of the model proceeds on a country-by-country basis as in Pesaran et al. (2004).[4] Specifically, all country-specific models, as well as the model for the common factors, are estimated by least squares in their VARX* form.[5] For each country-specific model we choose a relatively parsimonious lag structure by setting the lag order of the endogenous variables, p_i, equal to one. The lag order of foreign-specific and common variables, q_i, is also set equal to one. With respect to the model for oil prices, we fix the lag order of the endogenous variable p_x equal to one. Similarly, we set the lag order of the feedback variables q_x equal to one.

Despite the parsimonious lag structure, the model adequately captures the serial correlation of the modeled variables. The autocorrelation functions included in Panel (a) of Figure 1 indicate that most residuals are serially uncorrelated and therefore the model captures most of the persistence in the data. In this respect, Panel (b) of Figure 1 shows that the absolute values of all the eigenvalues of the estimated GVAR's companion matrix stand below unity. This confirms that the model captures well the complex dynamics and interactions among variables, and at the same that it is dynamically stable, so that shocks tend to die out with some inertia.

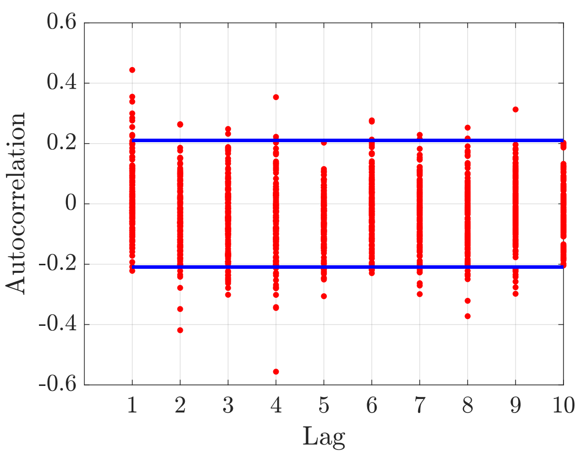
The country-by-country estimation of the model's parameters hinges on the exogeneity of the foreign variables, which is a formalization of the concept of small open economy from an econometric perspective. Following Pesaran et al. (2004), we can indirectly check whether a number of sufficient conditions for this assumption to hold are verified in our setup. First, weights used in the construction of foreign-specific variables should be small, in the sense that squared weights should tend to zero as the number of countries included in the GVAR increases. Panel (c) in Figure 1 reports the trade-based weights and shows that, with some exceptions, the vast majority of weights are small. The most notable exceptions refer to the large weights of United States with respect to Canada

[4] The direct estimation of equation (8) is unfeasible because of the large amount of parameters which greatly exceeds the number of available observations. In this respect, the country-by-country estimation allows for reducing the dimensionality of the model.

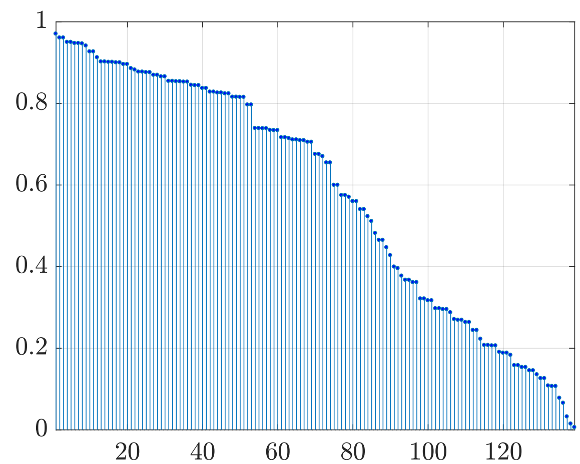
[5] Given the short estimation sample available, we abstract from explicitly identifying long-run relationships among variables, in line with Georgiadis (2016).

and Mexico, as well as the weights of the euro area with respect to Sweden, Switzerland, Turkey, and United Kingdom. Second, there should be cross-sectional weak dependence, meaning that the cross-dependence of the idiosyncratic shocks is sufficiently small so that it tends to zero as the number of economies tends to infinity. Panel (d) in Figure 1 plots the cumulative density function of the pairwise correlations across the estimated residuals (in absolute value). Most of pairwise correlations are low, for instance about 90% of the mass lies below 20%, hence this confirms that cross-sectional dependence is weak for most of residuals.

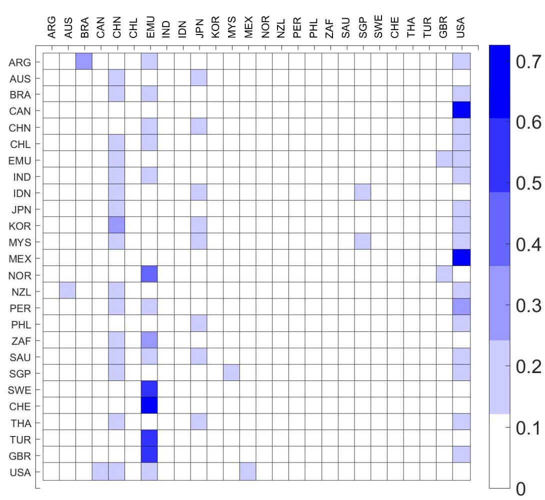
Figure 1: Diagnostics of the estimated GVAR model



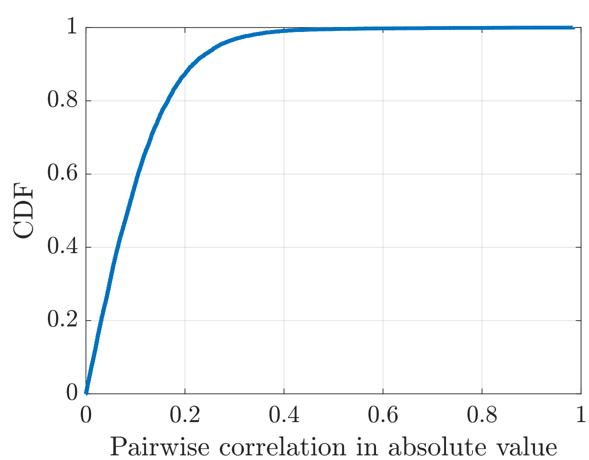
(a) Residual serial dependence



(b) Eigenvalues of the GVAR



(c) Trade-based weights matrix



(d) Residual cross-sectional dependence

3 Results

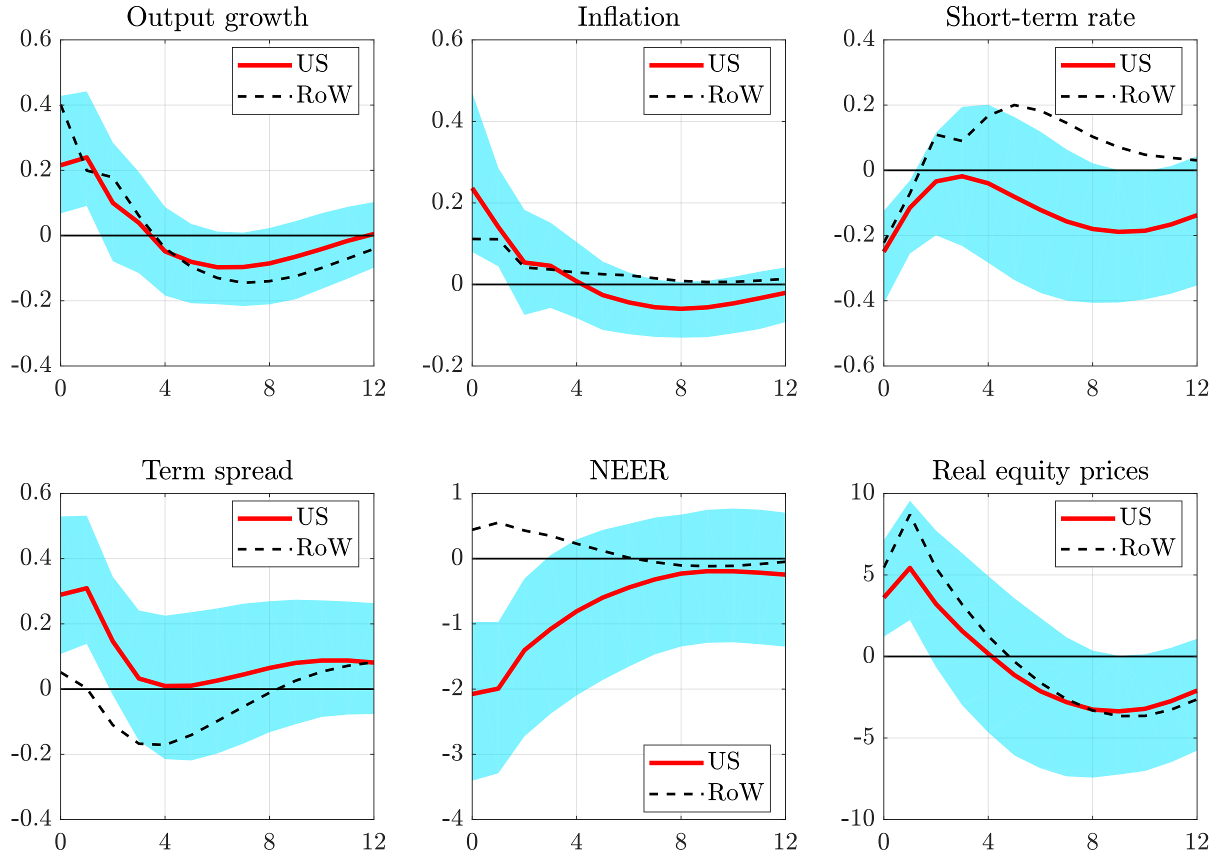
In this section we first present the international spillovers of US conventional monetary policy shocks, by looking at the effects on the rest of the world as a whole as well as country-by-country. We then present the same results related to US unconventional monetary policy. Finally, we analyze how spillback and third-country effects may play a role in determining the extent of the international spillovers arising from US monetary policy shocks.

3.1 Spillovers from US conventional monetary policy

Figure 2 reports the median responses of US variables and the associated 68% bands, to an expansionary conventional monetary policy shock which reduces the US short-term interest rate by 25 basis points on impact. For comparison, responses for the rest of the world are also reported, which are obtained by aggregating country-level responses using GDP weights. US GDP growth increases on impact by about 20 basis points, as well as CPI inflation, which increases by about 22 basis points. Estimated elasticities are in line with results reported in Baumeister and Benati (2013). The effective exchange rate depreciates on impact by about 2 percentage points, while real equity prices increase by nearly 4 percentage points. Interestingly, responses of output growth and equity prices in the rest of the world are of similar magnitude, if not greater, than those reported for the United States. In particular, growth in the rest of the world increases by 40 basis points on impact, while equity prices increase by roughly 5 percent on impact and reach a peak which averages 8 percent after one quarter. These results are consistent with the idea that the global financial cycle is largely driven by developments in the United States, as emphasized by Rey (2013).[6]

[6] In particular, we confirm elasticities in Rey (2016), in which a monetary surprise leading to a 20 basis points tightening in the one-year rate leads to an 8 percent decrease in the global asset price factor.

Figure 2: Expansionary CMP shock: domestic effects and on the rest of the world



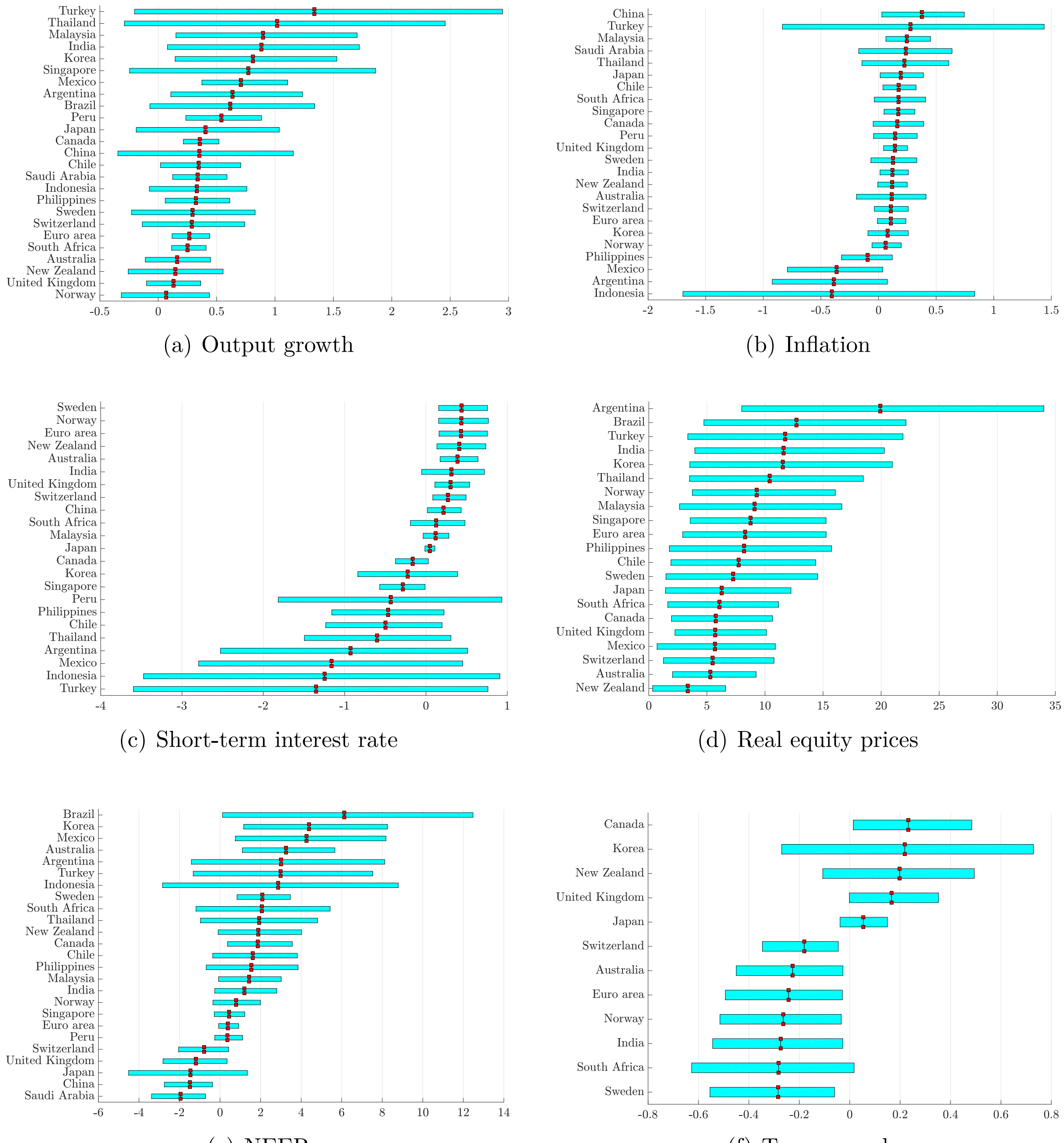
Notes: median responses for US variables in red, joint with the 16th and 84th percentiles, to an expansionary US conventional monetary policy shock which decreases on impact the US short-term rate by 25 basis points. Median responses for rest of the world in dashed black, constructed by aggregating country-specific responses using GDP-based weights.

These results suggest that spillovers to the rest of the world are sizable, however they mask substantial heterogeneity at the country level. Figure 3 plots the maximum absolute responses of each variable of each country, joint with the 16th and 84th percentiles. Spillovers on output growth are positive for all countries, and there is substantial heterogeneity across countries albeit the uncertainty surrounding these estimates is large. At a first sight, it appears that emerging economies feature stronger spillovers (for instance Turkey 1.34%, Thailand 1.02%, Malaysia 0.90%, and India 0.88%), while negligible effects are found in advanced economies (e.g. Norway 0.07%, UK 0.13%, euro area 0.27%). Spillover effects on inflation are generally positive: stronger effects are observed in China, Turkey, and Malaysia, even though other emerging economies such as Mexico, Argentina and Indonesia feature negative spillovers albeit substantial statistical uncertainty.

Regarding the short-term interest rate, we observe that effects are positive and significant for most of the advanced economies (e.g. euro area 0.43%, UK 0.30%), while sizable and negative effects, associated with high uncertainty, are found in emerging economies such as Turkey, Mexico, and Argentina. Further, spillovers on equity prices are generally statistically significant and again it appears that larger effects are found in emerging economies such as Argentina, Brazil, Turkey, and India.

Regarding the effects on the exchange rate, most of the countries observe an appreciation of their currency to different degrees, and even , with the exception of few countries such as Saudi Arabia, China, Japan, UK, and Switzerland, for which the US expansionary monetary policy shock lead to a depreciation of the respective currencies. Among these countries there are Saudi Arabia and China, whose currencies are to some extent anchored to the US Dollar. Finally, large heterogeneity is observed in the responses of the term spread, which can be either positive or negative, ranging from positive effects in Canada (0.23%), Korea (0.22%), and New Zealand (0.20%), to negative values in Sweden and South Africa (both -0.28%).

Figure 3: Country-level effects to an expansionary CMP shock



(a) Output growth

(b) Inflation

(c) Short-term interest rate

(d) Real equity prices

(e) NEER

(f) Term spread

Notes: maximum absolute responses, medians, 16th, and 84th percentiles, to an expansionary US conventional monetary policy shock which decreases on impact the US short-term rate by 25 basis points.

Next, we group countries according to their level of development, following the classification in Georgiadis (2016), as well as depending on their exchange rate regime, for which we employ information on wether countries actually anchor their currencies to the US Dollar according to the index developed in Ilzetzki et al. (2017).[7] Table 3 reports the classifications of countries, and shows that we are considering a relatively balanced sample in terms of income level (11 advanced and 14 emerging economies), while the majority of countries actually feature an anchor to the US Dollar (namely 17 countries, against 8 economies whose currency is freely floating or anchored to other currencies).

Table 3: Country classifications

Income level		FX regime	
Advanced	*Emerging*	*Anchor to USD*	*No anchor*
Australia	Argentina	Argentina	Australia
Canada	Brazil	Brazil	Euro area
Euro area	Chile	Canada	Japan
Japan	China	Chile	New Zealand
Korea	India	China	Norway
New Zealand	Indonesia	India	Sweden
Norway	Malaysia	Indonesia	Switzerland
Singapore	Mexico	Korea	United Kingdom
Sweden	Peru	Malaysia	
Switzerland	Philippines	Mexico	
United Kingdom	Saudi Arabia	Peru	
	South Africa	Philippines	
	Thailand	Saudi Arabia	
	Turkey	Singapore	
		South Africa	
		Thailand	
		Turkey	

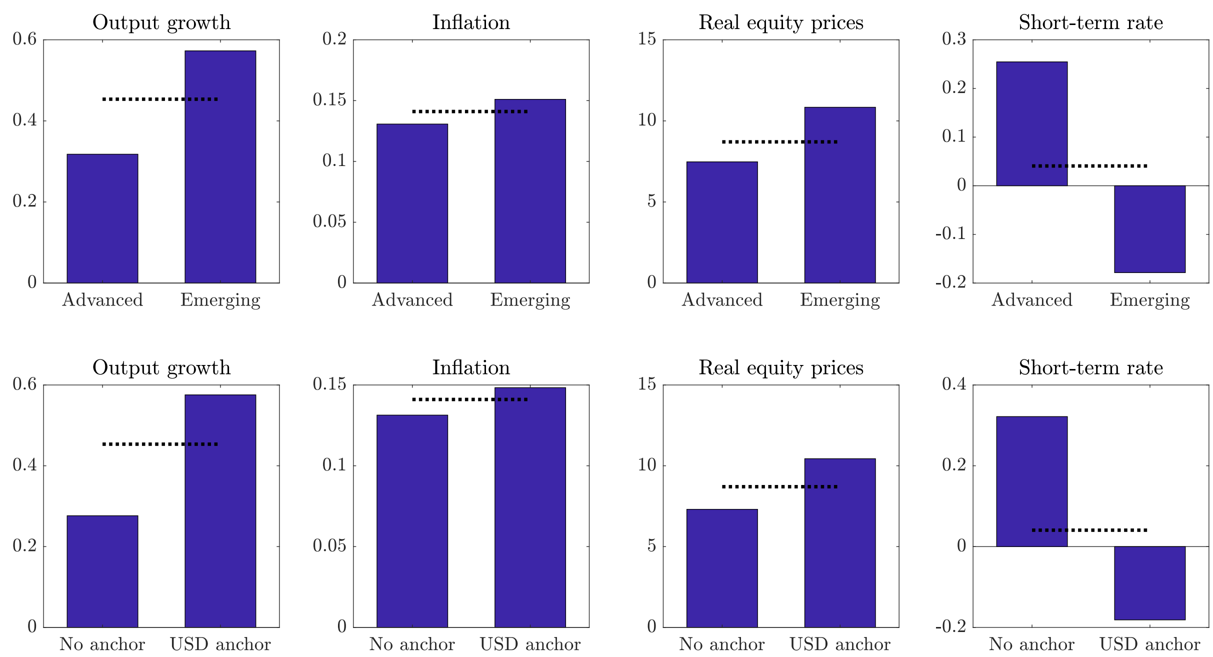
Notes: classification on income level is from Georgiadis (2016), on exchange rate is based on Ilzetzki et al. (2017).

We then aggregate country level results into our predefined groups, using GDP-based shares as weights. To get a preliminary sense of results, Figure 4 plots the average effects

[7]Specifically, the Ilzetzki et al. (2017) index is a dummy variable (equal to one if USD anchor holds) at annual frequency, and we define a country as having a USD anchor if it holds over the majority of our sample period. An interesting feature of this index is that it is relatively stable over time for our countries under consideration, with the exception of Turkey, which begins to hold the USD anchor starting from 2003.

over the different groups, while the dashed black line reports the average effect for the world excluding the US. We point out a number of interesting results. First, emerging economies receive relatively larger macroeconomic and financial spillovers, and the effect is particularly pronounced for output growth, whose effect is nearly twice (0.57%) the effect for advanced economies (0.32%). This difference can be partly explained by the behavior of the short-term interest rate of emerging economies, which falls by about 18 basis points in line with the exogenous drop of the US rate, while the opposite holds for advanced economies (whose rate increases by about 25 basis points). Second, economies whose currencies are anchored to the US Dollar also feature stronger spillovers on output growth and equity prices, and their short-term rates closely follow the US rate. Overall, spillover effects on inflation are similar across groups and in line with the average effect on the rest of the world (14 basis points increase).

Figure 4: Conventional monetary policy: effects across selected groups



Notes: maximum absolute responses for selected groups, obtained by aggregating country-level effects using GDP-based shares. Dashed black line refers to the effect in the rest of the world.

To get a clearer picture of previous results, Figure 12 in Appendix reports the country-level effects, grouped by the selected characteristics, where the dashed blue line reports the weighted averages for each group. Uncertainty surrounding the estimated is large, and especially so for emerging countries, which are also those that anchor their currency to the US Dollar. For instance, by inspecting the group of emerging economies, stronger spillovers on output growth are also associated with larger confidence bands which cover even the zero line, such as in Turkey and Thailand. A similar point can be made with respect to the effects on short-term interest rates, which are estimated with such high uncertainty to the extent that we cannot reject the null hypothesis of being statistically different from zero in many emerging economies. Hence, once accounting for statistical uncertainty, we do not find a robust relationship between estimated spillovers and the level of economic development of a country or the flexibility of its exchange rate, a result which confirms previous findings in Dedola et al. (2017).

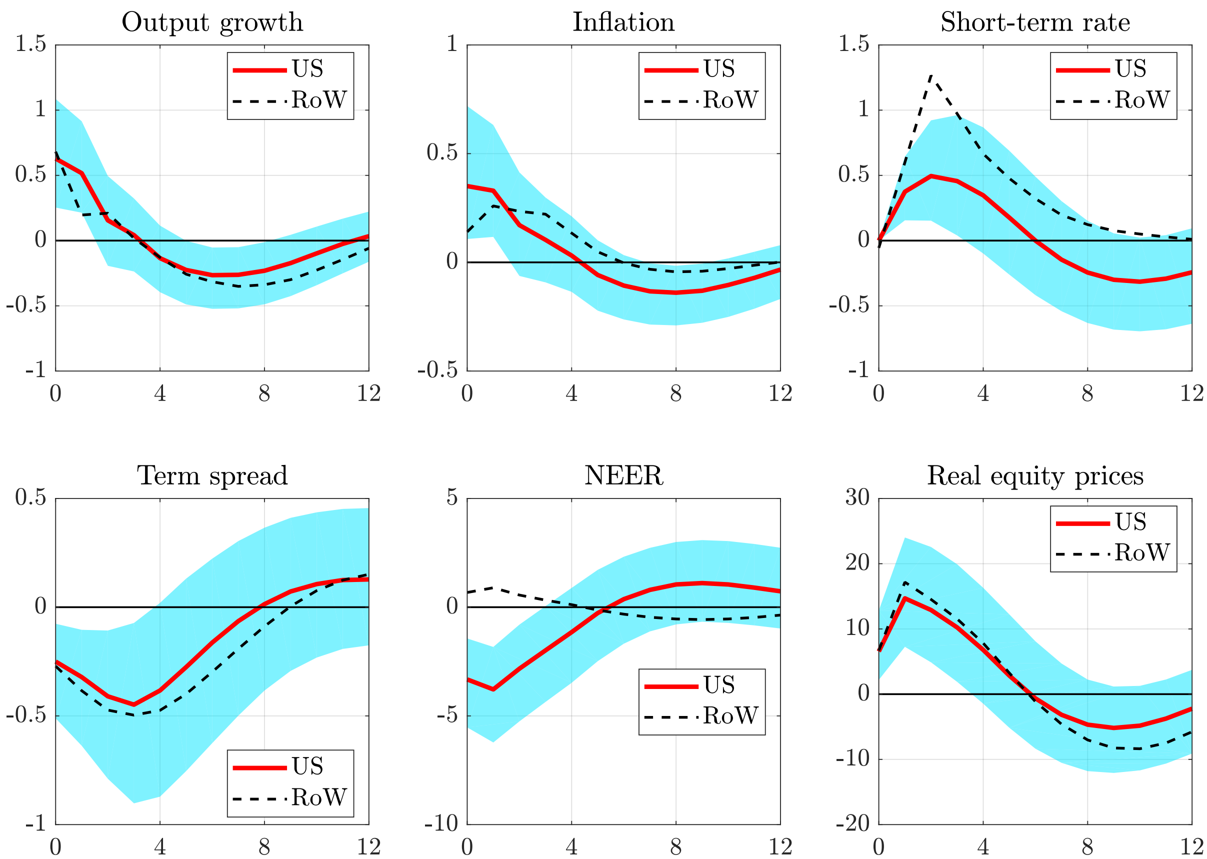
3.2 International effects of US unconventional monetary policy

We turn now to analyzing the international spillovers of a US unconventional monetary policy shock. Figure 5 reports the median responses of US variables and the associated 68% bands, to an exogenous reduction of the US long-short term spread by 25 basis points on impact. Again, for comparison, we report responses for the rest of the world. US GDP growth increases on impact by about 50 basis points, as well as CPI inflation, which increases by about 35 basis points. Also in this case, estimated elasticities are in line with results in Baumeister and Benati (2013). The effective exchange rate depreciates on impact by about 3.5 percentage points, while real equity prices increase by nearly 7 percentage points.

Again we observe that responses of several variables in the rest of the world closely follows the US counterparts, as in the case for output growth and equity prices. Such comovement also occurs in the responses of the term spread, while it was absent in case of the conventional monetary policy shock. Further, the US short-term interest rate, which is on impact constrained to be zero, increases and reaches a peak of about 50 basis points after three quarters. The response for the rest of the world is even stronger and reaches a peak of more than 100 basis points. As we will show later, such amplification is not occurring just in emerging economies but also in some key advanced ones.

Notice that the positive response of the short-term interest rate is due to the standard reaction of the central bank to offset the increase in inflation and output growth, see for instance Baumeister and Benati (2003).[8] We also implement an alternative simulation of the shock in which we impose a zero lower bound constraint on the short-rate, practically by zeroing out the structural US interest rate equation over three years. Figure 15 in Appendix shows that results are very similar to the benchmark case.

Figure 5: Expansionary UMP shock: domestic effects and on the rest of the world



Notes: median responses for US variables in red, joint with the 16th and 84th percentiles, to an expansionary US unconventional monetary policy shock which decreases on impact the US term spread by 25 basis points. Median responses for rest of the world in dashed black, constructed by aggregating country-specific responses using GDP-based weights.

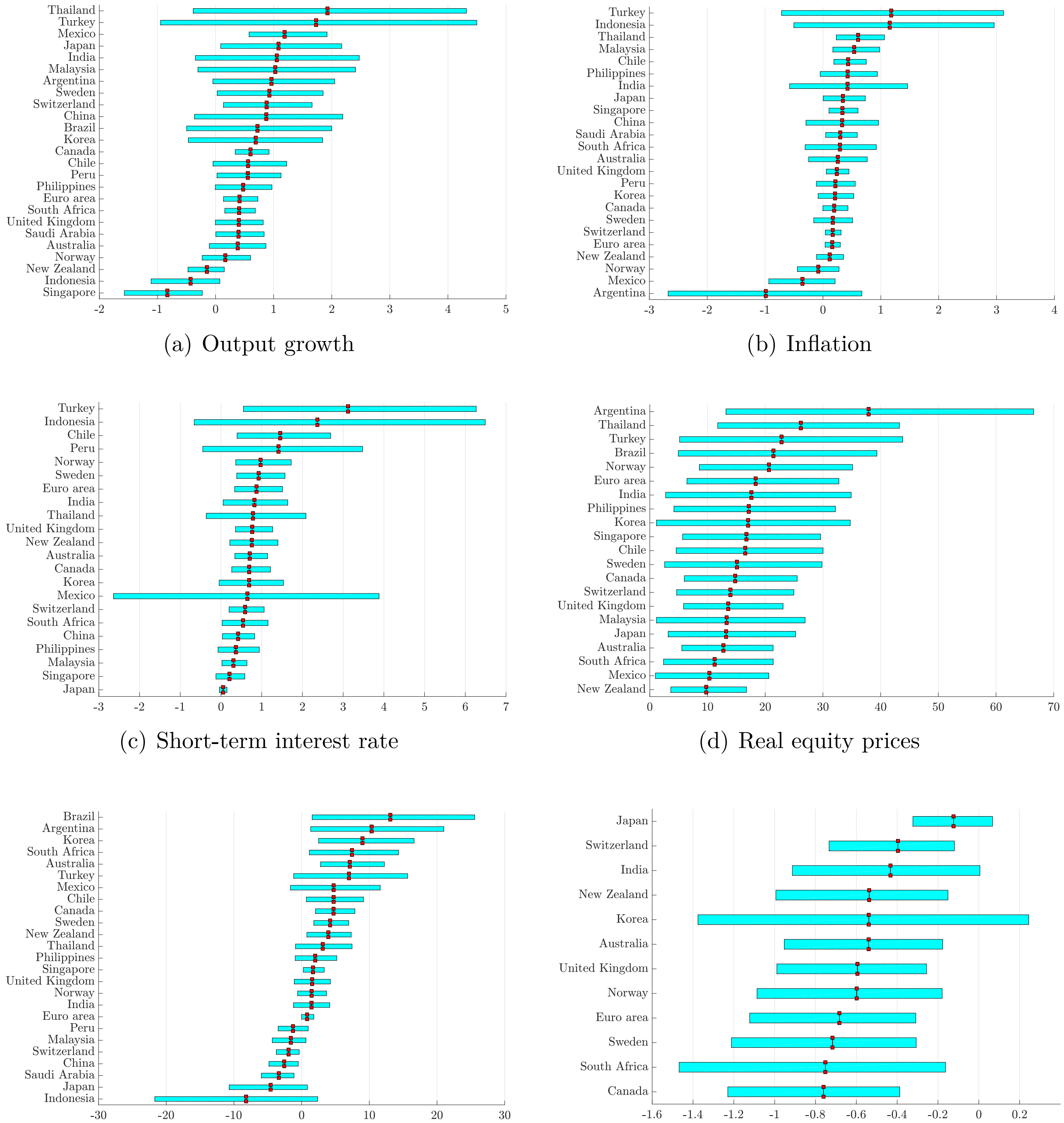
Further, Figure 3 plots the maximum absolute responses of each variable at the country level, joint with the 16th and 84th percentiles. Also in the case of the unconventional monetary policy shock we observe that spillovers on output growth are mostly positive

[8]This result also holds in Boeckx et al. (2017) and Burriel and Galesi (2018), which alternatively identify unconventional monetary policy shocks by extracting exogenous movements in the central bank's balance sheet.

for all countries and emerging economies feature stronger spillovers (for instance Thailand 1.93%, Turkey 1.73%, Mexico 1.19%). Similarly, spillover effects on inflation are generally more subdued and surrounded by high uncertainty. On the contrary we observe that effects on short-term rates are systematically positive, and particularly large for some emerging economies such as Turkey (3.12%), Indonesia (2.37%). Nonetheless, effects are large also in advanced economies such as the euro area (0.87%), United Kingdom (0.77%), and Canada (0.69%). In this respect we observe an overreaction also in the case of term spreads, whose effects are systematically negative in all economies.

Regarding the effects on the exchange rate, we observe again an appreciation of currencies in most of the countries. Among those countries which depreciate their currency we note again Saudi Arabia and China, following the depreciation of the US Dollar implied by the US monetary stimulus. Finally, spillovers on equity prices are statistically significant and positive, and those countries which feature the largest effects are emerging economies such as Argentina, Thailand, Turkey, and Brazil.

Figure 6: Country-level effects to an expansionary UMP shock



(a) Output growth

(b) Inflation

(c) Short-term interest rate

(d) Real equity prices

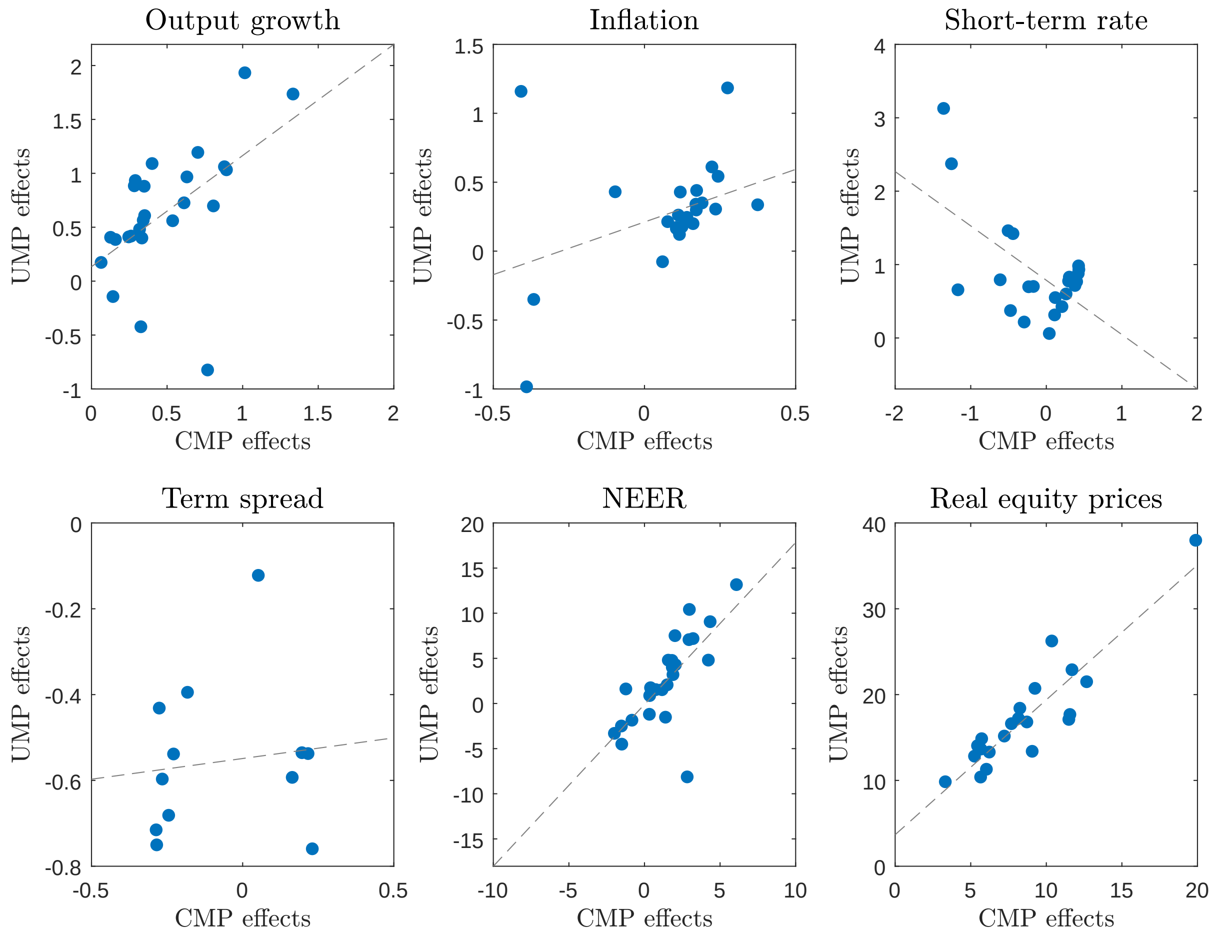
(e) NEER

(f) Term spread

Notes: maximum absolute responses, medians, 16th, and 84th percentiles, to an expansionary US unconventional monetary policy shock which decreases on impact the US term spread by 25 basis points.

At a first sight, it appears that some selected economies (in particular the emerging ones) are those which get mostly affected by the US monetary policy, regardless of whether the latter takes the form of conventional policy rate surprises or of unconventional measures aiming at decreasing the term spread. Figure 7 plots the country level responses to conventional (x-axis) and unconventional (y-axis) monetary policy shocks. Results suggest that in terms of output and equity prices spillovers, those countries which get mostly affected by conventional monetary policy shocks are also those which feature stronger effects due to unconventional policy measures. This relationship also holds for the effective exchange rate, and to a lesser extent for inflation. Hence we should expect that at least for these variables, some fixed country-specific characteristics are relevant to explain the heterogeneity in effects, regardless of which monetary policy instrument is used.

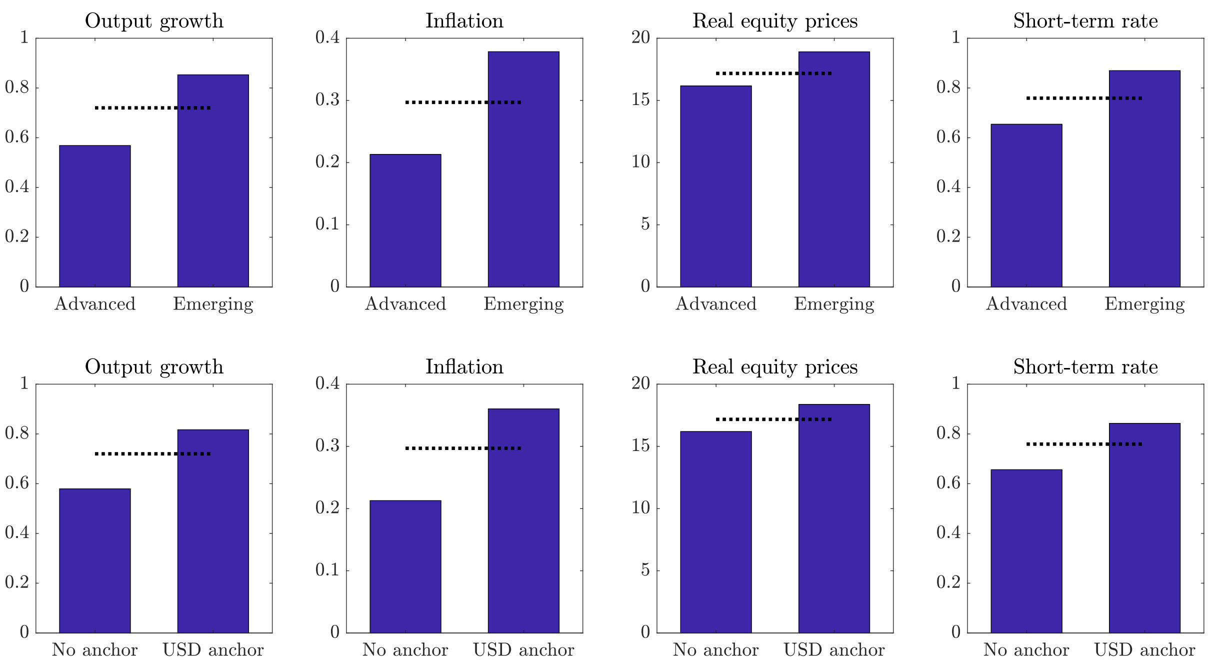
Figure 7: Conventional and unconventional monetary policy: country effects



Notes: x-axis reports the country-level maximum absolute responses to an expansionary US conventional monetary policy shock which decreases on impact the US short-term rate by 25 basis points; y-axis reports the corresponding statistics to an expansionary US unconventional monetary policy shock which decreases on impact the US term spread by 25 basis points. Regression line in dashed.

In Figure 8 we compare the average effects between advanced/emerging economies or between those countries which anchor their currency to the US Dollar and the rest of countries. At a first glance, those economies which anchor their currency to the US Dollar (as well as emerging economies) receive relatively larger spillovers in terms of output growth and equity prices. These economies also feature larger inflationary spillovers (36 basis points) and nearly twice the effects on advanced economies (21 basis points). Emerging economies are also those whose short-term rate reacts more to the shock (84 basis points increase) compared to advanced economies (65 basis points). The important caveat is that, as previously pointed out, these relationships are weak when considering the statistical uncertainty of the estimated effects, as reported in Figure 16 in Appendix.

Figure 8: Unconventional monetary policy: effects across selected groups



Notes: maximum absolute responses for selected groups, obtained by aggregating country-level effects using GDP-based shares. Dashed black line refers to the effect in the rest of the world.

3.3 Investigating the sources of international spillovers

We have shown that US monetary policy implies sizable and often statistically significant international spillovers in the rest of the world. This is particularly true for financial variables such as real equity prices, short- and long-term yields. These results bring some support to Rey's (2013) idea that the global financial cycle is largely driven by monetary developments in the United States. One question that we may pose is to what extent spillover effects are amplified by (i) spillback effects from the rest of the world to the US, and by (ii) third-country effects arising due to the interactions among receiving countries.

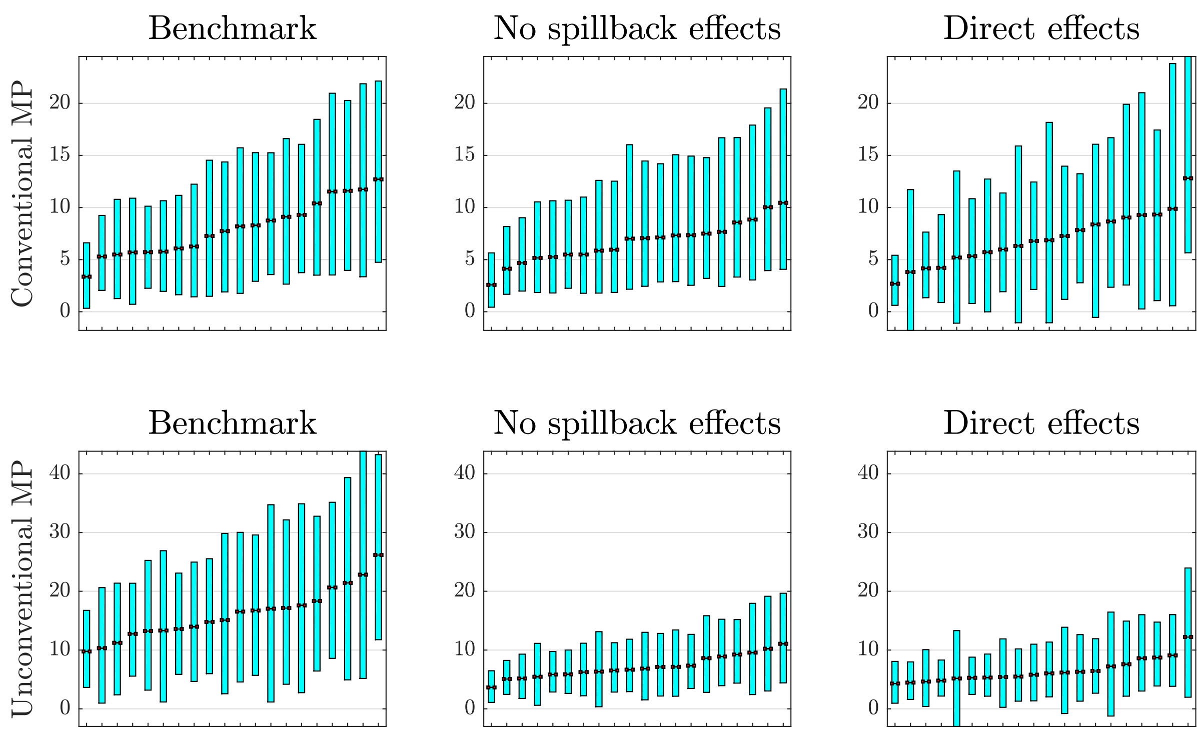
To answer this question, we perform two exercises. First, given the estimated parameters of the benchmark GVAR model we simulate exogenous monetary policy shocks by setting to zero all the coefficients of the foreign variables of the US model. In this way, the US model is completely exogenous to developments in the rest of the world, so that any potential spillback effect is shut down. The second exercise consists of, in addition to shutting down the spillback effects, to also preclude any bilateral interaction among all countries excluding the US. In practice, at the stage of obtaining the global solution of the model, for each receiving country we set to zero the trade-based weights of all countries excluding the US, while we set the US weight equal to one. In this way, each receiving country depends just on US developments, so that third-country effects are shut down.

Figure 17 in the Appendix reports the impulse responses of variables in the US and the rest of the world to a conventional monetary expansion which decreases the US short-term rate by 25 basis points, for three cases: (*i*) *Benchmark*, which allows for spillback and third-country effects; (*ii*) *No spillback effects*, which allows only for third-country effects; and (*iii*) *Direct effects*, which precludes both spillback and third-country effects. We observe that spillback effects amplify the international spillovers of output growth and inflation, and to a lesser extent those of financial variables. On the contrary, third-country effects appear not to be relevant in transmitting the shock, given that responses of the cases *No spillback effects* and *Direct effects* are virtually identical. Even when spillback and third-country effects are absent, the response of real equity prices in the rest of the world closely mimics the US counterpart, thus confirming the relevance of US developments in determining world equity prices.

Similarly Figure 18 in the Appendix reports the impulse responses of variables in the US and the rest of the world to a conventional monetary expansion which decreases the US term spread by 25 basis points, for the abovementioned cases. Spillback effects magnify international spillovers and make them more persistent, not just for output growth and inflation, but also for financial variables. Again, third-country effects appear not to be relevant in transmitting the shock. Again, real equity prices in the rest of the world respond in line with US equity prices even in the absence of an endogenous response of the US economy to the reaction of the rest of the world, as well as of any cross-country interactions among receiving economies.

Previous results suggest that third-country effects are not relevant for determining the magnitude of international spillovers. Hence at a first sight one may think that cross-country interactions are a unnecessary ingredient of the model. Figure (9) plots the country-level median peak responses of real equity prices, joint with the corresponding 16th and 84th percentiles, for the benchmark model and for the two counterfactuals which exclude either the spillback effects or both spillback and third-country effects. By comparing cases *No spillback effects* and *Direct effects*, we can observe that the inclusion of third-country effects allow for all country level effects being statistically different from zero. Hence we highlight that, for the specific purpose of our analysis, modeling cross-country interactions among receiving countries allows for a more precise assessment of the international spillovers.

Figure 9: Sources of spillovers on real equity prices: country-level responses



Notes: median responses for US variables in red, joint with the 16th and 84th percentiles, to expansionary US conventional and unconventional monetary policy shocks, for three cases: (*i*) *Benchmark*, which allows for spillback and third-country effects; (*ii*) *No spillback effects*, which allows only for third-country effects; and (*iii*) *Direct effects*, which precludes both spillback and third-country effects. Median responses for rest of the world in dashed black, constructed by aggregating country-specific responses using GDP-based weights.

4 Conclusions

TO BE COMPLETED

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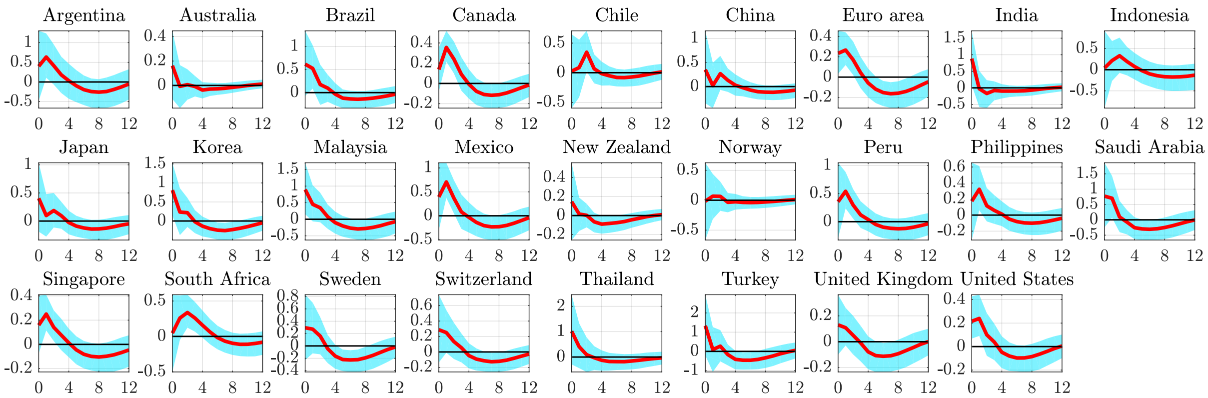
A Other Tables and Figures

Table 4: Data availability

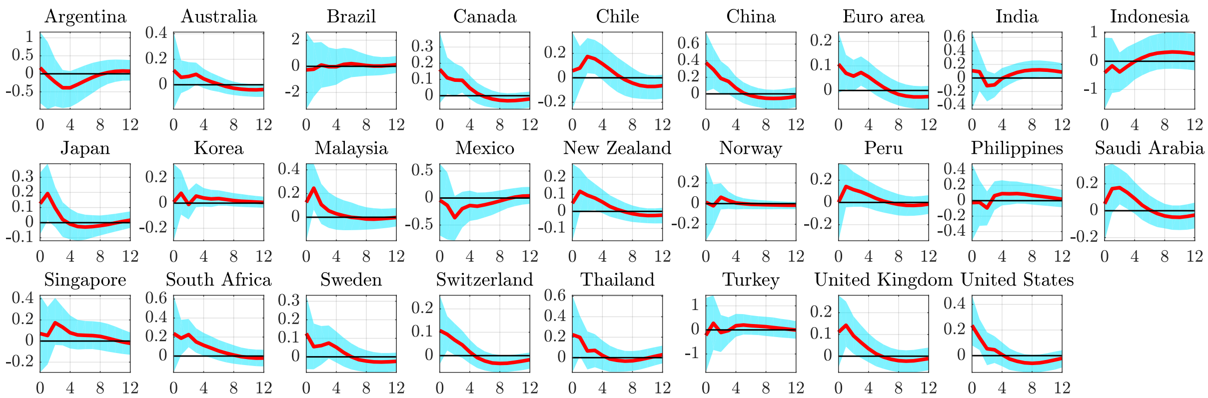
	Output growth	Inflation	Short-term rate	Term spread	NEER	Real equity prices
Argentina	X	X	X		X	X
Australia	X	X	X	X	X	X
Brazil	X	X	X		X	X
Canada	X	X	X	X	X	X
Chile	X	X	X		X	X
China	X	X	X		X	
Euro area	X	X	X	X	X	X
India	X	X	X	X	X	X
Indonesia	X	X	X		X	
Japan	X	X	X	X	X	X
Korea	X	X	X	X	X	X
Malaysia	X	X	X		X	X
Mexico	X	X	X		X	X
New Zealand	X	X	X	X	X	X
Norway	X	X	X	X	X	X
Peru	X	X	X		X	
Philippines	X	X	X		X	X
Saudi Arabia	X	X			X	
Singapore	X	X	X		X	X
South Africa	X	X	X	X	X	X
Sweden	X	X	X	X	X	X
Switzerland	X	X	X	X	X	X
Thailand	X	X	X		X	X
Turkey	X	X	X		X	X
United Kingdom	X	X	X	X	X	X
United States	X	X	X	X	X	X

Notes: quarterly data, 1994Q1-2016Q4. Data are from the GVAR Quarterly Database of Mohaddes and Raissi (2018), with the exception of equity prices in Brazil, Mexico, and Turkey which are from the OECD Main Economic Indicators database.

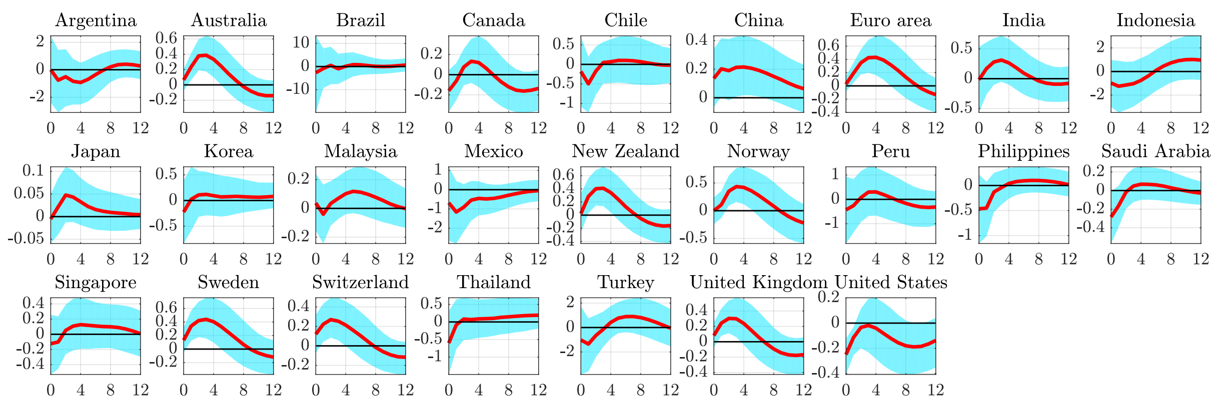
Figure 10: IRFs to an expansionary US conventional monetary policy shock



(a) Output growth



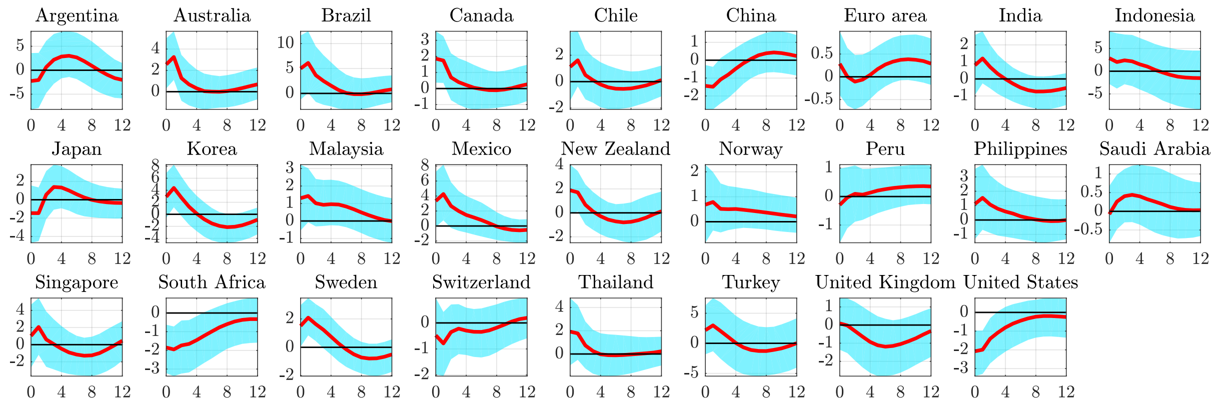
(b) Inflation



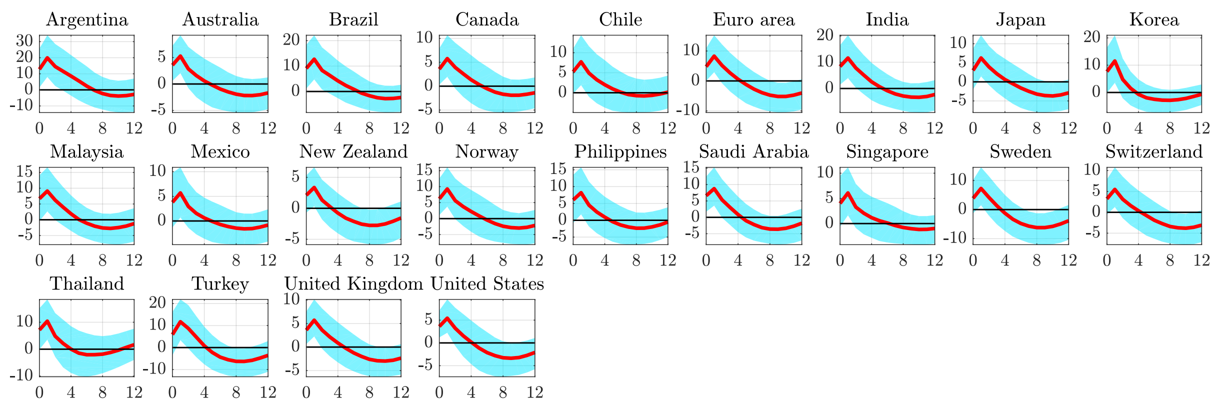
(c) Short-term interest rate

Notes: median responses in red, joint with the 16th and 84th percentiles, to an expansionary US conventional monetary policy shock which decreases on impact the US short-term rate by 25 basis points.

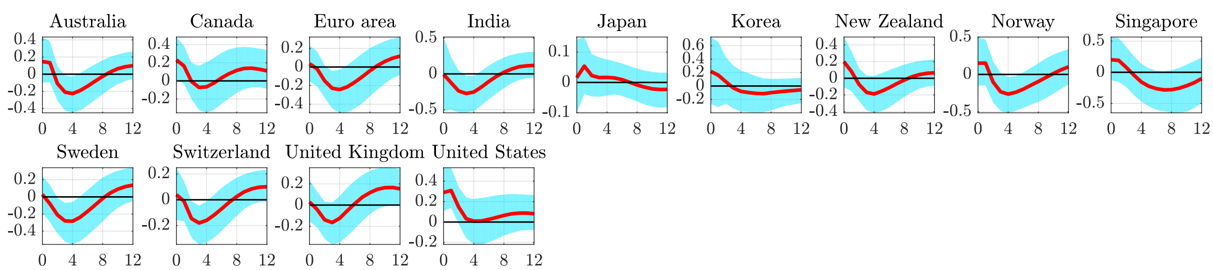
Figure 11: (Continued) IRFs to an expansionary US conventional monetary policy shock



(a) Nominal effective exchange rate



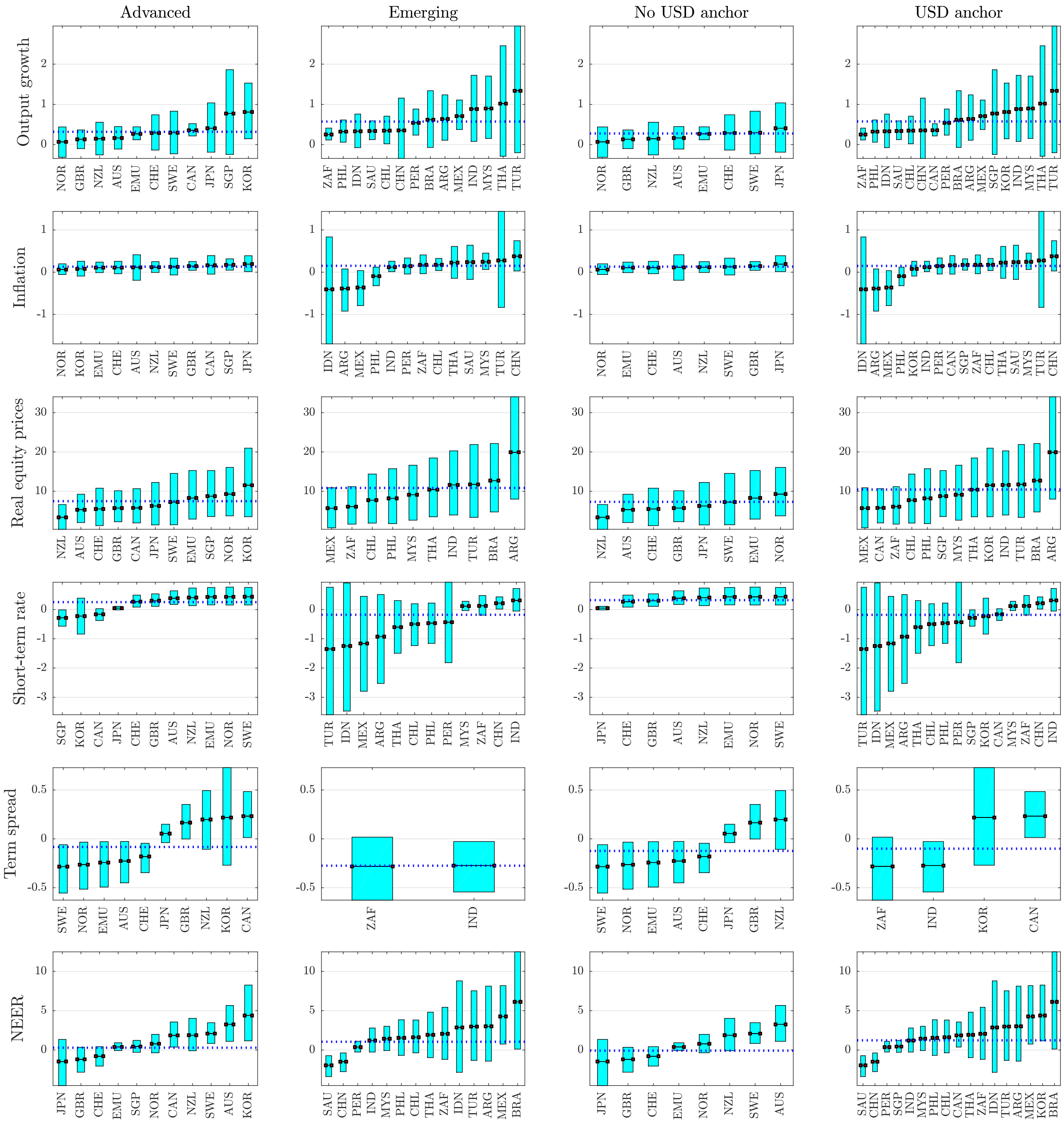
(b) Real equity prices



(c) Term spread

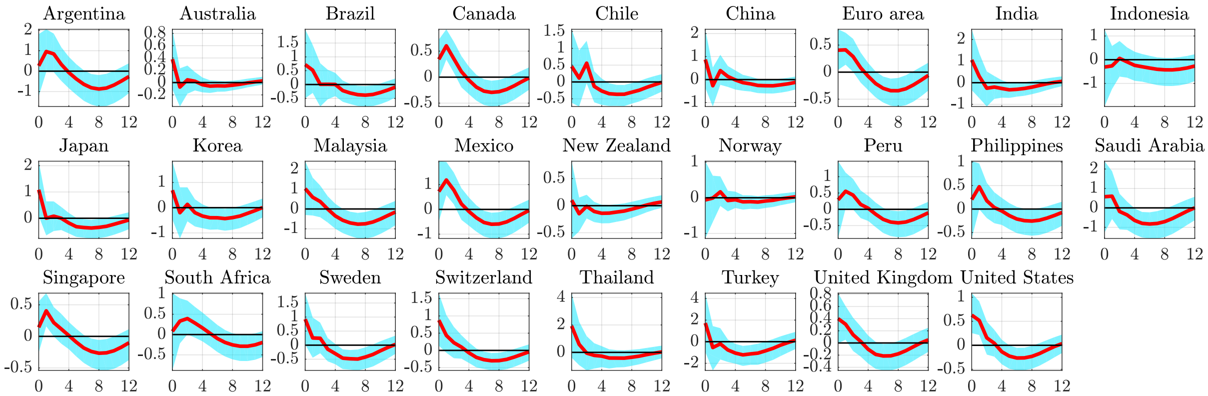
Notes: median responses in red, joint with the 16th and 84th percentiles, to an expansionary US conventional monetary policy shock which decreases on impact the US short-term rate by 25 basis points.

Figure 12: Conventional monetary policy: country level effects & characteristics

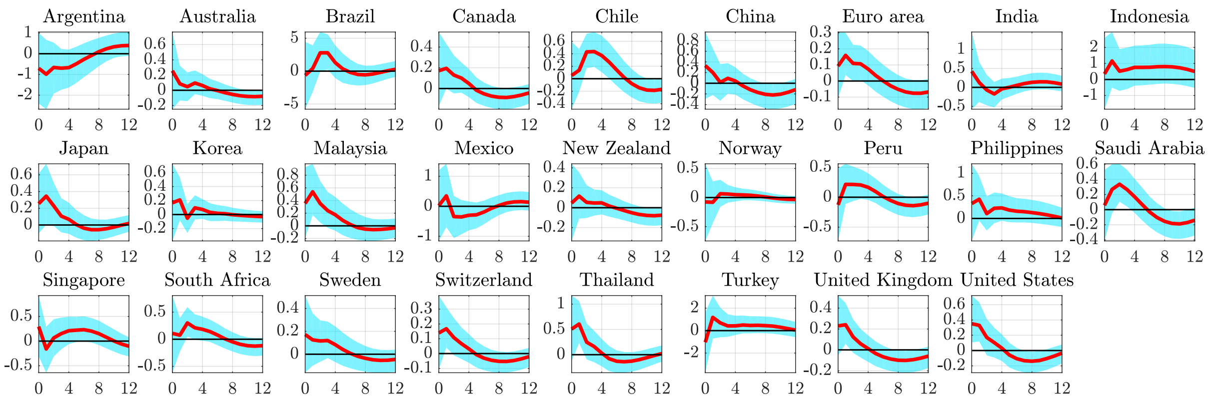


Notes: maximum absolute responses, medians, 16th, and 84th percentiles, to an expansionary US conventional monetary policy shock which decreases on impact the US short-term rate by 25 basis points. Dashed blue line refers to the effect in each country group, obtained by aggregating country-level median effects using GDP-based shares.

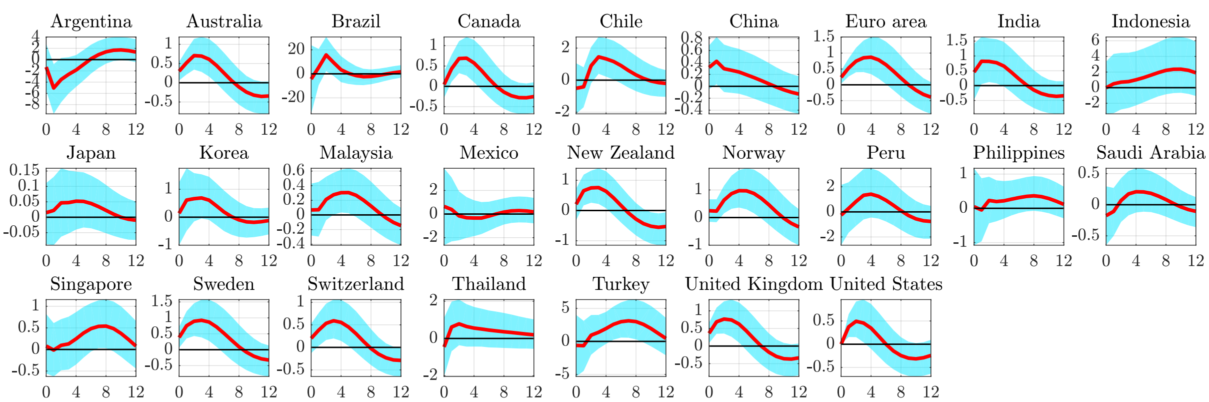
Figure 13: IRFs to an expansionary US unconventional monetary policy shock



(a) Output growth



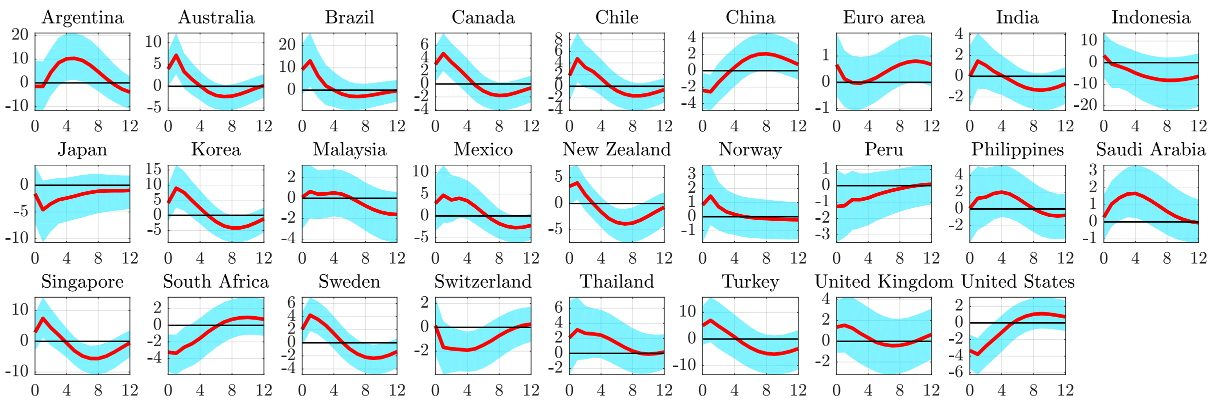
(b) Inflation



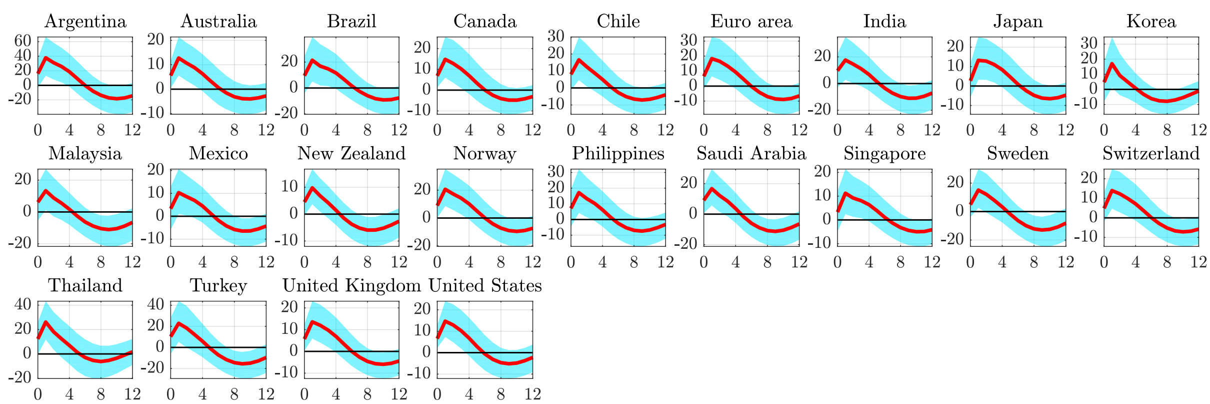
(c) Short-term interest rate

Notes: median responses in red, joint with the 16th and 84th percentiles, to an expansionary US unconventional monetary policy shock which decreases on impact the US term spread by 25 basis points.

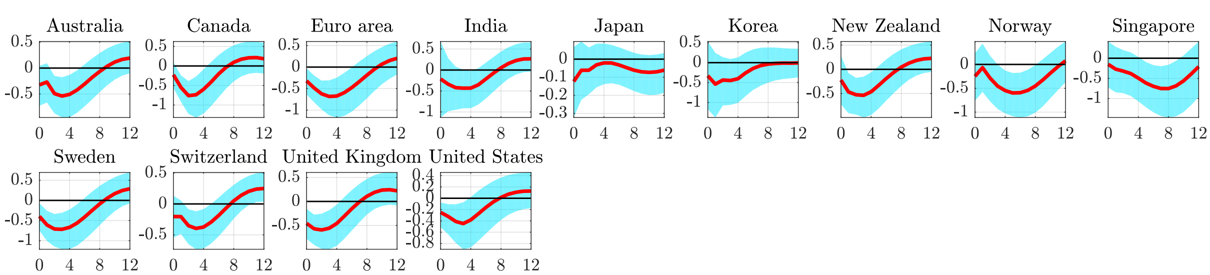
Figure 14: (Continued) IRFs to an expansionary US unconventional monetary policy shock



(a) Nominal effective exchange rate



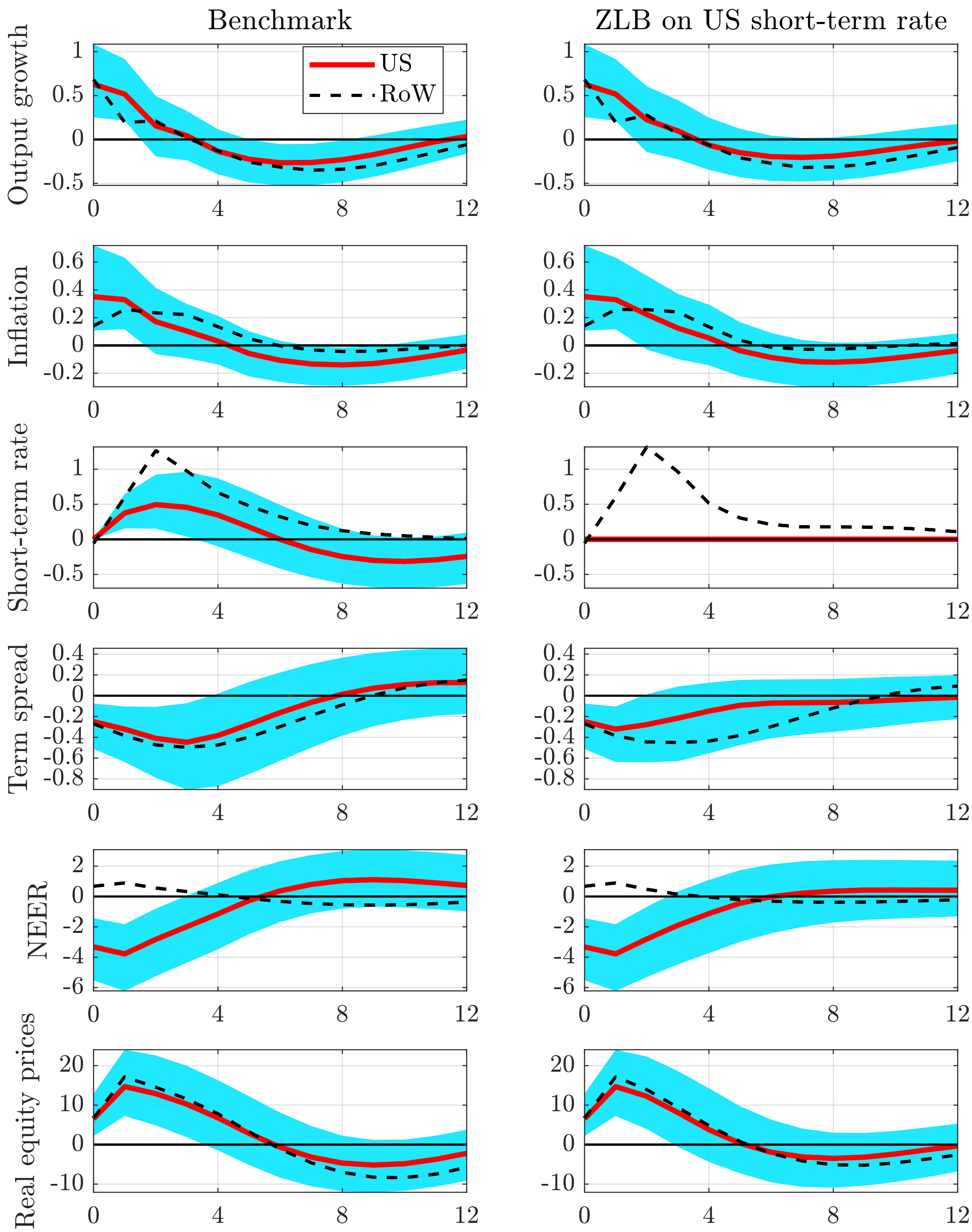
(b) Real equity prices



(c) Term spread

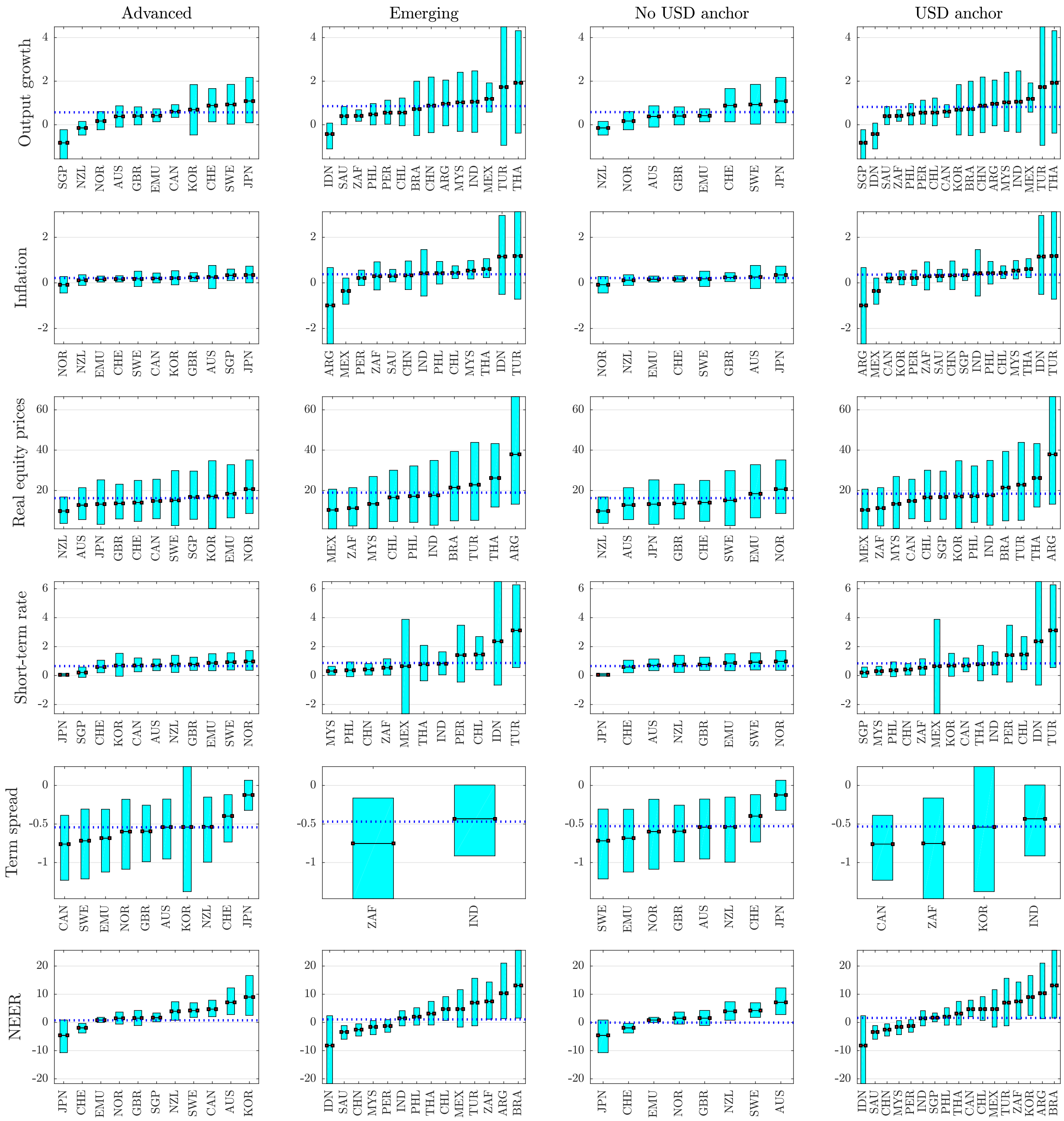
Notes: median responses in red, joint with the 16th and 84th percentiles, to an expansionary US unconventional monetary policy shock which decreases on impact the US term spread by 25 basis points.

Figure 15: Expansionary UMP shock: accounting for the zero lower bound



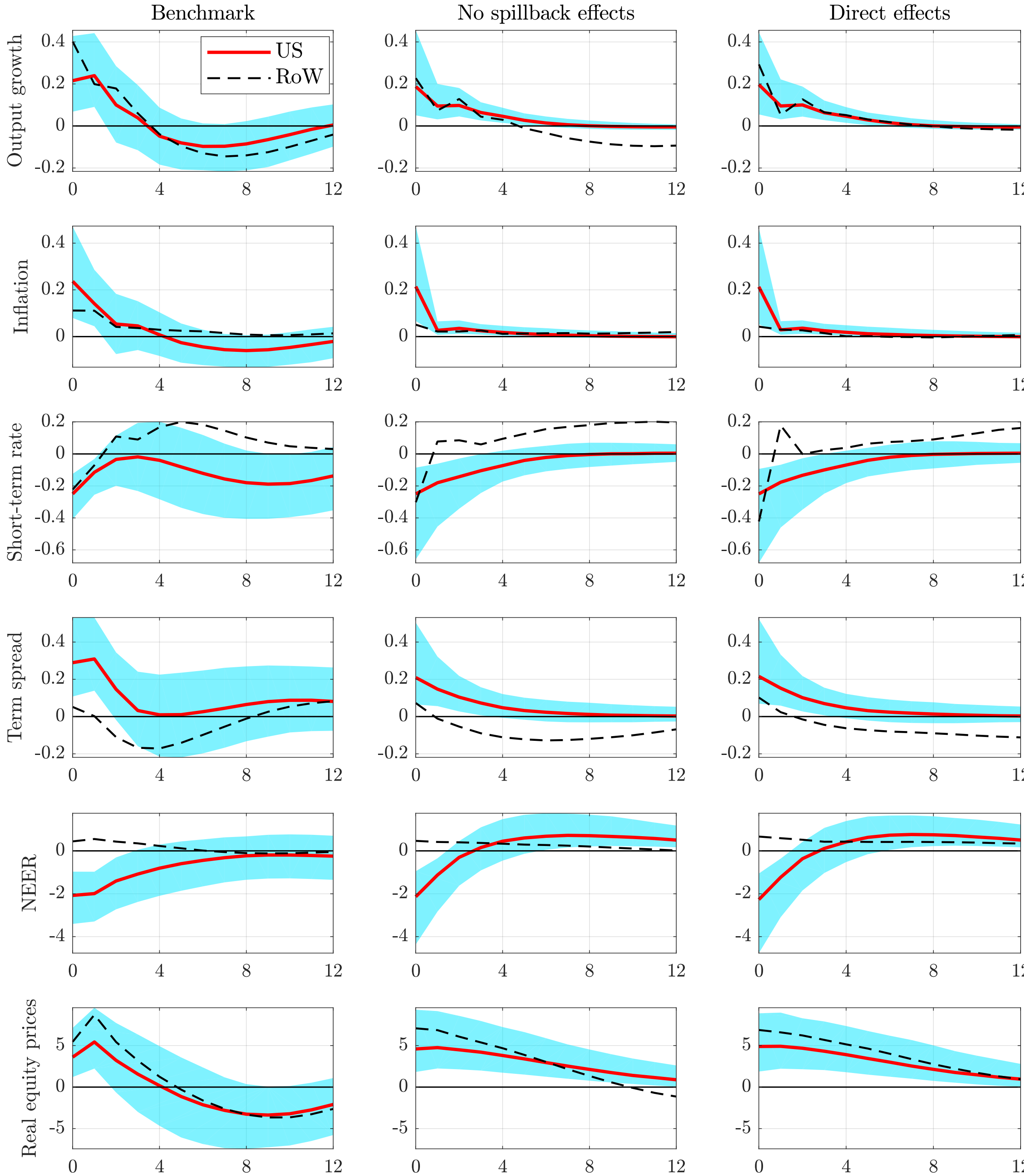
Notes: median responses for US variables in red, joint with the 16th and 84th percentiles, to an expansionary US unconventional monetary policy shock which decreases on impact the US term spread by 25 basis points. Median responses for rest of the world in dashed black, constructed by aggregating country-specific responses using GDP-based weights. *ZLB on US short-term rate* shuts down the coefficients of the structural US interest rate rule over three years after the shock.

Figure 16: Unconventional monetary policy: country level effects & characteristics



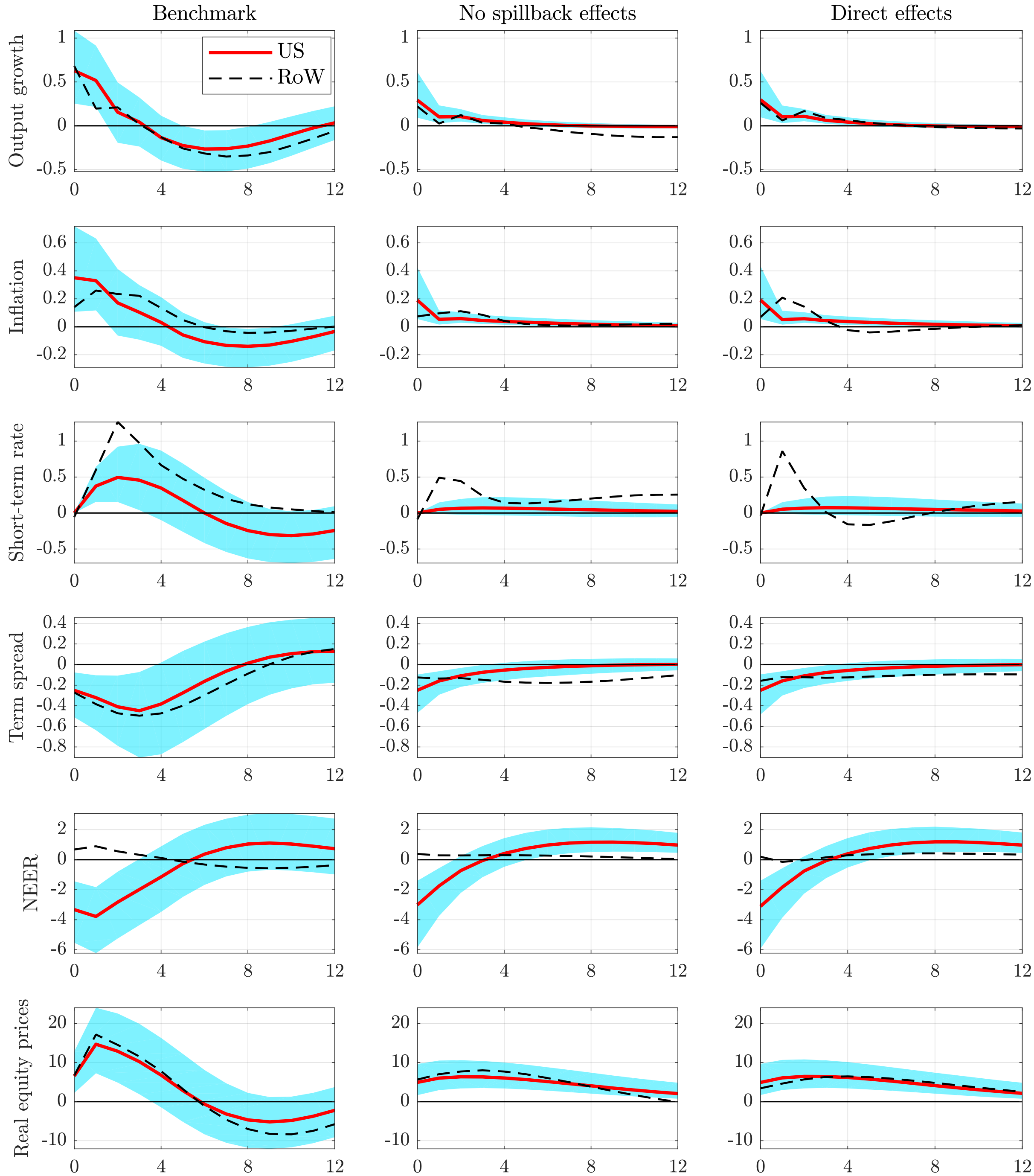
Notes: maximum absolute responses, medians, 16th, and 84th percentiles, to an expansionary US unconventional monetary policy shock which decreases on impact the US term spread by 25 basis points. Dashed blue line refers to the effect in each country group, obtained by aggregating country-level median effects using GDP-based shares.

Figure 17: Source of international spillovers: US conventional monetary policy



Notes: median responses for US variables in red, joint with the 16th and 84th percentiles, to an expansionary US conventional monetary policy shock which decreases on impact the US short-term rate by 25 basis points, for three cases: (*i*) *Benchmark*, which allows for spillback and third-country effects; (*ii*) *No spillback effects*, which allows only for third-country effects; and (*iii*) *Direct effects*, which precludes both spillback and third-country effects. Median responses for rest of the world in dashed black, constructed by aggregating country-specific responses using GDP-based weights.

Figure 18: Source of international spillovers: US unconventional monetary policy



Notes: median responses for US variables in red, joint with the 16th and 84th percentiles, to an expansionary US unconventional monetary policy shock which decreases on impact the US term spread by 25 basis points, for three cases: (i) *Benchmark*, which allows for spillback and third-country effects; (ii) *No spillback effects*, which allows only for third-country effects; and (iii) *Direct effects*, which precludes both spillback and third-country effects. Median responses for rest of the world in dashed black, constructed by aggregating country-specific responses using GDP-based weights.