

The Global Transmission of U.S. Monetary Policy

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Abstract

This paper studies the transmission of US monetary shocks across the globe by employing a high-frequency identification of policy shocks and large VAR techniques, in conjunction with a large macro-financial dataset of global and national indicators covering both advanced and emerging economies. Our identification controls for the information effects of monetary policy and allows for the separate analysis of tightenings and loosening of the policy stance. First, we document that US policy shocks have large real and nominal spillover effects that affect both advanced economies and emerging markets. Policy actions cannot fully isolate national economies, even in the case of advanced economies with flexible exchange rates. Second, we investigate the channels of transmission and find that both trade and financial channels are activated and that there is an independent role for oil and commodity prices. Third, we show that effects are asymmetric and larger in the case of contractionary US monetary policy shocks. Finally, we contrast the transmission mechanisms of countries with different exchange rates, exposure to the dollar, and capital control regimes.

Keywords: Monetary policy, Trilemma, Exchange Rates, 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 adoption of the US dollar by the transnational banking system and ever deeper trade and financial integration mean that the implications of Fed decisions extend well beyond the borders of the United States. A critical question for policymakers in advanced and emerging markets is how to adjust monetary policy to neutralise spillovers from US monetary policy actions. We contribute to this debate by providing robust evidence on the propagation of US monetary policy. We use a state-of-the-art high-frequency identification of monetary shocks and large data techniques to assess outcomes for global and national indicators covering 30 advanced and emerging economies.

The classic Mundell-Fleming model identifies two international transmission channels for US monetary policy. First, an increase in US interest rates has a contractionary effect domestically which translates to lower demand for both domestic and foreign goods (demand-augmenting effect). Second, as the dollar appreciates, foreign goods become relatively cheaper, moving the composition of global demand away from US goods and towards foreign goods (expenditure-switching effect). These two channels should at least partially offset each other. However, there can be a third, financial transmission channel – risk-taking and international credit – which occurs through the balance sheets of global financial intermediaries (Rey, 2013, 2016; Farhi and Werning, 2014; Bruno and Shin, 2015a,b). A Fed rate hike transmits along the yield curve at longer maturities and reduces the price of risky financial assets. Portfolio rebalancing by investors in the integrated global financial market determines capital outflows in foreign countries and induces upward pressure on foreign longer-term yields and downward price revisions of foreign assets. Furthermore, a higher US interest rate raises the funding cost of major global banks, which provide credit to many advanced and emerging economies. Due to such adverse balance sheet effects, financial conditions abroad may deteriorate substantially with powerful destabilising effects.

The combined effect of the three channels implies a difficult trade-off for central banks. Faced with a contractionary policy action in the US, a foreign central bank would want to lower its rate to counter the negative demand shock. However, such an action risks worsening the adverse balance sheet effects, leading to even larger capital

outflows and further destabilisation. As observed by [Rey \(2016\)](#) in her seminal work, this trade-off between open capital flows and independent monetary policies can reduce the Mundell and Fleming’s trilemma to a ‘dilemma’.¹

The effect of US monetary policy spillovers is ultimately an empirical question, yet the existing literature is still fairly limited due to the technical difficulties in identifying monetary policy shocks and summarising their transmission over hundreds of variables across several economies. In his Mundell-Fleming lecture, [Bernanke \(2017\)](#) summarised the challenges to the existent evidence. First, monetary policy actions are largely endogenous to the economic conditions and have strong signalling and coordination effects, also documented in the recent literature – see, for example, [Miranda-Agrippino and Ricco \(2017\)](#) and [Jarociński and Karadi \(forthcoming\)](#). Second, the limited availability of data at a higher frequency on financial and cross-border flows has constrained much of the literature.² Finally, there are many dimensions along which countries may differ – their cyclical positions and structural features such as trade exposure, financial exposure, openness to capital flows, exchange rate and policy regimes. These dimensions have been largely left unexplored due to a lack of data.

We take on these three challenges to provide robust estimates of the impact of US monetary policy across the globe. First, we employ a state-of-the-art high-frequency identification (HFI) obtained from intraday price revisions of federal funds futures in tight windows around policy announcements, as originally proposed by [Gürkaynak et al. \(2005\)](#) and adopted in the VAR literature by [Gertler and Karadi \(2015\)](#). We disentangle policy shocks from signalling effects, by directly controlling for the information channel

¹According to Mundell and Fleming’s Trilemma, a country can only choose two out of three simultaneously impossible objectives – free capital flow, independent monetary policy, and a flexible or targeted exchange rate. Hence, central banks of economies with a floating exchange rate can set interest rates autonomously with the goal of stabilising their economy, while allowing for free capital flows.

²Given the lack of data at a higher frequency on cross-border flows, a large part of the existent empirical research, using quarterly data, has reported the effects of US monetary policy on capital inflows and outflows taking place over long periods of time – i.e. 12-16 quarters – well beyond the expected time-scale for high-frequency phenomena. These reported effects are possibly due to other structural shocks contaminating the identification.

of monetary policy as proposed by [Miranda-Agrippino and Ricco \(2017\)](#).³ This is critical to not confounding the effects of monetary policy shocks with the propagation of other global shocks to which the Fed may be responding.

Second, we construct a large global dataset including a comprehensive set of macroeconomic and financial variables covering the US, 15 advanced and 15 emerging economies, and a rich set of global indicators. Importantly, we include a large dataset of indexes of credit flows and liquidity conditions.⁴ All of our data and our instrument for monetary policy shocks are at monthly frequency and span the period 1990:1 to 2018:9 – hence the coverage and the frequency of the data allow for the study of the effects of US policy on financial variables and capital flows at reasonably high frequency. Containing over 150,000 data-points in total, our dataset qualifies as ‘big data’.⁵

Third, we investigate the global transmission of US monetary policy shocks on the global economy as a whole and on 15 advanced and 15 emerging economies. Using the high-frequency instrument, we identify the effects of a US monetary policy shock in a large-scale Bayesian SVAR-IV/Proxy SVAR incorporating 30 global and US macroeconomic indicators (see [Stock and Watson, 2012](#) and [Mertens and Ravn, 2013](#)). Then, we study the responses of individual economies and provide median responses for selected groups of countries based on bilateral Bayesian SVAR-IV specifications.⁶ Our rich empirical framework allows us to control for the heterogeneity among countries due to their cyclical/financial market position via the VAR structure. Moreover, we group countries

³Our 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.

⁴We employ Cross Border Capital Ltd indicators on liquidity and financial conditions, covering all of the economies of interest at monthly frequency. The underlying data are mostly publicly available data from BIS, statistical offices, and markets. The dataset is described in [Table A.1](#) in the online appendix.

⁵Our dataset is between two and three orders of magnitude larger than the typical dataset used to study the domestic effects of U.S. monetary shocks, given the assessment of [Iacoviello and Navarro \(2018\)](#).

⁶We incorporate large information sets in our VAR models by employing Bayesian big data techniques. In particular, we estimate a battery of large Bayesian VARs with asymmetric Minnesota priors (see [Banbura et al., 2010](#), [Carriero et al., 2019](#) and [Chan, 2019](#)). In bilateral VARs, the asymmetric priors allow for parameter restrictions that rule out a direct response of the US policy variable to economic conditions in a foreign country. This is important in reducing parameter uncertainty and alleviates multicollinearity regression problems.

by their (i) income levels, (ii) degree of openness to capital, (iii) exchange rate regimes, (iv) dollar trade invoicing, and (v) gross dollar exposure to compare median responses across groups.

Our framework also delivers new insight into the channels of propagation of US monetary policy shocks, as well as on the potentially asymmetric response of foreign economies to loosening and tightenings in the US. We study these asymmetric effects (i) in the US, (ii) at the global level, (iii) for the advanced, and (iv) for the emerging economies. We also control for potential non-linearities and model misspecification by adopting a flexible multivariate local projection setting, in a robustness exercise.

We report a rich set of novel findings. First, we document that following a contractionary (expansionary) US monetary policy shock the global economy contracts (expands), in line with the US. OECD industrial production, CPI, global real economic activity and commodity prices exhibit negative (positive) responses, while foreign currencies depreciate (appreciate). This creates a striking visual image of the role of the Fed as the global central bank. Importantly, commodity prices, global risk appetite and global cross-border financial flows all contract (expand). All of them display a strong co-movement with US credit spreads and VIX. We interpret these results as supporting the idea that US monetary policy is a driver of the global financial cycle, confirming [Rey \(2013\)](#)'s observations.

Second, following US shocks, the 'median' advanced economy displays strong responses in output and CPI (less so for core CPI), which move in the same direction as the US counterparts. Importantly, its trade balance deterioration is a gauge for the relative strength of price and demand effects. The central bank attempts to counteract the recessionary pressure by lowering marginally its interest rate, but prices do not revert for at least 18 months. The trade-off between financial stability and countercyclical effects is evident. Indeed, the US monetary policy shock also moves the long end of the foreign economy's yield curve, which reduces the effectiveness of domestic monetary policy.⁷ Moreover, financial conditions deteriorate and cross-border flows turn negative. Importantly, the country-level responses are much less heterogeneous than previously reported. We read these results as a strong indication that due to the global financial

⁷Movements in risk premia impair the transmission of the policy shift to the long-end of the yield-curve, and hence to the economy. See also [Kalemli-Özcan \(2019\)](#).

cycle and credit-channel effects inflation-targeting central banks in advanced economies are confronted with an important trade-off and tend to fail in their price stabilisation mandates.

Third, the ‘median’ emerging economy responds similarly to the advanced counterpart. It contracts in response to contractionary US monetary policy shocks. Industrial production and prices decrease significantly, asset markets adjust downwards and long term interest rates increase, while risk appetite and financial conditions deteriorate. The responses of these variables are fairly homogeneous at country level, while interest rates, capital flows, and policy variables show a marked heterogeneity ascribable to different policy regimes. We analyse in detail the responses of some of the largest emerging economies – China, India, and Mexico – and compare policy regimes and outcomes while benchmarking them against the Euro Area. We further explore this heterogeneity by grouping the countries by structural characteristics. Importantly, advanced and emerging economies that are more open in terms of capital flows, as classified by the [Chinn and Ito \(2006\)](#)’s index, exhibit stronger negative responses of industrial production and CPI compared to less-open ones. This points to a potential role for capital controls as an additional policy tool.

Fourth, we provide new evidence on the relative importance of the channels at play. We study responses of the main macroeconomic indicators of interest to US policy shocks when selectively zeroing out transmission coefficients of the estimated VAR models on variables capturing some of the channels of interest. In particular, we consider the role of (i) the policy rate, (ii) oil and commodity prices, (iii) exchange rates, and (iv) financial indicators. For the advanced economies, we find that the contractionary response of oil and commodity prices is an important determinant of the contraction in CPI, while financial variables and cross-border flows matter for stock market and output responses. We obtain similar but less clear results for the emerging economies.

Finally, in analysing the differential responses to contractionary and expansionary US monetary policy shocks, we find some evidence of asymmetric effects. The responses of output and stock prices of the US, the global economy, and third countries are more persistent in a tightening than in a loosening. CPI instead shows downward rigidity, that is accounted for by the downward rigidity of oil and commodity prices.

This paper contributes to the literature on the transmission of US monetary policy in several respects. First, to the best of our knowledge it is the first to adopt a modern high-frequency identification of US monetary policy that controls for signalling effects and potential endogeneities. Second, it uses a comprehensive monthly dataset of US, global, and national macroeconomic variables including data on liquidity, risk appetite, and cross-border flows. Third, the use of large data techniques allows us to incorporate and compress into multivariate models information of hundreds of variables across 30 countries and the Euro Area. Fourth, we provide detailed results on the channels and the asymmetric response to tightenings and loosening.

Related Literature. Our work is closely related to [Rey \(2013\)](#)'s Jackson Hole lecture and to a number of her subsequent works with different co-authors [Miranda-Agrippino and Rey \(2015\)](#), [Passari and Rey \(2015\)](#) and [Gerko and Rey \(2017\)](#) which have documented 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. In this body of work H el ene Rey has argued that flexible exchange rates cannot fully insulate economies from the global financial cycle and provided evidence, by using a high-frequency identification, that US monetary policy is one of the main drivers of the global financial cycle. Our work is related to this, but distinguished by our use of an extensive set of countries and variables, and importantly a high-frequency identification that controls for information effects that are likely to appear as strong confounding factors at the international level. The works of [Dedola et al. \(2017\)](#), and [Iacoviello and Navarro \(2018\)](#) are the most closely related to ours in terms of data coverage. Compared to them, we use a cutting-edge SVAR-IV approach with only monthly data and a pure high-frequency identification, which does not rely on sign restrictions or recursive identification. Moreover, compared to the latter, we do not focus just 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. [Georgiadis \(2016\)](#) and [D ees and Galesi \(2019\)](#) have also used large panels of countries in a GVAR setting. Unlike this approach, we do not need to use GDP or trade weights to model international interactions, and we do not use

sign restrictions to identify monetary policy.⁸ Most of these works find spillovers of US monetary policy to prices and (sometimes) to real quantities, but report large heterogeneity in the response of individual countries.⁹ Our results only concern conventional monetary policy and not the more recent unconventional monetary policy actions, that are discussed in [Rogers et al. \(2014\)](#), [Rogers et al. \(2018\)](#), and in [Stavrakeva and Tang \(2015\)](#). More broadly, our results fits into the literature on reference (see [Ilzetzi et al., 2019](#)) and dominant currencies (see [Gourinchas and Rey, 2007](#), [Gourinchas et al., 2019](#) and [Gopinath et al., 2016](#)).

The structure of the paper is the following. Section 2 describes the methodology and the data used in our empirical exercises. Section 3 discusses the effects of U.S. monetary policy on the global economy. Section 4 and Section 5 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 6 focuses on some of the largest economies – the Euro Area, China, India, and Mexico. Section 7 explores the role of structural features: capital controls, exchange rate regimes, and the dollar exposure. Section 8 analyses potentially asymmetric responses to loosening and tightenings in the US. Section 9 concludes.

2 Data and Empirical Methodology

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 VAR techniques as in [Banbura et al. \(2010\)](#) and elicit asymmetric Normal Inverse-Wishart priors, while selecting optimal hyperparameters with the approach proposed

⁸Some early estimations of spillovers from the US monetary policy are in [Kim \(2001\)](#), [Canova \(2005\)](#) and in [Mackowiak \(2007\)](#). Other more recent contributions to this literature are in [Ehrmann and Fratzscher \(2009\)](#), [Bluedorn and Bowdler \(2011\)](#), [Akinci \(2013\)](#), [Ciccarelli et al. \(2012\)](#), [Feldkircher and Huber \(2016\)](#), [Bhattarai et al. \(2017\)](#), [Crespo Cuaresma et al. \(2018\)](#), [Cesa Bianchi and Sokol \(2017\)](#), [Vicendoa \(2019\)](#), [Gilchrist et al. \(2019\)](#), [Kalemli-Özcan \(2019\)](#).

⁹A related literature has focussed on spillovers of US monetary policy through banks using aggregate banking flows [Cetorelli and Goldberg \(2012\)](#), [Bremus and Fratzscher \(2015\)](#), [Buch and Goldberg \(2015\)](#), [Bruno and Shin \(2015b\)](#), [Argimon et al. \(2019\)](#), [Temesvary et al. \(2018\)](#), [Buch et al. \(2019\)](#), or using disaggregated (interbank and intragroup) flows [Reinhardt and Riddiough \(2015\)](#).

by [Giannone et al. \(2015\)](#). In the following, we describe the building blocks of our empirical specification: the dataset, the instrument for US monetary policy shocks, the VAR models and priors adopted.

2.1 Data

In total, our dataset contains over 150,000 data-points covering the US, 30 foreign economies, the Euro Area as an aggregate, and global economic indicators. All variables are monthly.¹⁰ Most of our data are publicly available and provided by national statistical offices, treasuries, central banks or international organisations (IMF, OECD, and BIS). We also employ liquidity and cross-border flows data at a global and national level from CrossBorder Capital Ltd, a private data provider specialised in the monitoring of global liquidity flows.

The dataset contains 16 US macro and financial indicators, including 5 macroeconomic aggregates (industrial production index, CPI, core CPI, export-import ratio, and trade volume), 5 financial indicators (stock price index, nominal effective exchange rate, excess bond premium from [Gilchrist and Zakrajšek \(2012\)](#), 10-year Treasury Bond yield rate, and VIX), and a monetary policy indicator (1-year Treasury constant maturity rate). Additionally, we include 5 financial and liquidity indices from CrossBorder Capital Ltd – financial conditions, risk appetite, cross-border flows, fixed income and equity holdings. The financial conditions index represents short-term credit spreads, such as deposit-loan spreads. Risk appetite is based on the balance sheet exposure of all investors between equity and bonds. The cross-border flows index captures all financial flows into a currency, including banking and all portfolio flows (bonds and equities). Finally, equity and fixed income holdings measure respectively holdings of listed equities and both corporate and government fixed income assets.

The dataset also includes 15 global economic indicators: industrial production, CPI, and stock price index of OECD countries, the differential between average short-term interest rate across 15 advanced economies in our dataset and the US, the global economic activity index constructed by [Kilian \(2019\)](#), CRB commodity price index, the global price of Brent crude oil, and 3 major currency exchange rates per USD – i.e.

¹⁰If the original series are collected at a daily frequency, we take the end-of-month value.

TABLE 1: Country coverage

| Advanced | Estimation sample | Emerging | Estimation Sample |
|-------------|-------------------|--------------|-------------------|
| Australia | 1990:01 - 2018:08 | Brazil | 1999:12 - 2018:09 |
| Austria | 1990:01 - 2018:09 | Chile | 1995:05 - 2013:11 |
| Belgium | 1990:01 - 2018:09 | China | 1994:08 - 2018:08 |
| Canada | 1990:01 - 2018:08 | Colombia | 2002:09 - 2018:09 |
| Denmark | 1999:10 - 2018:09 | Czech Rep. | 2000:04 - 2018:09 |
| Finland | 1990:01 - 2018:09 | Hungary | 1999:02 - 2018:09 |
| France | 1990:01 - 2018:09 | India | 1994:05 - 2018:04 |
| Germany | 1990:01 - 2018:09 | Malaysia | 1996:01 - 2017:12 |
| Italy | 1990:01 - 2018:09 | Mexico | 1998:11 - 2018:02 |
| Japan | 1997:10 - 2018:09 | Philippines | 1999:02 - 2018:02 |
| Netherlands | 1990:01 - 2018:09 | Poland | 2001:01 - 2018:09 |
| Norway | 1995:10 - 2018:09 | Russia | 1999:01 - 2018:06 |
| Spain | 1990:01 - 2018:09 | South Africa | 1990:01 - 2018:09 |
| Sweden | 2001:10 - 2018:09 | Thailand | 1999:01 - 2018:05 |
| UK | 1990:01 - 2018:08 | Turkey | 2000:06 - 2018:09 |

Notes: The table lists the advanced and emerging countries in our data set and reports the estimation sample for the exercises in Sections 4 and 5. The set of endogenous variables for the median AE and the median EME exercises are different (see notes in Table A.2).

Euro, Pound Sterling, and Japanese Yen.^{11,12} Finally, the dataset includes 5 world-aggregated liquidity indexes from CrossBorder Capital Ltd, that are the counterparts of US indices described above.¹³

At a national level, our dataset covers 30 economies – 15 advanced and 15 emerging (see Table 1).¹⁴ For each country in our sample and the Euro Area, we collect 15 indicators – industrial production, CPI, core CPI, stock price index, export-import ratio, trade volume, nominal bilateral exchange rate, short-term interest rate, policy rate, long-term interest rate, plus the five liquidity indices (financial conditions, risk appetite, cross-border flows, fixed income and equity holdings). Hence, we have at our

¹¹Table A.7 in the online appendix lists the short-term rates used in construction of the interest rate differential.

¹²Kilian (2019)'s index is the corrected and updated version of the global real economic activity index originally proposed in Kilian (2009) and criticised in Hamilton (2019).

¹³Table A.1 in the online appendix lists all global aggregates and the US variables in our dataset and details the sources, sample availability, and transformations.

¹⁴A comprehensive list of the countries and sample availability for each variable can be found in the online appendix, Table A.3.

disposal a set of variables that reflect the US counterparts for each economy.¹⁵

Our benchmark estimation sample generally spans January 1990 to September 2018 to minimise the impact of historical transformations of the global economy – e.g. the end of the Soviet bloc, or the accession of China to the WTO – and also to align the data with our US monetary policy instrument.^{16,17}

In Section 7 we classify the countries in our dataset based on selected observables – the degree of capital market openness, exchange rate regime, trade shares invoiced in USD, and dollar exposure. We divide countries into more or less-open capital markets based on Chinn and Ito (2006)’s index. We also provide a robustness check based on the measure provided in Fernández et al. (2016a). Classification into pegging, managed floating, and freely floating regimes is based on Ilzetzki et al. (2019). Data on the US dollar trade invoicing is from Gopinath (2015). Our measure of dollar exposure is based on Bénétrix et al. (2015).

2.2 Identification of the US Monetary Policy Shock

Recent literature on monetary policy shocks has documented the existence of a signalling channel of monetary policy, i.e. the fact that policy actions convey to imperfectly informed agents signals about macroeconomic developments (see Romer and Romer, 2000 and Melosi, 2017). Indeed, to informationally constrained agents a policy rate hike can signal either a deviation of the central bank from its monetary policy rule, i.e. a contractionary monetary shock, or better-than-expected fundamentals to which the monetary authority endogenously responds. Miranda-Agrippino and Ricco (2017) and Jarociński and Karadi (forthcoming) have shown that the high-frequency surprises obtained from intraday price revisions of federal funds futures in tight windows around central bank announcements combine policy shocks with information about the state of the economy due to the information disclosed through the policy action (see Gürkaynak et al., 2005 for the original high frequency methodology). Miranda-Agrippino and Ricco (2017) re-

¹⁵Table A.2 in the online appendix lists variables we collect for each country and the US counterparts, detailing the transformations.

¹⁶The estimation sample for the global exercise described in Section 3 spans 1990:01 to 2018:09. However, given the different availability of data across countries, the estimation sample used in the ‘median economy’ exercises described in Sections 4 and 5 varies. Table 1 in the online appendix details the estimation samples used in each bilateral system.

¹⁷All data sources are listed in the online appendix, in Tables A.1 and A.5.

lated these signalling effects of monetary policy to the emergence of the empirical price and output puzzles reported in the literature (see for example, [Ramey, 2016](#)), and they proposed a new high-frequency instrument for monetary policy shocks that accounts for informational rigidities.

As observed by [Bernanke \(2017\)](#), the fact that monetary policy has strong signalling and coordination effects is a major challenge to the identification of international spillovers of the Fed’s policy actions. An identification approach not disentangling monetary policy shocks from signals about macroeconomic and financial conditions would confound spillovers from US monetary policy and the effects of macroeconomic and global shocks. Hence, apparently strong effects could reflect factors that drive the global business and financial cycles – such as changes in risk appetite, oil shocks, trade shocks and technology shocks. For this reason, we adopt the informationally robust instrument proposed by [Miranda-Agrippino and Ricco \(2017\)](#) that directly controls for the signalling channel of monetary policy.

This 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:

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

where $FF4_m$ denotes the high-frequency market-based monetary surprise computed around the FOMC announcement indexed by m . $F_m^{cb} x_{q+j}$ denotes Greenbook forecasts for the vector of variables x at horizon $q + j$ that are assembled prior to each meeting, and $[F_m^{cb} x_{q+j} - F_{m-1}^{cb} x_{q+j}]$ 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 one FOMC decision per month; the monthly surprise simply equals the daily one in these cases. 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 accounts for the slow absorption of information by the agents – a crucial implication of models of imperfect information (see [Coibion and Gorodnichenko, 2015](#)). This instrument is available from January 1990 to December 2009. It is worth stressing that in the SVAR-IV/Proxy-SVAR approach of [Stock and Watson \(2012\)](#) and [Mertens and Ravn \(2013\)](#), in which the proxy is employed as an external instrumental variable, the VAR estimation sample needs not coincide with the sample over which the instrument is available.

2.3 BVARs and Asymmetric Priors

In our analysis we consider two main empirical specifications:

- A **US-global VAR** incorporating 30 variables, including 15 global economic indicators and 15 of the US macroeconomic indicators described above.¹⁸
- A battery of 31 **US-foreign country bilateral VARs**, each one containing 16 US macroeconomic variables, 15 financial and macroeconomic indicators of the

¹⁸Table [A.1](#) in the online appendix lists all global and the US variables in our dataset.

foreign economy, and two global controls, i.e. the global price of Brent crude oil and [Kilian \(2019\)](#)'s global economic activity index. We do this for each one of the 30 countries considered plus the Euro Area.¹⁹

Specifically, we consider bilateral VAR models with 12 lags of the endogenous variables – in line with the standard macroeconometric practice for monthly data – of the form:

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

where i is the index of the unit of interest (the global economy, one of the 30 economies considered or the Euro Area). The vector of endogenous variables, Y_{it} , consists of the macroeconomic and financial variables described in [Section 2.1](#) ($y_{1:n,t}^i$), together with the US counterparts ($y_{1:n,t}^{US}$), and, for the country models, the global controls ($x_{1:m,t}$):

$$Y_{it} = [(y_{1,t}^i, \dots, y_{n,t}^i), (y_{1,t}^{US}, \dots, y_{n,t}^{US}), x_{1,t}, \dots, x_{m,t}]' . \quad (4)$$

It is important to stress that the adoption of large endogenous information sets in our bilateral VAR models captures potentially rich economic dynamics at the country level, the US and periphery's positions in the business cycles, and the many potential channels through which the US monetary policy can affect the rest of the world. Importantly, global controls in the bilateral system allow for higher-order transmission channels induced by interactions among countries, that are important in correctly capturing international spillovers (see discussion in [Georgiadis, 2017](#)).

The use of large information sets requires efficient big data techniques to estimate the models. We adopt a Bayesian approach with informative Minnesota priors ([Litterman, 1986](#)). These are the most commonly adopted macroeconomic priors for VARs and formalise the view that an independent random-walk model for each variable in the system is a reasonable centre for the beliefs about their time series behaviour (see [Sims and Zha, 1998](#)). While not motivated by economic theory, they are computationally convenient priors, meant to capture commonly held beliefs about how economic time series behave. It is worth stressing that in scientific data analyses, priors on the

¹⁹Due to data availability, Core CPI, Fixed Income and Equity Holdings are used only in the endogenous set of advanced economies. Hence, the bilateral system of emerging economies includes only 12 domestic variables and 13 US variables.

model coefficients do not incorporate the investigator’s subjective beliefs: instead, they summarise stylised representations of the data generating process.

In particular, in estimating the VAR models we elicit asymmetric Minnesota priors that assume the coefficients A_1, \dots, A_p to be a priori independent and normally distributed, with the following moments²⁰

$$\mathbb{E} [(A_\ell)_{ij} | \Sigma] = \begin{cases} \delta_i & i = j, \ell = 1 \\ 0 & \text{otherwise} \end{cases} \quad \text{Var} [(A_\ell)_{ij} | \Sigma] = \begin{cases} \frac{\lambda_1^2}{f(\ell)} & \text{for } i = j, \forall \ell \\ \chi_{ij} \frac{\lambda_1^2}{f(\ell)} \frac{\Sigma_{ij}}{\omega_j^2} & \text{for } i \neq j, \forall \ell. \end{cases} \quad (5)$$

where $(A_\ell)_{ij}$ denotes the coefficient of variable j in equation i at lag ℓ and δ_i is either 1 for variables in levels or 0 for rates. The prior also assumes that lags of other variables are less informative than own lags, and that most recent lags of a variable tend to be more informative than distant lags. This intuition is embedded in the function $f(\ell)$, that we assume to be a harmonic lag decay – $f(\ell) = \ell^{\lambda_2}$, for $\lambda_2 = 2$. The factor Σ_{ij}/ω_j^2 accounts for different scales of variables i and j . In our specification, the hyperparameters ω_j^2 are fixed using sample information, i.e. the variance of residuals from univariate regressions of each variable onto its own lags. λ_1 is a hyperparameter that controls the overall tightness of the random walk prior.²¹

Taking one step further from the standard Minnesota priors, the hyperparameter χ_{ij} breaks the symmetry across the VAR equations and allows for looser or tighter priors for some lags of selected regressors in a particular equation i . The adoption of asymmetric priors complicates the estimation problem, as discussed in [Carriero et al. \(2019\)](#) and [Chan \(2019\)](#), making it impossible to use dummy variables to implement the priors. We employ the efficient methodology proposed in those papers to estimate our models.²²

In our setting, the hyperparameter χ_{ij} is crucially important, because it enables us

²⁰Tables [A.1](#) and [A.2](#) in the online appendix contain information about transformations and priors of all the variables discussed above.

²¹If $\lambda_1 = 0$, the prior information dominates, and the VAR shrinks to a vector of independent random walks or white noise processes according to the prior we impose. Conversely, as $\lambda_1 \rightarrow \infty$, the prior becomes less informative, and the posterior asymptotically only reflects sample information.

²²Standard Minnesota priors are implemented as Normal-Inverse Wishart priors that force symmetry across equations, because the coefficients of each equation are given the same prior variance matrix (up to a scale factor given by the elements Σ_{ij}). This implies that own lags and lags of other variables must be treated symmetrically. Hence, it is not possible to cast the Minnesota prior in its original formulation as presented in [Litterman \(1986\)](#), which imposes extra shrinkage on the cross-variable coefficients.

to rule out a direct response of some US variables to economic conditions in another country. Specifically, in the US-global system, we set $\chi_{ij} = 0$ for all coefficients directly connecting US indicators to major exchange rates, global liquidity and the OECD variables. This rules out a direct response of US indicators to these variables, while allowing the possibility of a direct response via the global economic activity, oil price, and commodity price index. It reduces potential collinearity problems between OECD aggregates and US counterparts, and among the exchange rates.²³ In the bilateral systems, we impose that all coefficients directly connecting the US variables to periphery country indicators are zero. However, global indicators allow for an indirect response via higher-order effects (as proposed in [Georgiadis, 2017](#)). These restrictions are of great importance in reducing parameter uncertainty and alleviating multicollinearity problems. This is particularly relevant in selectively studying the channels of transmission of US policy shocks.

2.4 Estimation of Median-Group Responses

In several exercises we estimate median group dynamic responses for selected groups of countries to US monetary policy shocks. The goal is to provide an indication about what responses of a synthetic ‘median’ economy to the shock would look like. The underlying groups of countries can be thought as being homogeneous along some specific structural characteristics, such as the degree of capital market openness, the exchange rate regime, or dollar exposure.

We estimate bilateral country VARs individually and obtain the median result across countries, which we interpret as the median group estimator. While less efficient than the pooled estimator under dynamic homogeneity, it delivers consistent estimates of the average dynamic effect of shocks if dynamic heterogeneity is present (see [Canova and](#)

²³Specifically, this assumption implies that all variables in the bottom half of Table [A.1](#) in the online appendix plus the last three variables of the top half (global economic activity, commodity price, and oil price) do not respond endogenously to the remaining variables in the top half of the table. They are however allowed to respond endogenously among themselves, so that global activity, commodity prices, and oil price directly affect all US variables.

Ciccarelli, 2013, for a discussion).²⁴ Importantly, we opt for the median group estimator instead of the mean group estimator in order to reduce the importance of outliers (e.g. episodes of hyperinflation in some countries within the sample period).

In our empirical approach, the estimation of confidence bands for the parameters of interest relies on the standard Gibbs sampling algorithm. For each bilateral VAR model, we obtain s draws (after burn-in) from the conditional posterior distribution of A , the companion matrix of equation 4 expressed in SUR form, and Σ , the corresponding variance-covariance matrix, and compute the impulse response for each draw. Now we have s impulse responses for each country, and the goal is to aggregate them into the responses of the ‘median’ economy. We do this by taking sequentially each draw of the impulse responses, starting with the first one, for each country and obtaining the median response across countries at each horizon.²⁵ Eventually, we are left with s draws that can be interpreted as the response of the ‘median’ economy to the shock. The aggregation algorithm is the following:

1. For each Gibbs sampler iteration, stack the impulse responses of all countries in the group and compute the median across countries at each horizon.
2. Repeat the procedure for each iteration and store all median 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.²⁶

²⁴If we were willing to assume that the data generating process featured dynamic homogeneity across countries (and to condition on the initial values of the endogenous variables), a pooled estimation with fixed effects, capturing idiosyncratic but constant heterogeneities across units, would be the standard approach to estimate the parameters of the model. However, in our setting dynamic heterogeneity seems to be a likely property of the systems.

²⁵This is equivalent to drawing without replacement a draw from the set of draws we have available for each country, and taking at each horizon the median value across countries. We proceed sequentially purely because of coding convenience.

²⁶For US indicators and global controls, we do not obtain the median across bilateral country-pair models, as we would be taking the median across several instances of the same country. We just stack all IRFs coming from the various bilateral models.

3 The Global Propagation of U.S. Monetary Policy

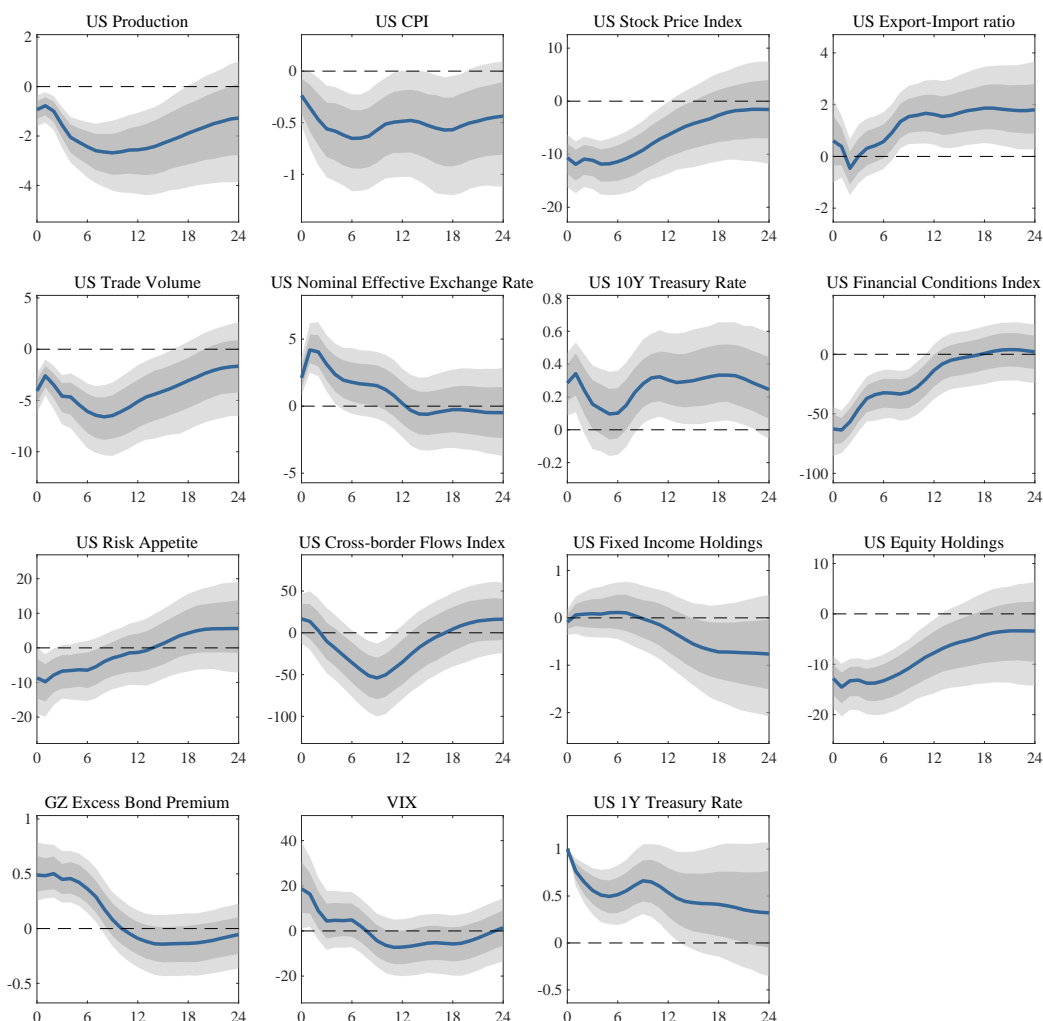
In this section we report the dynamic responses to conventional US monetary policy shocks obtained by estimating the US-Global BVAR, described in Section 2.3. Following the convention, we plot the responses to a contractionary monetary policy shock: it is important to observe that since the system is linear, responses for expansionary and contractionary shocks are symmetric. Results are obtained by employing the full sample from January 1990 to September 2018 for the estimation of the VAR coefficients. Impacts are identified via the instrument for conventional monetary policy shocks discussed in Section 2.2, that is available from January 1990 to December 2009. In each plot, we report median responses, 68% and 90% posterior coverage bands.

The US indicators in the VAR system have been constrained by means of the asymmetric priors to endogenously respond only to other US indicators and to a few proxies of global economic conditions – the global economic activity index, the commodity price index and the price of oil. The parameters of the equations of global variables are instead left unconstrained. In other words, the system allows US variables to be endogenously affected by the higher order response of the three proxies of global economic conditions – sometimes referred to as ‘spillback’ effects – while global variables respond endogenously to every other variable in the system. This alleviates some of the collinearity between global aggregates and US counterparts and allows for more precise estimates of the responses. The US monetary policy shock is normalised to induce a 100bp increase in our policy indicator, the 1-year Treasury constant maturity rate. All the IRFs reported in this section are jointly obtained in a large Bayesian VAR. We first assess the domestic effects of monetary policy shocks on the US economy, and then their propagation to the global economy.

3.1 Domestic Effects of U.S. Monetary Policy

Figure 1 reports the effects of a monetary policy tightening. The shock transmits along the yield curve by moving the shorter maturities more than the long end of the curve, as shown by the increase in the 10-year rates. The term spread decreases and the the yield curve flattens down, while prices of risky financial assets (the S&P index)

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 – 2018:09. BVAR(12) with asymmetric conjugate priors. Shaded areas are 68% and 90% posterior coverage bands.

strongly revise downwards. The policy hike affects both real and nominal quantities. US industrial production and CPI sharply contract on impact to remain significantly below equilibrium over a horizon of 24 months. Importantly, there is no trace of price or output puzzles in the responses.

The interest rate movement induces an exchange rate appreciation of the US dollar vis-à-vis the other currencies, as is visible in the positive response of the nominal effective exchange rate. Despite the dollar appreciation, the monetary policy contraction has an overall positive impact on the balance of trade and the exports-imports ratio

improves. This happens through a compression of imports that adjust downwards more than exports.²⁷ The overall effect of the shock on trade is negative and traded volumes contract. The demand-augmenting effect dominates the expenditure-switching effect: lower domestic demand makes imports fall more than exports, despite the US goods becoming more expensive.

The monetary tightening affects the financial system as is evident in the response of the indicators of financial distress: [Gilchrist and Zakrajšek \(2012\)](#)'s excess bond premium response soars on impact and remains above trend for roughly 10 months, with the VIX showing similar dynamics. The financial conditions index – an index of very short-term credit spreads, e.g. deposit loan spreads – also shows a deterioration in credit conditions. The broad picture of these responses indicates activation of the credit channel of monetary policy transmission ([Bernanke and Gertler, 1995](#)).

Interestingly, risk appetite is reduced by the policy tightening (risk-off). This is also visible in the response of equity holdings that fall significantly on impact while safe asset holdings slightly increase, pointing to a portfolio rebalancing towards less-risky assets.²⁸ Cross-border flows seem to indicate capital inflows on impact but the overall response is not significant, possibly due to the movement of capital to US dollar denominated assets held outside the US.

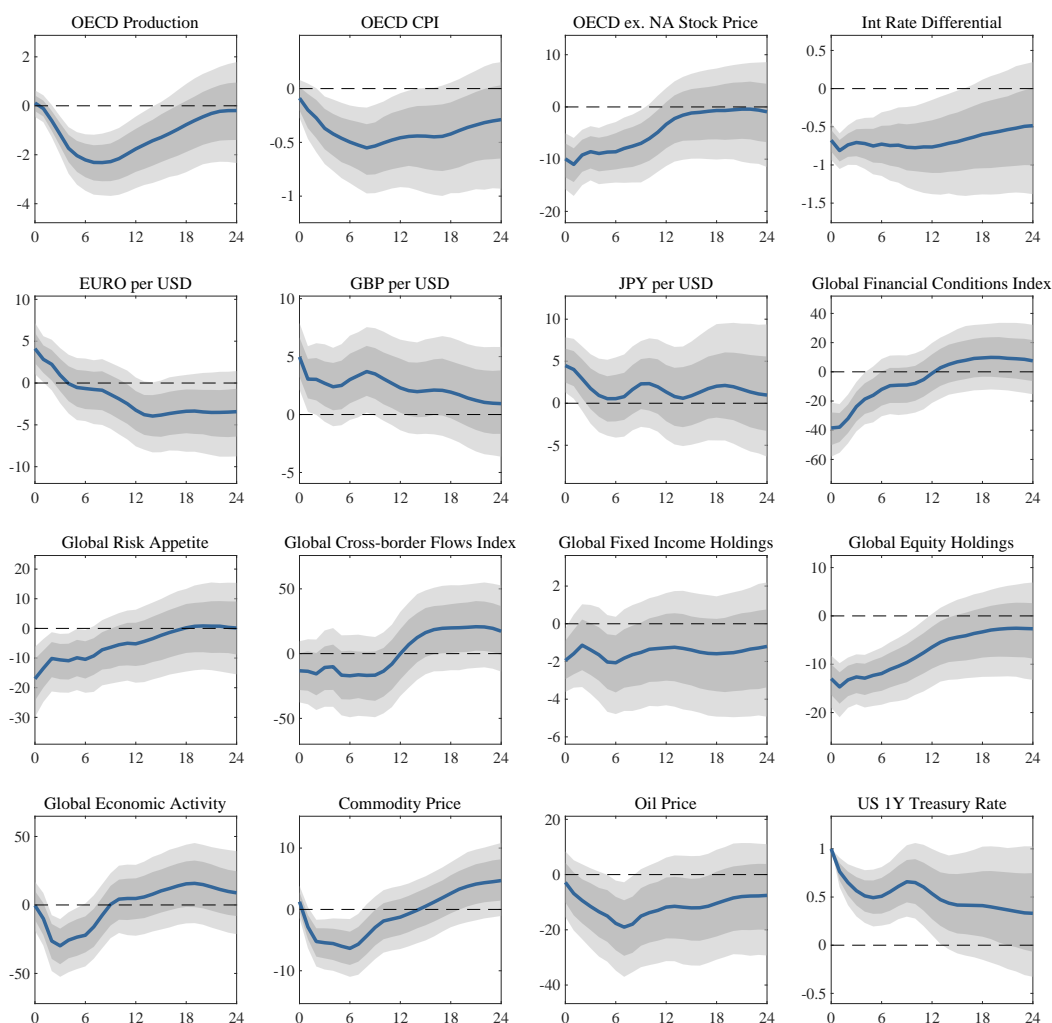
3.2 Global Spillovers

The global economy responds to US monetary policy tightenings by mirroring the economic contraction in the US, albeit with a slight delay. This is visible in [Figure 2](#), which displays the IRFs of a set of global indicators to the contractionary US monetary policy shock reported in [Figure 1](#) (IRFs are obtained from the same BVAR model). The broad picture is that there are strong spillovers from the US to the global economy to both real and nominal variables. OECD industrial production and global economic activity contract, with the trough of the former matching that of US output – around -2.5%.

²⁷In the benchmark model, we only include the import/export ratio and traded volumes to avoid collinearity problems. IRFs for imports and exports with a similar model are reported in [Miranda-Agrippino and Ricco \(2017\)](#).

²⁸This composite index obtained from CBC is computed as the difference between the equity exposure index and the bond exposure index. The two indexes are based on the balance sheet exposure of all investors by type in the relevant asset class.

FIGURE 2: 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 – 2018:09. BVAR(12) with asymmetric conjugate priors. Shaded areas are 68% and 90% posterior coverage bands. These responses are estimated jointly to those reported in the previous figure. The response of the policy indicator appears in both figures for readability.

OECD CPI declines, and the peak effect is of the same scale as its US counterpart – around -0.5%. Commodity prices, especially oil price, also contract.

The US dollar appreciation is visible in the exchange rate against three of the major currencies – the Euro, British Pound sterling, and Japanese Yen. The average interest rate differential between 15 advanced economies and the US falls by 0.7 percentage points on impact and does not revert for at least 18 months. This means that, on average, non-US central banks raise their interest rates by roughly 30bp in response to a

100bp movement in the US policy indicator. The contraction in the differential persists for at least one year.

Global risk appetite falls, and equity holdings decrease in both the US and the rest of the world, suggesting worldwide portfolio rebalancing towards safe assets (risk-off). These adjustments lead to a global contraction in cross-border flows, inducing outflows and immobilizing capital. The deterioration of global economic conditions and portfolio rebalancing out of risky assets put downward pressure on foreign asset prices, and the world's stock markets revise downwards.²⁹ Financial conditions tighten on impact, pointing to an increase in short-term rate spreads and activation of the financial channel.

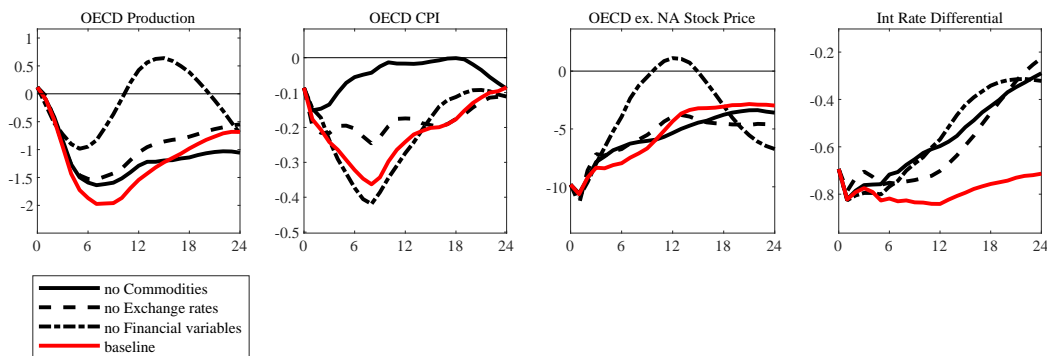
The landscape view of the response of global economy to US monetary policy provides a powerful image of the Fed as a global central bank. Interestingly, our results are consistent with [Rey \(2013\)](#)'s 'global financial cycle' argument: the dynamics of stock prices and other financial variables in the US and in the global economy appear to be synchronised and financial conditions deteriorate. These responses are also compatible with the risk-taking and credit channels of monetary policy ([Bruno and Shin, 2015b](#)): a contractionary shock shrinks asset demand and increases risk premia. Financial spreads increase, followed by a deterioration in financial and credit market conditions. A fall in asset prices pushes financial intermediaries to de-leverage to meet their value-at-risk constraints, and it further contracts the economy. Results in this section show that the financial channel operates not only domestically but also globally. We further investigate these mechanisms in the next sections by looking at advanced and emerging economies separately.

3.3 Disentangling the Channels

To gauge the importance of the various channels at play in the international propagation of the shock, we perform a counterfactual exercise (see, for example [Ramey, 1993](#) and [Uribe and Yue, 2006](#)) in which we shut down the feedback from specific endogenous variables that are thought to capture some channels of interest. In particular, we would

²⁹This index is a weighted average of stock prices in advanced economies excluding North America, so the commonality with US stock prices is not mechanical.

FIGURE 3: CHANNELS OF TRANSMISSION, GLOBAL ECONOMY



Note: Lines correspond to impulse responses obtained with the baseline specification (solid red); assuming the Brent crude and commodity prices do not react (solid black); exchange rates do not react (dashed black); financial conditions, risk appetite, cross-border flows, the excess bond premium, and VIX do not react (dashed-dotted black). Shock is normalised to induce a 100 basis point increase in the 1-year rate. High-frequency identification. Sample 1990:01 – 2018:09. BVAR(12). Equity and fixed-income holdings are not in the endogenous set to avoid collinearity issues.

like to answer the following question: how would the response of a variable of interest, e.g. CPI or industrial production in a foreign economy, differ if the U.S. monetary policy did not have a direct effect on exchange rates, liquidity, or commodity prices?

We proceed by selectively zeroing out the transmission coefficients of estimated VAR models on variables of interest and comparing the response of this modified system to our pre-zeroing-out benchmark. This back-of-the-envelope exercise can give us a sense of the relative importance of selected variables in the transmission of the shock.³⁰

Specifically, we employ the VAR model estimated in this section and sequentially shut down the following variables: (i) commodity and oil prices, (ii) nominal exchange rates, and (iii) some of the financial variables (financial conditions, risk appetite, and cross-border flows). This reveals the importance of commodity prices, the exchange rate channel, and the financial channel.

Figure 3 reports the median responses (without bands) for our set of experiments on the global economy.³¹ Two results stand out. First, OECD industrial production and the stock price contract less and rebound more quickly when the endogenous responses of financial conditions, risk appetite, and cross-border flows are shut. These results suggest that the financial channel plays a significant role in global spillovers, following

³⁰Results in this section are not to be interpreted as a policy exercise, since they are subject to Lucas' critique.

³¹A full set of responses can be found in the online appendix B.3.

the deepening of financial integration that started in the 1990s.

Second, the response of CPI becomes immaterial when oil and commodity prices cannot respond to the shock. It highlights that nominal contractionary effects are possibly due to the response of oil and commodities and their importance in the headline inflation basket. Once their effect is factored out, the upward pressure from the pass-through of higher dollar prices and the downward pressure from weaker demand roughly balance out. Finally, the role of three major exchange rates seems to be limited – they affect CPI and the stock price marginally and only in the medium run. No responses of the interest rate differential are qualitatively different relative to the baseline when we shut down any of the transmission channels. It suggests that no channel is predominant in explaining the transmission of U.S. policy shocks to the short-term rate spreads between the US and other advanced economies.

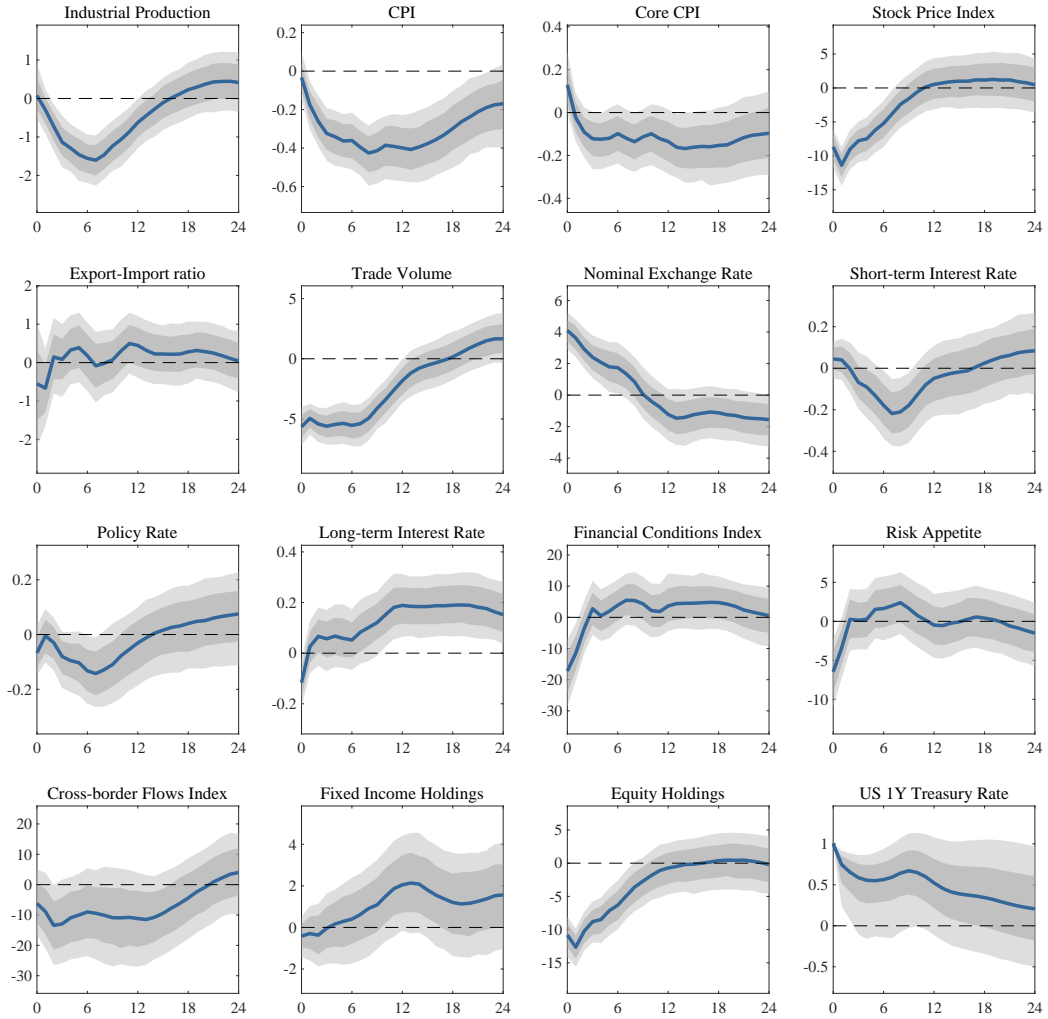
There are two caveats to the analysis in this section. First, some of the variables (for example, OECD indicators) mechanically capture the direct response of the US economy. Second, results only hold for global aggregates: they can mask large heterogeneity across countries in terms of cyclical positions, structural features, and financial market conditions, all of which could be important determinants of differential sensitivity to the shock. We further explore these dimensions in the next sections.

4 Transmission to Advanced Economies

We now focus on the effects of US monetary policy on advanced economies. In doing so, we study the responses to a US tightening obtained in a set of US-periphery bilateral VARs that include one of the advanced economies at the time. We estimate these bilateral systems for all 15 advanced economies in our sample (see Table 1 for a list of the countries included in our analysis). In these models, the asymmetric priors rule out a direct response of US variables to economic conditions in a periphery country, while spill-back effects via the global variables are still allowed. We present median IRFs, aggregated across countries, to a contractionary monetary policy shock.³² The US monetary policy shock is normalised to induce a 100bp increase in our policy indicator,

³²The IV used for identification of the MP shock and the methodology used for the aggregation of IRFs into the responses of the median advanced economy are discussed in Section 2.2.

FIGURE 4: IMPULSE RESPONSES OF THE MEDIAN ADVANCED ECONOMY



Note: Median responses of 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 reported in Table 1. BVAR(12) with asymmetric conjugate priors. Shaded areas are 68% and 90% posterior coverage bands.

the 1-year Treasury constant maturity rate. Importantly, since the system is linear, responses to expansionary and contractionary shocks are symmetric.

4.1 Median Responses of Advanced Economies

Figure 4 displays the impulse responses of the median advanced economy. Following a contractionary MP shock in the US, the currency of the median advanced economy depreciates. The demand-reducing effect from the US offsets the expenditure-switching effect: the overall trade volume drops while the export-import ratio does not change

significantly.

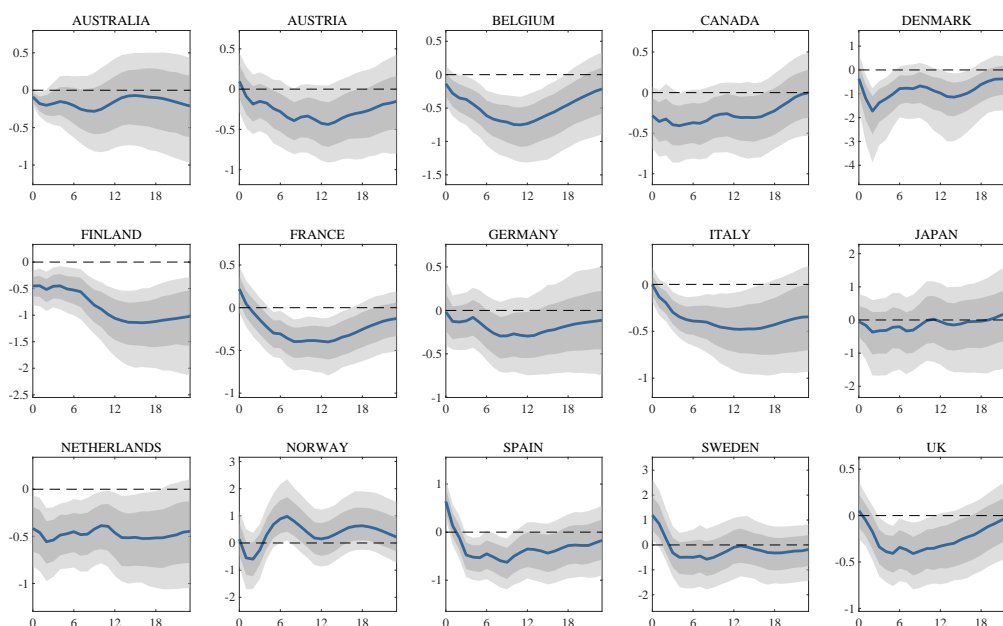
The US policy shock transmits to both real and nominal variables in the median advanced economy. There is a sharp decline in domestic industrial production, accompanied by a very persistent drop in CPI. Core CPI also falls, though it is only significant at the 68% level. The policy rate rate does not move on impact but subsequently eases for around 6 months. This is compatible with policy easing of a central bank responding to deteriorating internal conditions and following the Taylor rule. The easing is transmitted to the short-term interest rate, while the the long-term rate moves up, inducing a steepening of the yield curve. This indicates that movements in risk premia impair the transmission of the policy change to the long-end of the yield-curve, and hence to the economy (a similar disconnect but between short rates and monetary policy rates for emerging economies has been reported by [Kalemlı-Özcan, 2019](#)). Indeed, the economic contraction is sizeable but smaller than the one suffered by the global and the US economies (-2.5% in industrial production and -0.5% in CPI). Notably, flexible exchange rates and policy easing partially insulate the advanced economy, yet the US monetary shock contracts output in the median advanced country. Cross-border flows indicate outflows while financial conditions and risk appetite deteriorate, and investors switch their portfolios from risky to safe assets. This suggests both a portfolio rebalancing across assets and a risk-rebalancing across countries.

At the country level, responses are fairly homogeneous and do not show the degree of heterogeneity previously reported. This provides robustness to our results and justifies the choice of pooling across advanced economies to present median estimated IRFs. [Figure 5](#) shows the response of CPI to a contractionary US MP shock for 15 countries in our sample.³³ CPI is contracting for at least 11 out of 15 economies and the responses of the remaining countries are either not significant or marginally significant. Interestingly, Australia and Norway are commodities exporters.

Financial variables also respond in a strongly homogeneous way across countries. Stock prices ([online appendix B.5](#)) contract in all 15 countries, and the long-term government bond yields ([online appendix B.6](#)) shift upwards for all except Belgium and Spain. Cross-border flows ([online appendix B.7](#)) dry up with only few exceptions:

³³These 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 country itself.

FIGURE 5: RESPONSE OF CPI IN ADVANCED ECONOMIES

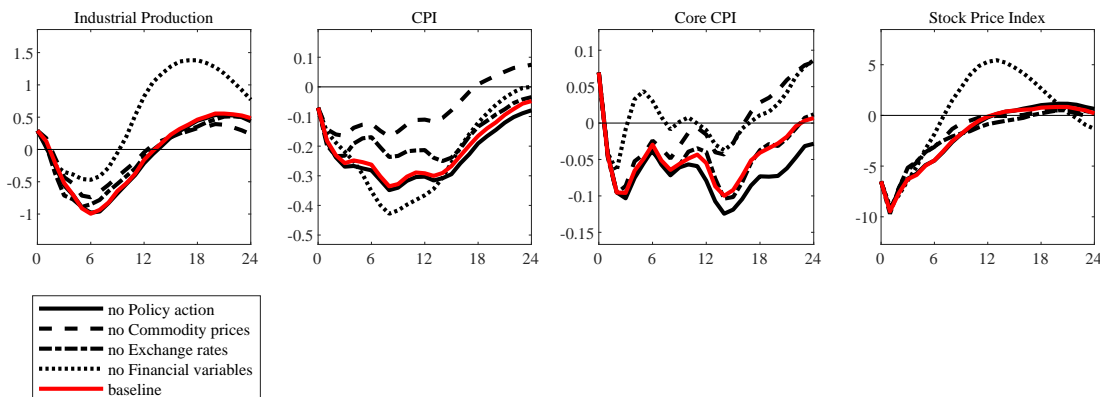


Note: Responses of CPI in 15 advanced economies to a contractionary US monetary policy shock, normalised to induce a 100 basis point increase in the 1-year rate. High frequency identification. Sample reported in Table 1. BVAR(12) with asymmetric conjugate priors. Shaded areas are 68% and 90% posterior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

France, Germany, Sweden, and UK. All financial variables display identical dynamics with both the US and the global economy – we read these results as a strong indication of credit-channel effects from the global financial cycle.

In sum, a contractionary US monetary policy shock leads to a recession in advanced economies. The financial channel seems to play a significant role in the transmission, given strong co-movements of financial variables with the US counterparts. As the global financial cycle negatively affects financial conditions, cross-border flows, and asset prices, the developed world suffers from credit shortages and the resulting contraction of the real economy. Traditional trade channels do not change the outcome substantially, as price and demand effects seem to offset each other. Central banks attempt to counteract the recessionary pressure by lowering interest rates marginally, but they tend to fail in their price stabilisation mandates: prices do not revert for at least 18 months.

FIGURE 6: CHANNELS OF TRANSMISSION, ADVANCED ECONOMIES



Note: Lines correspond to impulse responses obtained with the baseline specification (solid red); assuming the policy rate does not react (solid black); the Brent crude and commodity prices do not react (dashed black); exchange rates do not react (dashed-dotted black); financial conditions, risk appetite, cross-border flows, the excess bond premium, and VIX do not react (dotted black). Shock is normalised to induce a 100 basis point increase in the 1-year rate. High-frequency identification. Sample reported in Table 1. BVAR(12). Equity and fixed-income holdings are not in the endogenous set to avoid collinearity issues.

4.2 Disentangling the Channels

We further assess the importance of various transmission channels at play by selectively zeroing out the coefficients of some of the variables of interest in the estimated models, as done in the previous section. Along with the three sets of variables we examined in the global case – commodity and oil prices, exchange rates, and all financial variables – we also shut down the policy rate of advanced economies, as it is informative about the reaction of the monetary authority. This allows to assess the relative importance of the policy response, commodity prices, the exchange rate channel, and the financial channel in the transmission of the US monetary policy shock.

Figure 6 shows the median responses (without bands) for our set of experiments on 15 advanced economies.³⁴ Interestingly, as in the global economy case, industrial production and stock prices revert to equilibrium quickly and overshoot when the transmission via variables proxying for the financial channel – i.e. financial conditions, risk appetite, and cross-border flows – is shut. Conversely, headline CPI shows a mild contraction when oil and commodity prices are not allowed to propagate the shock. Interestingly, core CPI, which does not contain energy prices, shows a mild and not significant re-

³⁴A full set of responses can be found in Figure B.10, in the online appendix.

response with weaker dependence on commodity prices. The response of core CPI is largely explained by the financial variables and hence correlates with the output contraction. Absent that, there is an expansion of core prices possibly due to pass-through effects.

Financial variables and cross-border flows seem to be key in the transmission of the US shock to the stock market and real economy. Oil and commodity prices provide deflationary pressures on headline prices in advanced economies. The effects of central bank actions and exchange rates appear to be relatively small, possibly due to the movements in risk premia discussed above. The broad picture seems to indicate that the transmission of the US monetary policy shock activates financial channels that limit the action of central banks in advanced economies. However, the overall effect of the financial channel is mild and monetary policy can still operate via traditional inflation targeting and by easing economic conditions in response to adverse external shocks – this would correspond to the case of intermediate financial spillovers, in the classification proposed by [Gourinchas \(2018\)](#).

5 Transmission to Emerging Economies

Since the wave of financial crises in the emerging markets in the late 1990s there has been a step change in macroeconomic policy, with most central banks embracing floating exchange rates, the build up of large foreign exchange reserves, and a shift in government borrowing from foreign to national currencies.³⁵ Despite an improved resilience to external shocks, emerging markets are still thought to be more vulnerable to US monetary policy spillovers and deterioration of global financial conditions (see for example [Carstens and Shin, 2019](#)).

In this section, we try to provide an empirical assessment of the vulnerability of emerging markets to changes in US monetary policy. Emerging, developing and frontier economies are potentially a largely heterogeneous set of countries. Indeed, they can differ along several dimensions such as the monetary policy framework adopted, the

³⁵Emerging economies in our analysis have less flexible exchange rate regimes than the AEs. None of our EMEs is classified as a pure floater according to the classification of [Ilzetzki et al. \(2019\)](#) – we treat Czech Republic, Hungary, and Poland as floaters, since their currencies are anchored to the Euro. However, very few of them have hard pegs. We discuss this dimension in detail in Section 7.

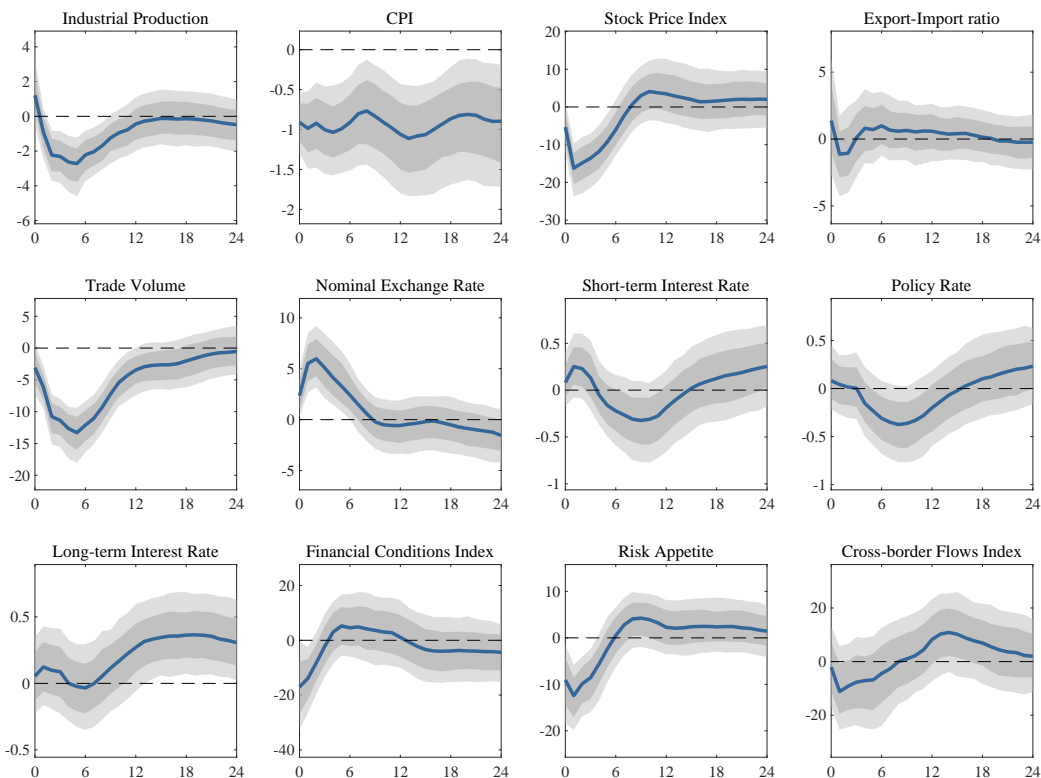
dependence on dollar denominated funds, the degree of invoicing in dollars, the size of their internal markets, and the degree of openness to capital flows. We explore these dimensions in steps. First, in this section, we discuss median responses to US monetary policy actions and contrast them with the advanced economies. As in the previous section, we present median IRFs, aggregated across countries, to a contractionary monetary policy shock. We also provide a first assessment of responses at a country level. Then in Section 6 we look at some of the largest emerging markets that are likely to display very different policy frameworks, and contrast them to the Euro Area. Finally, in Section 7 we look at the role of different policy regimes by grouping countries by their (i) degree of capital market openness and (ii) exchange rate regimes. Our online appendix reports additional exercises along other structural dimensions such as (iii) dollar trade invoicing and (iv) dollar gross exposure. It is important to stress that in this section and in the following two, since the system is linear, estimated responses to expansionary and contractionary shocks are symmetric. Bear in mind that when studying EMEs the quality and reliability of data may be a serious concern. In the light of this observation the use of a relatively recent sample and the median response is helpful in averaging out and alleviating potential data issues.

5.1 Median Responses of Emerging Economies

In the wake of an unexpected tightening of the US monetary policy stance, the economy of the median emerging country contracts, as shown in Figure 7. The national currency depreciates, indicating that the median emerging economy was adopting flexible exchange rates in the time-sample of interest. Yet, movement in the exchange rate is not enough to insulate the economy from strong spillover effects. The expenditure-switching channel is largely dominated by the other channels – demand and financial – and output, prices, and the stock market contract.

Interestingly, the effect of higher prices of imports is dominated by the contraction in demand and possibly subdued commodity prices. Headline inflation responds negatively, immediately, and sharply. The trough response of output in the median emerging economy is around -2.5% and in line with the US economy, while prices react even more strongly than in the US, with a very persistent drop of 1%. It is worth noticing that sev-

FIGURE 7: MEDIAN RESPONSE OF EMERGING ECONOMIES



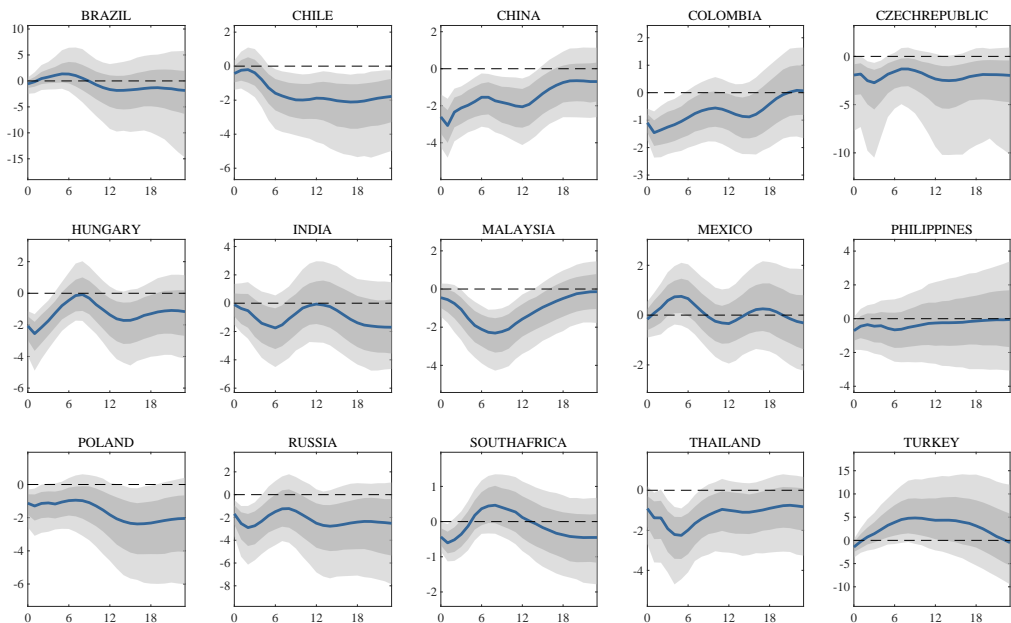
Note: Median responses of 15 emerging economies to a contractionary US monetary policy shock, normalised to induce a 100 basis point increase in the 1-year rate. High frequency identification. Sample reported in Table 1. BVAR(12) with asymmetric conjugate priors. Shaded areas are 68% and 90% posterior coverage bands.

eral countries in this sample are commodity exporters, and hence in aggregate the joint effect of lower commodity prices and lower aggregated demand puts downward pressure on the economy. These results are consistent with the findings in the literature, e.g. [Mackowiak \(2007\)](#) and [Iacoviello and Navarro \(2018\)](#), that emerging markets are more vulnerable to external shocks.

The joint contraction of output and prices, in line with the effect of a large demand shock, allows the central bank to lower its policy rate – potentially putting more downward pressure on the domestic currency. Yet, the policy easing is marginally transmitted to short rates but not long rates, suggesting that risk premia are limiting the effectiveness of the policy action. This evidence chimes with [Kalemli-Özcan \(2019\)](#), who argues that capital flows in and out of EMEs are sensitive to fluctuations in global investors’ risk perceptions, induced by changes in the US monetary policy.

Financial conditions and risk appetite deteriorate, while the stock market contracts.

FIGURE 8: RESPONSE OF CPI IN EMERGING ECONOMIES



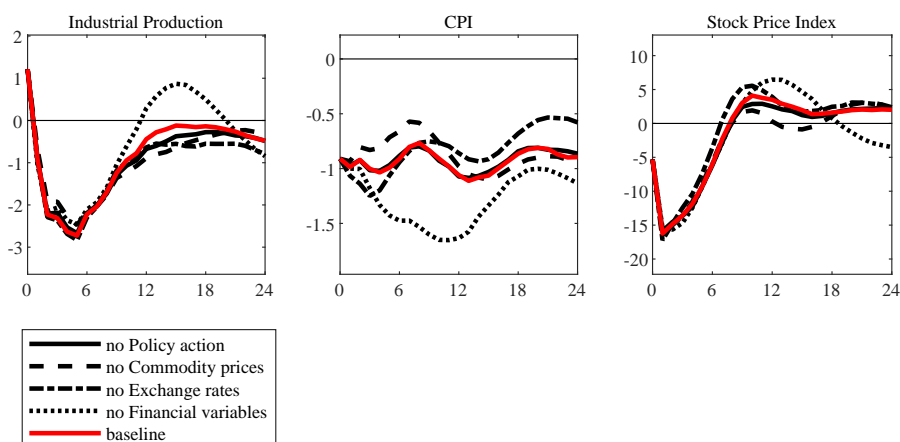
Note: Responses of CPI in 15 emerging economies to a contractionary US monetary policy shock, normalised to induce a 100 basis point increase in the 1-year rate. High frequency identification. Sample reported in Table 1. BVAR(12) with asymmetric conjugate priors. Shaded areas are 68% and 90% posterior coverage bands.

The response of cross-border flows indicates capital outflows, although this is not significant in the aggregate.³⁶ Importantly, exchange-rate and interest-rate changes move in the same direction: the currency depreciates against the dollar, while long-term yields rise and bond prices fall. This co-movement suggests that sovereign bonds have higher durations in dollar terms than in local currency terms, and hence are riskier to international investors (see discussion in Carstens and Shin, 2019).

Unlike the case of advanced economies, the median responses mask a larger degree of heterogeneity in some of the key variables. The response of CPI to a contractionary shock induces a price decline for 11 out of 15 economies (see Figure 8). Responses of Brazil, Mexico, Philippines, and Turkey are not significant at any levels. Industrial production generally shrinks, and stock prices tumble in all countries except Brazil and Malaysia (Figure B.11, in the online appendix). Interestingly, exchange rates, interest rates and cross-border flows show heterogeneity across countries. Long-term government

³⁶In general, emerging economies in our analysis have stricter capital controls than the advanced ones. The median value of Chinn-Ito index for AEs is 0.965, while it is only 0.338 for EMEs. It roughly indicates that the degree of openness to capital for the former is above top 5% in the world, while the latter is only 34%. Table A.8 in the online appendix reports average values of the index for all countries.

FIGURE 9: Channels of Propagation



Note: Lines correspond to impulse responses obtained with the baseline specification (solid red); assuming the policy rate do not react (solid black); the Brent crude and commodity prices do not react (dashed black); exchange rates do not react (dashed-dotted black); financial conditions, risk appetite, cross-border flows, the excess bond premium and VIX do not react (dotted black). Shock is normalised to induce a 100 basis point increase in the 1-year rate. High-frequency identification. Sample reported in Table 1. BVAR(12).

bond yields tend to move upwards, but responses are not significant in some cases (Figure B.12, in the online appendix). Cross-border flows are rather heterogeneous and country-specific risks seem to play a role among EMEs (Figure B.13, in the online appendix).

To disentangle the role of various transmission channels, we repeat the ‘zeroing-out’ experiment for the median EME. As with the AEs, we study the channels of transmissions of the US monetary policy shock by selectively zeroing-out the cross-coefficients of key variables: the policy rate, commodity and oil prices, exchange rates, and all financial variables. This provides evidence on the relative importance of the central bank’s policy reaction, commodity prices, the exchange rate channel, and the financial channel in the transmission of the US shock.³⁷ While not in contradiction with what we found for AEs, the counterfactual results reveal a limited differential role for each group of variables (Figure 9).³⁸ Output still bounces back more when the financial variables do not react, but now it happens only after 9 months. Shutting down oil and commodity prices reduces the extent of the fall in headline inflation, but only marginally. No channel seems to be predominant in the transmission to stock prices. Our interpretation

³⁷As discussed in section 3.3, we use the estimated coefficients on the model presented in this section, but set all coefficients on variables of interest in all equations to zero, including their impact responses.

³⁸The full set of responses can be found in the online appendix, Figure B.14.

is that the shock transmits rather evenly across the economy and different groups of variables capture similar mechanisms (or are rather ineffective, as the policy stance). It is worth observing that several of our economies are commodity exporters: hence, effects on price, production, and the stock market are likely to be transmitted via several variables in a similar way.

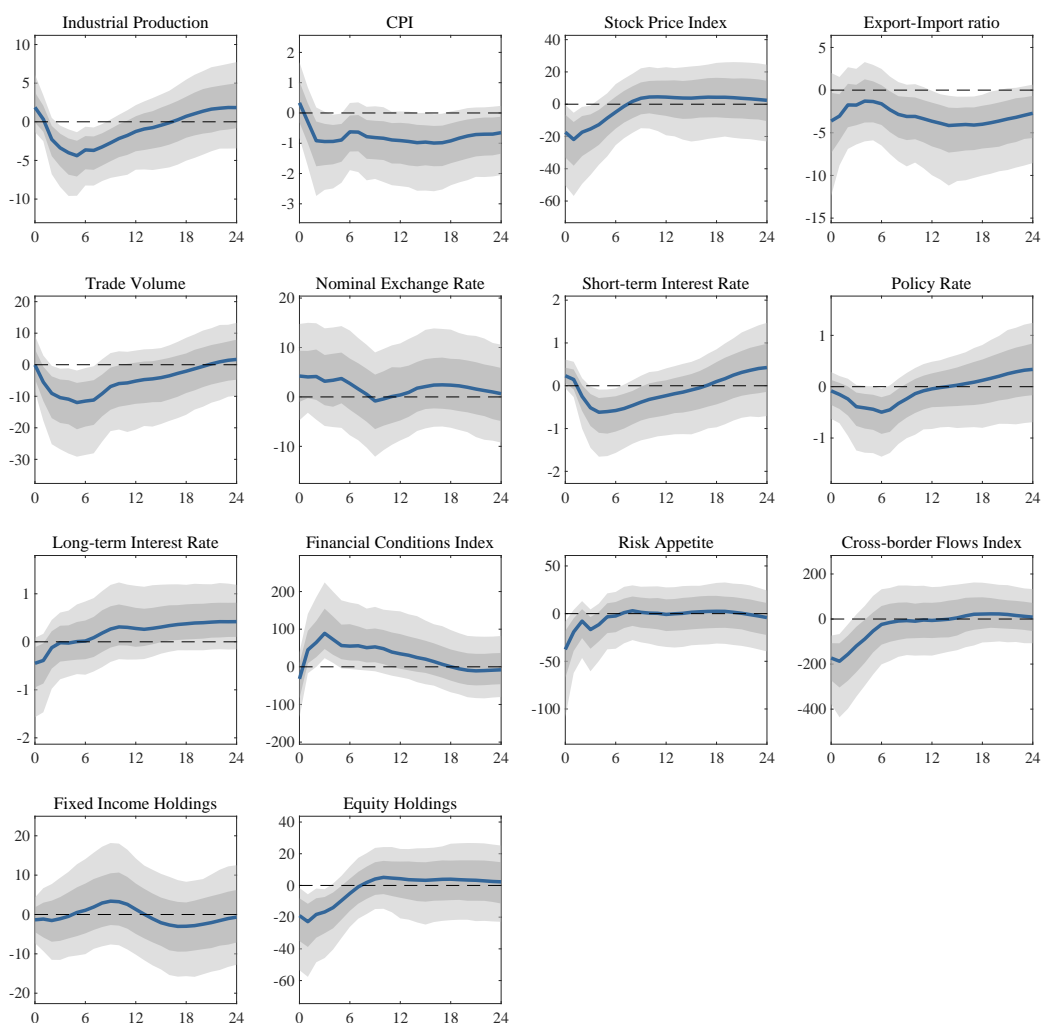
To summarise, emerging markets contract in response to a US monetary tightening. Stock prices, exchange rate, financial conditions, and risk appetite strongly co-move in the US, advanced, and emerging economies. Spillover effects are stronger for EMEs than AEs, with trough responses now almost one-to-one-with the US counterparts. As for advanced economies, prices fall in the median responses and across most of the EMEs in our sample. It suggests that the increase in imported prices is dominated by recessionary pressures at home. At least in the median country, as in the case of AEs, the overall effect of the financial channel is modest and monetary policy can operate by easing economic conditions in response to adverse external shocks (see discussion in [Gourinchas, 2018](#)). Importantly, responses of cross-border flows, policy rates, interest rates, and exchange rates are more heterogeneous than for AEs. This reflects more diverse structural characteristics, policy regimes, and the role of country-specific risks among EMEs. In the following sections, we explore some of these features.

6 Transmission to the Euro Area and Major EMEs

Are different policy regimes responsible for the heterogeneity we observe in the responses presented in the previous section? As a first step to test this hypothesis, we focus on the responses of some of the largest emerging economies with different policy regimes – Mexico, China, and India – and benchmark them against the Euro Area, a large economy with a flexible exchange rate and open capital markets. This exercise is helpful in analysing three different policy regimes: open capital markets and a floating rate (Mexico), closed capital markets and a crawling exchange rate (India), closed capital markets and a pegged exchange rate (China).

Figure 10 displays the responses of Euro Area aggregates to a contractionary US monetary policy shock. Similarly to the median advanced and emerging economies, the

FIGURE 10: EURO AREA



Note: Responses of Euro Area to a contractionary US monetary policy shock, normalised to induce a 100 basis point increase in the 1-year rate. High frequency identification. Sample 1999:01 – 2018:09. BVAR(12) with asymmetric conjugate priors. Shaded areas are 68% and 90% posterior coverage bands.

Euro Area also suffers recessionary effects. Output, prices, and the stock market all contract. Trade volume drops by more than in the US at the trough, and the export-import ratio also falls, indicating the prominence of the demand-reducing effect over the expenditure-switching one. The ECB’s policy rate responds to deteriorating internal conditions consistently with a Taylor rule and the easing is transmitted through the yield curve to longer maturities. The role of risk premia is marginally visible at longer horizons in the response of the long-term rate. The policy easing improves financial conditions, but it is not enough to stabilise the economy: CPI does not fully revert at

all horizons. Capital outflows and devaluation of equities are more severe for the EA than the median AE. The negative responses in capital flows, risk appetite, and equity holdings not only co-move but also display the same dynamics of the global economy. Overall, results suggest that the Euro Area experiences a substantial decline in economic activity due to reduced foreign demand and deteriorating internal conditions.

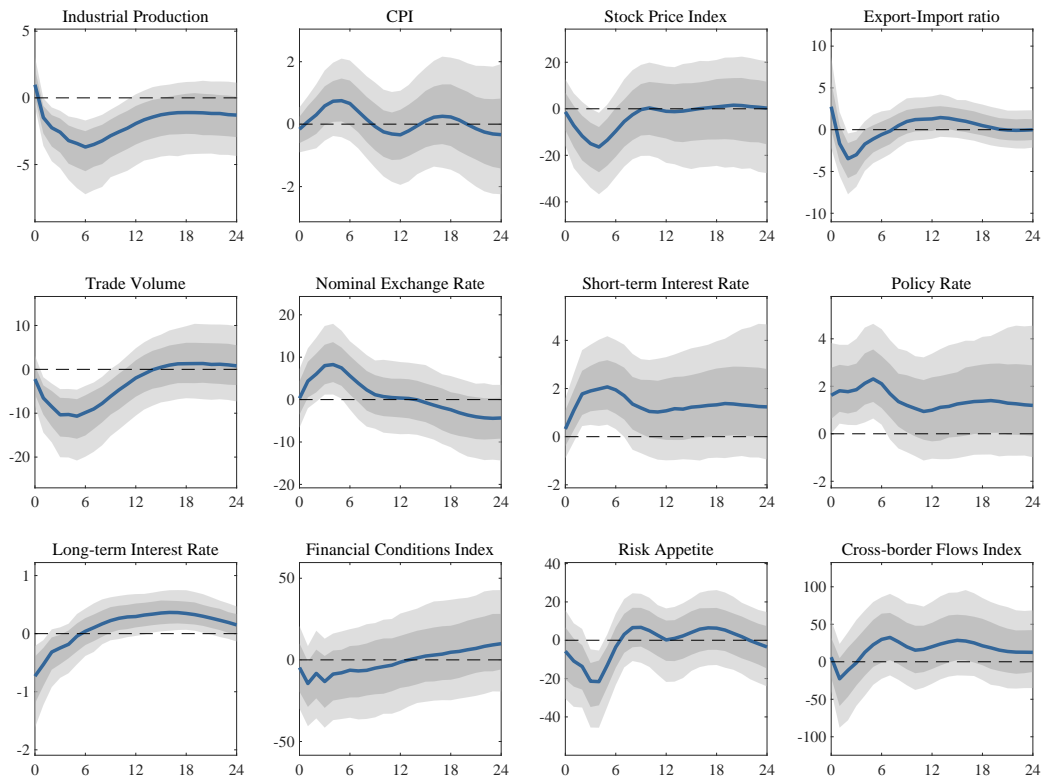
Now we focus on the responses of three major EMEs – Mexico, China, and India. Mexico is a managed floater and has one of the most flexible exchange rate regimes among EMEs, according to the classification of [Ilzetzki et al. \(2019\)](#). On average, across the sample, its Chinn-Ito index puts the country among the top third economies in terms of capital mobility. It is the most open capital market among non-European EMEs in our sample.³⁹ China on average employs a pre-announced crawling peg with strictly controlled capital markets and it has close ties to the US market in terms of trade and finance. In India, capital controls are as restrictive as in China, but the exchange rate regime is more flexible. India is relatively less connected to the US economy than the former two.⁴⁰

Figure 11 shows the response of Mexico to a US tightening. As the Peso depreciates, Mexico’s policy rate, followed by the short-term rate, rises. This is consistent with the ‘fear of floating’ argument: the Bank of Mexico is trying to shield its economy from excessive capital outflows. It appears successful: cross-border flows are steady and the contraction in risk appetite is short-lived. Financial conditions remain fairly stable as the monetary policy tightening contains credit spreads. However, with financial stability comes the cost of pushing the domestic economy into a recession: industrial production and stock prices contract. The response of headline inflation is insignificant, suggesting that the downward pressure on prices coming from the internal deflation offsets the upward pressure coming from the exchange rate pass-through. Mexico, similarly to the Euro Area, experiences a decline in exports due to lower foreign demand. Yet the very stark policy response is indicative of the extent to which the exposure to the US and to

³⁹Table A.8 in the online appendix reports the degree of openness to capital for the countries in our sample.

⁴⁰[Ilzetzki et al. \(2019\)](#) classifies both China and India as crawling peggers: their sample median values are 5 and 7, respectively. The sample average value of the [Chinn and Ito \(2006\)](#) index is 0.166 for both countries. Though roughly 86% of India’s exports and imports are invoiced in dollars, its gross dollar exposure is the second lowest among our sample of 15 EMEs. [Gopinath \(2015\)](#) and [Bénétrix et al. \(2015\)](#) for details.

FIGURE 11: MEXICO

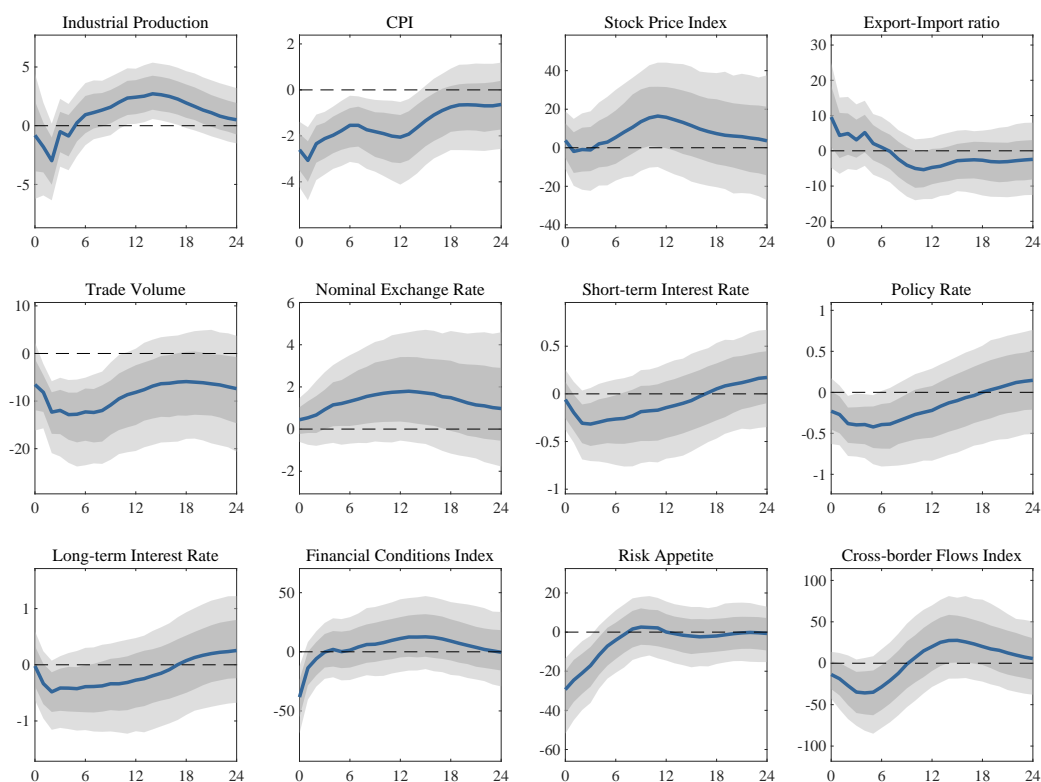


Note: Responses of Mexico to a contractionary US monetary policy shock, normalised to induce a 100 basis point increase in the 1-year rate. High frequency identification. Sample 1998:11 – 2018:02. BVAR(12) with asymmetric conjugate priors. Shaded areas are 68% and 90% posterior coverage bands.

capital flows limits the policy space of the central bank.

Next, we report China’s responses in Figure 12. Consistently with the crawling peg adopted by the People’s Bank of China (PBC), the exchange rate depreciates slowly and only slightly. Noticeably, it does not revert at all horizons, suggesting a potential ‘fear of appreciation’ due to concerns about the trade balance. The policy rate shows a loosening of the policy stance that is transmitted through the yield curve. In the absence of open capital markets, the policy stance is fully effective. However, cross-border flows denote an outflow of capital from China – potentially reflecting unsterilised market interventions from the PBC. The policy response insulates the economy: contraction in output is short-lived and followed by some expansion possibly due to the combined internal easing and the currency devaluation. Stock prices do not react on impact. Yet risk appetite and financial conditions deteriorate. Prices decline significantly on impact and remain below trend for over 16 months.

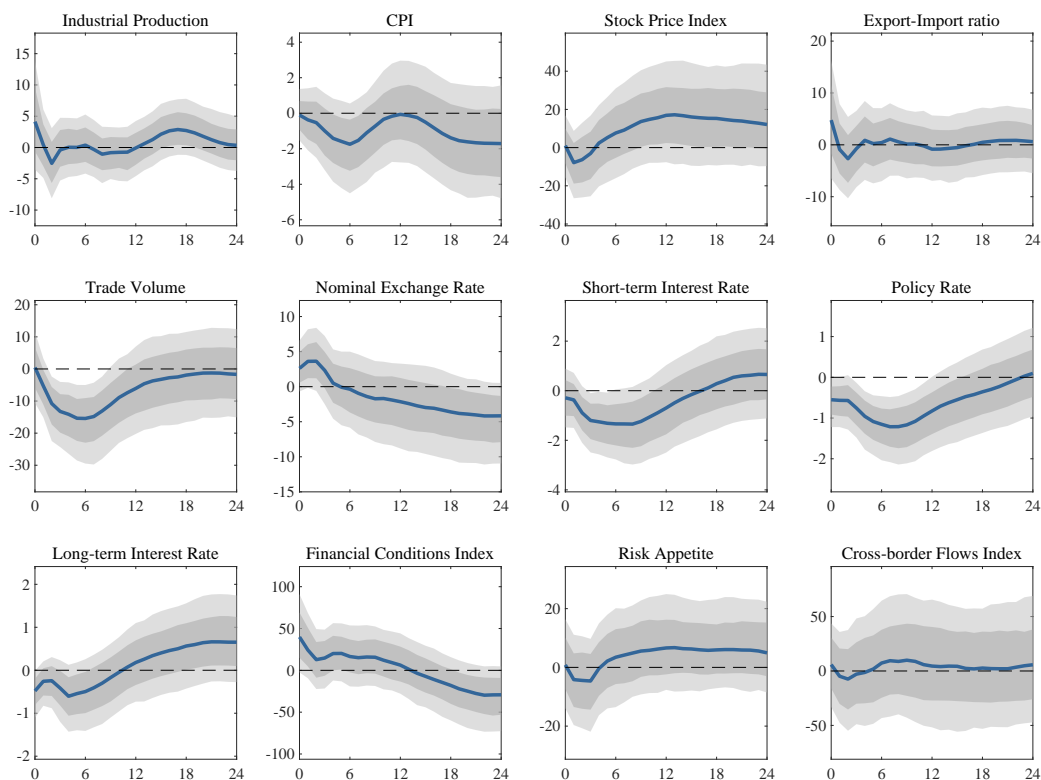
FIGURE 12: CHINA



Note: Responses of China to a contractionary US monetary policy shock, normalised to induce a 100 basis point increase in the 1-year rate. High frequency identification. Sample 1994:08 – 2018:08. BVAR(12) with asymmetric conjugate priors. Shaded areas are 68% and 90% posterior coverage bands.

Finally, in India policy spillovers to a contractionary US shock are limited (see Figure 13): industrial production, CPI and the stock market do not react significantly to the shock at any horizons. The Reserve Bank of India (RBI) loosens its monetary policy stance and cross-border flows remain stable. The lack of movement in capital flows may not be surprising, since India strictly controls its capital market. The policy loosening transmits to short and long rates. The exchange rate first depreciates but quickly reverts to equilibrium. Trade volume contracts significantly, but the overall effect on output seems to be offset by an increasing internal demand, driven by the policy stimulus. India seems to be able to set an autonomous monetary policy and fully sterilise the shock. This result suggests that other structural dimensions might also play a role in the transmission of the US shock: for instance, India's gross dollar exposure is the second lowest among our sample of EMEs, according to [Bénétrix et al. \(2015\)](#). Thanks to a modest economic and financial integration between its economy and the US, the

FIGURE 13: INDIA



Note: Responses of India to a contractionary US monetary policy shock, normalised to induce a 100 basis point increase in the 1-year rate. High frequency identification. Sample 1994:05 – 2018:04. BVAR(12) with asymmetric conjugate priors. Shaded areas are 68% and 90% posterior coverage bands.

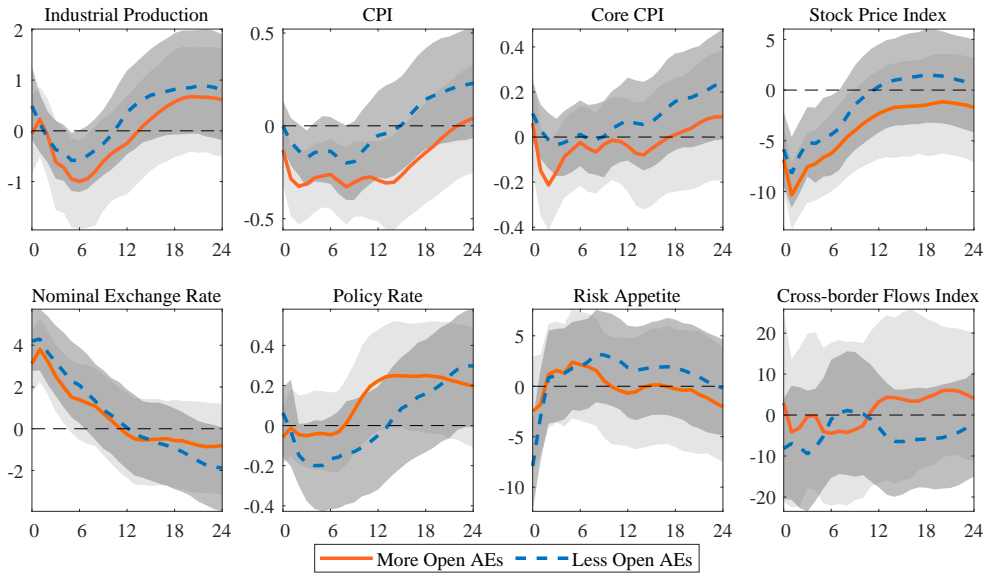
RBI might be facing a weaker trade-off compared to Mexico and China.

Our country-level analyses provide evidence of the role of different policy regimes in the transmission of the shock. Spillover effects are more severe in a relatively open capital market (Mexico) than in more closed ones (China and India). Differences in responses of the latter two EMEs point out that other dimensions, e.g. gross dollar exposure and trade linkages, might also play an important role.

7 Capital Controls and FX regimes

In this section, we further explore the role of different policy regimes by grouping countries by their (i) degree of openness to capital and (ii) exchange rate regimes, the two key dimensions of the classical trilemma. First, we compare open to less-open capital markets by grouping them on the basis of [Chinn and Ito \(2006\)](#)'s index and by studying

FIGURE 14: ADVANCED ECONOMIES WITH MORE V. LESS OPENNESS TO CAPITAL



Note: Orange line – median responses of 5 AEs (Canada, Denmark, Germany, Netherlands, and UK), whose overall capital restriction corresponds to the bottom 1/3 among 15 advanced economies. Dotted blue line – median responses of 6 AEs (Australia, France, Italy, Norway, Spain, and Sweden), whose overall capital restriction corresponds to the top 1/3. Data on capital restrictions are from the Chinn-Ito index. Shock is normalised to induce a 100 basis point increase in the 1-year rate. BVAR (12). Shaded areas are 90% posterior coverage bands.

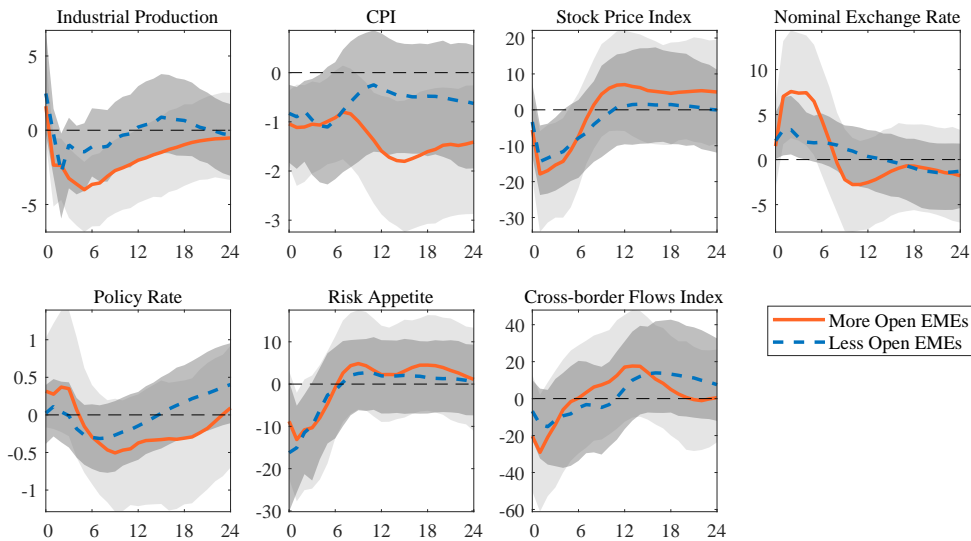
advanced and emerging markets separately.⁴¹ Then, we compare median responses of relative peggers, managed floaters, and free floaters by adopting the classification of Ilzetzki et al. (2019). We also briefly discuss the role of dollar trade invoicing and gross dollar exposure in the transmission of US monetary policy.

In Figure 14, we report the median responses of AEs with more and less openness to capital, based on the Chinn-Ito index, which measures the degree of de jure capital market openness of a country. To construct open and less-open country groups, we calculate the arithmetic average of the Chinn-Ito index over the sample period for each country.⁴² Then, we classify countries in the top tercile as more open capital markets and countries in the bottom tercile as less open ones. The group of more open capital markets consists of 5 AEs: Canada, Denmark, Germany, Netherlands and the UK; while the relatively less open markets are Australia, France, Italy, Norway, Spain, and

⁴¹Pooling all countries and constructing groups based on average values of Chinn and Ito (2006)'s index would simply return the division between AEs and EMEs.

⁴²We use the *ka_open* index, which is a continuous measure and ranges between 0 and 1. The higher the number is, the more open a country's capital market is.

FIGURE 15: EMERGING ECONOMIES WITH MORE V. LESS OPENNESS TO CAPITAL



Note: Orange line – median responses of 5 EMEs (Chile, Czech Republic, Hungary, Mexico, and Poland), whose overall capital restriction corresponds to the bottom 1/3 among 15 advanced economies. Dotted blue line – median responses of 5 EMEs (Brazil, India, South Africa, Thailand and Turkey), whose overall capital restriction corresponds to the top 1/3. Data on capital restrictions are from the Chinn-Ito index. Shock is normalised to induce a 100 basis point increase in the 1-year rate. BVAR (12). Shaded areas are 90% posterior coverage bands.

Sweden.⁴³ Importantly, all countries in both groups adopt a flexible exchange rate regime during our sample period, 1990 – 2018. We obtain median responses of each group by aggregating the IRFs from the countries’ bilateral models as described in Section 2.4.

Figure 14 shows that spillover effects from the US are relatively stronger for economies that have more open capital markets. Responses of output and CPI are (marginally) more negative, significant, and persistent if the capital markets are more globally integrated. Responses of other variables are mostly identical: co-movements among stock prices, exchange rates, and the risk-appetite are in line with results shown in the previous sections. It is important to stress that all the AEs have a high degree of openness to capital, so the difference between the two groups is only marginal.⁴⁴

Next, we compare the median responses of EMEs with more and less openness to capital. Focusing on EMEs is more informative about the role of capital openness since countries are more heterogeneous in this respect. Indeed, the difference between the two groups is now significantly larger: the average value of the Chinn-Ito index for more and

⁴³Table A.8 in the online appendix contains more information about the classification.

⁴⁴The average value of the Chinn-Ito index for more and less open AEs is 0.998 and 0.897 respectively.

less open EMEs is 0.469 and 0.354 respectively.⁴⁵ Chile, the Czech Republic, Hungary, Mexico, and Poland have more open capital markets, while Brazil, India, South Africa, Thailand, and Turkey have relatively closed capital markets.⁴⁶ Importantly, the two groups do not only differ in terms of capital openness but also in terms other structural features: for example, we find a prevalence of floaters among more open markets and a prevalence of peggers among less open ones.

Differences in spillover effects between EMEs with open and closed capital markets are stark (see Figure 15). Output turns significantly negative for the open markets and the median response stays below trend for almost two years. The output response of less open countries, however, is mostly not significant and reverts quickly. CPI responses of the two groups overlap for 6 months, but only open markets experience a significant fall afterwards. Importantly, cross-border flows contract on impact for more open markets, while they are mostly unresponsive for the other group. Also, even though the nominal exchange rate depreciates for both groups, it depreciates more for the open markets. Responses of cross-border flows and the exchange rates validate our classification. Finally, we find almost no difference in the responses of stock prices, policy rates, and risk appetite.

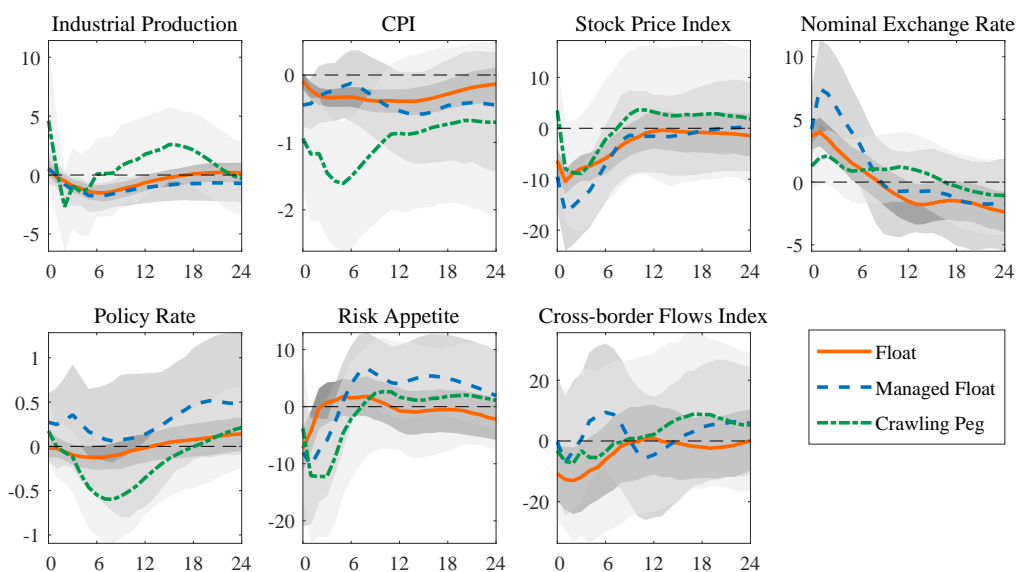
To explore the role of exchange rate regimes, we classify countries into three different groups: (i) floaters, (ii) managed floaters, and (iii) crawling peggers. We assign each country to the regime corresponding to its sample median value of [Ilzetzi et al. \(2019\)](#)'s classification.⁴⁷ In our sample, there are 17 floaters (all AEs except Canada, plus the Czech Republic, Hungary, and Poland), 6 managed floaters (Brazil, Canada, Chile, Colombia, Mexico, and South Africa), and 4 crawling peggers (China, India, the Philippines, and Thailand). As before, we obtain median group responses by aggregating IRFs from the countries' bilateral models. Note that unlike the previous exercise on capital controls, here we use all 30 countries in our sample.

⁴⁵To classify countries, we follow the same approach as the AEs – i.e. we take countries whose sample average of the Chinn-Ito index falls into the top and bottom tercile as more and less open capital markets respectively.

⁴⁶Table A.8 in the online appendix provides additional details.

⁴⁷We use [Ilzetzi et al. \(2019\)](#)'s 'fine' classification to construct the three exchange rate regimes. If a country's sample median value of the index is 14, we treat it as a floater. If the value is 12, it is classified as the managed floater. All values below 12 fall into the crawling peg category. Table A.9 in the online appendix contains more information about our criteria.

FIGURE 16: EXCHANGE RATE REGIMES



Note: Orange line – median responses of 17 floaters (15 advanced economies except Canada, plus Czech Republic, Hungary, and Poland), Dotted blue line – median responses of 6 managed floaters (Brazil, Canada, Chile, Colombia, Mexico, and South Africa), Green dash-dotted line – median responses of 4 crawling peggers (China, India, Philippines, and Thailand). Data on exchange rate regimes are from Ilzetzi et al. (2019). Shock is normalised to induce a 100 basis point increase in the 1-year rate. BVAR (12). Shaded areas are 90% posterior coverage bands.

We compare the median responses of the three different exchange rate groups in Figure 16. First, the exchange rate response validates our classification: it depreciates for the first two groups but does not react for the crawling pegs. A stronger depreciation in the managed float group as compared to the free floaters further corroborates our sample composition. Indeed, managed floaters consist of EMEs, while the majority of free floaters are AEs. Second, the US monetary policy spillover affects all regimes – output, CPI, stock prices, and risk appetite contract in all three groups, but recessionary effects are minimal for the floaters. Crawling peggers seem to suffer the most severe deflation by fully importing the US monetary policy shock. The trough response of output is also the strongest for peggers, although bands are large. The policy response reveals that while floaters (marginally) and peggers (strongly) loosen their policy rates, the managed floaters have to hike them, possibly to avoid capital outflows. This group is indeed formed by countries that combine managed but flexible exchange rates with relatively more open capital markets. Interestingly, the policy rate seems to stabilise capital flows: cross-border flows remain steady for this group. Conversely, floaters

experience significant capital outflows in the absence of the capital controls that shield the peggers.

We conclude this section by conducting two other group analyses based on other measures that are closely related to the exchange rate regime: (i) share of trade invoiced in dollars and (ii) gross dollar exposure. We use data from [Gopinath \(2015\)](#) to classify countries between high and low dollar trade invoicing. We follow [Bénétrix et al. \(2015\)](#) to divide countries between high and low exposure to the dollar.⁴⁸ Here we focus on EMEs, as this is an important dimension for those economies only. As we did for the degree of capital openness, we select countries that are in the top and bottom tercile in terms of the sample average of the two measures, then we compare their median responses.⁴⁹ Figures [B.15](#) and [B.16](#) in the online appendix echo our results in [Figure 16](#): countries with a high degree of dollar trade invoicing/gross dollar exposure display responses that are similar to those of crawling peggers, while economies that are less dependent on the dollar behave similarly to managed floaters. Finally, we conduct a robustness check on capital controls by using a different index, constructed by [Fernández et al. \(2016b\)](#). Results in [Figure B.17](#) in the online appendix are consistent with those in [Figure 15](#) reported above.

To summarise, our results suggest that the degree of openness to capital flows and the exchange rate regime are two important dimensions for understanding the global transmission of US monetary policy. The responses of industrial production and CPI are stronger and more negative for economies that have more open capital markets. Neither flexible nor the ‘middle-ground’ exchange rate regimes can fully insulate economies from US monetary policy shocks that transmit through both financial and classic channels. Importantly, different policy dimensions and country characteristics – exchange rate regime, openness of capital markets, dollar trade invoicing, and gross dollar exposure – appear to be related, and the choice of the regime might be endogenous and determined by country-specific deeper structural features.

⁴⁸[Gopinath \(2015\)](#) reports the fraction of a country’s exports/imports invoiced in a foreign currency. We construct a measure of gross dollar exposure for each country by taking the sum of USD total assets and liabilities as a percentage of GDP from the dataset of [Bénétrix et al. \(2015\)](#).

⁴⁹See [Tables A.10](#) and [A.11](#) in the online appendix for details about the classifications.

8 Asymmetric Effects of US Monetary Policy Shocks

A question that has important policy implications is whether there are asymmetries in the transmission of contractionary and expansionary monetary policy shocks. In the case of US monetary loosening, financial conditions in third countries ease and capital flows into local bonds and risky assets. When these favourable conditions are reversed abruptly, the foreign economy may be exposed to rapid capital outflows with powerful destabilising effects. Such a mechanism may induce ‘fear of floating’, asymmetries in the policy response of foreign monetary authorities to positive and negative US monetary policy shocks, and foreign exchange market interventions to avoid sudden and large depreciations of the currency.

A different argument recently advanced is that when a peripheral country has positive net assets denominated in dollars, a loosening in the US causes the local currency to appreciate vis-à-vis the dollar, making the value of foreign assets fall. The total wealth in the economy shrinks, potentially leading to a contraction in local consumption and investment. This mechanism – often mentioned with reference to China – would explain why we might observe asymmetric responses such as ‘fear of appreciation’ (see discussion in [Georgiadis and Mehl, 2016](#); [Han and Wei, 2018](#)).

While these narratives may match the pattern of some crises in the emerging markets and popularly reported facts, the empirical evidence is still relatively thin. This section provides novel evidence about asymmetry in the macroeconomic responses to US monetary policy tightenings and loosening.

We proceed in two steps. First, we divide our monetary policy instrument into positive (tightening) and negative (loosening) parts. Then we identify the shock in the models presented in the above sections using these two different external instruments. We run this exercise for the US, at the global level, and for advanced and emerging economies. This amounts to assuming that while the system is still linear, tightenings and loosening are two different types of shock with distinct transmissions.⁵⁰ For ease

⁵⁰This has to be seen as a reduced form stylised way to gauge the extent of the different impacts of tightenings and loosening while maintaining large information sets. Alternatively, one could explore the same effects using a Local Projections approach. However, the gain in flexibility in the IRFs could be offset by the increase in the uncertainty of the estimates and the reduction in data points used for the estimation.

of comparison, we flip the loosening response and normalise both shocks to induce a 100 basis point increase in the US 1-year rate. Hence, for instance, a negative response of US production to the loosening shock in the chart means that the actual response is expansionary.

A note of caution is needed here. An important part of our analysis concerns emerging markets. Yet, in looking at emerging countries and splitting the sample of our IV, data issues are likely to be amplified and a few episodes in a few countries can end up driving the results. To mitigate this issue, we narrow the cross-section of countries and extend the sample by dropping variables for which the time series were shorter. This allows us to include the monetary tightening episodes of the 1990s (and their effects) in our estimation.⁵¹

8.1 Asymmetries in the US responses

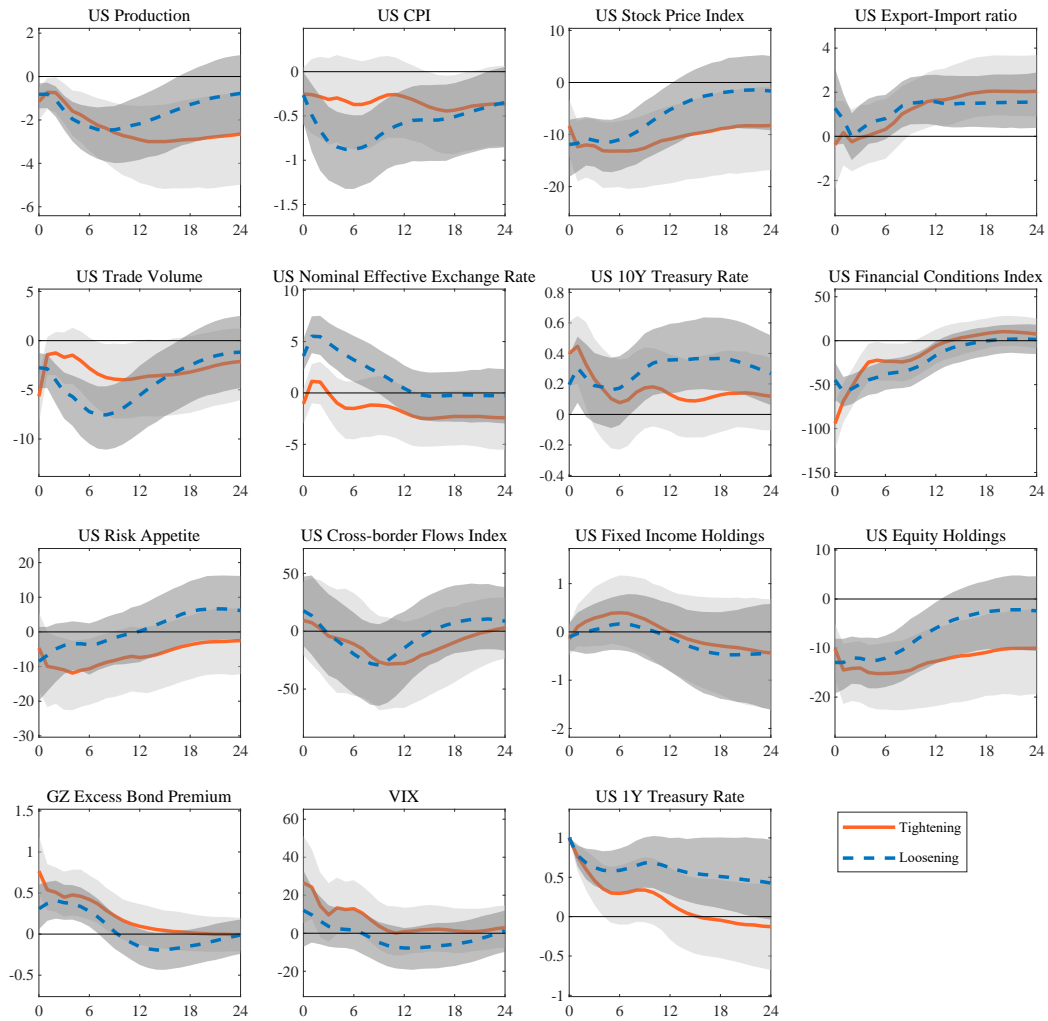
The domestic effects of monetary policy tightenings and loosening are relatively symmetric, with marginally stronger real effects in tightenings as shown by the response of industrial production (in Figure 17).⁵² The interesting exception is the response of CPI, which is remarkably asymmetric: it decreases marginally but not significantly in case of a tightening, while expanding significantly in a loosening. This is an indication of downward rigidity in prices to the monetary policy shock. Trade volume also reacts slightly less to tightenings than to loosening, possibly indicating a difference in the monetary responses in third countries and hence in the exchange rates.

Marginal differences are also evident in the variables capturing financial channels – risk appetite, excess bond premium, and the VIX – that respond more to contractionary monetary policy. This is matched by the deeper rebalancing of risky assets in contractions. Interestingly the responses of the policy indicator, the U.S. 1-year treasury rate,

⁵¹To obtain samples starting from the early 1990s, we implement the following modifications in our sample of EMEs: first, we drop two countries, Thailand and Russia, where all the available output series start from the late 1990s. Second, we interpolate backwards a few important indicators, namely output and stock prices, for some of EMEs. This would have otherwise greatly reduced our sample. The endogenous set includes industrial production, CPI, stock prices, export/import ratio, trade volume, nominal exchange rate, short-term and policy rates, financial conditions, risk appetite and cross-border flows.

⁵²The stronger effects of a contractionary monetary policy shock compared to an expansionary one are in line with the recent literature on asymmetric responses to MP shocks (see, for example, Cover, 1992; Tenreyro and Thwaites, 2016; Barnichon and Matthes, 2018; Angrist et al., 2018)

FIGURE 17: ASYMMETRIC SHOCKS TO THE US ECONOMY



Note: Orange line – domestic responses to a contractionary US monetary policy shock. Dotted blue line – domestic responses to an expansionary US monetary policy shock. Shocks are normalised to induce a 100 basis point increase in the 1-year rate. High frequency identification. Sample 1990:01 – 2018:09. BVAR(12) with asymmetric conjugate priors. Shaded areas are 90% posterior coverage bands.

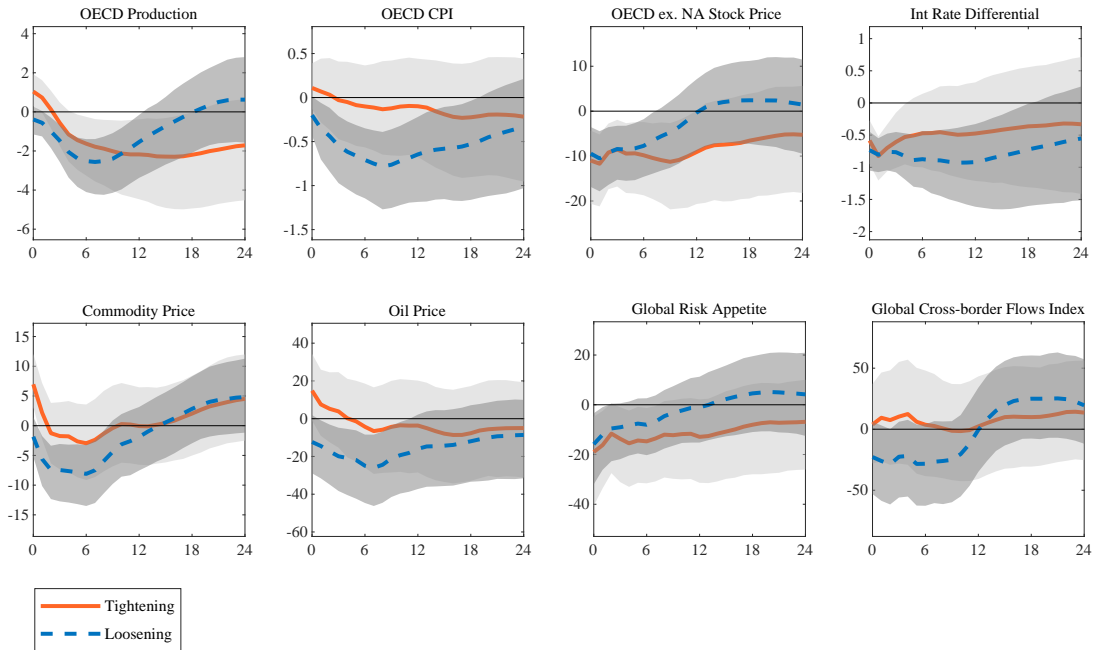
highlight differences in the duration of tightening and loosening cycles.

8.2 Asymmetries in the Global Transmission and AEs

The global economy responds to the shocks in an asymmetric manner (Figure 18).⁵³ Industrial production contracts slightly more and for longer during contractions, but the difference is not statistically significant. The price responses are strongly asymmetric.

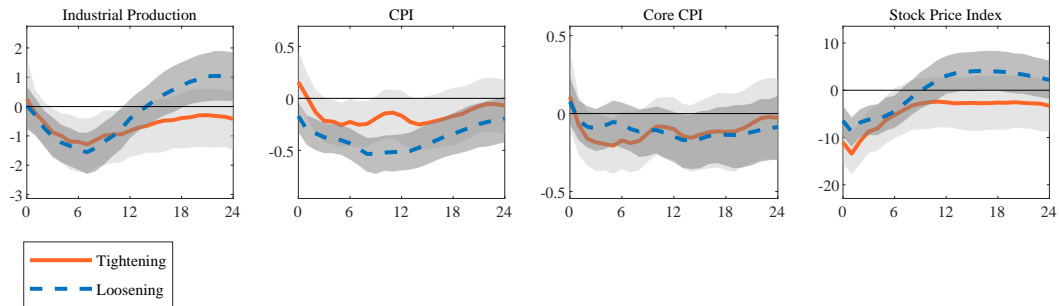
⁵³A full set of responses can be found in the online appendix, Figure B.2 for the global economy and Figure B.9 for advanced economies.

FIGURE 18: ASYMMETRIC SHOCKS TO THE GLOBAL ECONOMY



Note: Orange line – global responses to a contractionary US monetary policy shock. Dotted blue line – global responses to an expansionary US monetary policy shock. Shocks are normalised to induce a 100 basis point increase in the 1-year rate. High frequency identification. Sample 1990:01 – 2018:09. BVAR(12) with asymmetric conjugate priors. Shaded areas are 90% posterior coverage bands.

FIGURE 19: ASYMMETRIC SHOCKS TO THE MEDIAN ADVANCED ECONOMY

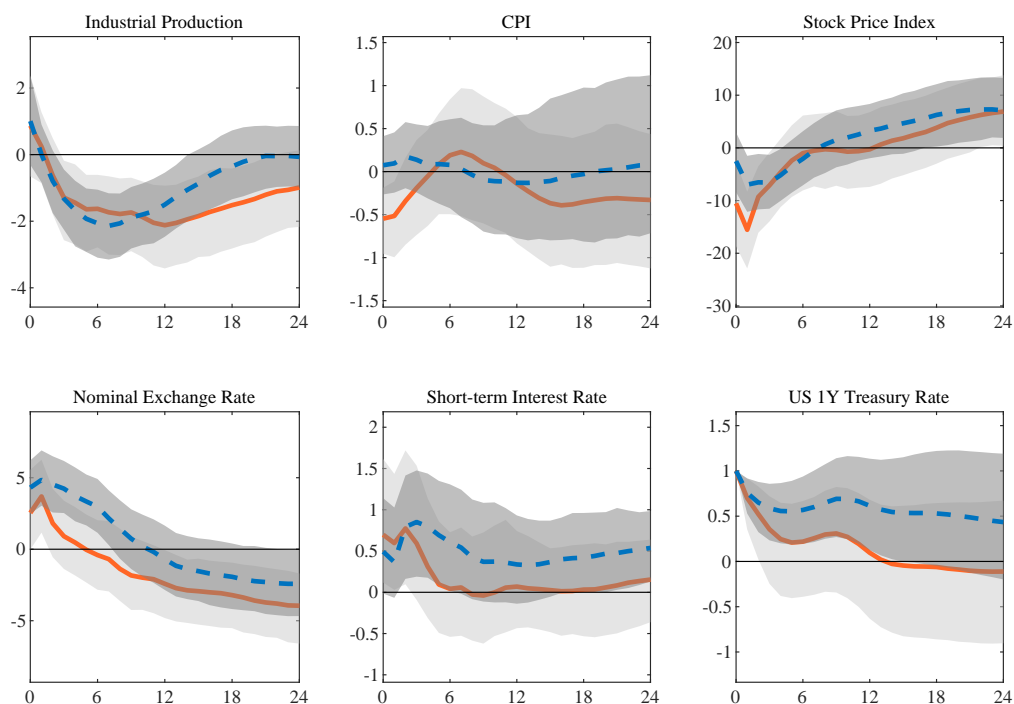


Note: Orange line – median responses of 15 advanced economies to a contractionary US monetary policy shock. Dotted blue line – median responses of 15 advanced economies to an expansionary US monetary policy shock. Shocks are normalised to induce a 100 basis point increase in the 1-year rate. High frequency identification. Sample 1990:01 – 2018:09. BVAR(12) with asymmetric conjugate priors. Shaded areas are 90% posterior coverage bands.

Commodity prices and the oil price do not experience meaningful changes after tightenings while they adjust upward in a loosening. This is reflected in the lack of reaction of OECD CPI after a tightening relative to its expansion in a loosening.

A similar pattern is visible in the median responses of our 15 advanced economies to

FIGURE 20: ASYMMETRIC SHOCKS TO THE MEDIAN EMERGING ECONOMY



Note: Orange line – median responses of 13 emerging economies to a contractionary US monetary policy shock. Dashed blue line – median responses of 13 emerging economies to an expansionary US monetary policy shock. Shocks are normalised to induce a 100 basis point increase in the US 1-year rate. High frequency identification. Sample varies from between 1990:01 and 1993:11 to between 2017:12 and 2018:09. BVAR(12) with asymmetric conjugate priors. Shaded areas are 90% posterior coverage bands.

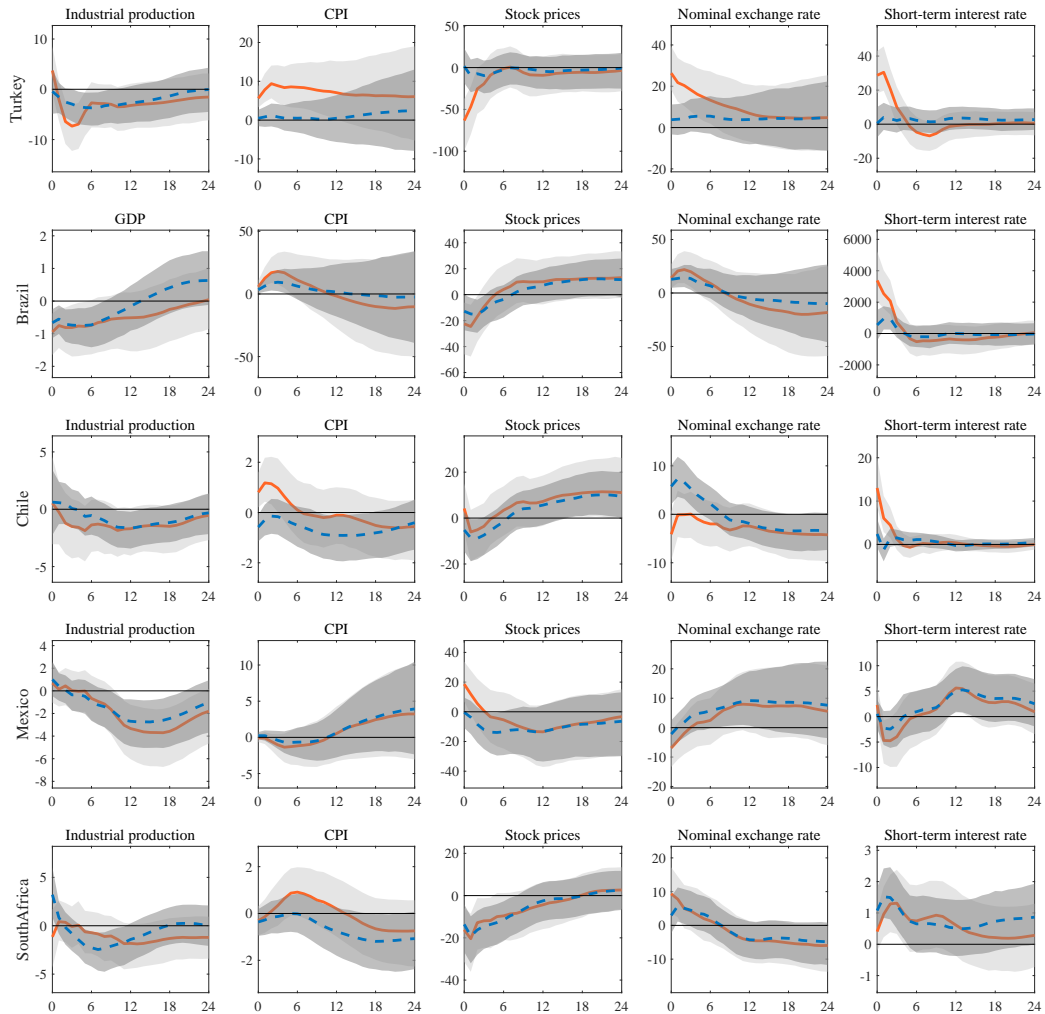
contractionary and expansionary shocks (Figure 19). Here, the asymmetry is marked, with a deeper and longer contraction in output and the stock market in a tightening. CPI contracts in tightenings and expands in loosening but the downward rigidity of prices is very visible.⁵⁴

8.3 Asymmetries in Emerging Economies

Following a tightening in the US, the median emerging economy displayed in Figure 20 experiences a larger drop in the stock market and a more prolonged recession when compared to a loosening. The domestic policy response can be assessed by observing the response of the short-term interest rate and the asymmetries in the response of the

⁵⁴One interesting result from this chart is that patterns of the ‘2.5-lemma’ are not clear, in contrast to Han and Wei (2018): real spillover effects are evident in both tightenings and loosening. Their findings might be capturing a downward rigidity in CPI, not a lack of monetary autonomy. As Rey (2016) pointed out, measuring monetary autonomy via the metric of correlation among short-term rates does not fully take into account the financial spillover channels.

FIGURE 21: ASYMMETRIC SHOCKS: 5 EMES



Note: Orange line – median responses of each EME to a contractionary US monetary policy shock. Dashed blue line – median responses of each EME to an expansionary shock. Shocks are normalised to induce a 100 bp rise in the US 1-year rate. High frequency identification. Sample as in Table A.12 (online appendix). For Brazil, we replace IP by monthly GDP interpolated backwards from 1996:01 to 1990:01. BVAR(12) with asymmetric priors. Shaded areas are 90% posterior coverage bands.

nominal exchange rate. The depreciation of the currency in a tightening is limited when compared to the appreciation in a loosening. In the aggregate the fear of depreciation trumps the fear of appreciation.⁵⁵

Policy responses and country structural features are a large part of the story. We zoom in on single countries – Turkey, Brazil, Chile, Mexico, and South Africa – to provide a more granular view of how policy regimes and country-specific fragilities interact

⁵⁵These results are in line with those displayed in Figure 7, with the notable exception of short-term rates. It is important to remember that the sample length and pool of countries are different.

in shaping asymmetric responses to US policy shocks. This is an interesting pool of countries that either experiences currency crises (Mexico in 1994, Brazil in 1999, and Turkey in 2001) or conducted particularly prudent monetary policy (Chile, South Africa) for fear of exposing themselves to global shocks.⁵⁶

The responses show remarkable differences when compared to the median aggregated ones. Following a tightening, global financial conditions worsen and capital starts flowing out of an economy; this is visible in the responses of the domestic currencies that fall in all countries but Chile. Interestingly, the Chilean peso only reacts to a loosening, which would be consistent with ‘fear of depreciation’. Inflation tends to rise due to imported goods becoming more expensive. The price responses are now very different from the aggregate ones. All the 5 EMEs experience a price hike following the US tightening. We observe particularly dramatic rises in Turkey and Brazil. For instance, Turkey’s CPI increases by 5% on impact for a tightening and the effect persists for 12 months. For a loosening the response of prices is not significant, as there is no effect on the exchange rate.

Central banks react to the exchange rates plummeting by hiking rates in the attempt of steadying the economy. In fact, in all cases except Mexico, we observe an increase in the short-term rate response upon a US tightening and a decrease in the case of a loosening. This in turn exacerbates the contraction of the national economy. In particular, we observe a dramatic surge in the short-term rate on impact for Turkey, Brazil, and Chile. This may bear the pattern of the crises experienced by these countries, and is an indication of strong financial spillovers as discussed in [Gourinchas \(2018\)](#). Indeed, if investors have limited trust in the central bank, expectations can become self-fulfilling with the currency falling, interest rates and inflation rising, and the economy deteriorating. Overall, the responses show a pattern of an emerging market crisis similar to what described by [Carstens and Shin \(2019\)](#).⁵⁷

⁵⁶For Brazil, we replace industrial production by monthly GDP interpolated backward from 1996:01 to 1990:01. The results we obtain by using industrial production are qualitatively similar.

⁵⁷[Hoek et al. \(2020\)](#) provide evidence that while the signalling channel of US monetary policy (good macro news - higher policy rates) generates only modest spillovers, contractionary MP shocks can lead to a significant tightening of EME financial conditions.

9 Conclusion

We studied how US monetary policy is transmitted across the globe by employing a high-frequency identification of policy shocks and large VAR techniques. Our identification controls for the information effects of monetary policy while allowing for the separate analysis of tightenings and loosening of the policy stance. Incorporating a large dataset of macroeconomic and financial indicators at a monthly frequency, we study the effects of US monetary policy shocks on the global economy, the Euro Area, 15 AEs and 15 EMEs. We also provide median responses for selected groups of countries based on their income levels, the degree of openness to capital, exchange rate regimes, dollar trade invoicing, and gross dollar exposure. Our study provides evidence on the channels of propagation of US monetary policy shocks overseas, as well as documenting asymmetries in the responses of peripheral economies to expansionary and contractionary US shocks.

We report a set of novel findings. First, we find that a US monetary tightening induces macro and financial contractionary responses in the US and across the globe. This testifies to the role of dollar as a global currency. Second, US monetary policy spillovers affect both advanced economies and emerging markets, irrespectively of their monetary policy regime. The country-level responses are much less heterogeneous than previously reported. Third, AEs and EMEs that are more open to capital experience stronger real and nominal effects compared to less-open ones. This highlights a potential role for capital controls as an additional policy dimension. Fourth, by disentangling the channels of transmission, we observe that contractionary responses of commodity prices and financial variables are important determinants of negative spillover effects on output and prices. Finally, we find that the responses of output and stock prices of the US, the global economy, and third countries are more persistent in a tightening than in a loosening. CPI instead shows downward rigidity, that is accounted for by the downward rigidity of oil and commodity prices. Importantly, the policy responses of countries that have been affected by currency crises are remarkably asymmetric.

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