The Global Transmission of U.S. Monetary Policy

Preliminary Version, do not circulate

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Abstract

How does US monetary policy affects the rest of the world? This paper provides evidence on how policy actions are transmitted across the global economy by employing a high frequency identification of policy shocks, together with large VAR techniques. We study the transmission of US monetary policy over a comprehensive set of global indicators, and national macroeconomic and financial variables covering both advanced and emerging economies. First, we document that a US monetary tightening induces symmetric macro and financial contractionary responses in the US and across the globe. This testifies the role of the dollar as a global currency. Second, we show that the spillovers of US monetary policy affect both advanced economies and emerging markets, irrespectively of their monetary policy regime. Finally, we investigate some of the channels through which the effects propagate and find a differential role for trade, exchange rates liquidity flow, and commodity prices.

Keywords: Monetary policy, Trilemma, Exchange Rates, International Transmission, Foreign Spillovers.

JEL Classification: E5, F3, F4, C3.

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1 Introduction

What is the global impact of US monetary policy actions? The deepening of trade and financial integration in the globalised economy and the emergence of a global banking system adopting the US dollar as dominant global currency has given the Fed a responsibility with economic and financial stability implications reaching beyond the borders of the United States. This paper explores the trade-offs created by the global role of US monetary policy as perceived by both for the Fed and the central banks across the world.

The literature has identified mainly three transmission channels for US monetary policy (see, for example, Rey, 2016). First, the trade channel: an increase in US interest rates has a contractionary effect domestically, which translates to lower demand for both domestic and foreign goods. The size of the US economy makes this effects of global relevance. Second, the exchange rate channel: as the dollar appreciates, foreign goods become relatively cheaper, moving the composition of world's demand away from US goods and towards foreign goods. This price effects offsets, at least partially, the US income/demand effect. Hence, on balance, there may be either a positive or negative demand shock that hits the foreign economy, depending on the relative magnitude of price and demand effects. A third channel is the international credit channel, which occurs through the balance sheet of global financial intermediaries (Rey, 2013; Bruno and Shin, 2015). A hike in the US interest rate raises the funding cost of major global banks, who provide credit to many advanced and emerging economies. It also decreases the value of their dollar denominated risky assets, causing adverse balance sheet effects. As a result, a foreign economy suffers from credit shortage and successive contraction of the real economy.

According to Mundell and Fleming's Trilemma, a country can only choose two out of three simultaneously impossible objectives – free capital flows, independent monetary policies, and flexible or targeted exchange rates. Hence, central banks of economies featuring a floating exchange rate can set interest rates autonomously with the goal of stabilising their economy, while allowing for free capital flows. However, the three channels we described point to the existence of a trade-off: whenever the domestic central bank lowers the interest rate to counter a negative demand shock coming from the US, that will worsen the negative balance sheet effects discussed above. Conversely, whenever the central bank rises the interest rate to offset these balance sheet effects, that will deflate the domestic economy by reducing consumption and investment. In her seminal work, Rey (2016) has observed that this may induce a trade-off between open capital flows and independent monetary policies, reducing the trilemma to a 'dilemma'.

Rey (2016) and Miranda-Agrippino and Rey (2015) have documented the emergence of a 'global financial cycle' in the form of a common factor in international asset prices, and different types of capital flows, closely related to the VIX, and potentially stirred by the monetary policy in the US. They have traced this to the emergence of financial globalisation and in particular the role of global banks, and observed that the global financial cycle constrains national monetary policies regardless of the exchange rate regime.[1]

Bernanke (2017) has summarised some of the open questions in the debate and observed that the positive association across assets may be due to global shocks, as well as to policy actions and their signalling and coordination effects. Second, most of the empirical research has found effects of US monetary policy taking place over long periods of time – i.e. three to four years – well beyond the expected time-scale for high-frequency phenomena such as capital inflows and outflows. Finally, he observed that the heterogeneity among countries may be an important determinant of differential sensitivity to global shocks, as due to their cyclical position, structural features, and financial market conditions.

This paper tries to provide empirical answer the open questions on the impact of US monetary policy as driver of global adjustment and on its transmission to economies across the globe. Our empirical approach deals with the concerns discussed above, in the following steps.

First, we employ a state of the art high-frequency identification (HFI) à la Gertler and Karadi (2015), obtained from high frequency movement of federal funds future

[1] Specifically, Rey (2016)'s global financial cycle is empirically defined as the positive correlation of risky assets across different economies. When risky assets do well in the US they also tend to do well in third countries. Hence in period of sustained growth there may be gross capital inflows to other advanced markets and emerging economies. Conversely, in periods of negative risk, capital outflows bring higher financial volatility, and declines in leverage. The cyclical effects of the policy actions of the Fed can activate these flows, creating volatility and changes in risk-taking – hence US monetary policy is one of the drivers of the financial cycle.

markets, in tight windows around policy announcements. We disentangle policy shocks from signalling effects, by directly controlling for the information channel of monetary policy as proposed by Miranda-Agrippino and Ricco (2017).[2]

Second, we construct a rich global dataset including a comprehensive set of macroeconomic and financial variables covering the US along with 15 advanced and 15 emerging economies, as well as a large set of global indicators. Importantly, we also adopt in our analysis a unique dataset of indexes of credit flows and liquidity conditions.[3] All of our data, as well as our instrument are at monthly frequency – hence the coverage and the frequency of the data allows for the study of the effects of US policy on financial variables at reasonably high frequency.

Finally, we investigate the global transmission of US monetary policy shocks both on the global economy as a whole and on 15 advanced and 15 emerging economies. We identify the effects of a US monetary policy shock using our instrument in a medium-scale Bayesian SVAR incorporating 27 global and US macroeconomic indicators.[4] Then, we move to individual economies and mean-group responses based on bilateral Bayesian VAR specifications, which additionally take into account interactions with the rest of the world.[5] In doing so we group countries by their income level and degree of financial openness and compare mean responses across groups. This rich empirical framework allows to control for the heterogeneity among countries due to their cyclical/financial market position via the VAR structure and the use of an exogenous instrument, but also to assess the transmission of US monetary policy conditional on country structural characteristics.

Our findings are as follows. First we document that following a contractionary US monetary policy shock the global economy contracts, in line with the American one.

[2]Our instrument is constructed as the residual of a regression of high-frequency market surprises of Gürkaynak et al. (2005) onto their own lags and Greenbook forecasts and revisions. In doing so we directly control for the informational component of the policy announcements, due to the systematic component of the monetary policy rule. Hence, we define monetary policy shocks as the component of market surprises triggered by policy announcements, unforecastable by past market surprises and orthogonal to the central bank's macroeconomic forecasts.

[3]We employ CrossBorderCapital Ltd indicators on liquidity and financial conditions, covering all of the economies of interest at monthly frequency. The dataset is described in Table B.1 in the appendix.

[4]In doing so, we adopt the SVAR-IV/Proxy VAR approach of Stock and Watson (2012) and Mertens and Ravn (2013).

[5]We efficently incorporate large/medium information sets in our VAR models by employing modern Bayesian techniques (see Banbura et al., 2010), and impose standard statistical Normal Inverse-Wishart priors while selecting optimal hyperparameters with the approach proposed by Giannone et al. (2015).

OECD industrial production, CPI, global real economic activity and commodity price exhibit negative responses, while foreign currencies depreciate. This provides a striking visual image of the role of the Fed as global central banker.

Second and importantly, commodity prices, global risk appetite and global cross-border financial flows all contract. All of them manifest a strong co-movement with US credit spreads and VIX. We interpret this results as causal evidence on the effects of US monetary policy as a driver of the global financial cycle, confirming Rey (2013)'s observations.

Third, following US shocks, a 'mean' advanced economy displays strong negative responses in output and CPI, which move in the same direction as their US counterparts. Importantly, trade balance deteriorates providing a gauge on the relative strength of price and demand effects. The central bank attempts to counteract recessionary pressure by lowering its interest rate, but prices do not revert back for at least 18 months. The US monetary policy shock also moves the long end of a foreign economy's yield curve, while financial conditions deteriorate, and cross-border flows turn negative. We read these results as a strong indication that due to credit-channel effects from the global financial cycle, inflation-targeting central banks in advanced economies are confronted with an important trade-off and tend to fail in their price stabilisation mandates.

Fourth, capital controls may offer better protection to a country's real economy from US monetary policy shocks. Comparing responses of financially open and less-open advanced economies, classified based on the Chinn-Ito Index, strong negative responses of industrial production and CPI become more muted for the latter group. Responses of other variables, including the policy interest rate, are almost identical. A similar phenomenon emerges when we compare mean responses of emerging economies. However, the majority of the sample in the latter group has less-open financial markets.

Finally, we provide some evidence on the relative importance of the channels at play, by exploiting the structure of the estimated VAR models. We study the response of the main variables of interest to US policy shocks, when selectively zeroing out the transmission coefficients on (i) commodity price variables, (ii) trade variables, (iii) exchange rates, and (iv) financial indicators. Our analysis reveals important and differential effects of these channels on CPI and industrial production.

This paper contribute to the literature on the transmission of US monetary policy in two aspects. First, to the best of our knowledge, it is the first to adopt a modern high-frequency identification of US monetary policy, while controlling for signalling effects, and potential endogeneity. Second, it employs a comprehensive monthly dataset of US, global and national macroeconomic variables, including data on liquidity, risk appetite and cross-border flows. The important works of Dedola et al. (2017) and Iacoviello and Navarro (2018) are most closely related to ours. Compared to the first, we use a SVAR-IV approach with only monthly data and a pure high-frequency identification, that does not rely on sign restrictions. Compared to the second, we do not focus only on the GDP responses of foreign economies but on a wider set of indicators, and we do not have to rely on a recursive identification with timing restrictions that can be problematic in analysing financial variables.

The structure of the paper is the following. Section 2 reviews the literature on the international transmission of US monetary policy shock. Section 3 describes the methodology and the data used in our empirical exercises. Section 4 discusses the effects of U.S. monetary policy on the global economy. Section 5 and Section 6 study the transmission of US shocks to a set of advanced and emerging economies respectively, and explore the domestic dilemmas faced by the domestic central banks. Section 7 focusses on the transmission channels and provides counterfactual experiments to disentangle them. Section 8 concludes.

2 Related Literature

A small but influential emprical literature has analysed international spillover effects of the U.S. monetary policy shocks. The early work of Kim (2001) examined the international transmission of US monetary policy shocks for G7 countries, using structural VARs. He found that expansionary US monetary policy shocks drive booms in these advanced economies. The decline of the world interest rate, rather than changes in trade balance, seems to be a major driver behind this mechanism. Canova (2005) estimated the effects of various US macroeconomic shocks on eight Latin American economies, using multiple single-country VARs and sign restrictions to identify US shocks. He found that US monetary policy shocks generate strong fluctuations in Latin America, and floaters and currency boarders exhibit similar output but different inflation and interest rate responses. Using also the SVAR and sign restrictions, Mackowiak (2007) finds that the output and price level in Asian and Latin American emerging markets respond even more than the US ones to monetary policy shocks. di Giovanni and Shambaugh (2008) explored the connection between interest rates in major industrial countries and real output growth in third economies, using a random-coefficients panel OLS model. They found that high interest rates in the former group have a contractionary effect on the real GDP of the latter, with the effect centred on countries with fixed exchange rate regimes.

To account for the rising interdependencies among economies, Canova and Ciccarelli (2009) proposed a panel VAR approach, which is able to cover unit-specific dynamics, lagged interdependencies, and structural time variations. Using this method, Ciccarelli et al. (2012) investigated heterogeneity and spillovers in macro-financial linkages across G7 and European economies, finding that the transmission of shocks tend to be faster and deeper among financial variables than real variables. Bhattarai et al. (2017) estimated the spillover effects of US monetary policy using a monthly panel VAR for 15 emerging economies. They found that following a US monetary tightening, such countries suffer from adverse real and financial effects: their long-term country spread and short-term policy rate rise and the domestic stock prices decline.

Using a medium-scale Bayesian VAR, Miranda-Agrippino and Rey (2015) provide evidence of the interaction between US monetary policy, real activity, and global financial variables (credit spreads, credit flows, bank leverage and global factor in asset prices). Dedola et al. (2017) adopt a BVAR model with sign restrictions replicating the responses to US monetary policy shocks in Gertler and Karadi (2015), and then use a single-country variable regression onto the identified shocks to estimate the impacts. They found that usual characteristics in the Mundell-Fleming framework – i.e., exchange rate regimes, the degree of capital market openness, and the trade intensity – do not explain heterogeneity in countries' responses. Georgiadis (2016) assessed the international spillover from the same shocks using a Global VAR model, finding that countries receiving large spillover effects also experience stronger drops in market expectations of their output growth around the 'taper tantrum'. Iacoviello and Navarro (2018) investigated a large panel of 50 advanced and emerging economies and obtained GDP responses of each country to the US monetary shock using local projection methods. They found that the trade openness with the US and the exchange rate regime explain a large portion of contraction in the real activity of an advanced economy, while the financial vulnerability only matters for the emerging economies.

3 Data and Empirical Methodology

In order to study the effects of US monetary policy shocks to other countries and the global economy, we adopt a SVAR-IV (also known as Proxy-SVAR) approach (see Stock and Watson, 2012 and Mertens and Ravn, 2013). We estimate our models with Bayesian large VARs techniques as in Banbura et al. (2010), and impose standard statistical Normal Inverse-Wishart priors while selecting optimal hyperparameters with the approach proposed by Giannone et al. (2015). In the following, we first describe our dataset and then our instrument for US monetary policy shocks.

3.1 Data

For our empirical analysis, we use two main datasets. The first set, used for the global analysis, consists of 27 variables in total. All variables are collected at a monthly frequency.[6] There are 13 US macroeconomic indicators, including 3 macroeconomic aggregates (industrial production index, CPI, and trade balance), 5 financial indicators (stock price index, nominal effective exchange rate, Gilchrist and Zakrajšek (2012) excess bond premium, 10-year Treasury Bond yield rate, and VIX), and a monetary policy indicator (1-year Treasury constant maturity rate). Additionally, we include 4 liquidity indexes (financial conditions, policy liquidity, risk appetite, and cross-border flows) that are informative of financial market movements.[7]

[6] If the original series are collected at a daily frequency, we take the end-of-month value.

[7] We employ data by CrossBorderCapital Ltd. The financial conditions index represents short-term credit spreads, such as deposit-loan spreads. The policy liquidity index measures both the size of central bank balance sheets as well as significant changes in their composition. Risk appetite is based on the balance sheet exposure of all investors between equity and bonds. Finally, the cross-border flows index captures all financial flows into a currency - including banking and all portfolio flows (bonds and equities).

The dataset also includes 14 global economic indicators: the industrial production and CPI index of OECD countries, CRB commodity price index, the differential between and average short-term interest rate across the 15 advanced economies in our dataset and the US,[8] the world stock price index, the global price of Brent crude oil, the global economic activity index constructed by Hamilton (2019), and 3 major currency exchange rates per USD – i.e. Euro, Japanese Yen, and Pound Sterling. Finally, the dataset includes 4 world-aggregated liquidity indexes from CrossBorderCapital Ltd. In order to include VIX, align the data to the instrument, and facilitate comparison across the bilateral BVARs, our sample starts from January 1990 and ends in June 2017.[9]

The country level dataset, used to examine individual and mean-group responses of 30 economies, consists of 22 variables for each country considered in the analysis.[10] For each country of interest we collect 11 indicators – industrial production, CPI, stock price index, trade balance, nominal exchange rate, short-term interest rate, long-term interest rate, plus 4 liquidity indexes. These variables enter the bilateral VARs along with the 11 US counterparts, and two global controls – i.e. the global price of Brent crude oil and Hamilton (2019)'s global economic activity index.[11] In doing so we try and capture a rich endogenous information set, controlling for the country position in the business cycles, endogenous interactions and the global economic cycle. Again, we set the estimation period from January 1990 to June 2017, in order to minimise the effect of structural change in the global economy and measurement errors in the data collection process, and to align the sample to the instrument.[12]

3.2 Identification of the US Monetary Policy Shock

We adopt the instrument proposed by Miranda-Agrippino and Ricco (2017) to identify US monetary policy shocks.[13] The high-frequency instrument is available from January 1990 to December 2009.

[8]Table B.5 in the appendix reports details on the short-term rates used.

[9]Table B.1 in the Appendix describes sources and availability of data in detail.

[10]A full list of the countries and sample availability for each variable can be found in the Appendix, Table B.3.

[11]Table B.2 in the Appendix contains information about transformations and priors of all the variables discussed above.

[12]Data sources are listed in the Appendix, Table B.4.

[13]Appendix A describes SVAR identified with external instruments in detail.

The instrument is obtained in three steps. First, the high-frequency market-based surprises in the fourth federal funds futures (FF4) around FOMC announcements of Gürkaynak et al. (2005) are projected on Greenbook forecasts and forecast revisions for real output growth, inflation (measured as the GDP deflator) and the unemployment rate. The following regression is run at FOMC meeting frequency:

$$FF4_m = \alpha_0 + \sum_{j=-1}^{3} \theta_j F^{cb}_m x_{q+j} + \sum_{j=-1}^{2} \vartheta_j \left[F^{cb}_m x_{q+j} - F^{cb}_{m-1} x_{q+j} \right] + MPI_m. \quad (1)$$

where $FF4_m$ denotes the high-frequency market-based monetary surprise computed around the FOMC announcement indexed by m. $F^{cb}_m x_{q+j}$ denotes Greenbook forecasts for the vector of variables x at horizon $q+j$ that are assembled prior to each meeting, and $\left[F^{cb}_m x_{q+j} - F^{cb}_{m-1} x_{q+j} \right]$ denotes revisions to forecasts between consecutive FOMC meetings. The forecast horizon is expressed in quarters, and q denotes the current quarter. These forecasts are typically published a week prior to each scheduled FOMC meeting and can be thought of as a proxy of the information set of the FOMC at the time of making the policy decision. For each surprise, the latest available forecast is used.

Second, the monthly instrument $\overline{MPI}_t$ is constructed by summing the daily MPI_m within each month. In the vast majority of cases, there is only a FOMC decision per month, in these cases the monthly surprise simply equals the daily one. Similarly, months without FOMC meetings are assigned a zero.

Finally, the autoregressive component in the monthly surprises is removed. Let $\overline{MPI}_t$ denote the result of the monthly aggregation described in the previous step. Our monthly monetary policy instrument MPI_t is constructed as the residuals of the following regression:

$$\overline{MPI}_t = \phi_0 + \sum_{j=1}^{12} \phi_j \overline{MPI}_{t-j} + MPI_t \, . \quad (2)$$

The intuition for the construction of this instrument is that the Greenbook forecasts (and revisions) directly control for the information set of the central bank, and hence for the macroeconomic information transferred to the agents through the announcement (the signalling channel of monetary policy). The removal of the autoregressive components, instead accounts for the slow absorption of information by the agents – a crucial implication of models of imperfect information (see Coibion and Gorodnichenko, 2015).

3.3 Estimation of Domestic Economy and Mean-Group Responses

Impulse responses for the global system are obtained in a Large Bayesian VAR (see Banbura et al., 2010).[14] In Sections 5 and 6, we adopt a bilateral VAR framework (augmented with two global controls) in order to examine the effects of US monetary policy on a third country. In other words, we estimate the following VAR(12) model for each one of the 30 advanced/emerging economies considered:

$$Y_{it} = c_i + \sum_{j=1}^{p} A_{ij} Y_{i,t-j} + u_{it}, \quad i = 1, ..., 30, \quad p = 12 \tag{3}$$

where the vector of endogenous variables, Y_{it}, consists of the 11 macroeconomic and financial variables of the country of interest, the 11 US counterparts, and the two global controls (described in Section 3.1):

$$Y_{it} = [(y_{i,1t}, ..., y_{i,nt}), (y_{US,1t}, ..., y_{US,nt}), x_{1t}, x_{2t}]', \quad n = 11 \tag{4}$$

Finally, we run the following algorithm to obtain mean-group (i.e. 'mean advanced' and 'mean emerging' economy) responses to the shock:

1. For each Gibbs sampler iteration, stack the impulse responses of all countries in the group and compute the mean across countries at each horizon.

2. Repeat the procedure for each iteration and store all mean values obtained.

3. Sort these values and pick the median and corresponding bands at each horizon.

4. Repeat the above steps for all the variables in the endogenous set.[15]

[14] We lay out the details in Appendix B.

[15] For US counterparts and global controls, we do not average out different bilateral country-pair models. We just stack up all IRFs and pick the median and bands.

Importantly, when studying emerging economies we take the median-group response instead of the mean in order to control for outliers (e.g. episodes of hyperinflation in some countries within the sample period).

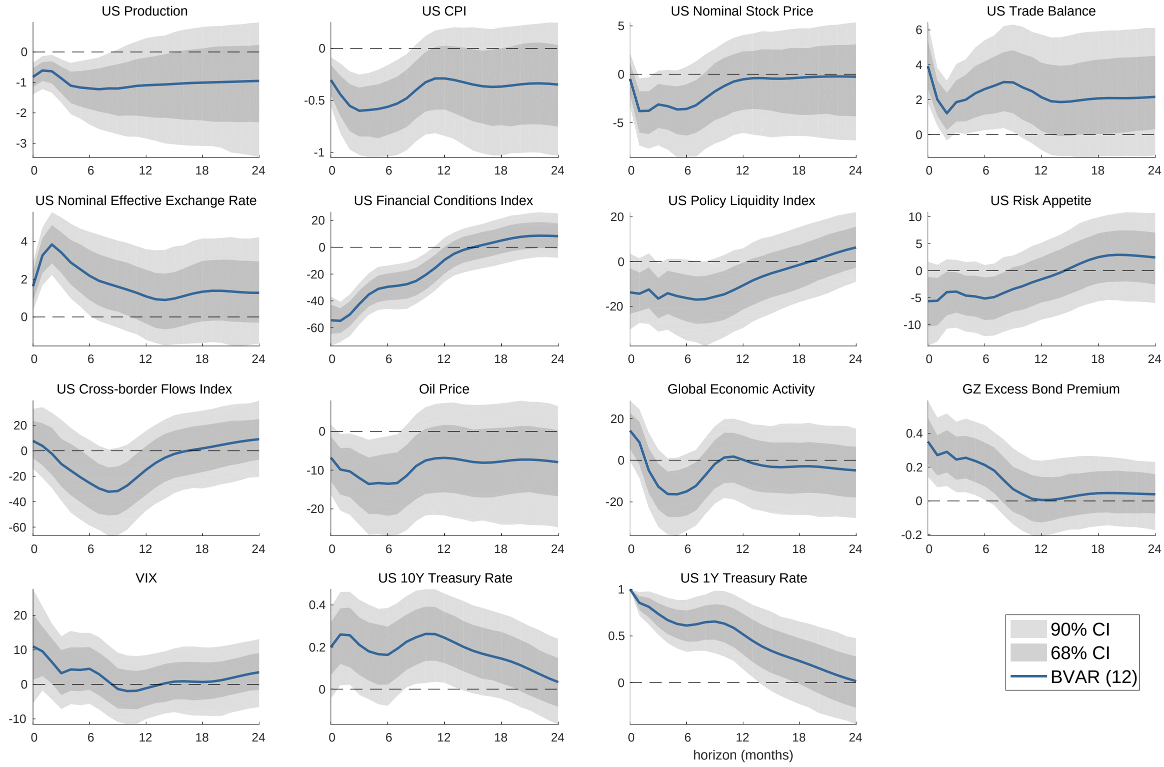
4 Global Effects of U.S. Monetary Policy Shocks

To assess our approach, we start by reporting the responses of US economic variables to the identified monetary policy shocks. Impulse response functions are obtained by estimating a BVAR with 12 lags from January 1990 to June 2017. In each plot, we report median responses, 68% and 90% posterior coverage bands. The US monetary policy shock is normalised to induce a 100bp increase in our policy indicator (1-year Treasury constant maturity rate).

Figure 1 shows that the effects of a tightening of monetary policy are contractionary and close to textbook predictions. Indeed, following an unexpected tightening by the Fed, US industrial production and CPI contract, while the exchange rate hikes. There is also evidence of the credit channel of monetary policy, due to financial frictions: excess bond premium, corporate bond spread, and mortgage spread increase and peak after 6 months. The term spread decreases significantly on impact, and hence the yield curve flattens up to 1 year.

Figure 2 reports the effects of a contractionary US monetary policy shock onto the global economy. The model we estimate is a Large VAR including, in addition to the reported variables, also the US variables in Figure 1. Global aggregates show evidence of strong spillover effects from US monetary policy. OECD industrial production, oil price, global real economic activity, and commodity prices exhibit slightly delayed negative responses. The trough of the response of OECD production is almost 1:1 with the US one – around -1%. The average interest rate differential between 15 advanced economies and the US falls by 0.5 percentage points on impact and stagnates for one year, while the response of the US 1 year treasury rate quickly reverts back to trend after 6 months. This implies that central banks raise the interest rate by 50bp on impact but quickly lower it below trend afterwards, in order to dampen negative spillovers from the US. All major exchange rates depreciate, with the Japanese Yen being hit the most but being

Figure 1: Domestic Effects of U.S. Monetary Policy Shocks



Note: Domestic responses to a contractionary US monetary policy shock, normalised to induce a 100 basis point increase in the 1-year rate. High frequency identification. Sample 1990:01 - 2017:06. BVAR(12) with optimal tightness hyperparameter computed as in Giannone et al. (2015). Shaded areas are 68% and 90% posterior coverage bands.

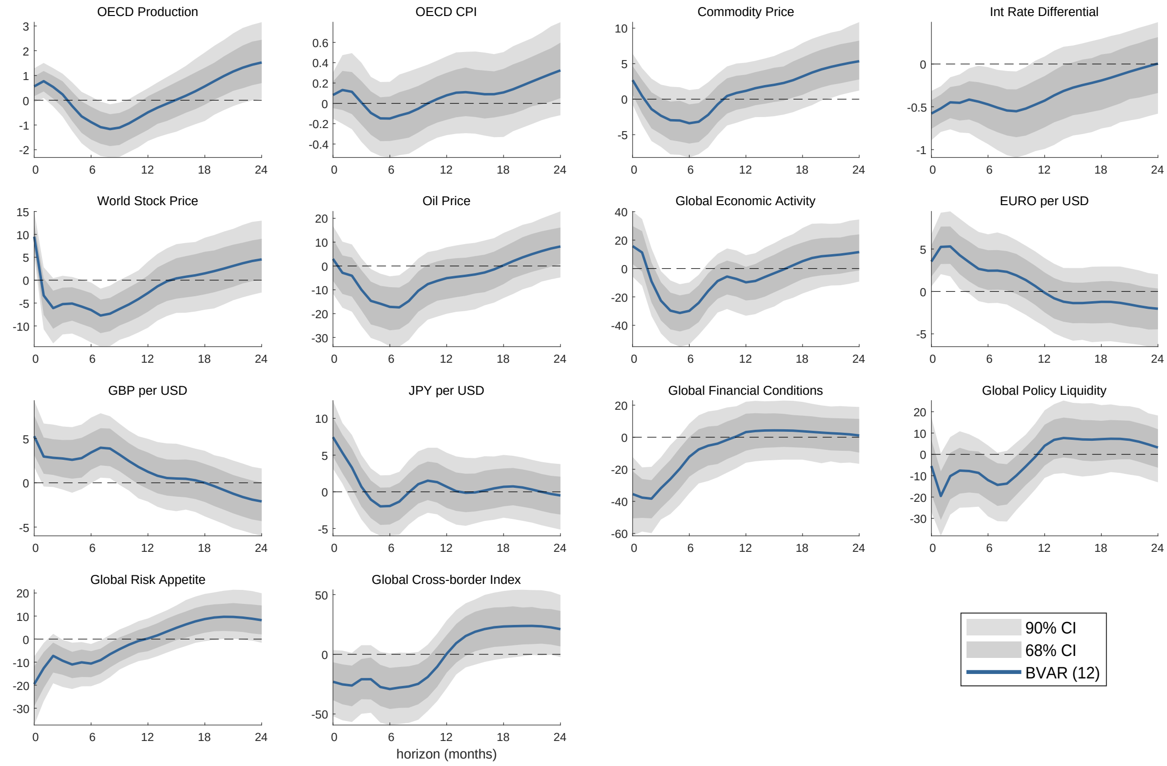
also the fastest one to recover. OECD CPI exhibits a contraction albeit non-significant. All in all, global variables seem to mimic their US counterparts, giving us a sense of the level of integration of the global economy.

Global financial variables – the world stock price,[16] the three exchange rates, oil and commodities prices – all contract. Interestingly, risk appetite in both the US and the rest of the world is reduced while liquidity and cross-border flows dry up. The responses of liquidity indexes also support the global financial cycle argument. Measures of financial conditions, policy liquidity, and risk appetite display identical dynamics both in the US and the global economy. Financial conditions worsens drastically on impact and reverts back after 9-10 months.

Our results are also in line with the 'risk-taking channel' of monetary policy in Bruno and Shin (2015): a contractionary shock shrinks asset demand and thus increases the

[16]Since this index is a weighted average of stock prices in advanced economies excluding North America, the commonality is not a mechanical effect.

Figure 2: The Global Effects of U.S. Monetary Policy Shocks



Note: Global responses to a contractionary US monetary policy shock, normalised to induce a 100 basis point increase in the 1-year rate. High frequency identification. Sample 1990:01 - 2017:06. BVAR(12) with optimal tightness hyperparameter computed as in Giannone et al. (2015). Shaded areas are 68% and 90% posterior coverage bands.

risk premium (raising the value of VIX). It brings down the asset price further and forces financial intermediaries to deleverage even more (reducing the supply of credit) to meet their value-at-risk constraints, leading to a 'vicious cycle'. The results in this section show that this channel not only operates domestically but also globally, following a deepening of trade and financial integration after 1990s. Then if the capital markets are open, the global financial cycle constrains domestic monetary policy and amplifies the spillover effects from the US to the real economy. We further investigate this mechanism in the next three sections.

5 Transmission to Advanced Economies

In this section we focus our attention on advanced economies. After having shown the global recessionary effects of MP shocks generated in the US, we want to study what is the average reaction of an advanced economy to these shocks. In line with our findings on the global economy, we observe a strong contraction of industrial production and CPI that mimics the domestic recessionary dynamics of the US. This suggests that the central banks of advanced economies confront harsh trade-offs in fulfilling their price-stabilisation mandate, when facing MP shocks from the centre country.

We proceed as follows: we estimate a bilateral model including the US and one advanced economy, for all advanced economies in our sample.[17] As before, estimation includes the standard Normal-Inverse-Wishart prior and the structural form is recovered using the IV approach described above. Having obtained IRFs to a MP shock for all bilateral models, we aggregate them as to obtain the 'mean advanced economy' impulse responses.[18]

Figure 3 displays the impulse responses of the mean advanced economy. Following a contractionary MP shock in the US, the currency of the mean advanced economy depreciates. However, this does not translate to higher export, as the demand-reducing effect in the US more than offsets the expenditure-switching effect towards periphery goods. The short-term interest rate drops upon impact and subsequently falls up to 6 months ahead. We interpret this as the attempt at stabilising output of the central bank of the mean advanced economy: further depreciation of the domestic currency pushes export, but also the net worth of borrowers increases via the increase in asset prices.

The liquidity indexes show a strong deterioration in financial conditions and risk appetite (measured as the difference between equity and bond exposure). Policy liquidity, which proxies the size of the central bank balance sheet, grows in line with the monetary policy loosening of the first 6 months. There is a net outflow of liquidity (see cross-border flows index) that is probably exacerbated by the monetary policy loosening in the domestic economy.

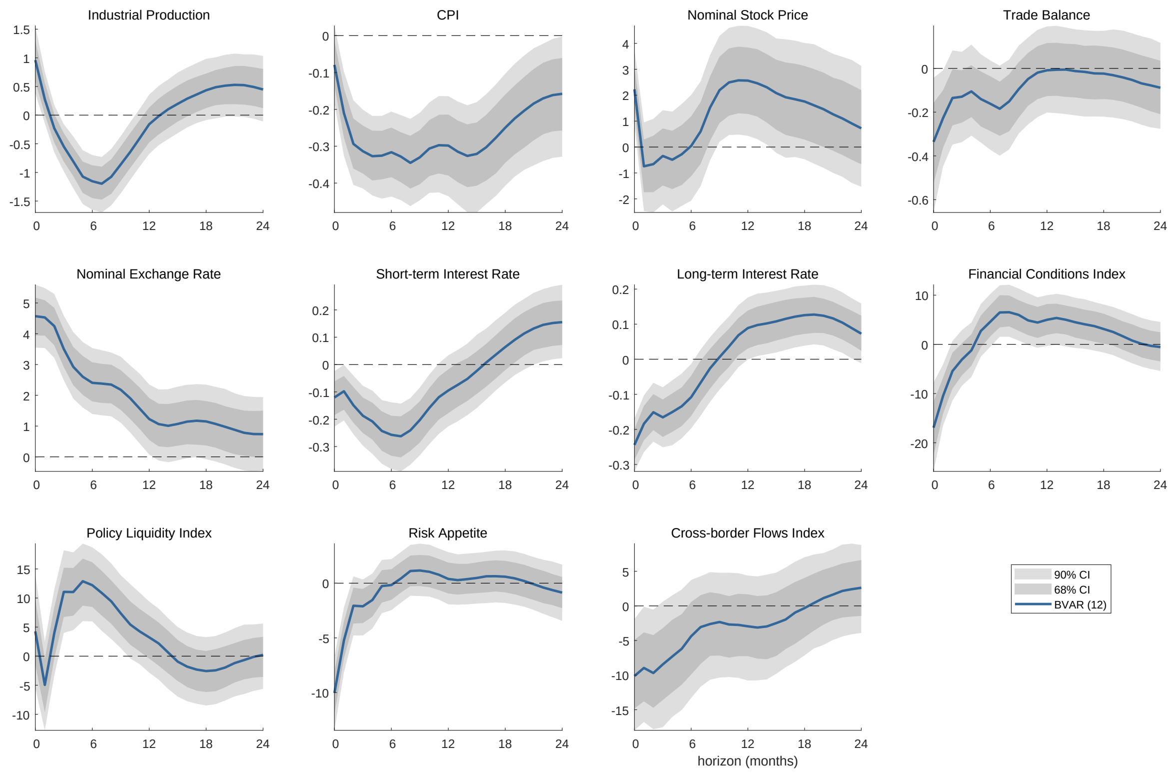
Stabilisation of output is not achieved: there is a sharp decline in domestic industrial production, accompanied by a very persistent drop in CPI. Overall, we conclude that inflation-targeting central banks in advanced economies tend to struggle in fulfilling their price stabilisation mandates when facing a MP shock coming from the US.

A potential issue in our approach lies in the aggregation of responses across econom-

[17] Table B.6 in the Appendix reports the classification of countries that we adopt in our analysis.

[18] The IV used for identification of the MP shock and the methodology used for the aggregation of IRFs into the responses of the mean advanced economy are discussed in Section 3.2.

Figure 3: Impulse response functions of the mean advanced economy



Note: Mean responses of advanced economies to a contractionary US monetary policy shock, normalised to induce a 100 basis point increase in the 1-year rate. High frequency identification. Sample 1990:01 - 2017:06. BVAR(12). Shaded areas are 68% and 90% posterior coverage bands.

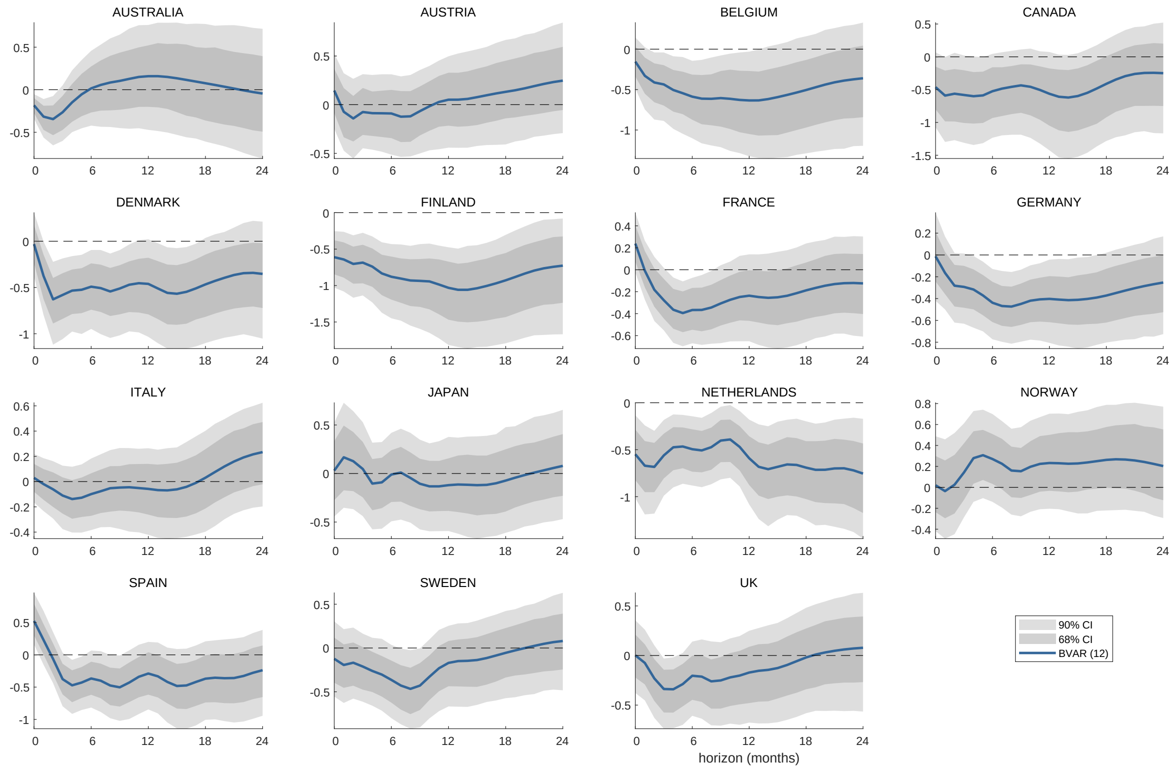
ies: averaging across potentially largely different responses could confound the underlying heterogeneity. Reassuringly, we observe fairly homogeneous responses for almost all advanced economies. Figure 4 shows the response of CPI to a contractionary US MP shock for all advanced economies in our sample.[19] CPI is contracting for 11 out of 15 economies and, of the remaining 4, only Norway displays an expansion.

Responses are more heterogeneous for short-term interest rate and the policy rate. The responses of these variables are displayed in Figure 5 and Figure 6. Across the two variables, responses are qualitatively very similar. This suggests that 3-month treasury bills and interbank rates, which are usually longer than policy rates in our dataset, are a good proxy for policy rates.

Across countries, Eurozone countries display similar dynamics, reacting negatively on impact and slowly moving back to trend. Less surprisingly, nearly all other countries

[19]These are the IRFs that we obtain from the bilateral models. In other words, each country's subplot comes out of a model that includes only the US and the country itself.

FIGURE 4: RESPONSE OF CPI IN ADVANCED ECONOMIES

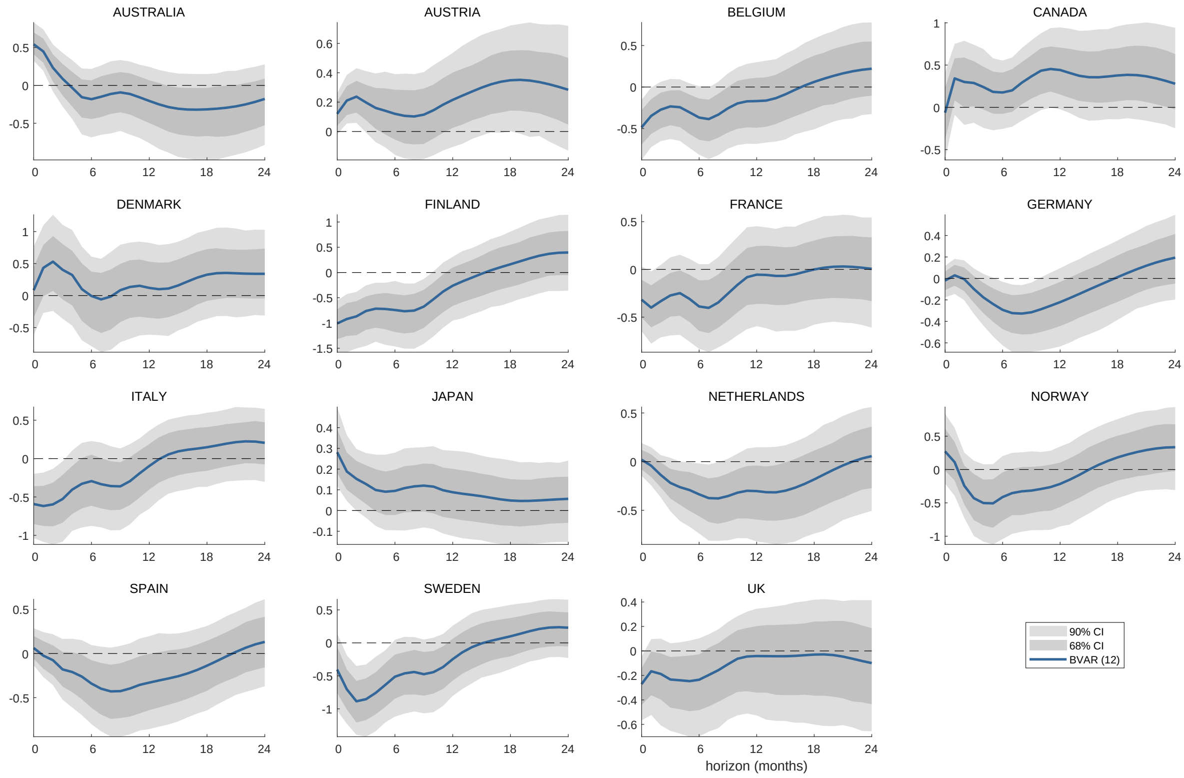


Note: Responses of CPI in 15 advanced economies to a contractionary US monetary policy shock, normalised to induce a 100 basis point increase in the 1-year rate. High frequency identification. Sample 1990:01 - 2017:06. BVAR(12). Shaded areas are 68% and 90% posterior coverage bands.

tend to react positively on impact, with the exception of the UK.[20] The Eurozone response coupled with the delayed negative responses of Sweden and Norway set the shape of the mean advanced country response.

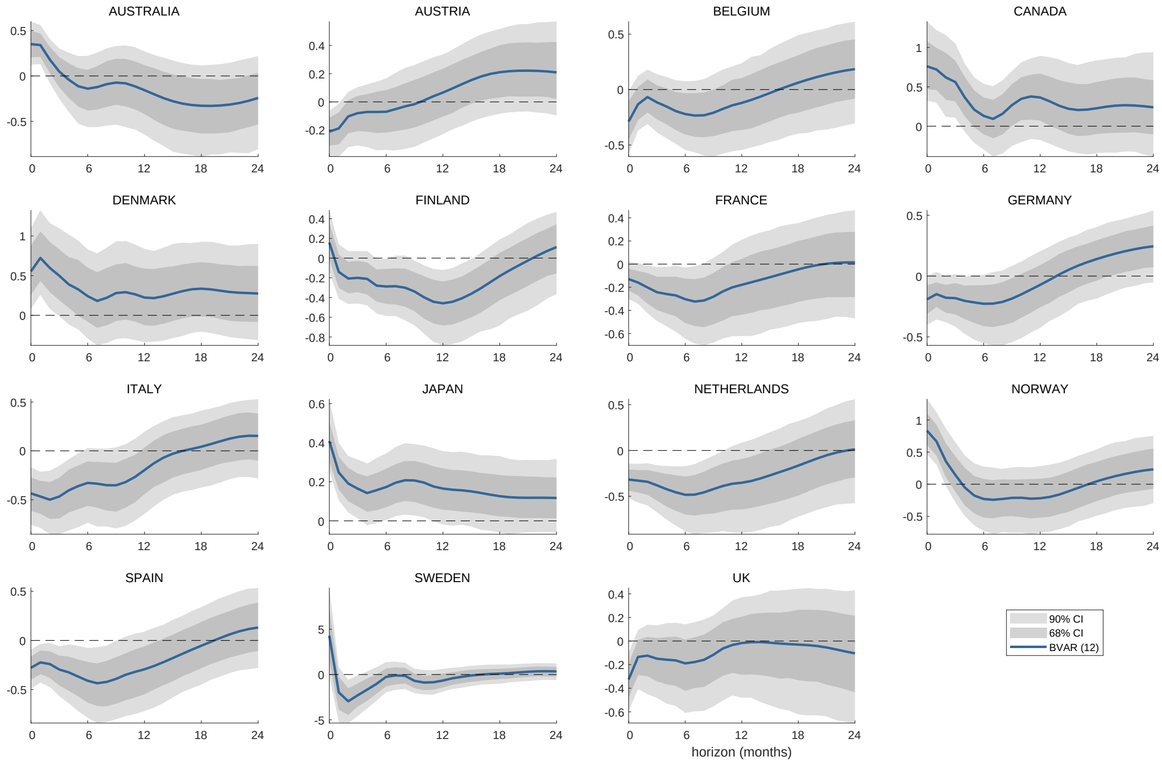
[20]Sweden short-term rate shows a negative impact, but the reaction of the policy rate is positive. The same goes for Denmark and Canada.

Figure 5: Response of Short-term interest rates in Advanced Economies



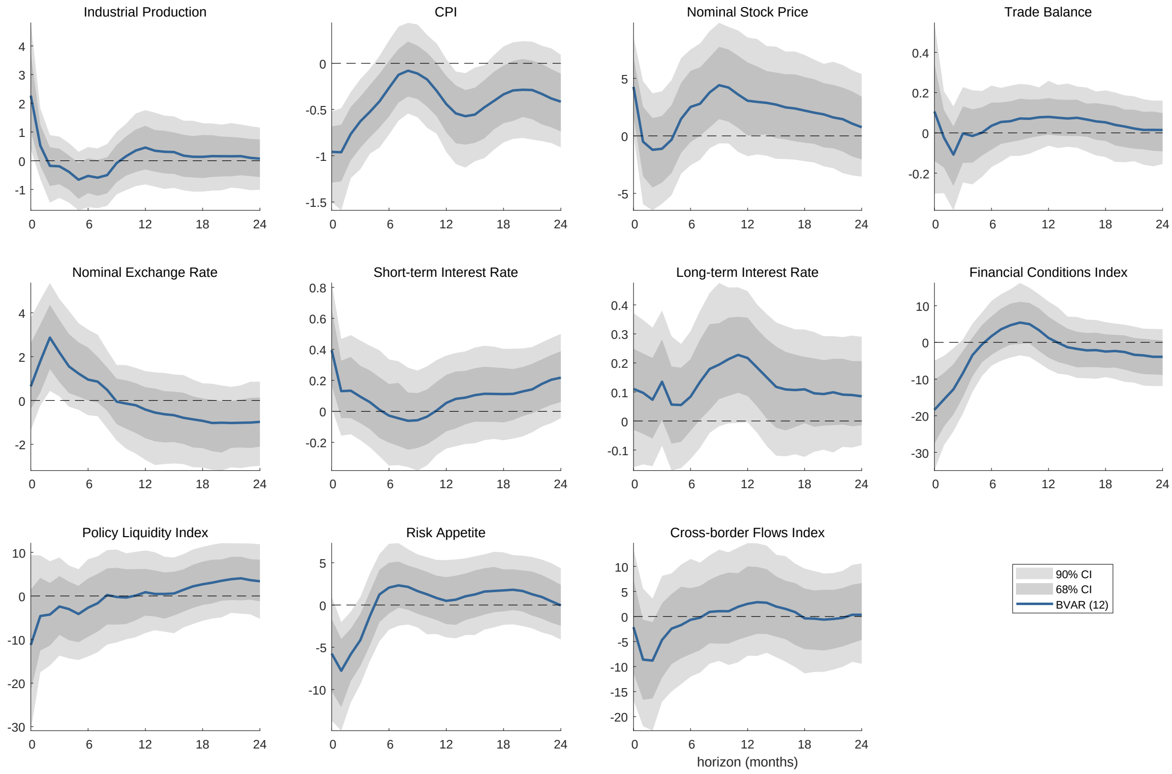
Note: Responses of Short-term interest rates in 15 advanced economies to a contractionary US monetary policy shock, normalised to induce a 100 basis point increase in the 1-year rate. High frequency identification. Sample 1990:01 - 2017:06. BVAR(12). Shaded areas are 68% and 90% posterior coverage bands.

Figure 6: Response of Policy rates in Advanced Economies



Note: Responses of Policy rates in 15 advanced economies to a contractionary US monetary policy shock, normalised to induce a 100 basis point increase in the 1-year rate. High frequency identification. Sample 1990:01 - 2017:06. BVAR(12). Shaded areas are 68% and 90% posterior coverage bands.

Figure 7: Mean Response of Emerging Economies



Note: Median responses of emerging economies to a contractionary US monetary policy shock, normalised to induce a 100 basis point increase in the 1-year rate. High frequency identification. Sample varies from 1990:01 - 2017:06 for longest (Mexico) to 2002:09 - 2017:06 for shortest (Colombia). BVAR(12). Shaded areas are 68% and 90% posterior coverage bands.

6 Transmission to Emerging Economies

6.1 Median response of Emerging Economies

Figure 7 reports the median response of the 15 emerging economies.[21] As in the case of global advanced economies, we find evidences of spillover effects from the US Monetary Policy shock. Output contracts with a delay, prices fall immediately, and the exchange rate depreciates against the dollar. Interestingly, unlike advanced economies, trade balance does not deteriorates – it is indistinguishable from zero at all horizons. Like advanced economies, macroeconomic indicators move in the same direction with the US counterparts. However, spillover effects are more muted in emerging economies peak

[21] We report the median, instead of the mean, response for emerging economies due to the possible presence of strong outliers. Hyperinflation breaks out in Brazil and Turkey during our estimation period. Figures B.3 and B.4 in the Appendix report both mean and median responses for comparison. Discrepancies between the two turn out to be quite small.

responses of output and exchange rates are less than half of the case in figure 3. CPI drops more at impact, but it reverts back to the trend more quickly.[22]

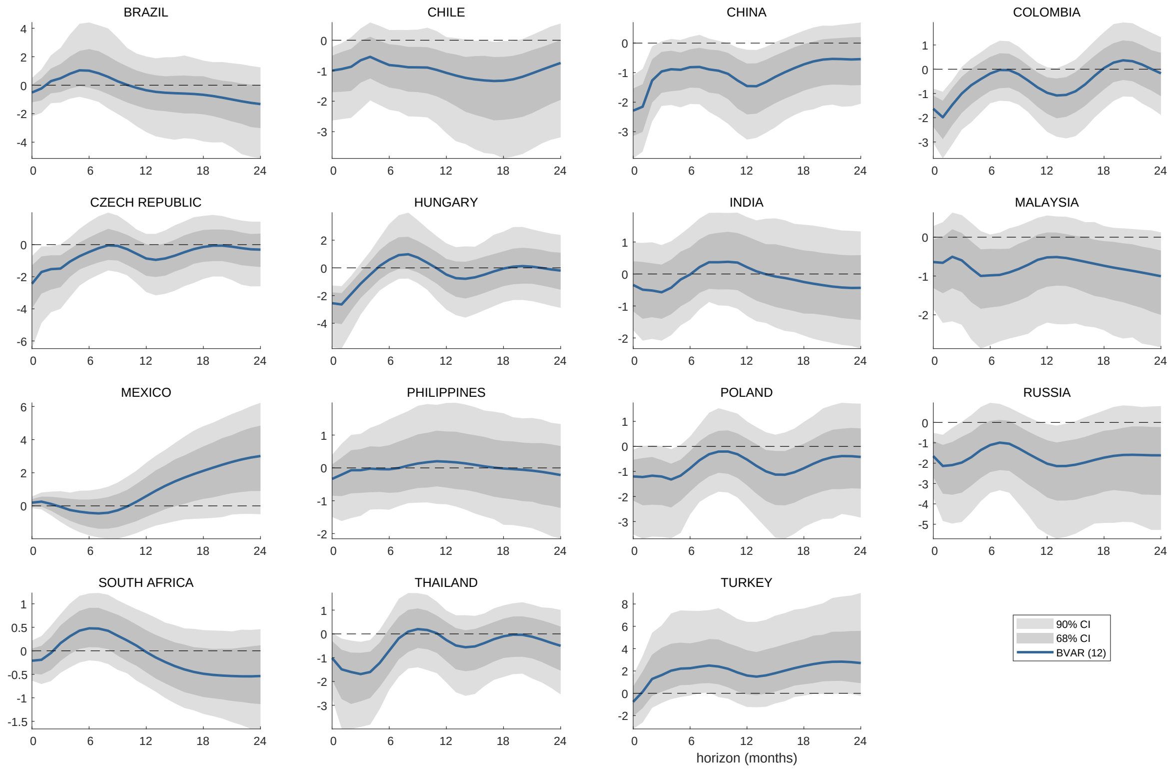
Interestingly, stock prices, exchange rate, financial conditions, and risk appetite strongly co-move in the US, advanced, and emerging economy. Though responses at the impact are weaker in the latter case, dynamics strikingly resemble those of advanced economies. Industrial production and cross-border flows also move in the same fashion in both advanced and emerging countries. We think of such evidence as corroborating the view that global financial cycle triggered by US monetary policy changes plays an important role in creating spillovers. Then muted responses in Figure 7 might be related to the fact that most emerging economies in our analysis have a lesser degree of capital mobility.[23]

In contrast to the advanced economy case, short-term interest rate rises at impact and stays above the trend. Though the impact response is only a half, it closely follows dynamics of US monetary policy indicator. The central bank balance sheet, measured by the policy liquidity index, deteriorates accordingly. Taking account of trade balance and exchange rate responses, one possible reason behind such results is the fact that a majority of emerging economies in the sample are relatively fixed exchange rate regimes. Another explanation might be a pervasive presence of dollar-denominated foreign debts in emerging economies, which constrains central banks' actions in order to avoid adverse balance sheet effects. Last but not the least, we cannot rule out the case that it is just a byproduct of aggregation. Emerging economies in our sample are more heterogenous than advanced ones, where a half of samples belong to a Eurozone. The median may not capture the overall effect well enough in this case – hence we turn to examine responses across countries, as we did in the last section.

[22]Since data on long-term interest rates are only available from the late 1990s for most emerging economies, our analysis may suffer from small sample problems. In the Appendix figure B.6, we repeat the same exercise without the long-term rate in order to extend the sample size. It helps to reduce the sampling uncertainty, but does not change the main conclusions.

[23]The median value of Chinn-Ito index for advanced economies is 0.965, while it is only 0.338 for emerging ones. It roughly indicates that the degree of financial market openness for the former is above top 5% in the world, while the other is only 34%. Table B.6 in the Appendix contains average values of the index for all countries and groups.

Figure 8: Response of CPI in Emerging Economies



Note: Responses of CPI in 15 emerging economies to a contractionary US monetary policy shock, normalised to induce a 100 basis point increase in the 1-year rate. High frequency identification. Sample varies from 1990:01 - 2017:06 for longest (Mexico) to 2002:09 - 2017:06 for shortest (Colombia). BVAR(12). Shaded areas are 68% and 90% posterior coverage bands.

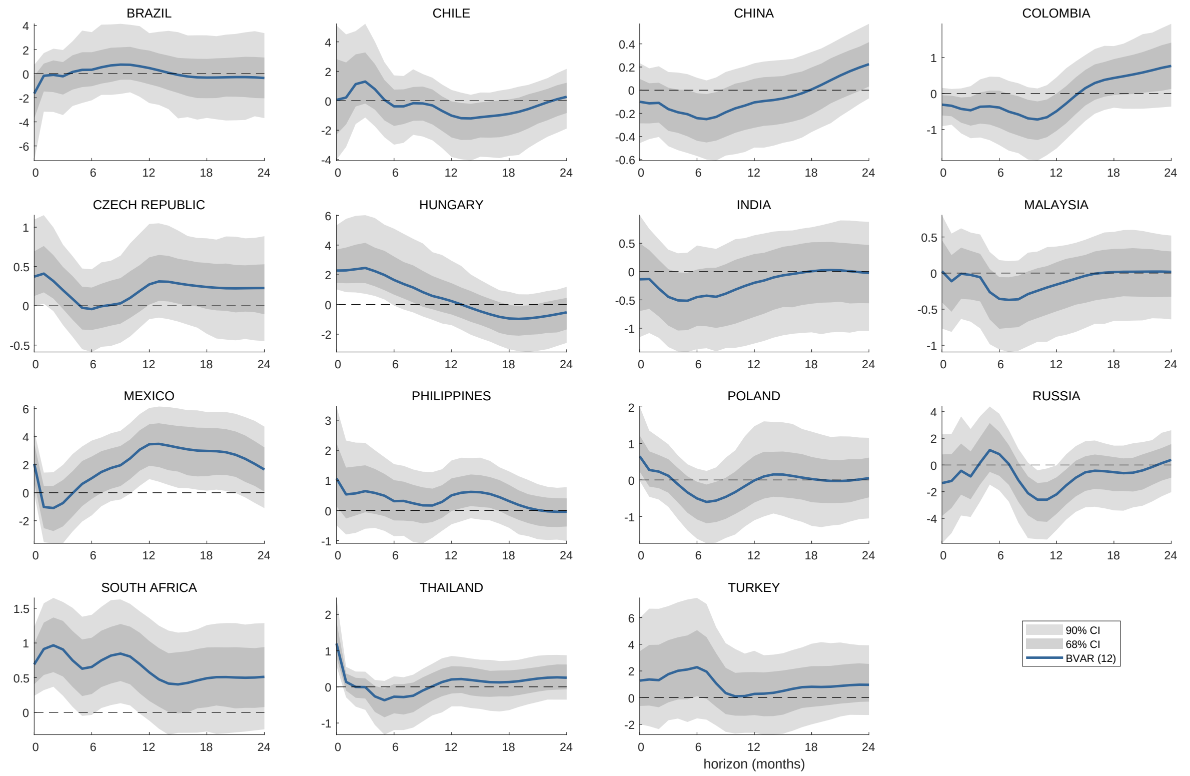
6.2 Domestic Dilemmas on US Monetary Policy Shocks

Figure 8 manifests a stronger heterogeneity in price price responses across emerging economies. Since a majority of samples start after late 1990s, there is clearly more sampling uncertainty.[24] Still, we can roughly divide countries into three groups: Colombia, Czech Republic, Hungary, Poland, and Thailand experience a price fall more than US CPI at impact but quickly recovers within two quarters. China, Malaysia, and Russia undergo a persistent deflation immediately after the shock, resembling responses of advanced economies. Finally, Brazil, Chile, India, Philippines, and South Africa do not seem to react to the US monetary surprise. It is hard to comment about Mexico and turkey, since their responses seem to be driven by hyperinflation in the 1990s.

Unlike advanced economies, responses of short-term rates in emerging countries tend

[24]Table B.3 in the Appendix reports a full list of the countries and sample availability for each variable.

Figure 9: Response of Short-term interest rates in Emerging Economies



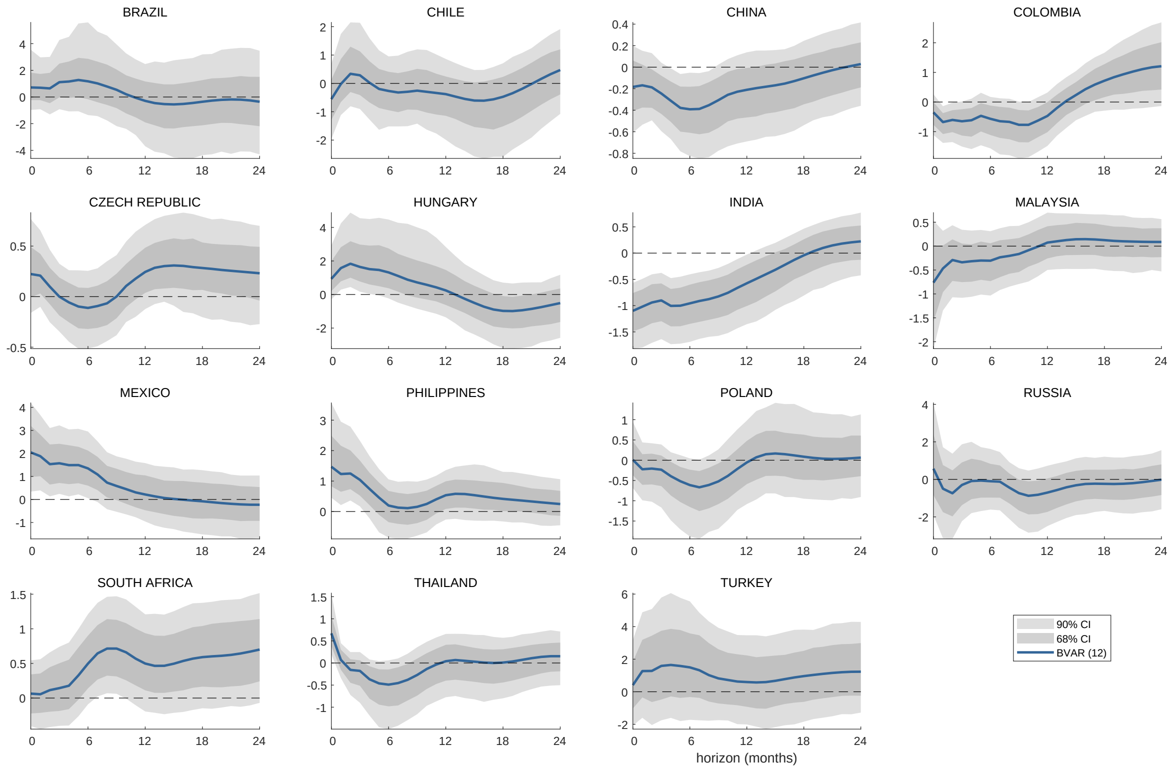
Note: Responses of Short-term interest rates in 15 emerging economies to a contractionary US monetary policy shock, normalised to induce a 100 basis point increase in the 1-year rate. High frequency identification. Sample varies from 1990:01 - 2017:06 for longest (Mexico) to 2002:09 - 2017:06 for shortest (Colombia). BVAR(12). Shaded areas are 68% and 90% posterior coverage bands.

to increase more in line with the US monetary policy tightening. Figure 9 shows that the majority, including those experience a price fall at the impact, raises short-term rates. The peak response of Eastern European countries and Thailand is comparable with the size of the US shock. China and Malaysia are similar to advanced economies not only in the price response but also the short-term rate: central banks attempts to counteract the economic downturn, but they fail to satisfy stabilisation mandates.

To further investigate the choice of policymakers, we replace the short-term rate with policy rate and obtain responses in figure 10.[25] Responses of policy rates are mostly in line with short-term rates, except for Mexico and South Africa. Two channels may lead to a country's monetary dependence from the US. First, the 'fear of floating': concerned about large capital outflows after the hike in US interest rate, central banks try to reduce the differential. Second, due to increase in the funding cost of global

[25]The median response of emerging countries for all variables with the policy rate in the system is available in Figure B.5 in the Appendix.

Figure 10: Response of Policy rates in Emerging Economies



Note: Responses of Policy rates in 15 emerging economies to a contractionary US monetary policy shock, normalised to induce a 100 basis point increase in the 1-year rate. High frequency identification. Sample varies from 1990:01 - 2017:06 for longest (Mexico) to 2002:09 - 2017:06 for shortest (Colombia). BVAR(12). Shaded areas are 68% and 90% posterior coverage bands.

banks, the international credit channel may exacerbate domestic financial conditions and borrower's balance sheet. Here we find that both channels are present. Results are also consistent with Rey (2016) 's claim that a short-term rate is not always the best measure of policy autonomy: a few discrepancies among CPI, short-term and policy rate responses in both advanced and emerging suggests an amplification effect from the international credit channel.

6.3 Effectiveness of Capital Controls

We conclude this section by testing effectiveness of capital controls. In Figure 11, we report median responses of financially more and less open emerging economies respectively, based on the Chinn-Ito index.[26] We classify the following 5 countries into a more

[26] To classify countries, we first calculate averages of the Chinn-Ito index (ka_open) , which ranges from 0 to 1. The higher the number is, the more open the financial market is) from 1990-2015 for each economy. Then, we consider countries in the top tercile as more financially open markets, and the

open financial market: Chile, Czech Republic, Hungary, Malaysia, and Mexico. A relatively less open market consists of Brazil, China, Colombia, India, and South Africa. More than a trifold gap in the degree of financial market openness between the two groups allows us to explore the role of capital controls. [27]

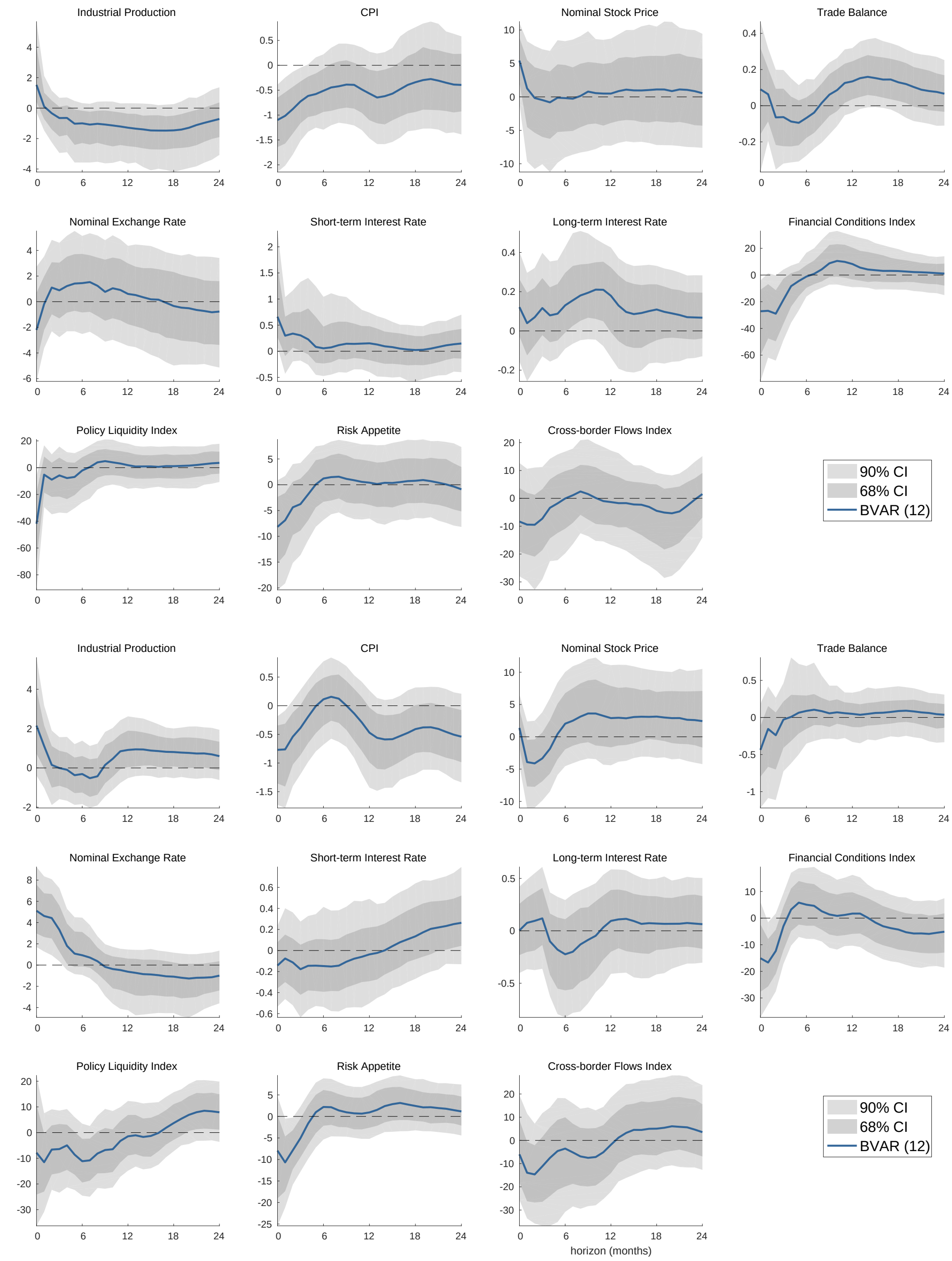
Figure 11 shows that spillover effects from the US is relatively stronger in the former group. Responses of output and CPI is more negative and persistent if the financial market is more globally engaged. Exchange rate does not react much in a more open economy but depreciates in a less open case, in line with the movement of short-term interest rate: the former tends to increase short-term rates after a US monetary shock. Such an action from 'fear of floating' results in less capital outflows compared to the latter. However, the international credit channel causes a quite persistent credit crunch, slowing down recovery in financial conditions compared to a more restricted capital mobility.

To conclude, results corroborate the view that financial market openness is an important channel of global financial cycle, policy dependence and the spillover effect from the US monetary policy in both advanced and emerging economies. There are some caveats to this conclusion, however: the sampling uncertainty is quite large for emerging economies due to a short sample size, and heterogeneity within groups is still sizeable enough to cause potentially aggregation issues.

bottom tercile as less open ones. Median responses are robust even if we classify countries by above and below the median values.

[27]The average value of Chinn-Ito index across 5 relatively more open countries (Chile, Czech Republic, Hungary, Malaysia, and Mexico) is 0.632, while it is only 0.203 for less open ones (Brazil, China, Colombia, India, and South Africa). Table B.6 in the Appendix contains more information about the classification.

Figure 11: Emerging Economies with more v. less open Financial Market



Note: Median responses of 5 emerging economies with more open financial market (top panel) and less open financial market (bottom panel) to a contractionary US monetary policy shock. The former group consists of Chile, Czech Republic, Hungary, Malaysia, and Mexico. The latter group includes Brazil, China, Colombia, India, and South Africa. Shock is normalised to induce a 100 basis point increase in the 1-year rate. High-frequency identification. BVAR (12). Shaded areas are 68% and 90% posterior coverage bands.

7 Disentangling the Channels

In order to quantify the importance of the various channels that at play in the international propagation of U.S. MP shocks, we perform a counterfactual exercise as for example in Ramey (1993) and Uribe and Yue (2006). In particular we would like to try to answer the following question – how would the response of a variable of interest, as for example CPI or industrial production in a third country, differ if the U.S. monetary policy did not have a direct effect on trade, exchange rates, liquidity, or commodity prices? This is equivalent to a thought experiment in which some of the transmission channels are closed. To answer this question, we use the coefficients estimated in the models presented in the previous sections, but set to zero all coefficients of the equation for the variable one wants to constrain, including its impact response.

To make this exercise as clear as possible, we adopt the same baseline model used in Section 5 for the mean advanced economy and in Section 6 for the mean emerging economy. We shut down sequentially the following variables: trade balance, nominal exchange rate and oil price. This is going to reveal the importance of the trade channel, the exchange rate channel and the price of oil in the transmission of the shock. Finally, we will shut down simultaneously three liquidity indices: the financial conditions index, risk appetite and the cross-border flows index. We will leave the policy liquidity index open as it is informative about the reaction of the monetary authority rather than movements in private capital.

7.1 Channels in advanced economies

Figure 12 displays the median responses (without bands) for our set of experiments on the mean advanced economy. The baseline specification is represented by the solid red line; the solid black line assumes that net trade does not react to the shock nor endogenously; dashed black line assumes the nominal exchange rate does not react; the dash-dotted black line assumes that the spot price of Brent does not react; finally, the dotted black line assumes financial conditions, risk appetite and cross-border flows do not react.

The IRFs show that the response of industrial production for the domestic economy is not qualitatively different, relative to the baseline, when we shut down any of the transmission channels. This suggests that no channel is predominant in explaining the transmission of U.S. policy shocks to the output of the mean advanced country. However, we observe that the drop in domestic industrial production is more muted when nominal exchange rate, oil price or the liquidity channel are shut down.

Conversely, domestic CPI and short-term rates display different dynamics when oil price, liquidity or trade balance are shut down. Both domestic CPI and the short-term rate pick up much quicker relative to the benchmark when oil or liquidity are shut. Conversely, the shock is more persistent if trade balance is closed. Moreover, stock price rebounds much more if trade balance is shut, consistently with the short-term rate falling further. Also depreciation is more persistent without trade balance. Interestingly, policy liquidity is more muted when oil price is shut.

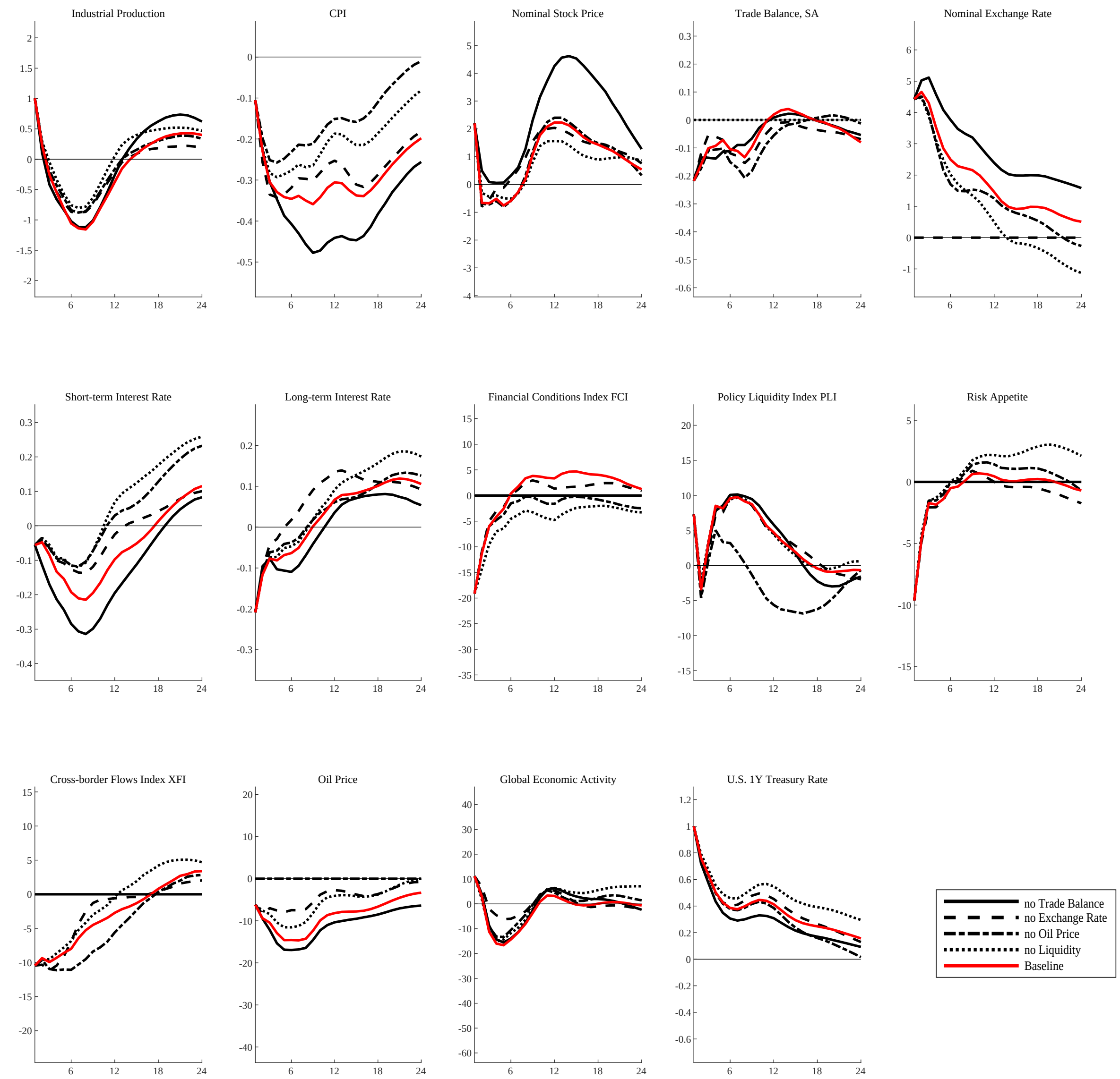
7.2 Channels in emerging economies

We repeat the same exercise for the median emerging economy.[28] Figure 13 shows the median responses (without bands). Again, the baseline specification is represented by the solid red line; the solid black line assumes that net trade does not react to the shock nor endogenously; dashed black line assumes the nominal exchange rate does not react; the dash-dotted black line assumes that the spot price of Brent does not react; finally, the dotted black line assumes financial conditions, risk appetite and cross-border flows do not react.

Interestingly, the response of the median emerging economy is very similar to that of the mean advanced economy. As for the mean advanced economy, industrial production does not change relative to the baseline. CPI and short-term rates maybe display a smaller volatility across experiments, but both CPI and the interest rate are sensitive to shutting down trade balance, which makes more persistent the negative effect of the shock. Even though the effect of the shock on trade balance is quite limited, it seems that CPI recover more quickly when export is allowed to rise; at the same time there is no need to lower the interest rate that much to stimulate the economy. The real effect

[28] As discussed in Section 6, we use a different aggregation method for emerging economies to avoid problems with outliers.

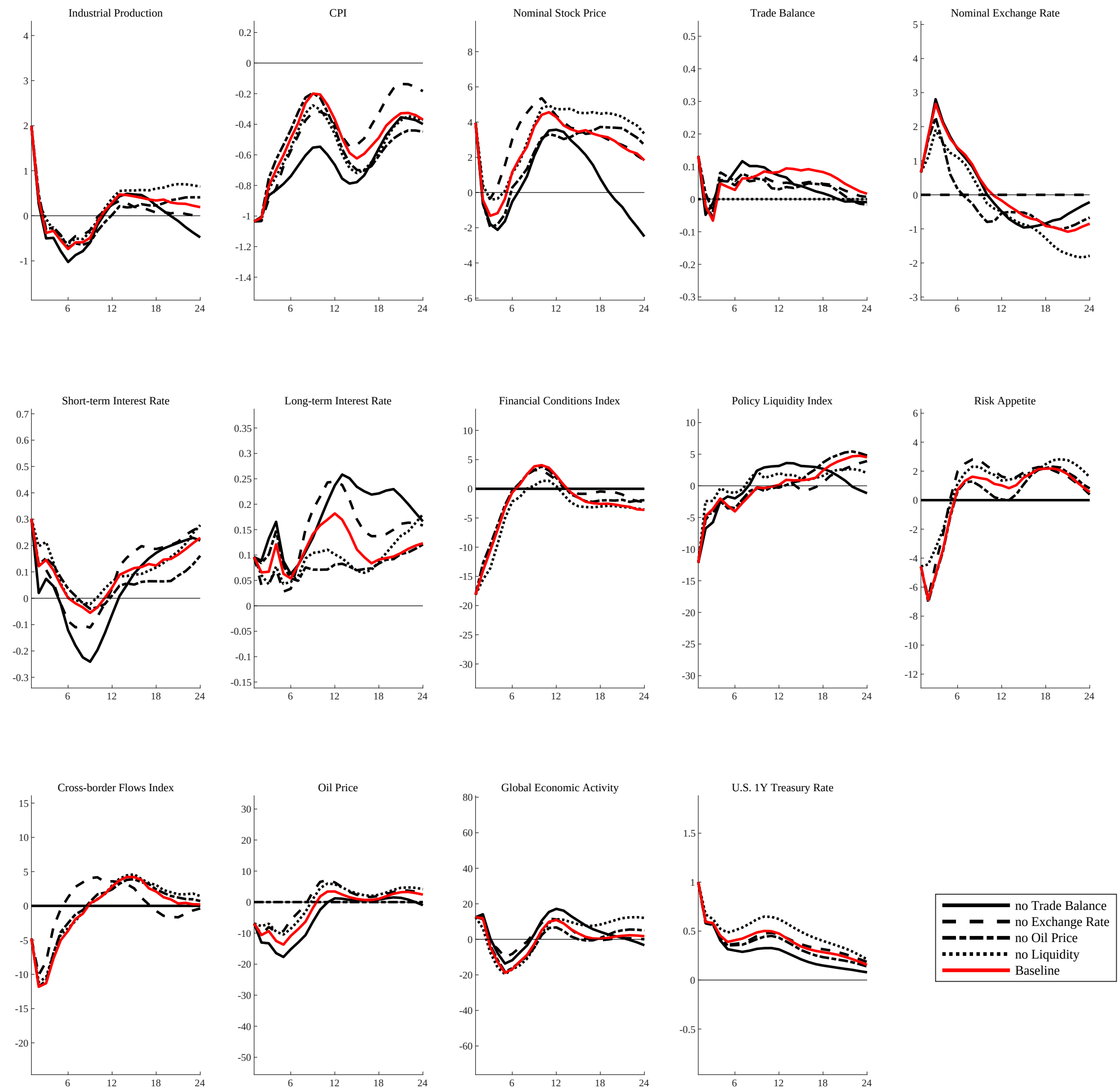
Figure 12: Transmission Channels in Advanced Economies



Note: IRFs of the endogenous variables of the mean advanced economy (see Table B.6 for the list of countries in the advanced group), the global economic activity index and the price of Brent to a contractionary U.S. monetary policy shock. Shock is normalised to induce a 100 basis point increase in the 1-year rate. High-frequency identification. Sample 1990:01 - 2018:08. BVAR(12). Lines correspond to the median IRF obtained with the baseline specification (solid red); assuming net trade does not react to the shock nor endogenously (solid black); assuming the nominal exchange rate does not react (dashed black); assuming that the spot price of Brent does not react (dash-dotted black); finally, assuming financial conditions, risk appetite and cross-border flows do not react (dotted black).

on industrial production, however, is very small.

Figure 13: Transmission Channels in Emerging Economies



Note: IRFs of the endogenous variables of the median emerging economy (see Table B.6 for the list of countries in the emerging group), the global economic activity index and the price of Brent to a contractionary U.S. monetary policy shock. Shock is normalised to induce a 100 basis point increase in the 1-year rate. High-frequency identification. Sample 1990:01 - 2018:08. BVAR(12). Lines correspond to the median IRF obtained with the baseline specification (solid red); assuming net trade does not react to the shock nor endogenously (solid black); assuming the nominal exchange rate does not react (dashed black); assuming that the spot price of Brent does not react (dash-dotted black); finally, assuming financial conditions, risk appetite and cross-border flows do not react (dotted black).

8 Conclusion

In the paper we provided evidence on how US monetary policy is transmitted to the global economy by using large VAR techniques and high frequency identification of policy shocks. We employed a comprehensive set of global indicators to explore the effects of US monetary policy on the global economy as an aggregate. We also used national macroeconomic and financial variables covering a large sample of advanced and emerging economies to estimate the mean- and median-group spillovers for advanced and emerging economies. We find that a US monetary tightening induces symmetric macro and financial contractionary responses in the US and across the globe. This testifies the role of the dollar as a global currency. We also show that the spillovers of US monetary policy affect both advanced economies and emerging markets, irrespectively of their monetary policy regime. We document a differential effect of US monetary policy for emerging economies that are less financially open relative to more open ones, pointing at the role of capital controls in shielding economies from global financial fluctuations. As a last exercise, we investigate some of the channels through which the effects propagate and find a differential role for trade, exchange rates liquidity flow, and commodity prices.

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A SVAR with External Instruments

In this paper, we use the SVAR with External Instruments (Stock and Watson, 2012; Mertens and Ravn, 2013) as the main identification strategy for the US Monetary Policy shock. The key advantage of this scheme is relaxed timing restrictions. The standard SVAR identification requires a particular ordering among macroeconomic indicators; the identifying assumption is that 1) slow-moving variables such as output and price indices (GDP and CPI) react to monetary surprises after one quarter at least, and 2) the Central Bank only considers past observations of fast-moving variables when the policy decisions take place. However, such a timing restriction is difficult to be justified when financial variables are also included in the conditioning set.

Let Y_t a set of n endogenous variables that constitute the economic system of a country, i.e.
$Y_t = [y_{1t}, ..., y_{Nt}]'$. In this analysis, y_{1t} corresponds to the US monetary policy variable, i.e. the one-year Treasury constant maturity rate (GS1), hence the same for every economy.[29]. Then consider the following reduced-form VAR(p):

$$Y_t = c + A_1 Y_{t-1} + ... + A_p Y_{t-p} + u_t \tag{A.1}$$

where C is a n×1 vector of variable-specific intercepts, A_i , i = 1...p, is the n×n matrix which collects the autoregressive coefficients, and u_t is a n×1 vector of innovations ('error terms') from N(0, Σ) where the variance $\Sigma = \text{E}(u_t u_t')$.

The Structural VAR representation of the system (1) is:

$$B_0^{-1} Y_t = c + B_1 Y_{t-1} + ... + B_p Y_{t-p} + e_t \tag{A.2}$$

where $A_i = B_0 B_i$, i = 1...p, and the reduced-form VAR innovations are:

$$u_t = B_0 e_t \tag{A.3}$$

Here the problem is that the matrix B_0 cannot be identified: there are n^2 free parameters in B_0, the covariance matrix of reduced-form innovations $\Sigma = \text{E}(u_t u_t') = B_0 B_0'$ only let us impose n(n+1)/2 restrictions. Hence, we need additional restrictions to identify elements in

[29] Here the interest rate is only ordered first to ease explanation. Moreover, the ordering of variables is irrelevant in the proxy SVAR scheme.

B_0.

To deal with this issue, Stock and Watson introduces an instrumental (proxy) variable z_t and assumes that is correlated only with the structural shocks of interest but not with all other shocks in the system. In other words, the identification is achieved under the following key conditions:

$$E(z_t e'_{1,t}) = k \quad E(z_t e'_{2,t}) = 0 \tag{A.4}$$

where e_t is now partitioned as $e_t = [e_{1,t}, \, e_{2,t}]'$, $e_{1,t}$ collecting the shocks of interest and $e_{2,t}$ all the remainders. Now suppose $e_{1,t}$ only includes the US Monetary Policy shock, and the instrument z_t satisfies the conditions (4). Let $S_{xy} = E(x_t y'_t)$ and partition the matrix B_0 such that:

$$B_0 = \begin{bmatrix} b_{11} & b_{12} \\ b_{21} & b_{22} \end{bmatrix}$$

from conditions (3) and (4), we derive the following:

$$b_{21} b_{11}^{-1} = S_{zu'_1}^{-1} S_{zu'_2} \tag{A.5}$$

Here $S_{zu'_1}^{-1} S_{zu'_2}$ corresponds to the Two-stage Least Squares estimator obtained by regressing $u_{1,t}$ on z_t in the first stage and then $u_{2,t}$ on the fitted $u_{1,t}$ in the second stage. The equation above implies that we can estimate the ratio $b_{21} b_{11}^{-1}$ by using only information contained in the instrument z_t and reduced-form innovations u_t. When there is only one number of structural shocks to be identified, the restrictions imposed in the Proxy SVAR lead closed-form solution for the identification of elements of interest in the matrix B_0, i.e. b_{11}:

$$\begin{gathered} b_{11} = [Q_{11} - (Q_{21} - b_{21} b_{11}^{-1} Q'_{11})' G^{-1} (Q_{21} - b_{21} b_{11}^{-1} Q_{11})]^{1/2}] \\ G \equiv b_{21} b_{11}^{-1} Q_{11} (b_{21} b_{11}^{-1})' - (Q_{21} (b_{21} b_{11}^{-1})' + b_{21} b_{11}^{-1} Q'_{21}) + Q_{22} \end{gathered}$$

where $Q_{i,j}$, j=1,2 denotes partitions of $\Sigma = \mathrm{E}(u_t u'_t)$, the covariance matrix of reduced-form VAR innovations.

B Large BVARs

Let the model be:

$$\mathbf{Y}_t = \mathbf{C} + \sum_{l=1}^{p} A_l \mathbf{Y}_{t-l} + \mathbf{e}_t \tag{B.1}$$

The Minnesota prior shrinks the coefficients of this model towards the following random walk representation:

$$\mathbf{Y}_t = \mathbf{C} + \mathbf{Y}_{t-1} + \mathbf{e}_t$$

In other words, it is imposing the belief that coefficients on more recent lags provide more reliable information than those on further lags, and that own lags explain more variation of a given variable than cross variable lags. The Minnesota prior is implemented by imposing for the prior distribution of the coefficients the following mean:

$$\mathbb{E}\left(A_{ij}^{l}\right) = \begin{cases} 1, & j = i,\, l = 1 \\ 0, & \text{otherwise} \end{cases}$$

and a covariance matrix, $\mathbb{V}\left(A_{ij}^{l}\right)$, whose elements are defined as follows:

$$\sigma_{a_{ii}}^2 = \left(\frac{\lambda_1}{l^{\lambda_3}}\right)^2 \quad \text{own lag coefficients}$$
$$\sigma_{a_{ij}}^2 = \left(\frac{\sigma_i^2}{\sigma_j^2}\right)\left(\frac{\lambda_1 \lambda_2}{l^{\lambda_3}}\right)^2 \quad \text{cross variable coefficients}$$

where $l = 1, \ldots, p$ indicates the lag and $i, j = 1, \ldots, n$ identifies the element of A^l. The coefficient on the constant term is diffuse and given by:

$$\sigma_{c_i}^2 = \sigma_i^2 \left(\lambda_1 \lambda_4\right)^2 \quad \text{slope coefficient}$$

σ_i^2 and σ_j^2 are scaling coefficients adjusting the variance of each coefficient by its relative size. They usually correspond to the standard deviations obtained by the estimation of univariate AR(p) models for each of the n variables. For what concerns the other parameters of the prior variance:

1. λ_4 is a very large parameter expressing the idea that little is known about the constant term, so that variance is high for its coefficient.

2. λ_3 is a scaling parameter indicating how confident we are that the coefficients converge

to zero as we increase the lags.

3. λ_2 controls the importance of the lags of other variables relative to own lags.

4. λ_1 is the overall tightness parameter. It controls the importance of the prior belief relative to the information contained in the data. $\lambda_1 = 0$ implies that the posterior is equal to the prior. As λ_1 grows, the prior becomes more and more uninformative, and in the limit the posterior corresponds to the OLS estimates.[30]

Litterman's original formulation of the Minnesota prior assumes the covariance matrix of the residuals to be diagonal. To allow for correlation among the residuals of different variables, Kadiyala, Karlsson (1997) propose a Normal Inverse Wishart (NIW) prior. Model (B.1) can be easily rewritten in seemingly unrelated regression (SUR) form:

$$\mathbf{Y} = \mathbf{X}B + \mathbf{e} \tag{B.2}$$

where,

$$\mathbf{Y} = \underset{T\times n}{\begin{bmatrix} \mathbf{Y}_1' \\ \mathbf{Y}_2' \\ \vdots \\ \mathbf{Y}_T' \end{bmatrix}}, \quad \mathbf{X} = \underset{T\times(np+1)}{\begin{bmatrix} \mathbf{Y}_0' & \cdots & \mathbf{Y}_{1-p}' & 1 \\ \mathbf{Y}_1' & \cdots & \mathbf{Y}_{2-p} & 1 \\ \vdots & \ddots & \vdots & \vdots \\ \mathbf{Y}_{T-1}' & \cdots & \mathbf{Y}_{T-p}' & 1 \end{bmatrix}}, \quad B = \underset{(np+1)\times n}{\begin{bmatrix} A_1' \\ \vdots \\ A_p' \\ C' \end{bmatrix}}, \quad \mathbf{e} = \underset{T\times n}{\begin{bmatrix} \epsilon_1' \\ \epsilon_2' \\ \vdots \\ \epsilon_T' \end{bmatrix}}$$

The Normal Inverse Wishart prior has then the form:

$$vec\,(B)\,|\Psi \sim N\,(vec\,(B_0)\,, \Psi \otimes \Omega_0) \qquad \text{with} \;\; \Psi \sim IW\,(S_0, \alpha_0)$$

where the prior parameters B_0, Ω_0, S_0 and α_0 are chosen so that the moments of the prior distribution of the coefficients coincide with $\mathbb{E}\left(A_{ij}^l\right)$ and $\mathbb{V}\left(A_{ij}^l\right)$ given above, and the expectation of Ψ coincides with the residual covariance matrix of the Minnesota prior.

The prior beliefs can be integrated into the posterior distribution of the model parameters by adding T_d 'dummy observations' $\mathbf{Y}_d$ and $\mathbf{X}_d$ to the system in (B.2). This is equivalent to

[30] Giannone et al. (2015) provide a method to optimally choose the informativeness of the tightness parameter λ_1. Their approach consists in treating this parameter as an additional coefficient of the model that we want to estimate, as it is done in hierarchical modelling.

imposing the NIW prior with the following prior parameters:

$$
\begin{aligned}
B_0 &= \left(\mathbf{X}_d'\mathbf{X}_d\right)^{-1}\mathbf{X}_d'\mathbf{Y}_d \\
\Omega_0 &= \left(\mathbf{X}_d'\mathbf{X}_d\right)^{-1} \\
S_0 &= \left(\mathbf{Y}_d - \mathbf{X}_d'B_0\right)'\left(\mathbf{Y}_d - \mathbf{X}_d'B_0\right) \\
\alpha_0 &= T_d - k
\end{aligned}
$$

In order for these prior parameters to match the required prior moments, the dummy observations have to be constructed as follows:

$$
\mathbf{Y}_d = \begin{bmatrix} \operatorname{diag}\left(\sigma_1,\ldots,\sigma_n\right)/\lambda_1 \\ \mathbf{0}_{n(p-1)\times n} \\ \operatorname{diag}\left(\sigma_1,\ldots,\sigma_n\right) \\ \mathbf{0}_{1\times n} \end{bmatrix} \qquad \mathbf{X}_d = \begin{bmatrix} J_p \otimes \operatorname{diag}\left(\sigma_1,\ldots,\sigma_n\right)/\lambda_1 & \mathbf{0}_{np\times 1} \\ \mathbf{0}_{n\times np} & \mathbf{0}_{n\times 1} \\ \mathbf{0}_{1\times np} & \left(1/\lambda_1\lambda_4\right) \end{bmatrix}
$$

where $J_p = \operatorname{diag}\left(1^{\lambda_3}, 2^{\lambda_3},\ldots,p^{\lambda_3}\right)$. Setting the prior for Ψ to be an improper prior of the form $\Psi \sim |\Psi|^{-(n+3)/2}$, the posterior distribution of the model coefficients has the form:

$$
vec\left(B\right)|\Psi,\mathbf{Y} \sim N\left(vec\left(\bar{B}\right), \Psi \otimes \left(\mathbf{X}_*'\mathbf{X}_*\right)^{-1}\right) \qquad \text{with } \; \Psi|\mathbf{Y} \sim IW\left(\bar{\Sigma}, T_d + 2 + T - k\right)
$$

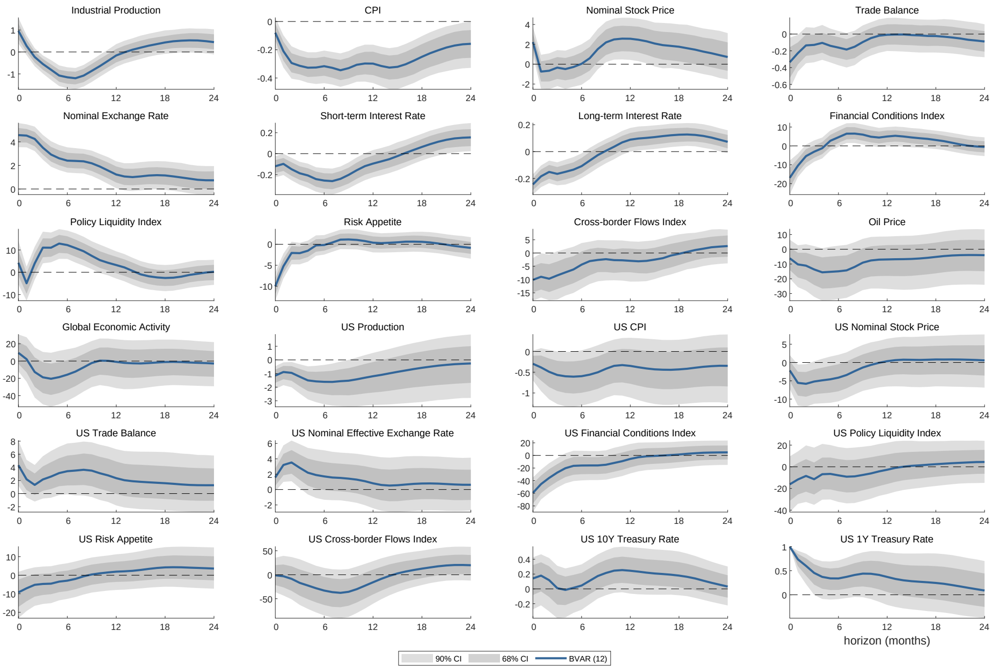
where:

$$
\begin{aligned}
\bar{B} &= \left(\mathbf{X}_*'\mathbf{X}_*\right)^{-1}\mathbf{X}_*'\mathbf{Y}_* \\
\bar{\Sigma} &= \left(\mathbf{Y}_* - \mathbf{X}_*'\bar{B}\right)'\left(\mathbf{Y}_* - \mathbf{X}_*'\bar{B}\right) \\
\mathbf{X}_* &= \left(\mathbf{X}', \mathbf{X}_d'\right) \\
\mathbf{Y}_* &= \left(\mathbf{Y}', \mathbf{Y}_d'\right)'
\end{aligned}
$$

The posterior mean of the coefficients can therefore be obtained by simple OLS regression of $\mathbf{Y}_*$ on $\mathbf{X}_*$.

The dummy observation implementation allows for the introduction of additional types of prior that can be included on top of the NIW prior. In large models where variables that typically present unit roots are introduced in levels, it is quite likely to draw from the posterior distribution coefficients that are explosive for at least one equation. The co-persistence (or single-unit-root) prior and the sum-of-coefficients (or no-cointegration) prior force the model to be stationary by favoring unit-root draws rather than explosive draws from the posterior.

Figure B.1: Mean Response of 15 Advanced Economies



Note: Median responses of advanced economies to a contractionary US monetary policy shock, normalised to induce a 100 basis point increase in the 1-year rate. Identification achieved through informationally-robust high frequency instrument. Sample 1990:01 - 2017:06. BVAR(12). Numbers in the y-axis in each plot is in percentage points, except the trade balance. Shaded areas are 68% and 90% posterior coverage bands.

Table B.1: Global variables

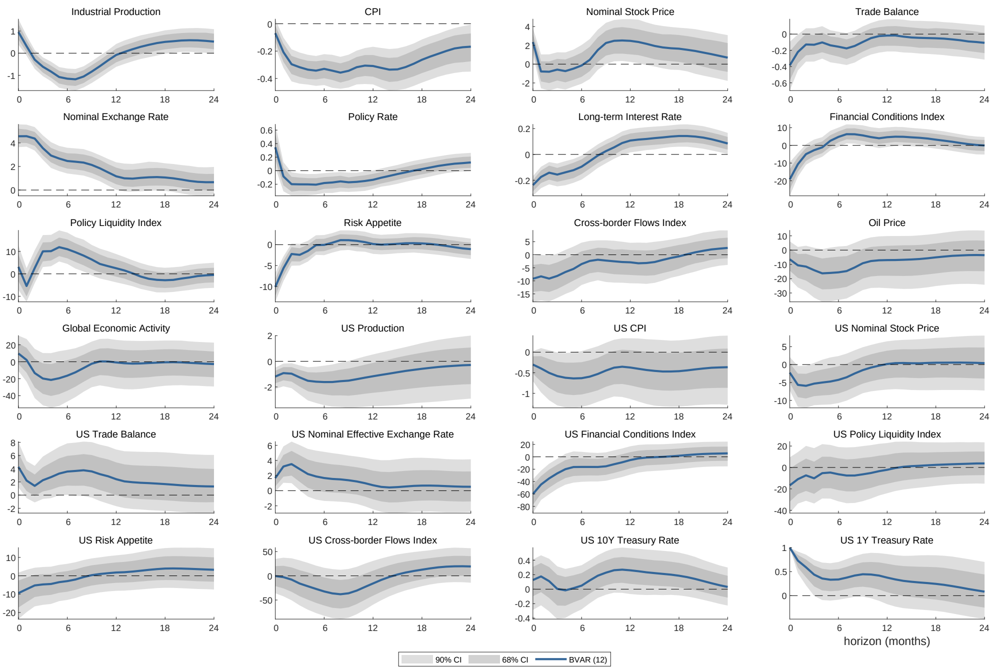
Variable Name	Description	Source	Code	Start date	End date	Logs	RW
OECD Production	Industrial production index of OECD countries	DATASTREAM	OCOPRI35G	1990m1	2017m6	•	•
OECD CPI	Consumer price index of OECD countries	DATASTREAM	OCOCP009F	1990m1	2017m6	•	•
Commodity Price	CRB commodity price index	DATASTREAM	T80440 U$	1990m1	2017m6	•	•
Interest Rate Differential	Average of 15 advanced economies to U.S. short term interest rate differential	IMF, OECD, FRED	1990m1	2017m6			
World Stock Price	World stock price index (excluding North America)	DATASTREAM	TOTMKEF U$	1990m1	2017m6	•	•
Oil Price	Crude Oil Dated Brent U$/BBL, End of Month	DATASTREAM	S219FD U$	1990m1	2017m6	•	•
Global Economic Activity	Kilian (2018) Global Economic Activity Index	Lutz Kilian		1990m1	2017m6		
Euro per USD	US Dollar Exchange Rate,monthly average	BIS		1990m1	2017m6	•	
GBP per USD	Exchange Rates, National Currency Per U.S. Dollar, End of Period	IMF		1990m1	2017m6	•	
JPY per USD	Exchange Rates, National Currency Per U.S. Dollar, End of Period	IMF		1990m1	2017m6	•	
Global Financial Conditions Index		CrossBorder Capital, Ltd.	GLOCBCFCI	1990m1	2017m6		
Global Policy Liquidity Index		CrossBorder Capital, Ltd.	GLOCBCPLI	1990m1	2017m6		
Global Risk Appetite		CrossBorder Capital, Ltd.	GLOCBCRA	1990m1	2017m6		
Global Cross-border Flows Index		CrossBorder Capital, Ltd.	GLOCBCXFI	1990m1	2017m6		
US Production	Production of total industry, SA, 2015=100	OECD MEI		1990m1	2017m6	•	•
US CPI	CPI: 01-12-All items, 2015=100	OECD		1990m1	2017m6	•	•
US Unemployment	U.S. unemployment rate	FRED	UNRATE	1990m1	2017m6		
US Stock Price	Share prices, 2015=100	OECD MEI		1990m1	2017m6	•	•
US Nominal Effective Exchange Rate	BIS Nominal Effective Exchange Rate, narrow basket	BIS		1990m1	2017m6	•	
GZ Excess Bond Premium	Gilchrist and Zakrajek excess bond premium	FRED		1990m1	2017m6		
GZ Spread	Gilchrist and Zakrajek spread	FRED		1990m1	2017m6		
VIX	Chicago Board Options Exchange, CBOE volatility index	FRED	VIXCLS	1990m1	2017m6	•	
US Financial Conditions Index		CrossBorder Capital, Ltd.	CBCFCI	1990m1	2017m6		
US Policy Liquidity Index		CrossBorder Capital, Ltd.	CBCPLI	1990m1	2017m6		
US Risk Appetite		CrossBorder Capital, Ltd.	CBCRA	1990m1	2017m6		
US Cross-border Flows Index		CrossBorder Capital, Ltd.	CBCXFI	1990m1	2017m6		
US Trade Balance	Net Trade, Billion USD, SA	OECD		1990m1	2017m6		
US Term Spread 10Y-1Y	10-Year minus 1-Year Treasury Constant Maturity Rate, Percent, End of Month, NSA	FRED	DGS10	1990m1	2017m6		
US Mortgage Spread	U.S. 30-Year Fixed Rate Mortgage Average minus U.S. 10Y bond rate, NSA	FRED	MORTGAGE30US	1990m1	2017m6		
US Home Price	Case-Shiller US Home Price Index	DATASTREAM	USCSHP.ME	1990m1	2017m6	•	•
US Consumer Sentiment	University of Michigan Consumer Sentiment Index	FRED	UMCSENT	1990m1	2017m6		•
1Y Treasury Rate	U.S. One-year treasury constant maturity rate, End of Month	FRED	DGS1	1990m1	2017m6		

Notes: The table lists all variables included in the analysis of the reaction of the global economy to monetary policy shocks originating in the USA. *Log* indicates logarithmic transformation of a variable. *RW Prior* means that a Random Walk prior is assigned for the variable. The monetary policy variable used is the U.S. one-year treasury constant maturity rate.

Table B.2: Transformations

Variable	Description	Logs	RW
Industrial Production	Domestic industrial production index	1	1
CPI	Domestic consumer price index	1	1
Stock Price	Index of financial market prices, Equities	1	1
Trade Balance	Domestic net exports in goods ($ Billion)	0	1
Nominal Exchange Rate	National Currency Per US Dollar, End of Period	1	0
Short-term Interest Rate	Domestic 3-month interest rate	0	0
Long-term Interest Rate	Domestic 10-year government bond yields	0	0
Financial Conditions Index	Measure of short-term credit spreads, e.g. deposit-loan spreads	1	0
US Policy Liquidity Index	Measure of the size of central bank balance sheet	1	0
US Risk Appetite	Measure based on the balance sheet exposure of all investors	0	0
US Cross-border Flows Index	Measure of all financial flows into a currency	1	0

Figure B.2: Mean Response of 15 Advanced Economies with Policy Rate



Note: Median responses of advanced economies to a contractionary US monetary policy shock, normalised to induce a 100 basis point increase in the 1-year rate. Identification achieved through informationally-robust high frequency instrument. Sample 1990:01 - 2017:06. BVAR(12). Numbers in the y-axis in each plot is in percentage points, except the trade balance. Shaded areas are 68% and 90% posterior coverage bands.

Table B.3: Data coverage

	Industrial Production	CPI	Stock Price	Trade Balance	Exchange Rate	Short-term Rate	Policy Rate	Long-term Rate
AUSTRALIA	Jan 1990 - Jun 2017	Jan 1990 - Jun 2017	Jan 1990 - Jun 2017	Jan 1990 - Jun 2017	Jan 1990 - Jun 2017	Jan 1990 - Jun 2017	Jan 1990 - Jun 2017	Jan 1990 - Jun 2017
AUSTRIA	Jan 1990 - Jun 2017	Jan 1990 - Jun 2017	Jan 1990 - Jun 2017	Jan 1990 - Jun 2017	Jan 1990 - Jun 2017	Jan 1990 - Jun 2017	Jan 1990 - Jun 2017	Jan 1990 - Jun 2017
BELGIUM	Jan 1990 - Jun 2017	Jan 1990 - Jun 2017	Jan 1990 - Jun 2017	Jan 1990 - Jun 2017	Jan 1990 - Jun 2017	Jan 1990 - Jun 2017	Jan 1990 - Jun 2017	Jan 1990 - Jun 2017
BRAZIL	Jan 1990 - Jun 2017	Jan 1990 - Jun 2017	Jan 1990 - Jun 2017	Jan 1990 - Jun 2017	Jan 1990 - Jun 2017	Jan 1990 - Jun 2017	Jan 1990 - Jun 2017	Dec 1999 - Jun 2017
CANADA	Jan 1990 - Jun 2017	Jan 1990 - Jun 2017	Jan 1990 - Jun 2017	Jan 1990 - Jun 2017	Jan 1990 - Jun 2017	Jan 1990 - Jun 2017	Jan 1990 - Jun 2017	Jan 1990 - Jun 2017
CHILE	Jan 1991 - Jun 2017	Jan 1990 - Jun 2017	Jan 1990 - Jun 2017	Jan 1990 - Jun 2017	Jan 1990 - Jun 2017	Jan 1990 - Jun 2017	May 1995 - Jun 2017	Aug 1994 - Nov 2013
CHINA	Jan 1990 - Jun 2017	Jan 1990 - Jun 2017	Dec 1990 - Apr 2017	Jan 1992 - Jun 2017	Jan 1990 - Jun 2017	Jan 1990 - Jun 2017	Mar 1990 - Jun 2017	Jan 1990 - Jun 2017
COLOMBIA	Jan 1990 - Jun 2017	Jan 1990 - Jun 2017	Jan 1991 - Jun 2017	Jan 1991 - Jun 2017	Jan 1990 - Jun 2017	Jan 1990 - Jun 2017	Apr 1995 - Jun 2017	Sep 2002 - Jun 2017
CZECH REP.	Jan 1990 - Jun 2017	Jan 1991 - Jun 2017	Jan 1994 - Jun 2017	Jan 1991 - Jun 2017	Jan 1990 - Jun 2017	Jan 1993 - Jun 2017	Dec 1995 - Jun 2017	Apr 2000 - Jun 2017
DENMARK	Jan 1990 - Jun 2017	Jan 1990 - Jun 2017	Jan 1990 - Jun 2017	Jan 1990 - Jun 2017	Jan 1990 - Jun 2017	Jan 1990 - Jun 2017	Jan 1990 - Jun 2017	Jan 1990 - Jun 2017
FINLAND	Jan 1990 - Jun 2017	Jan 1990 - Jun 2017	Jan 1990 - Jun 2017	Jan 1990 - Jun 2017	Jan 1990 - Jun 2017	Jan 1990 - Jun 2017	Jan 1990 - Jun 2017	Jan 1990 - Jun 2017
FRANCE	Jan 1990 - Jun 2017	Jan 1990 - Jun 2017	Jan 1990 - Jun 2017	Jan 1990 - Jun 2017	Jan 1990 - Jun 2017	Jan 1990 - Jun 2017	Jan 1990 - Jun 2017	Jan 1990 - Jun 2017
GERMANY	Jan 1990 - Jun 2017	Jan 1990 - Jun 2017	Jan 1990 - Jun 2017	Jan 1990 - Jun 2017	Jan 1990 - Jun 2017	Jan 1990 - Jun 2017	Jan 1990 - Jun 2017	Jan 1990 - Jun 2017
HUNGARY	Jan 1990 - Jun 2017	Jan 1990 - Jun 2017	Jan 1991 - Jun 2017	Jan 1991 - Jun 2017	Jan 1990 - Jun 2017	Jan 1990 - Jun 2017	Jan 1990 - Jun 2017	Feb 1999 - Jun 2017
INDIA	Jan 1990 - Jun 2017	Jan 1990 - Jun 2017	Jan 1990 - Apr 2017	Jan 1990 - Jun 2017	Jan 1990 - Jun 2017	Jan 1993 - Jun 2017	Jan 1990 - Jun 2017	May 1994 - Jun 2017
ITALY	Jan 1990 - Jun 2017	Jan 1990 - Jun 2017	Jan 1990 - Jun 2017	Jan 1990 - Jun 2017	Jan 1990 - Jun 2017	Jan 1990 - Jun 2017	Jan 1990 - Jun 2017	Jan 1990 - Jun 2017
JAPAN	Jan 1990 - Jun 2017	Jan 1990 - Jun 2017	Jan 1990 - Jun 2017	Jan 1990 - Jun 2017	Jan 1990 - Jun 2017	Jan 1990 - Jun 2017	Jan 1990 - Jun 2017	Jan 1990 - Jun 2017
MALAYSIA	Jan 1990 - Jun 2017	Jan 1990 - Jun 2017	Jan 1990 - Jun 2017	Jan 1990 - Jun 2017	Jan 1990 - Jun 2017	Jan 1990 - Sep 2015	Nov 1995 - Jun 2017	Jan 1996 - Jun 2017
MEXICO	Jan 1990 - Jun 2017	Jan 1990 - Jun 2017	Jan 1990 - Jun 2017	Jan 1990 - Jun 2017	Jan 1990 - Jun 2017	Jan 1990 - Jun 2017	Nov 1998 - Jun 2017	Jan 1990 - Jun 2017
NETHERLANDS	Jan 1990 - Jun 2017	Jan 1990 - Jun 2017	Jan 1990 - Jun 2017	Jan 1990 - Jun 2017	Jan 1990 - Jun 2017	Jan 1990 - Jun 2017	Jan 1990 - Jun 2017	Jan 1990 - Jun 2017
NORWAY	Jan 1990 - Jun 2017	Jan 1990 - Jun 2017	Jan 1990 - Jun 2017	Jan 1990 - Jun 2017	Jan 1990 - Jun 2017	Jan 1990 - Jun 2017	Jan 1990 - Jun 2017	Jan 1990 - Jun 2017
PHILIPPINES	Jan 1996 - Jun 2017	Jan 1990 - Jun 2017	Jan 1990 - Jun 2017	Jan 1990 - Jun 2017	Jan 1990 - Jun 2017	Jan 1990 - Jun 2017	Mar 1992 - Jun 2017	Feb 1999 - Jun 2017
POLAND	Jan 1990 - Jun 2017	Jan 1990 - Jun 2017	May 1991 - Jun 2017	Jan 1991 - Jun 2017	Jan 1990 - Jun 2017	Jun 1991 - Jun 2017	Jan 1993 - Jun 2017	Jan 2001 - Jun 2017
RUSSIA	Jan 1993 - Jun 2017	Jan 1992 - Jun 2017	Sep 1997 - Jun 2017	Jan 1991 - Jun 2017	May 1992 - Jun 2017	Jan 1997 - Jun 2017	Jan 1992 - Jun 2017	Jan 1999 - Jun 2017
SOUTH AFRICA	Jan 1990 - May 2017	Jan 1990 - Jun 2017	Jan 1990 - Jun 2017	Jan 1990 - Jun 2017	Jan 1990 - Jun 2017	Jan 1990 - Jun 2017	Jan 1990 - Jun 2017	Jan 1990 - Jun 2017
SPAIN	Jan 1990 - Jun 2017	Jan 1990 - Jun 2017	Jan 1990 - Jun 2017	Jan 1990 - Jun 2017	Jan 1990 - Jun 2017	Jan 1990 - Jun 2017	Jan 1990 - Jun 2017	Jan 1990 - Jun 2017
SWEDEN	Jan 1990 - Jun 2017	Jan 1990 - Jun 2017	Jan 1990 - Jun 2017	Jan 1990 - Jun 2017	Jan 1990 - Jun 2017	Jan 1990 - Jun 2017	Jan 1990 - Jun 2017	Jan 1990 - Jun 2017
THAILAND	Jan 1999 - Jun 2017	Jan 1990 - Jun 2017	Jan 1997 - Jun 2017	Jan 1990 - Jun 2017	Jan 1990 - Jun 2017	Jan 1992 - Jun 2017	Jan 1994 - Jun 2017	Jan 1990 - Jun 2017
TURKEY	Jan 1990 - Jun 2017	Jan 1990 - Jun 2017	Jan 1990 - Jun 2017	Jan 1990 - Jun 2017	Jan 1990 - Jun 2017	Jan 1990 - Jun 2017	Jan 1990 - Jun 2017	May 2000 - Jun 2017
UK	Jan 1990 - Jun 2017	Jan 1990 - Jun 2017	Jan 1990 - Jun 2017	Jan 1990 - Jun 2017	Jan 1990 - Jun 2017	Jan 1990 - Jun 2017	Jan 1990 - Jun 2017	Jan 1990 - Jun 2017

Notes: Four liquidity indexes (Financial conditions Index, Policy Liquidity Index, Risk Appetite, Cross-border Flows Index) from CrossBorder Capital, Ltd. are available for the entire period (Jan 1990 - Jun 2017), except the following economies: Brazil (Risk Appetite from Dec 1991), China (Risk Appetite from Aug 1994), Czech Rep. (Financial conditions from May 1992, Policy Liquidity from Jan 1994, Risk Appetite from Dec 1996), Hungary (Risk Appetite from Oct 1994), Poland (Risk Appetite from Aug 1994), Russia (Financial conditions from Feb 1993, Policy Liquidity from Jan 1995, Risk Appetite from Jan 1997), and Turkey (Risk Appetite from May 1991).

Table B.4: Data sources for endogenous variables

	Industrial Production	CPI	Stock Price	Trade Balance	Exchange Rate	Short-term Rate	Policy Rate	Long-term Rate
AUSTRALIA	DATASTREAM	DATASTREAM	OECD MEI	OECD MEI	IMF IFS	OECD MEI	BIS	IMF IFS
AUSTRIA	OECD MEI	OECD MEI	OECD MEI	OECD MEI	IMF IFS	OECD MEI	ECB	IMF IFS
BELGIUM	OECD MEI	OECD MEI	OECD MEI	OECD MEI	IMF IFS	DATASTREAM	ECB	DATASTREAM
BRAZIL	OECD MEI	OECD MEI	OECD MEI	OECD MEI	IMF IFS	IMF IFS	BIS	IMF IFS
CANADA	OECD MEI	OECD MEI	OECD MEI	OECD MEI	IMF IFS	IMF IFS	BIS	IMF IFS
CHILE	DATASTREAM	IMF IFS	IMF IFS	IMF IFS	IMF IFS	IMF IFS	IMF IFS	DATASTREAM
CHINA	DATASTREAM	IMF IFS	IMF IFS	OECD MEI	IMF IFS	DATASTREAM	OECD MEI	DATASTREAM
COLOMBIA	OECD MEI	OECD MEI	OECD MEI	OECD MEI	IMF IFS	OECD MEI	BIS	DATASTREAM
CZECH REP.	OECD MEI	OECD MEI	OECD MEI	OECD MEI	IMF IFS	OECD MEI	BIS	IMF IFS
DENMARK	OECD MEI	OECD MEI	OECD MEI	OECD MEI	IMF IFS	OECD MEI	BIS	IMF IFS
FINLAND	OECD MEI	OECD MEI	OECD MEI	OECD MEI	IMF IFS	IMF IFS	OECD MEI	IMF IFS
FRANCE	OECD MEI	OECD MEI	OECD MEI	OECD MEI	IMF IFS	IMF IFS	ECB	IMF IFS
GERMANY	OECD MEI	OECD MEI	OECD MEI	OECD MEI	IMF IFS	OECD MEI	IMF IFS	OECD MEI
HUNGARY	OECD MEI	OECD MEI	OECD MEI	OECD MEI	IMF IFS	IMF IFS	BIS	OECD MEI
INDIA	IMF IFS	IMF IFS	IMF IFS	IMF IFS	IMF IFS	DATASTREAM	BIS	DATASTREAM
ITALY	OECD MEI	OECD MEI	OECD MEI	OECD MEI	IMF IFS	OECD MEI	ECB	IMF IFS
JAPAN	OECD MEI	OECD MEI	OECD MEI	OECD MEI	IMF IFS	IMF IFS	OECD MEI	DATASTREAM
MALAYSIA	IMF IFS	IMF IFS	IMF IFS	IMF IFS	IMF IFS	IMF IFS	BIS	DATASTREAM
MEXICO	OECD MEI	OECD MEI	OECD MEI	OECD MEI	IMF IFS	OECD MEI	BIS	DATASTREAM
NETHERLANDS	OECD MEI	OECD MEI	OECD MEI	OECD MEI	IMF IFS	OECD MEI	ECB	IMF IFS
NORWAY	OECD MEI	OECD MEI	OECD MEI	OECD MEI	IMF IFS	OECD MEI	Norges Bank	OECD MEI
PHILIPPINES	DATASTREAM	IMF IFS	IMF IFS	IMF IFS	IMF IFS	IMF IFS	BIS	DATASTREAM
POLAND	OECD MEI	OECD MEI	OECD MEI	OECD MEI	IMF IFS	OECD MEI	BIS	OECD MEI
RUSSIA	OECD MEI	OECD MEI	OECD MEI	OECD MEI	IMF IFS	OECD MEI	BIS	OECD MEI
S.AFRICA	DATASTREAM	OECD MEI	OECD MEI	OECD MEI	IMF IFS	IMF IFS	BIS	IMF IFS
SPAIN	OECD MEI	OECD MEI	OECD MEI	OECD MEI	IMF IFS	OECD MEI	ECB	IMF IFS
SWEDEN	OECD MEI	OECD MEI	OECD MEI	OECD MEI	IMF IFS	IMF IFS	Riksbank	IMF IFS
THAILAND	DATASTREAM	IMF IFS	IMF IFS	IMF IFS	IMF IFS	DATASTREAM	DATASTREAM	IMF IFS
TURKEY	DATASTREAM	OECD MEI	OECD MEI	OECD MEI	IMF IFS	IMF IFS	IMF IFS	IMF IFS
UK	OECD MEI	OECD MEI	OECD MEI	OECD MEI	IMF IFS	BOE	BIS	IMF IFS

Notes: acronyms correspond to the following sources. IFS: IMF International Financial Statistics database, OECD MEI: OECD Main Economic Indicators database, DATASTREAM: Thomson-Reuters Datastream database.

Table B.5: Sources of short term interest rates

	Short-term interest rate	Source
AUSTRALIA	Interbank 3 Month	OECD MEI
AUSTRIA	VIBOR 3 month	OECD MEI
BELGIUM	T-bill Rate (3 months)	DATASTREAM
BRAZIL	Deposit Rate (90 day)	IMF IFS
CANADA	T-bill Rate (3 months)	IMF IFS
CHILE	Deposit Rate (90 day)	IMF IFS
CHINA	Deposit Rate (90 day)	DATASTREAM
COLOMBIA	Deposit Rate (90 day)	OECD MEI
CZECH REP.	PRIBOR 3 Month	OECD MEI
DENMARK	CIBOR 3 Month	OECD MEI
FINLAND	HELIBOR 3 Month	IMF IFS
FRANCE	T-bill Rate (3 months)	IMF IFS
GERMANY	FIBOR 3 Month	DATASTREAM
HUNGARY	T-bill Rate (3 months)	IMF IFS
INDIA	Lending Rate	DATASTREAM
ITALY	T-bill Rate (3 months)	DATASTREAM
JAPAN	T-bill Rate (3 months)	IMF IFS
MALAYSIA	T-bill Rate (3 months)	IMF IFS
MEXICO	T-bill Rate (3 months)	OECD MEI
NETHERLANDS	AIBOR 3 month	OECD MEI
NORWAY	NIBOR 3 month	OECD MEI
PHILIPPINES	Deposit Rate (90 day)	IMF IFS
POLAND	WIBOR 3 month	OECD MEI
RUSSIA	Interbank 1-3 Month	OECD MEI
SOUTH AFRICA	T-bill Rate (3 months)	IMF IFS
SPAIN	Interbank 3 Month	OECD MEI
SWEDEN	T-bill Rate (3 months)	IMF IFS
THAILAND	Interbank 1 Month	DATASTREAM
TURKEY	Deposit Rate (90 day)	IMF IFS
UK	T-bill Rate (3 months)	Bank of England

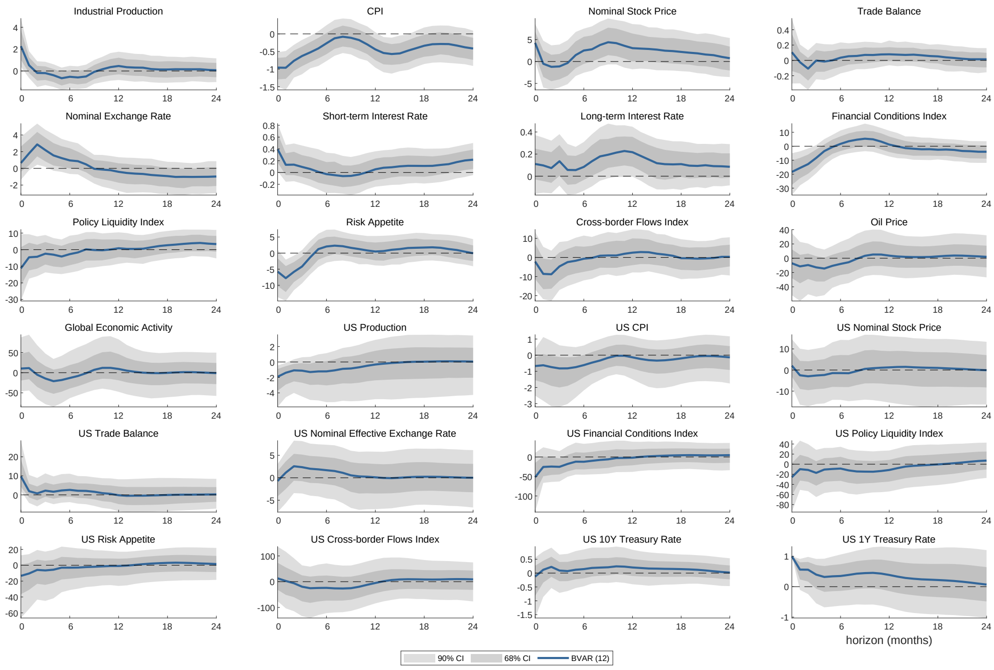
Table B.6: Classification of countries by Financial Market Openness

Chinn-Ito Index, 1990-2015 Average					
ADVANCED	AUSTRALIA	0.814	EMERGING	BRAZIL	0.262
	AUSTRIA	0.965		CHILE	0.517
	BELGIUM	0.965		CHINA	0.147
	CANADA	1		COLOMBIA	0.272
	DENMARK	0.993		CZECH REP.	0.839
	FINLAND	0.965		HUNGARY	0.653
	FRANCE	0.944		INDIA	0.166
	GERMANY	1		MALAYSIA	0.513
	ITALY	0.944		MEXICO	0.640
	JAPAN	0.988		PHILIPPINES	0.393
	NETHERLANDS	1		POLAND	0.315
	NORWAY	0.886		RUSSIA	0.432
	SPAIN	0.898		SOUTH AFRICA	0.169
	SWEDEN	0.942		THAILAND	0.338
	UK	1		TURKEY	0.310
ADVANCED	MEDIAN	0.965	EMERGING	MEDIAN	0.338

	Advanced		Emerging	
	Open (Top 33%)	Less Open (Bottom 33%)	Open (Top 33%)	Less Open (Bottom 33%)
	CANADA	AUSTRALIA	CHILE	BRAZIL
	DENMARK	ITALY	CZECH REP.	CHINA
	GERMANY	NORWAY	HUNGARY	COLOMBIA
	NETHERLANDS	SPAIN	MALAYSIA	INDIA
	UK	SWEDEN	MEXICO	SOUTH AFRICA
Average	0.998	0.897	0.632	0.203

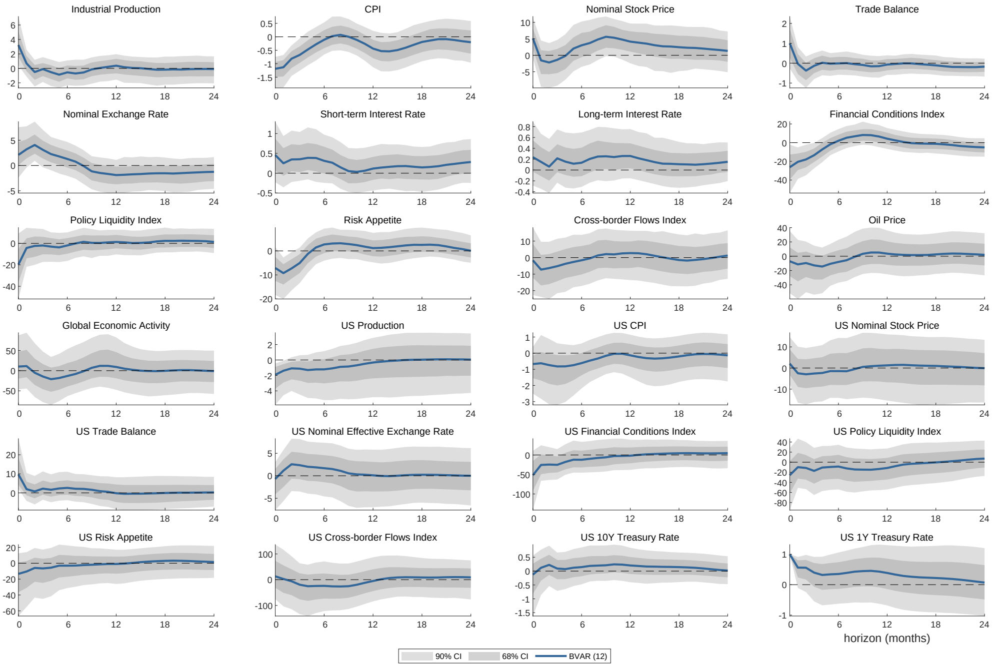
Notes: The measure of Financial openness is the arithmetic mean of Chinn-Ito (2006) *ka_open* index, which has the value from 0 (mostly closed) to 1 (mostly open), for the sample period used in the analysis.

Figure B.3: Median Response of 15 Emerging Economies



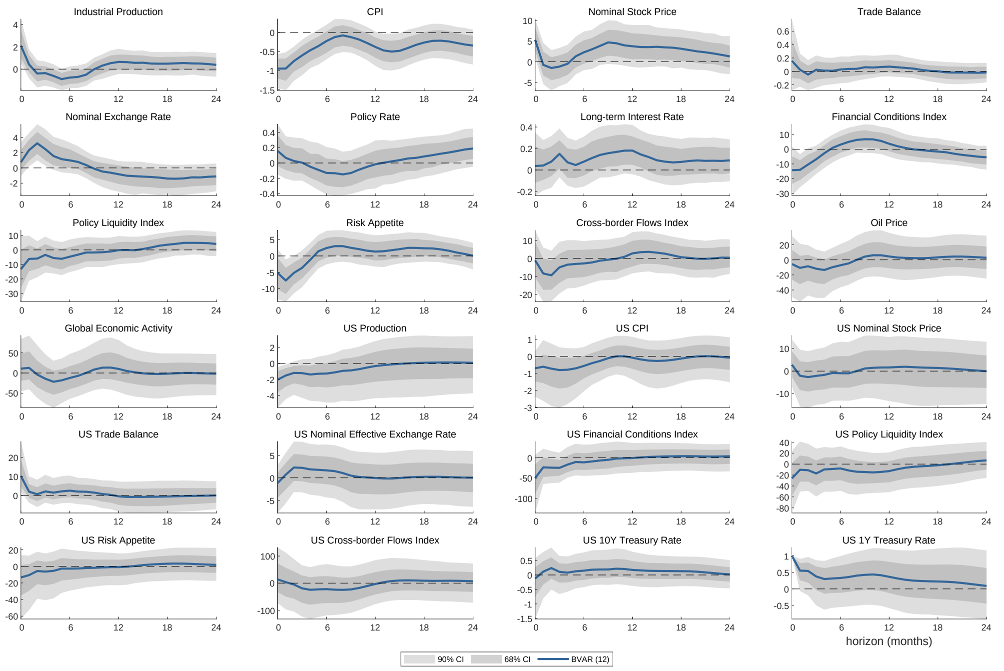
Note: Median responses of emerging economies to a contractionary US monetary policy shock, normalised to induce a 100 basis point increase in the 1-year rate. Identification achieved through informationally-robust high frequency instrument. Sample varies from 1990:01 - 2017:06 for longest(Mexico) to 2002:09 - 2017:06 for shortest(Colombia). BVAR(12). Numbers in the y-axis in each plot is in percentage points, except the trade balance. Shaded areas are 68% and 90% posterior coverage bands.

Figure B.4: Mean Response of 15 Emerging Economies



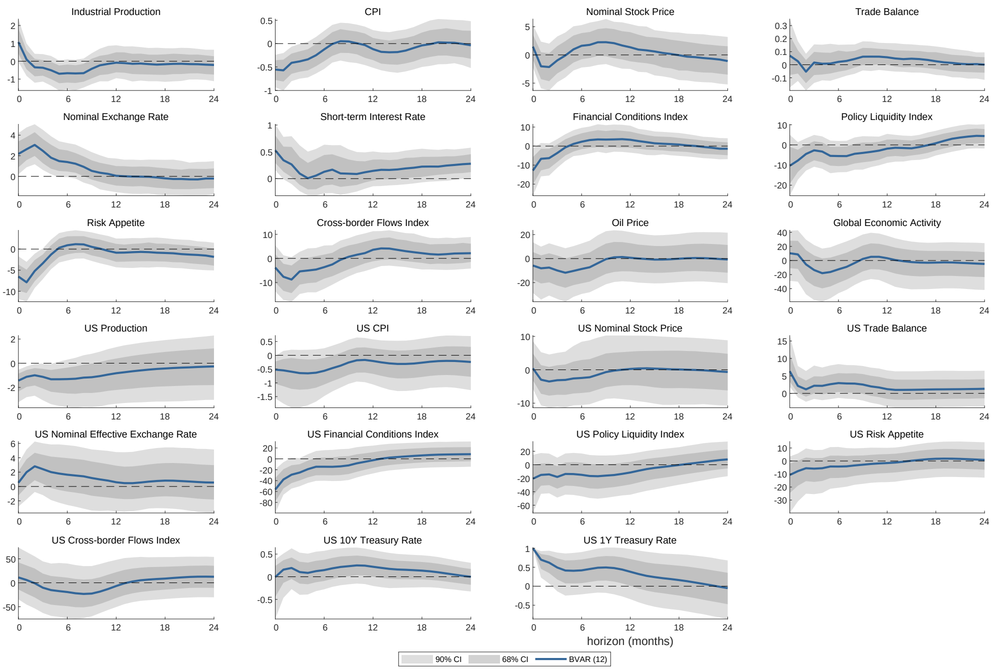
Note: Mean responses of emerging economies to a contractionary US monetary policy shock, normalised to induce a 100 basis point increase in the 1-year rate. Identification achieved through informationally-robust high frequency instrument. Sample varies from 1990:01 - 2017:06 for longest(Mexico) to 2002:09 - 2017:06 for shortest(Colombia). BVAR(12). Numbers in the y-axis in each plot is in percentage points, except the trade balance. Shaded areas are 68% and 90% posterior coverage bands.

Figure B.5: Median Response of 15 Emerging Economies with Policy Rate



Note: Median responses of emerging economies to a contractionary US monetary policy shock, normalised to induce a 100 basis point increase in the 1-year rate. Identification achieved through informationally-robust high frequency instrument. Sample varies from 1990:01 - 2017:06 for longest(Mexico) to 2002:09 - 2017:06 for shortest(Colombia). BVAR(12). Numbers in the y-axis in each plot is in percentage points, except the trade balance. Shaded areas are 68% and 90% posterior coverage bands.

Figure B.6: Median Response of 15 EMEs- longer sample without long rate



Note: Median responses of emerging economies to a contractionary US monetary policy shock, normalised to induce a 100 basis point increase in the 1-year rate. Identification achieved through informationally-robust high frequency instrument. Sample varies from 1990:01 - 2017:06 for longest(Mexico) to 1999:01 - 2017:06 for shortest(Thailand). BVAR(12). Numbers in the y-axis in each plot is in percentage points, except the trade balance. Shaded areas are 68% and 90% posterior coverage bands.