The Global Transmission of U.S. Monetary Policy

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Abstract

US monetary policy impacts global economic conditions, with tightenings causing recessions worldwide. Our findings, using a state-of-the-art identification and a comprehensive dataset encompassing 30 economies, indicate that restrictive US policy shocks significantly contract output and prices in both advanced and emerging economies. Financial channels are crucial for the transmission to real variables, as they impair foreign central banks' control over domestic conditions by destabilising the medium- to long-term yield curve. Commodity and oil prices shape the transmission of US policy shocks to headline inflation, with tightenings exerting downward pressure on inflation globally.

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JEL Classification: E5, F3, F4, C3.

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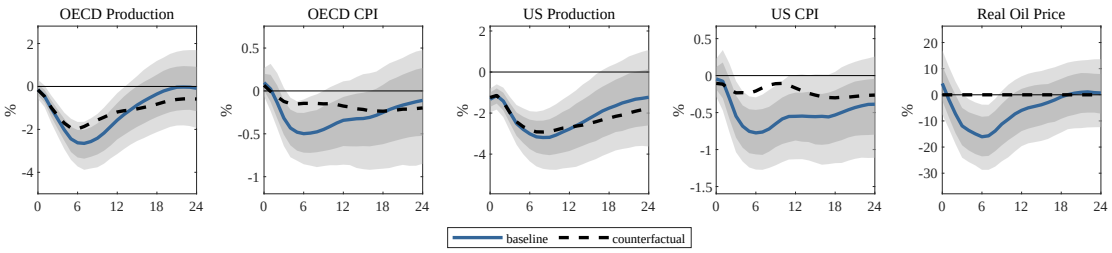
1 Introduction

The status of the US dollar as the world's reserve currency and its dominant role in global trade and financial markets means that the Federal Reserve's decisions have a far-reaching impact beyond the US. The recent tightening of monetary policy in the United States has sparked a renewed debate about the potentially destabilising effects of spillovers from US policy shocks on frontier and emerging markets, as well as on advanced economies like the UK and the Euro Area. The classic Mundell-Fleming model identifies two channels of international transmission of monetary policy. On the one hand, an increase in US interest rates has a contractionary effect on domestic demand, which leads to lower demand for both domestic and foreign goods ('demand-reducing' effect). On the other hand, the appreciation of the dollar makes foreign goods relatively cheaper, leading to a shift in demand away from home-produced goods and towards foreign goods ('expenditure-switching' effect). These two channels partially offset each other.

In addition to these traditional channels, US monetary policy can affect the rest of the world through financial linkages (Rey, 2013, 2016; Farhi and Werning, 2014; Bruno and Shin, 2015a,b; Miranda-Agrippino and Rey, 2020). 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 can put upward pressure on foreign long-term yields and downward pressure on the prices of foreign risky assets. This determines a positive correlation between the price of US and foreign assets and can trigger a sudden deterioration of financing and financial conditions abroad, characterised by retrenchment and destabilising capital outflows from foreign countries.

From an empirical point of view, the overall impact of policy spillovers and the relative strength of different channels are important open questions, plagued with technical difficulties. In his Mundell-Fleming lecture, Bernanke (2017) outlined some of the challenges and issues with existing evidence on this topic. First, monetary policy actions are largely endogenous to economic conditions and have strong signalling and coordination effects. Second, the limited availability of high-frequency data on financial and cross-border flows has constrained much of the literature. Finally, there are many dimensions along which countries may differ that can influence the transmission of external shocks – their cyclical positions and structural features such as trade exposure, openness to foreign capital, exchange rate and policy regimes.

Figure 1: Spillovers from a US tightening and the commodity price channel



Note: The monetary policy and oil supply news shocks, in the structural counterfactual scenario, are respectively identified with the high-frequency IV of Miranda-Agrippino and Ricco (2021) and the OPEC announcements IV of Känzig (2021). Sample 1990:01 – 2018:12. Shaded areas are 68% and 90% posterior coverage bands for the baseline scenario.

We take on these three challenges to provide precise estimates of the impact of US monetary policy across the globe. First, we use a high-frequency identification (HFI) strategy for conventional monetary policy shocks that is robust to the information channel of monetary policy (Romer and Romer, 2004; Melosi, 2017). This strategy exploits intra-day revisions in the price of federal funds futures around FOMC announcements as an instrument to identify monetary policy shocks. To isolate exogenous variation in market expectations about the policy rate, it controls for the potential disclosure of information by the Fed to market participants, using the methodology proposed by Miranda-Agrippino and Ricco (2021).[1] Second, we compile an extensive and harmonised monthly dataset that includes a wide range of macroeconomic and financial variables for the US, 15 advanced economies (AEs), and 15 emerging markets (EMs), as well as a comprehensive set of global indicators. This dataset also incorporates country-specific and aggregate harmonised monthly indexes of credit flows and liquidity conditions.[2] The dataset includes over 150,000 observations, spanning the period from 1990:1 to 2018:12. Third, we use Bayesian Vector Autoregression (BVAR) techniques to efficiently deal with the dataset and examine the international transmission of US monetary policy.

In our empirical analysis, we first offer a landscape view of the effects of a monet-

[1]Not controlling for the information channel of monetary policy when identifying monetary policy shocks can confound the effects of monetary policy with the propagation of other macroeconomic shocks that are revealed by the central bank via its rate setting decision, resulting in an endogeneity problem.

[2]Along with official data from the IMF, we employ CrossBorder 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 and obtainable from the BIS and various statistical offices.

ary tightening on the world economy employing global economic indicators (Figure 1 provides an overview of some key results). Second, we focus on country-level data and median estimators to compare the average transmission of the shock in advanced and emerging markets. Third, we provide evidence on the importance of the different channels of transmission. A structural counterfactual analysis with identified oil and monetary policy shocks is used to assess the importance of commodity prices in the transmission of the tightening (also displayed in Figure 1).[3] Furthermore, we perform a decomposition of the propagation by zeroing out the reduced-form coefficients on a set of channel-specific variables. Finally, we propose an alternative channel decomposition analysis based on conditional forecasts. Fourth, we examine the role of country characteristics by conditioning the responses to exchange rate regimes, the openness of capital markets, exposure to the dollar, and the share of dollar trade invoicing. Finally, we investigate potential asymmetries in the propagation of the shock, particularly in fragile economies.

Our research delivers a series of new results and confirms some of the previous findings on spillover effects. First, a US monetary policy tightening has large and fairly homogeneous real and nominal contractionary spillover effects on both AEs and EMs. Previous studies have reported, on average, contractionary effects on output but generally mixed results on prices, with heterogeneous effects at the country level (Dedola et al., 2017; Iacoviello and Navarro, 2019; Miranda-Agrippino and Rey, 2020). Our results confirm that both real variables and prices contract in most economies – except the most fragile ones, where spillover effects are inflationary – with a relatively homogenous pattern of responses across countries. Although varying in magnitude, the responses of real, nominal, and financial variables abroad align with the domestic effects of US monetary policy. This alignment provides a striking visual image of the role of the Fed as the global central bank.

Second, we show that commodity and oil prices play a crucial role in the transmission of US policy shocks to headline inflation worldwide. On the one hand, a tightening of US monetary policy makes commodity imports more expensive for the rest of the world, due to an appreciation of the dollar and to the fact that commodities are mostly invoiced in dollars. On the other hand, the same tightening reduces demand for commodities,

[3]The counterfactual scenario assumes that a sequence of structurally identified oil supply news shocks completely offsets the response of the real price of oil to the monetary policy impulse, maintaining it at steady state at all horizons (see Antolin-Diaz et al., 2021, for the methodology).

both directly via lower domestic demand for imports, and indirectly via tighter global financial conditions, which puts downward pressure on commodity prices. The second effect generally dominates. Our structural scenario analysis shows that the bulk of the contraction in headline inflation abroad can be ascribed to the reduction in commodity prices (Figure 1). Moreover, we show that headline inflation abroad decreases following a US tightening, matching the contraction in commodity prices, while core inflation remains mostly unaffected. This is a novel empirical finding that has been recently formalised in a model by Akinci et al. (2022).

Finally, while the contraction of both output and prices might simplify the policy problem for non-US central banks, the presence of strong financial spillovers limits the effectiveness of their policy responses and reduces the degree of insulation provided by exchange rates. Our results indicate that changes in risk premia, triggered by a US tightening, shift up the long end of the yield curve, thereby tightening financial conditions abroad despite the policy easing of the central bank. This mechanism accounts for the sizeable spillover effects on foreign economies, including advanced economies with inflation targeting and flexible exchange rates. However, a comparative analysis shows that, for both real and nominal variables, the spillovers are larger in countries with more rigid exchange rate regimes. These findings extend the important results of Kalemli-Özcan (2019) on the short- to medium-term response of the yield curve in emerging markets and demonstrate that this mechanism is at play not only in those economies but also in advanced ones, with stronger effects at medium- to long-term maturities. These results also provide new insights to the Trilemma debate and the constraints on monetary independence imposed by financial integration (see Rey, 2013). Additionally, we find that AEs and EMs with more open capital markets experience stronger negative responses in industrial production and CPI than those with less open capital markets.

We employ a simple model to elucidate how the relative strengths of financial channels and the commodity price channel shape the overall transmission to prices and real variables, conditioning the policy problem of the foreign central banks. This model rationalises the observed contractionary responses in prices and real variables across both advanced and emerging economies, attributing these effects to substantial financial frictions and strong commodity price spillovers. In particularly fragile economies characterised by significant financial spillovers and a high pass-through of imported prices, the

model forecasts upward pressure on prices due to the deterioration of terms of trade following a US tightening. As a result, the central bank is compelled to implement domestic tightening measures to stabilise the economy and the exchange rate. Interestingly, the impulse response functions for the most fragile economies in our sample display this response pattern, typical of currency crises.

Our results have significant policy implications. The depth and reach of the international spillover effects of US monetary policy call for macro-prudential policies and potentially the activation of multiple monetary policy tools to mitigate external shocks. Although flexible exchange rates offer a substantial degree of insulation, they cannot completely shield against spillovers through financial variables, which constrain the ability of central banks to fully stabilise the economy. For most countries in our sample, a US monetary policy shock manifests as a negative demand shock that contracts prices and output, calling for a loosening of the domestic policy stance. However, fluctuations in risk premia destabilise long-term maturities and impede the transmission of conventional monetary policy along the yield curve, potentially necessitating interventions to steady the yield curve and support financial conditions.

The structure of the paper is as follows: the remainder of this section provides a review of the relevant literature. Section 2 describes the methodology and data used in our empirical analyses. Section 3 discusses the effects of US monetary policy on the global economy, studies the transmission of US shocks to a set of advanced economies (AEs) and emerging markets (EMs), explores the transmission channels of these shocks, and highlights the differences and similarities in responses across countries. Section 4 introduces a simplified model to rationalise our key empirical findings on the relative importance of different channels. Section 5 investigates the asymmetric responses of fragile economies to US tightenings and loosenings. Section 6 explores how structural features such as exchange rate regimes, capital flow management, and dollar exposure influence the transmission of shocks. Section 7 concludes.

Related Literature. Our work closely relates to Rey (2013)'s Jackson Hole lecture and subsequent works, which have documented the existence of a 'Global Financial Cycle' manifested as a common factor across international asset prices and various types of capital flows (Passari and Rey, 2015; Gerko and Rey, 2017; Miranda-Agrippino and Rey,

2020; Miranda-Agrippino et al., 2020).[4] Building on these studies, we explore the international spillovers of conventional US monetary policy using an informationally robust identification strategy across a large cross-section of countries and variables. We connect to an extensive body of literature that has typically reported sizeable real and/or nominal effects with significant heterogeneity across countries and time periods.[5,6] We complement these earlier results by identifying and isolating the role of commodity prices in the international propagation of US monetary policy, by highlighting the role of term premia in impairing domestic central banks' efforts to stabilise the economy, and by demonstrating more robust patterns of response with the adoption of modern econometric and identification techniques.

The literature generally finds that monetary policy has a significant impact on commodity prices (Frankel, 2008; Akram, 2009; Neri and Nobili, 2010; Anzuini et al., 2012; Rosa, 2014). However, to the best of our knowledge, we are the first to show that the transmission to inflation abroad of a US monetary policy tightening is generally deflationary and most of this contraction is explained by the contraction in commodity prices resulting from lower global demand for commodities.[7]

The studies by Dedola et al. (2017) and Iacoviello and Navarro (2019) are the most closely related to ours in terms of focus of research and data coverage. Compared to these and other prior studies, we adopt a state-of-the-art high-frequency identification strategy that crucially controls for the information channel of monetary policy and Bayesian techniques that, combined with a large set of indicators and countries, provide a landscape view on the international transmission of US monetary policy shocks (see also Miranda-

[4]Recent papers documenting capital flow cycles include Forbes and Warnock (2012a); Cerutti et al. (2019); Acalin and Rebucci (2020); Jordà et al. (2019).

[5]Early contributions to the study of US monetary policy spillovers include: Kim (2001), Forbes and Chinn (2004), Canova (2005), Maćkowiak (2007), Craine and Martin (2008), Ehrmann and Fratzscher (2009), Wongswan (2009), Bluedorn and Bowdler (2011), Hausman and Wongswan (2011), Fukuda et al. (2013). Numerous studies have examined the effects of US monetary policy on Europe, or vice versa, or compared the spillovers from the US and the Euro Area. Among others are Ehrmann and Fratzscher (2005), Fratzscher et al. (2016), Brusa et al. (2020), Ca' Zorzi et al. (2020). Another stream of literature has focused on spillovers to EMs in various contexts: Chen et al. (2014), Takats and Vela (2014), Aizenman et al. (2016), Ahmed et al. (2017), Anaya et al. (2017), Bhattarai et al. (2017), Siklos (2018), Coman and Lloyd (2022), Vicondoa (2019), Bhattarai et al. (2021).

[6]While our focus is on conventional monetary policy, a number of works have discussed spillovers from unconventional monetary policy actions, for instance: Neely (2012), Bauer and Neely (2014) (long-term yields), Stavrakeva and Tang (2015) (exchange rates), Fratzscher et al. (2018) (portfolio flows), Rogers et al. (2018) (risk premia), Curcuru et al. (2018) (conventional vs. unconventional).

[7]Neri and Nobili (2010) find that a US monetary policy tightening is expansionary for the Euro Area, via the contraction in commodity prices. More recently, Ider et al. (2023) and Miranda-Pinto et al. (2023) have also studied how monetary policy propagates via commodity prices.

Agrippino and Rey, 2020; di Giovanni et al., 2022; Cesa-Bianchi and Sokol, 2022).[8]

Our results add to the literature that explores financial spillovers through cross-border bank lending and international credit channels, whereby an appreciation of the dollar triggers valuation effects, and to the literature on the risk-taking channel, whereby US monetary policy influences the risk profiles and leverage of financial institutions, firms, and investment funds.[9,10] We quantify the importance of the financial channel relative to other channels, finding that it explains most of the transmission not only to stock prices, but also to real activity.

Our results on policy regimes speaks to the literature that shows that short-term rates in countries with flexible exchange rate regimes are less correlated with the policy rate of the central country than those with fixed regimes, suggesting the effectiveness of flexible rate arrangements in insulating an economy from global shocks.[11] Our findings shed new light on this topic by showing that movements in risk premia along the maturity structure of the yield curve impair the effectiveness of domestic countercyclical monetary policy, thereby impairing the transmission of domestic monetary policy impulses.

We also revisit previous findings on capital flow management, which have highlighted the limited effectiveness of these measures (see, for example, Miniane and Rogers, 2007). While abstaining from the side-effects of such policies, our results suggest that financial openness plays a potentially significant role in determining the extent of spillovers originating from the US.[12] Similar findings regarding both conventional and unconventional monetary policies have been recently documented by Kearns et al. (2018).

Finally, and more broadly, our results speak to the literature on reference currencies (see Ilzetzki et al., 2019) and dominant currencies (see Gourinchas and Rey, 2007;

[8] A few papers, such as Georgiadis (2016), Feldkircher and Huber (2016), and Dées and Galesi (2021), have also used large panels of countries in Global VAR settings. Compared to these, our approach offers more modelling flexibility as we refrain from using GDP or trade weights to model international interactions and avoid imposing restrictions on the signs of the responses to identify monetary policy shocks.

[9] On the cross-border bank lending channel see, among others: Cetorelli and Goldberg (2012); Bruno and Shin (2015a); Cerutti et al. (2017); Temesvary et al. (2018); Avdjiev and Hale (2019); Buch et al. (2019); Morais et al. (2019); Albrizio et al. (2020); Bräuning and Ivashina (2020).

[10] Studies on the risk-taking channel include, among others, Adrian and Song Shin (2010); Ammer et al. (2010); Devereux and Yetman (2010); Borio and Zhu (2012); Bekaert et al. (2013); Morris and Shin (2014); Bruno and Shin (2015a); Adrian et al. (2019); Cesa-Bianchi and Sokol (2022); Kaufmann (2020).

[11] See, for instance, Shambaugh (2004); Obstfeld et al. (2005, 2004); di Giovanni and Shambaugh (2008); Goldberg (2013); Klein and Shambaugh (2015); Obstfeld (2015); Aizenman et al. (2016); Georgiadis and Mehl (2016); Obstfeld et al. (2019); Kalemli-Özcan (2019).

[12] Side effects of capital flow management measures are discussed, for instance, in Forbes (2007); Forbes et al. (2016); Erten et al. (2019).

Maggiori, 2017; Gourinchas et al., 2019; Maggiori et al., 2019; Gopinath et al., 2020).

2 Data and empirical methodology

A central challenge to the study of the international propagation of US monetary policy is how to efficiently extract the dynamic causal relationships from a vast number of time series covering both global and national variables. Our approach combines three elements: a novel harmonised dataset spanning a large number of countries and variables (described in Section 2.1); a high-frequency informationally robust identification of US monetary policy shocks (presented in Section 2.2); and state-of-the-art Bayesian dynamic models able to handle large information sets (discussed in Section 2.3).

2.1 Data

Our dataset contains over 150,000 data-points covering the US, 30 foreign economies, the Euro Area as an aggregate, and global economic indicators from 1990 to 2018. 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 flow data at a global and national level from CrossBorder Capital Ltd, a private data provider specialising in the monitoring of global liquidity flows.[13] All variables are monthly.[14]

In terms of global aggregates, the dataset includes 16 indicators: industrial production, CPI, and stock price index of OECD countries, the differential between average short-term interest rate across 15 AEs in our dataset and the US, the global economic activity index of Kilian (2019), the real CRB commodity price index, the real global price of Brent crude oil, and 3 major currency exchange rates per USD: Euro, Pound Sterling, and Japanese Yen. It also includes gross inflows and outflows of EMs from the IMF Balance of Payments (BOP) and four world-aggregated liquidity indexes from CrossBorder

[13]The advantage of using this data relative to other public sources is the availability at monthly frequency, the historical depth, and the vast global coverage.

[14]If the original series are collected at a daily frequency, we take the end-of-month value, as is standard in the literature.

Capital Ltd (financial conditions, risk appetite, fixed income and equity holdings).[15] The financial conditions index represents short-term credit spreads, including the deposit-loan spreads. Risk appetite is based on the balance sheet exposure of all investors between equity and bonds. It measures their allocation between 'risky' assets (equities and corporate bonds) and 'safe' assets (government bonds, cash, and gold bullion).[16] Finally, equity and fixed income holdings measure the holdings of listed equities and both corporate and government fixed income assets, respectively.[17]

At the national level, our dataset covers 30 economies (15 AEs and 15 EMs in Table 1), plus the US and the Euro Area as a whole. For each of these countries, 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 five liquidity indices (financial conditions, risk appetite, net cross-border flows, fixed income and equity holdings). The cross-border flows index captures all financial flows into a currency, including banking and all portfolio flows (bonds and equities). It is estimated from national trade and current account data, movements in foreign exchange reserves, and (interpolated) quarterly data on net FDI flows. For the US, we also collect the excess bond premium from Gilchrist and Zakrajšek (2012), the VIX index, and the IMF BOP gross inflows and outflows. We substitute the nominal bilateral exchange rate with the nominal effective exchange rate and exclude the short-term interest rates. Instead, the monetary policy indicator is the 1-year treasury constant maturity rate.

Our benchmark estimation sample spans January 1990 to September 2018 to minimise the impact of historical transformations of the global economy – e.g. the end of the Cold War and the transition of China to a market economy – and also to align the data

[15]Following the convention, we construct gross inflows and outflows from the IMF BOP data. For instance, gross inflows are the sum of the net incurrence of liabilities in direct, other, and portfolio investment flows from the financial account. Gross outflows are the sum of the net acquisition of assets in the three components above. We interpolate the resulting series, originally at a quarterly frequency, to obtain monthly observations.

[16]These indices vary between 0 and 100, with 50 indicating 'neutral' relative to a 40-month moving average.

[17]Table E.2 in the Online Appendix lists all global aggregates and the US variables in our dataset and details the sources, sample availability, and transformations. EM inflows and outflows are the sum of inflows/outflows of 15 EMs in our dataset, plus Hong Kong, which has played the role of the financial centre for China since 1999. Table E.3 in the Online Appendix lists the variables we collect for each country and the US counterparts, detailing the transformations. Table E.4 in the Online Appendix lists the short-term rates used to construct the interest rate differential.

Table 1: Country coverage

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

Notes: The table lists the advanced and emerging countries in our data set and reports the estimation sample for the exercises in Sections 3 and 6.

with our US monetary policy instrument.[18] In Section 6 we classify the countries in our dataset based on selected observables: the degree of capital market openness, exchange rate regimes, 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. (2016). 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). Countries are divided into groups based on the median over the sample period of these indices.[19]

2.2 Identification of the US monetary policy shock

High-frequency market surprises around monetary policy announcements have been used extensively to identify monetary policy shocks (Gürkaynak et al., 2005; Gertler and

[18] The estimation sample for the global exercise described in Section 3 spans the period from 1990:01 to 2018:12. However, given the different availability of data across countries, the estimation sample used in the 'median economy' exercises described in Section 3 varies. Table 1 details the estimation samples used in each bilateral system.

[19] Although this method for grouping countries necessarily misclassifies some countries for some periods, our results in Section 6 validate our classification.

Karadi, 2015). The rationale is that any movement observed in a set of asset prices in a tight 30-minute window around FOMC announcements captures unexpected changes in market beliefs about the monetary policy stance. This approach provides an instrument to identify the causal effects of monetary policy. However, recent literature has documented the existence of a signalling channel of monetary policy that questions the exogeneity of this instrument. Monetary policy actions convey to imperfectly informed agents signals about the Fed's view of the state of the economy (Romer and Romer, 2000; Melosi, 2017). Intuitively, 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 is endogenously responding. Miranda-Agrippino and Ricco (2021) and Jarociński and Karadi (2020) show that high-frequency surprises combine policy shocks with information about the state of the economy due to the information disclosed through the policy action.

To obtain a clean measure of conventional monetary policy, we adopt the informationally robust instrument of Miranda-Agrippino and Ricco (2021) that directly controls for the signalling channel of monetary policy. This instrument is constructed by regressing high-frequency market surprises in the fourth federal fund future onto a set of Greenbook forecasts for output, inflation, and unemployment.[20] Intuitively, the Greenbook forecasts and revisions directly control the information set of the central bank, hence the macroeconomic information transferred to the agents through the announcement: the signalling channel of monetary policy. This instrument is available from January 1990 to December 2009. We identify conventional US monetary policy shocks using this informationally robust instrument in a Proxy SVAR/SVAR-IV setting (Stock and Watson, 2012; Mertens and Ravn, 2013).

[20]We focus on conventional monetary policy because of the additional complications connected to identifying other dimensions of monetary policy. In principle, it is possible to obtain instruments that capture forward guidance or quantitative easing while controlling for information effects by complementing the procedure in Swanson (2021) with the methodology of Miranda-Agrippino and Ricco (2021). See Degasperi and Ricco (2021) for a discussion.

2.3 BVARs and asymmetric priors

In our analysis, we consider two main empirical specifications:[21]

- A **US-global VAR** incorporating 32 variables: 16 for the global economy and 16 for the US.
- A battery of 31 **US-foreign country bilateral VARs** covering the 30 countries considered plus the Euro Area. Each model contains 16 US macroeconomic variables, 15 foreign financial and macroeconomic indicators, and three global controls: the global price of Brent crude oil, the CRB commodity price index, and Kilian (2019)'s global economic activity index.

The adoption of large endogenous information sets in our bilateral VAR models captures the rich economic dynamics at the country level and the many potential channels through which US monetary policy can affect the rest of the world. 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). In line with the standard macroeconometric practice for monthly data, we consider VAR models that include 12 lags of endogenous variables.

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). In particular, in estimating the VAR models, we elicit asymmetric Minnesota priors, which break the symmetry across the VAR equations and enable us to set tighter priors for some lags of selected regressors in a particular equation. This allows us to rule out a direct response of selected US variables to economic conditions in other countries. Specifically, in the US-global system, we allow the US variables, the oil price, and the commodity price index to respond endogenously to each other but to respond to global conditions only via the global economic activity index.

[21] Table E.2 in the Online Appendix lists all global and US variables in our specification. Due to data availability, Core CPI, Fixed Income, and Equity Holdings are used only in the endogenous set of AEs. Hence, the bilateral system of EMs includes only 12 domestic variables and 15 US variables. Table E.1 in the Online Appendix reports the specifications for each exercise.

Similarly, in the bilateral systems, we impose a tight prior for all coefficients directly connecting US variables to periphery country indicators. In other words, the US variables, the commodity price index, the oil price, and the global economic activity index do not endogenously respond to the periphery country indicators but can react with each other. Therefore, we allow for an indirect response of US variables via higher-order effects (as proposed in Georgiadis, 2017). These restrictions reduce parameter uncertainty and alleviate multicollinearity problems, which are particularly relevant when studying the transmission channels of US monetary policy.

The adoption of asymmetric priors complicates the estimation problem, making it impossible to use dummy variables to implement the priors. Instead, we employ the efficient methodology proposed in Chan (2022).[22] The tightness of the priors' hyperparameters is estimated by using the optimal prior selection approach proposed by Giannone et al. (2015).

2.4 Estimation of median-group responses

In several exercises, we estimate median group dynamic responses to US monetary policy shocks for selected groups of countries based on some common structural characteristic. The goal is to provide an indication of how a synthetic 'median' economy, representative of the underlying group, would be affected by the shock. To do this, we aggregate the bilateral VARs to 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 Ciccarelli, 2013, for a discussion).[23] Moreover, our approach affords us more modelling flexibility than global VARs, where GDP or trade weights are necessary to model international interactions. Importantly, we opt for the median group estimator instead of the mean group estimator to reduce the importance of outliers (e.g. episodes of hyperinflation in some countries within the

[22]Standard 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. This implies that own lags and lags of other variables must be treated symmetrically.

[23]If 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.

sample period).

The estimation of posterior coverage bands for the parameters of interest relies on the standard Gibbs sampling algorithm. We aggregate the country responses into 'median' economy responses as follows: we take one draw out of the distribution of impulse responses of a specific variable for each country and compute the median at each horizon across countries. We repeat this for all available draws and for all variables. This delivers structural impulse responses for each variable that can be interpreted as the response of the 'median' economy to the shock. What we report in the charts are the median, 68%, and 90% posterior coverage bands computed over these 'median' draws.[24]

2.5 Disentangling the channels of transmission

To quantify the relative importance of the various channels through which shocks are transmitted, we undertake a series of counterfactual exercises: a structural scenario analysis to isolate the commodity price channel; a channel decomposition exercise; and an exercise based on conditional forecasts. The structural scenario analysis is obtained by adapting the methodology of Antolin-Diaz et al. (2021).[25] This approach allows us to analyse the importance of the commodity price channel by comparing scenarios where variables respond freely to a monetary policy impulse against scenarios where responses of channel-specific variables to the same monetary impulse are neutralised by counteracting oil shocks, thus maintaining them at steady state.[26]

This approach cannot be easily extended to the analysis of more complex channels, where the response of a considerable number of variables has to be neutralised by as many identified shocks. In such a case, it is difficult to achieve a credible identification strategy for all the shocks needed. Another approach involves a channel decomposition exercise in the spirit of Ramey (1993) and Uribe and Yue (2006). The results in Section 3.3 are based on this methodology. This method consists in zeroing out, in the estimated VAR, the transmission coefficients on the channel-specific variables to compare the responses from the restricted and the unrestricted models. A larger difference across responses implies a greater role for the considered channel. This technique is primarily intended to highlight

[24] See the Online Appendix, Section B, for additional details.

[25] Breitenlechner et al. (2022) provides a discussion on how to adapt the methodology of Antolin-Diaz et al. (2021) to compare impulse responses under different scenarios.

[26] The sequence of oil shocks is identified using the instrument based on OPEC announcements provided in Känzig (2021).

the marginal contributions of specific variables to the transmission of the shock, so its merits should not be assessed against a Lucas critique type of argument.

We provide robustness to the results obtained with this approach by re-estimating the decomposition into the various channels of transmission using an alternative methodology, based on conditional forecasts (Waggoner and Zha, 1999). In this exercise, the importance of a channel in propagating the shock is assessed by comparing a scenario where all variables are unrestricted in the way they respond to the monetary policy impulse to a scenario where the response of the set of variables related to the channel of interest is prevented by counteracting sequences of shocks. Differently from structural scenario analysis, these counteracting shocks are unidentified: they are convolutions of all the shocks orthogonal to the US monetary policy one. Hence, this is not a structural scenario analysis as in Figure 1, where we can give a structural interpretation to the channels being zeroed out, but rather a conditional forecast, where the response of a selected set of variables is offset by a sequence of innovations in their own equations.

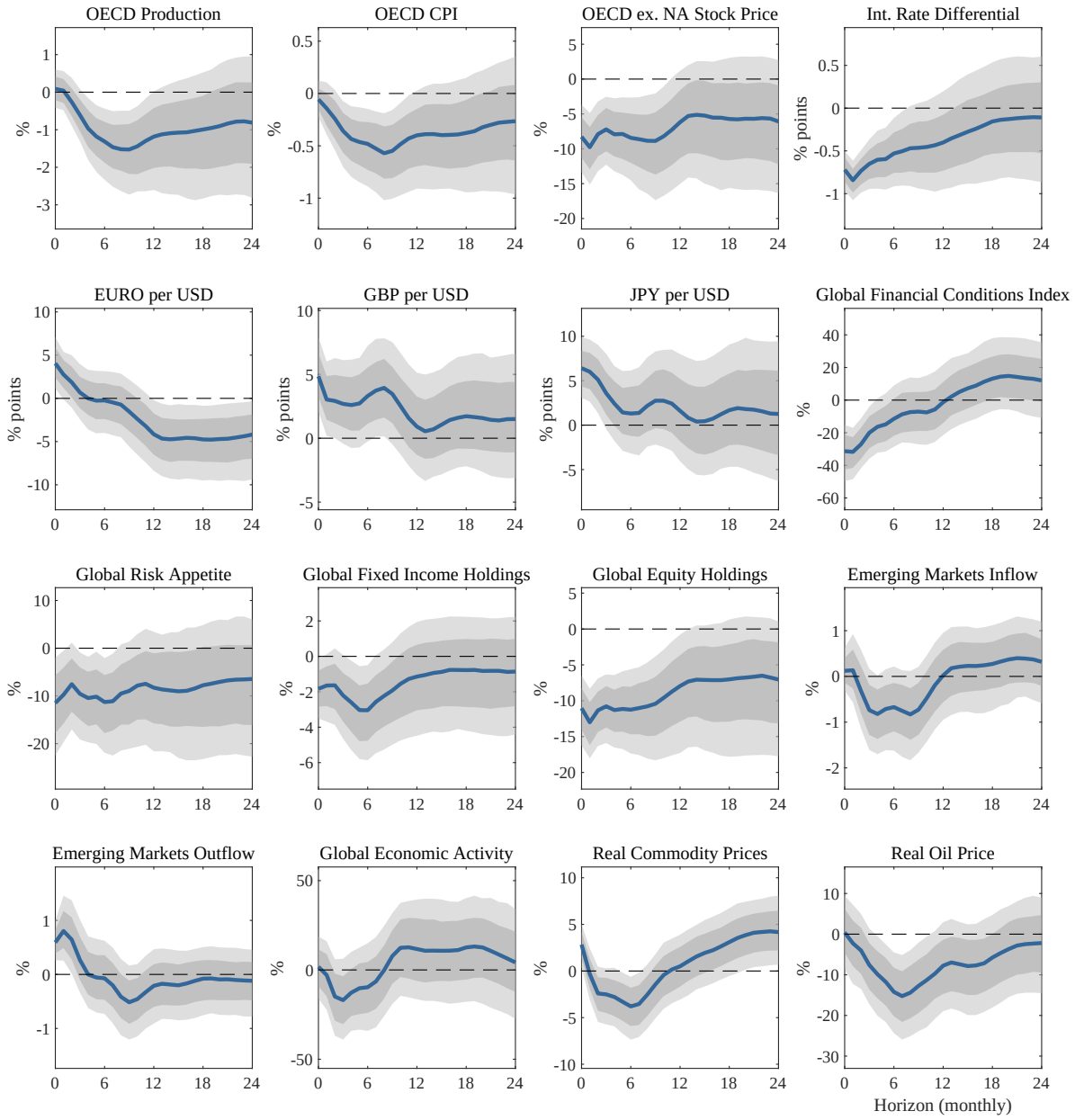
3 The global propagation of U.S. monetary policy

What are the effects of US monetary policy actions on the global economy and how are they transmitted? We answer these questions in three steps. First, we focus on global aggregates. We estimate a bilateral VAR incorporating 32 US and global variables on the sample from January 1990 to December 2018 and trace the impulse responses to a US monetary policy tightening. Second, we study how US monetary policy transmits differentially to AEs and EMs. We estimate 30 bilateral VARs, each one incorporating variables for the US and for one of the 30 countries in our sample, and aggregate the individual country responses into median responses for AEs and EMs. Third, we perform an analysis of the channels of international transmission of US monetary policy by combining structural counterfactuals and a channel decomposition exercise.

3.1 U.S. tightenings and global aggregates

Following a tightening of US monetary policy, the global economy contracts sharply (Figure 2). A monetary tightening that increases the US 1-year treasury rate by 1% causes a contraction in OECD industrial production by 1.5% and a contraction in OECD

Figure 2: Global Effects of US Monetary Policy



Note: Global responses to a contractionary US monetary policy shock, normalised to induce a 100bp increase in the US 1-year treasury constant maturity rate. Informationally robust high-frequency identification. Sample 1990:01 – 2018:12. BVAR(12) with asymmetric conjugate priors. Shaded areas are 68% and 90% posterior coverage bands. These responses are estimated jointly to those reported in Figure F.1, in the Online Appendix, which also shows the response of the policy indicator.

CPI by 0.5% at the trough, roughly 6 months after the shock. The deterioration of global economic activity is also visible in the downward adjustment of real commodity (-5%) and oil prices (-15%).

Global financial conditions deteriorate. Global risk appetite falls, and equity holdings decrease, suggesting worldwide portfolio rebalancing towards safe assets, in a risk-off scenario. These adjustments, marked by an appreciation of the dollar vis-à-vis major currencies, lead to a global contraction in cross-border flows, inducing outflows and immobilising capital particularly in EMs: they experience both a contraction in inflows and a sharp surge in outflows (Forbes and Warnock, 2012b).[27] 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.[28]

The landscape view of the response of the global economy to US monetary policy provides a powerful image of the Fed as a global central bank. The global and domestic effects of US monetary policy are similar in magnitude: following the shock, production in the US declines by 2.5%, while prices contract by 0.5%.[29] Consistently with the literature on the 'global financial cycle', the dynamics of stock prices and other financial variables in the US and the global economy are largely synchronised, conditionally on a US tightening (Rey, 2013).

In line with the responses of global aggregates, the contractionary effects of a US monetary tightening are also evident at the country level. Both the median AE and EM experience contraction in output, persistent deflationary pressure on CPI, and sharp tightening of financial conditions. The effects on the two median countries differ in magnitude but present strong similarities in the dynamics (Figure 3).[30]

Following a negative shock that increases the US 1-year rate by 1%, industrial production contracts by 1.4% for the median AE and by 2.5% for the median EM, at the trough, roughly 6 months after the shock. At the same time, CPI contracts by 0.4% for the AE and by 1% for the EM. These results indicate that in both groups, the effect of higher import prices is dominated by the contraction in aggregate demand and in commodity prices. The responses of the AE include core CPI, which also falls, although it is only

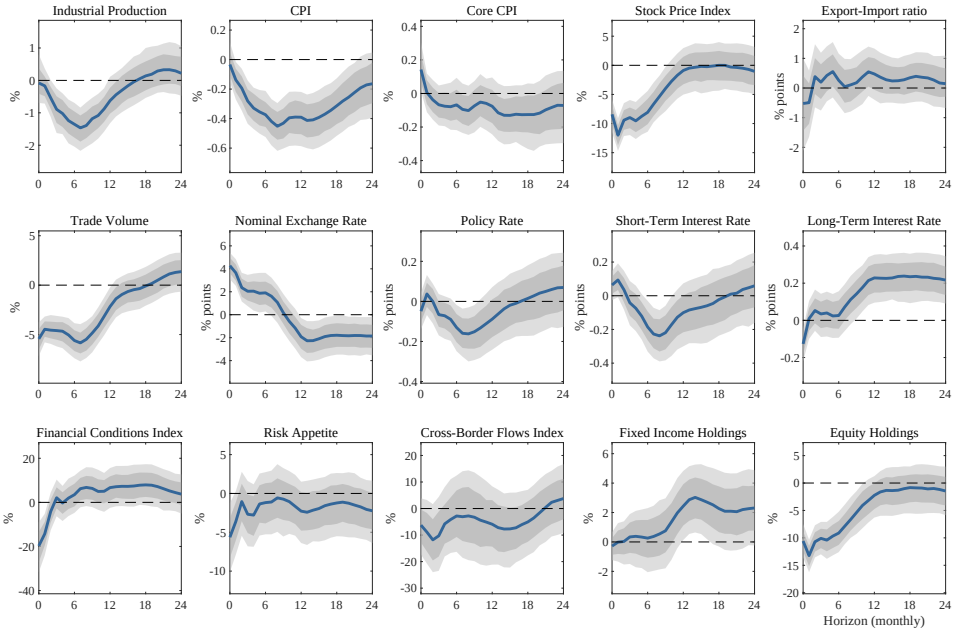
[27] Although EMs mostly finance themselves by issuing debt denominated in local currency, global investors may hold assets in local currency but incur liabilities predominantly in dollars (Carstens and Shin, 2019). This 'original sin redux' exposes EMs to capital flights in a risk-off scenario, which amplifies the risk of default and currency devaluation. These dynamics are probably less relevant for AEs, where risk premia reflect mostly duration risk and global risk aversion.

[28] The OECD ex. NA stock price index is a weighted average of stock prices in AEs excluding North America, so the comovement with US stock prices is not mechanical.

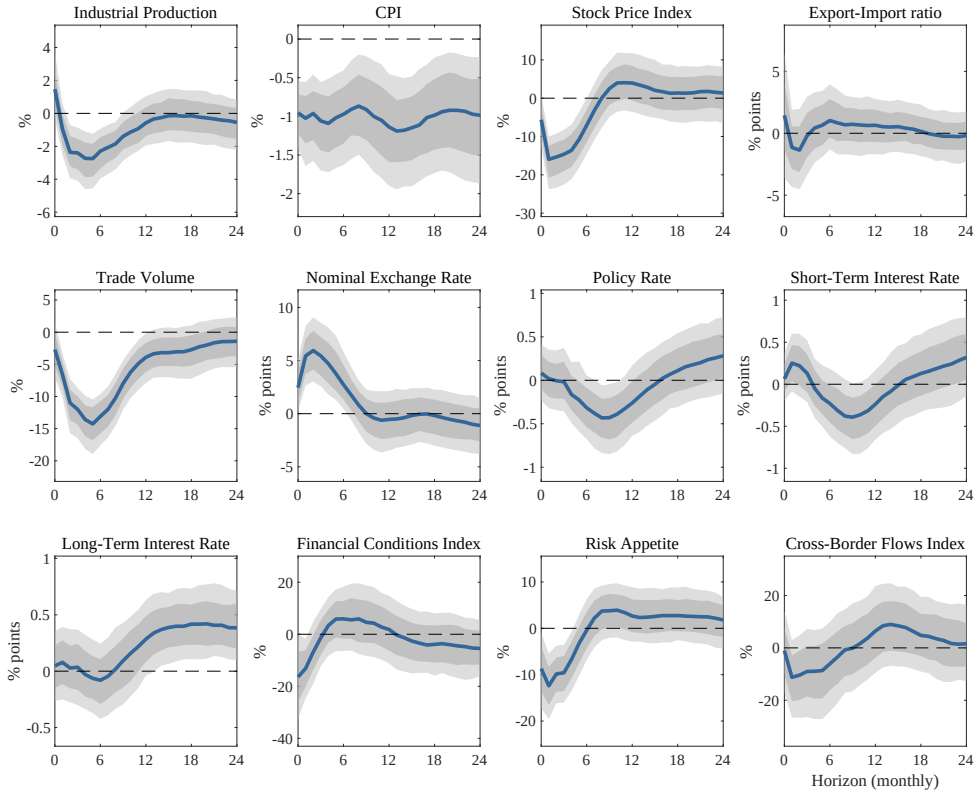
[29] The US domestic impulse responses are reported in Figure F.1 in the Online Appendix.

[30] It is important to stress that the quality and reliability of EMs data are of concern in any empirical exercise. The use of a relatively recent sample and the adoption of a median estimator help in averaging out and alleviating potential data issues.

Figure 3: Median Responses of Advanced and Emerging Economies



(a) Median Advanced Economy



(b) Median Emerging Economy

Note: Median responses of the 15 AEs and 15 EMs to a contractionary US monetary policy shock, normalised to induce a 100bp increase in the US 1-year treasury constant maturity rate. Informationally robust high-frequency identification. Sample reported in Table 1. BVAR(12) with asymmetric conjugate priors. Shaded areas are 68% and 90% posterior coverage bands.

significant at the 68% level. This points to the importance of commodity and oil prices in the transmission of the shock to consumer prices. Indeed, in line with our results from the global VAR, oil and commodity prices contract respectively by 20% and 5% at the trough, roughly 6 months after a US tightening (Figure F.2 in the Online Appendix shows the pooled responses across AEs). This contraction is consistent with the compression in global demand after the shock. Notably, this finding contrasts with Kilian and Zhou (2022)'s result that an exogenous increase in the US real interest rate causes only a modest and short-lived decline in the real price of oil (see also Frankel, 2008; Akram, 2009).[31] It is also interesting to notice that the negative comovement between commodity prices and the strength of the dollar induced by a US monetary policy tightening conforms with the observed negative correlation in these two series starting in the mid-1990s (Fratzscher et al., 2014).

In both median economies, the domestic currency depreciates vis-à-vis the dollar.[32] Far from being stimulative of domestic export, we find that the demand-reducing effect of the US tightening dominates over the expenditure-switching effect: gross trade volumes plummet by 6% for the AE and by 13.5% for the EM, while changes in the export-import ratio are insignificant, pointing to a symmetric contraction of export and import (similarly to Gopinath et al., 2020).

The US tightening triggers a risk-off scenario. Financial conditions and risk appetite deteriorate. The stock market plummets, and investors shift their asset allocation away from riskier investments. At the same time, capital flows out of EMs, albeit the response is only significant in the aggregate at the 68% level.[33] Overall, for both economies, financial channels seem to play a major role in the transmission of the shock.

An interesting case study is the Euro Area – a large economic bloc with a flexible exchange rate and open capital markets. Following a US monetary tightening, the Euro Area also suffers from recessionary effects, with production contracting by 4% and CPI by 1% at the trough, roughly 5 months after the shock (Figure F.3 in the Online Appendix).

[31] Notice that the interest rate shock in Kilian and Zhou (2022) is not a nominal monetary policy shock, as in the current paper, but a shock to the longer-term U.S. real rate of interest controlling for global shocks.

[32] EMs in our analysis have less flexible exchange rate regimes than AEs. None of our EMs is classified as a pure floater, and very few of them have hard pegs. We discuss this dimension in detail in Section 6.

[33] In general, the EMs in our analysis have stricter capital controls than the advanced ones. The median value of the Chinn-Ito index for AEs is 0.965, while it is only 0.338 for EMs. Table E.5 in the Online Appendix reports the average values of the index for all countries.

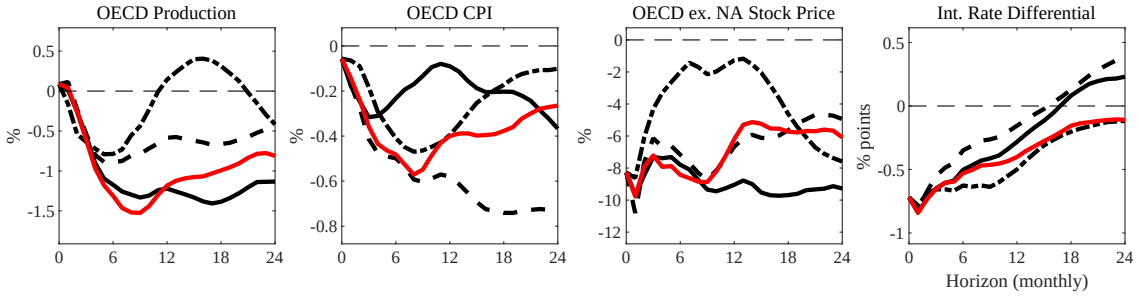
This result is in line with the effects on the median AE and comparable to the results in Ca' Zorzi et al. (2020).

3.2 Propagation through risk premia

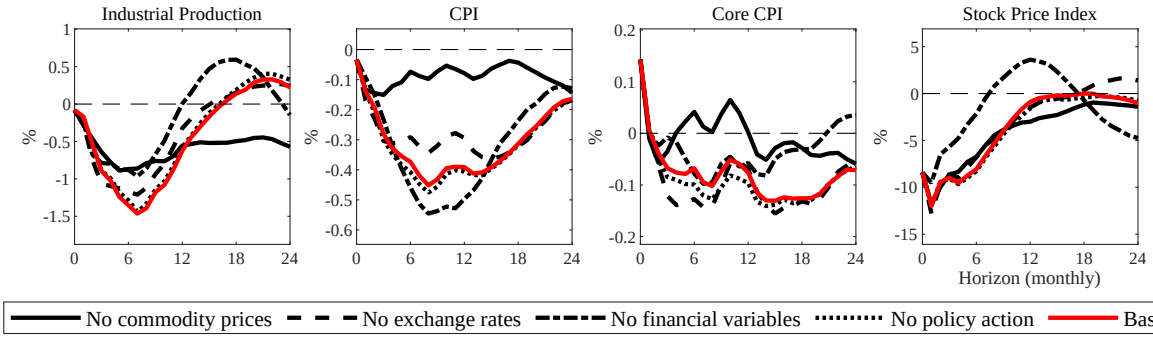
A US monetary tightening appears as a negative demand shock to the rest of the world. In both the median AE and EM, the central bank reacts to the contractionary pressure by easing the policy stance (Figure 3). In this sense, EMs' monetary policy is not pro-cyclical, as it is sometimes found in the literature that uses short-term market rates, which conflate policy stance and risk premia, as a proxy for policy rates (see De Leo et al., 2022, for a recent discussion). Indeed, in the AE, the policy easing is transmitted neatly to the short-term interest rate, while in the EM, the pass-through is only marginal. This is consistent with the result in Kalemli-Özcan (2019) of a disconnect between short-term and monetary policy rates in EMs.

For the median EM, the monetary authority eases monetary conditions with a lag. The effect materialises roughly 3 to 6 months after the shock and persists for 12 to 16 months. At the trough, the policy rate is cut by 50bp. The policy easing is not transmitted along the yield curve, as the short-term rate does not respond significantly and the long-term yields move upwards, although with a lag of 12 months. Long-term yields start to increase when the monetary policy normalisation begins. They increase by roughly 50bp. For the median AE, the responses are similar for what concerns the dynamics and the timings. The difference is in the magnitudes. The policy rate decreases by 20bp and long-term yields rise by 20bp. On impact the long-term yields drop, albeit not significantly. They revert back almost immediately, against the policy action. Overall, for both economies, the long-term rate moves up, inducing a steepening of the yield curve. This suggests that movements in risk premia impair the transmission of the policy action to the long end of the yield curve, hence to the economy, not only for EMs but also for AEs. Movements in risk premia limit the policy space in both groups of countries and create a powerful stumbling block on the ability of domestic central banks to respond to deteriorating economic conditions.

Figure 4: Disentangling the Channels of Transmission



(a) Channels of Transmission, Global economy



(b) Channels of Transmission, Advanced Economies

Note: Lines correspond to median 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), the policy rate does not react (dotted). The shock is normalised to induce a 100bp increase in the US 1-year treasury constant maturity rate. Informationally robust high-frequency identification. Sample for Figure 4a: 1990:01–2018:12. Sample for Figure 4b reported in Table 1. BVAR(12) with asymmetric conjugate priors. A full set of responses can be found in the Online Appendix, Figures F.6 and F.7.

3.3 Financial channels and the commodity price channel

What is the relative importance of the various channels at play in the international propagation of the shock? We address this question using (i) a structural scenario analysis that isolates the commodity price channel, (ii) a channel decomposition exercise that quantifies the role of different sets of channel-specific variables in the propagation of the shock in reduced form, (iii) a scenario analysis based on conditional forecast.

The commodity price channel explains a sizeable share of the contraction in OECD CPI. Figure 1 reports the responses of selected global and US variables to a contractionary US monetary policy shock in a baseline scenario where no other shock affects the system

(blue solid line) and in a counterfactual structural scenario where a sequence of oil supply news shocks completely offsets the response of the real price of oil to the monetary policy impulse.[34] When the commodity price channel is shut, the contraction in OECD prices becomes immaterial, pointing to the importance of this channel for the propagation of the shock abroad. The result indicates that the downward pressure on OECD CPI from lower demand for commodities and tighter financial conditions exceeds the upward pressure from the appreciation of the dollar. Also the response of US prices is greatly reduced, suggesting that commodity prices might have an important role in propagating the shock domestically.

Next, we perform a channel decomposition analysis (Figure 4). We employ the VAR models estimated in this section and sequentially shut down the following sets of variables: (i) real commodity and oil prices, (ii) nominal exchange rates, and (iii) a set of financial variables (financial conditions, risk appetite, cross-border flows, VIX, and Excess Bond Premium). This allows us to assess the relative importance of commodity prices, the exchange rate channel, and the financial channel in the transmission of the shock. In the case of the median AE, we also consider the role of (iv) the domestic policy rate, which gauges the importance of the endogenous response of the domestic monetary authority.[35]

Two results stand out. First, industrial production and the stock price contract less and rebound more quickly when the transmission via financial variables is shut, suggesting that financial channels play a major role in the global propagation of US monetary policy shocks. Second, the response of CPI becomes immaterial when oil and commodity prices cannot respond to the shock. This result is novel and shows that the contractionary effect of the shock on consumer prices is in fact driven by the contraction in oil and commodity prices, because of their importance in the headline inflation basket. This is what we label the commodity price channel. 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.

The effects of central bank actions and exchange rates appear relatively small. This is

[34] The shock is normalised to induce a 100bp increase in the US 1-year treasury constant maturity rate. The model is a BVAR(12) with asymmetric conjugate priors. The variables included in the endogenous set are listed in Table E.2 in the Online Appendix.

[35] It is important to notice that the set of variables used to capture the financial channel does not include all of the forward looking variables in the system, for instance commodity prices and exchange rates. As a consequence, the system controls for expectations about the future state of the economy.

not a surprise, given the limited propagation of the policy impulse due to the movements in risk premia that are prominent in the baseline results. The impairment in the transmission of domestic monetary policy is the main reason why we observe recessionary effects, as the central bank is not able to counteract the contractionary shock. In AEs, core CPI, which does not contain energy prices, shows a mild response with weaker dependence on commodity prices. The response of core CPI is partly explained by commodity prices and partly by financial variables. The role of the commodity price channel is due to the pass-through of higher commodity prices (relative to baseline) from headline to core prices. The role of the financial channel is due to the transmission from the real side, which recovers more quickly relative to the baseline, to the nominal side of the economy.[36]

As a robustness check, we re-estimate the channel decomposition using conditional forecasts. Results largely mirror those of Figure 4: the financial channel primarily contributes to the decline in production and stock prices, while the commodity price channel accounts for most of the contraction in CPI (Figures C.1 and C.2 in the Online Appendix). We also provide the channel decomposition based on conditional forecasts for the median emerging economy. The results are similar to what we find for AEs (Figure C.3 in the Online Appendix).

In broad terms, US monetary policy shocks induce (i) a strong contraction of real variables by activating financial channels and (ii) deflationary pressure via commodity prices. Overall, our results are fairly homogeneous across countries, both AEs and to a lesser degree EMs (see Section D in the Online Appendix). Indeed, EMs in our sample differ along several dimensions: the monetary policy framework adopted, the degree of openness to capital flows, the dependence on dollar-denominated funds, and the prevalence of invoicing in dollars. Some or all of these characteristics are likely to result in heterogeneous responses. Before exploring these dimensions further in Sections 5 and 6, we provide a framework to rationalise the results on median responses and the role of channels in the next section.

[36]The channel decomposition exercise for the median EM, while not in contradiction with what we find for the AE, reveals a limited differential role for each group of variables (Figure F.8). Output still bounces back more when the financial variables do not react, but now it happens only after 9 months. Shutting the oil and commodity prices channel reduces the extent of the fall in headline inflation, but only marginally. No channel seems to be predominant in the transmission to stock prices.

4 A generalised Mundell-Fleming framework

The empirical results in the previous section show a common qualitative pattern for the median AE and EM, albeit with different quantitative effects. A tightening in the US induces an economy-wide contraction with a decline in output and asset prices, downward pressure on prices, depreciation of the exchange rate and contraction of trade volumes, and an overall tightening of financial conditions with the term premium moving against the domestic central bank easing. While such a pattern may be expected for AEs, it contrasts with the standard narrative about currency crises in EMs triggered by a monetary tightening in the US. There, the deep devaluation of the domestic currency forces the domestic central bank to tighten in order to stem the sharp outflows of capital and the mounting inflationary pressure.

This section provides a rationalisation of these results using a stylised Mundell-Fleming type model that is generalised to study the effects of the financial and commodity price channels, which in our empirical analysis appear to dominate the output and price responses over the standard demand and exchange rate mechanisms. We build on Blanchard (2017) and Gourinchas (2018), which introduce financial spillovers and risk premia in a Mundell-Fleming setting with only real variables.

A domestic small open economy and the US – a large economy – are described by the following system of equations

$$Y = \underbrace{\xi - c\left(I - \Pi^{e}\right)}_{\text{domestic demand}} + \underbrace{a\left(Y^{US} - Y\right) + b\left(E + \Pi^{US} - \Pi\right)}_{\text{net export}} - \underbrace{f\left(E + \Pi^{US} - \Pi\right)}_{\text{financial spillovers}} , \tag{1}$$

$$Y^{US} = \xi^{US} - c\left(I^{US} - \Pi^{e,US}\right) , \tag{2}$$

$$E = \underbrace{d\left(I^{US} - I\right) + E^{e}}_{\text{UIP}} + \underbrace{gI^{US} + \chi}_{\text{risk premia}} , \tag{3}$$

$$\Pi = eY + mE + hC , \tag{4}$$

$$\Pi^{US} = eY^{US} + hC , \tag{5}$$

$$C = lY^{US} , \tag{6}$$

where lowercase letters are the non-negative parameters of the model, and the variables are in deviation from the steady state. The nominal exchange rate, E, is defined as such that an increase corresponds to a depreciation of the domestic currency. Domestic

output Y is a function of domestic demand, net exports, and financial spillovers. Domestic demand depends positively on a demand shifter, ξ, and negatively on the domestic real interest rate, $R = I - \Pi^e$. Net exports are increasing both in US output, Y^{US}, and in the real exchange rate, $\epsilon = E + \Pi^{US} - \Pi$, and decreasing in the domestic output. Financial spillovers impact domestic absorption and depend negatively on the real exchange rate, as in Gourinchas (2018). The financial spillover term captures different mechanisms through which an appreciation of the US dollar can affect the domestic economy via financial links. The relative importance of financial spillovers is gauged by the parameter f, with the model reverting to the standard Mundell-Fleming case for $f = 0$.

US output, Y^{US}, depends positively on a demand shifter, ξ^{US}, and negatively on the real interest rate, $I^{US} - \Pi^{e,US}$. The exchange rate E depends on the interest rate differential and the expected exchange rate E^e – the uncovered interest rate parity (UIP) determinants – and a risk premia term that is a function of interest rates in the US, plus an independent shock χ.

Domestic inflation, Π, is a function of the domestic output gap – a static Phillips curve –, the exchange rate, and the price of commodities, C. The last term captures direct spillovers to domestic prices via commodities and oil prices: a reduction in US demand can induce an adjustment in commodity prices that, in turn, transmits to headline inflation. Under the assumptions of dominant-currency pricing, US inflation Π^{US} is a function of US output but does not depend on the exchange rate.

Solving Equations (1) to (6), we find the effects on domestic output and inflation of an exogenous shift in the US nominal policy rate:[37]

$$\frac{\partial Y}{\partial I^{US}} = \frac{1}{\psi}\left[(1-m)\left(bd - fd + (b-f)\,g\right) - ac - ce\,(b-f)\right] \ , \tag{7}$$

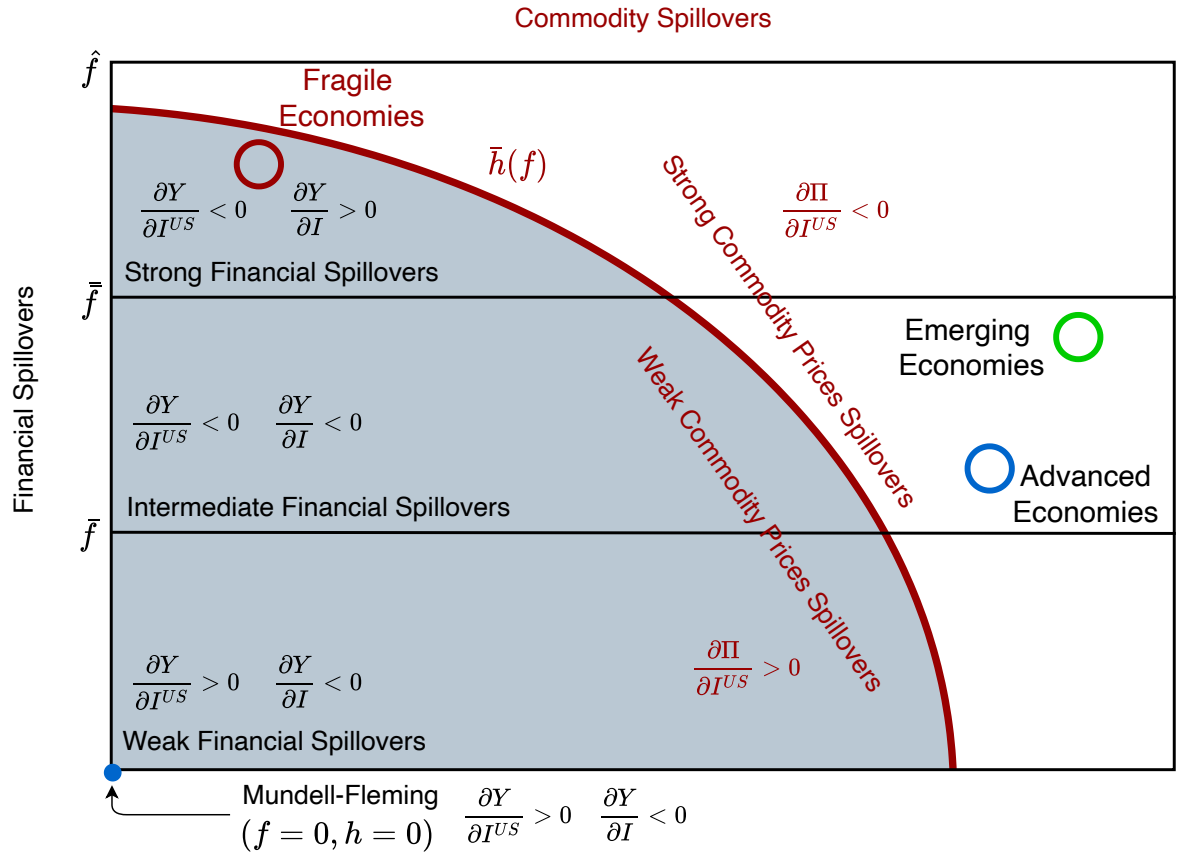
$$\frac{\partial \Pi}{\partial I^{US}} = e\frac{\partial Y}{\partial I^{US}} + m\,(d+g) - hlc \ . \tag{8}$$

First, we discuss the transmission to output (Eq. 7). In the standard Mundell-Fleming, the effect of a US tightening on domestic output is given by $bd - ac$.[38] bd captures the

[37] We assume that the expectational variables Π^e, $\Pi^{e,US}$ and E^e are known constant, that we set to zero for the sake of simplicity. A detailed discussion of the model and its solution is reported in the Online Appendix, Section A.

[38] In fact, absent financial spillovers (i.e. $f = g = \chi = 0$) and excluding any effect on domestic output coming from movements in prices (i.e. $e = m = h = 0$), the model reduces to the standard Mundell-Fleming, as a special case.

Figure 5: Real and Nominal Spillovers



Notes: This schematic representation of the channels assumes that both thresholds $\bar{f}$ and $\bar{\bar{f}}$ exist. Conditions for existence are given by Eq. A.14 and Eq. A.15 in the Online Appendix. It also assumes that in the classic Mundell-Fleming model, at the bottom-left corner of the diagram, a US monetary policy tightening has an expansionary effect abroad.

expenditure-switching channel, while ac is the demand-augmenting effect. The sign of $bd - ac$ determines the baseline 'classic' transmission – i.e. whether a tightening in the US is expansionary or contractionary for the domestic economy, absent other channels. The financial channels are represented by fd, which captures the negative effect of a dollar appreciation on domestic output via financial spillovers, and by $(b - f)\, g$, which represents the effect of risk premia. Specifically, bg captures the stimulative effect of risk premia on domestic output via the trade balance, and fg represents the negative effect via financial spillovers. Finally, the terms ceb and cef represent the effects of lower US prices via the exchange rate and financial spillovers, respectively.

Second, we consider the response of prices (Eq. 8). The first term reflects the transmission from the real to the nominal side of the economy via the Phillips curve. The second term, $m\,(d + g)$, captures the direct effect of the appreciation of the dollar on im-

port prices coming from the interest rate differential (md) and higher risk premia (mg). The third term is the effect on domestic inflation of lower commodity prices.

To explore the relative importance of financial and commodity price channels compared to the classic channels, let us focus on the case in which the expenditure-switching channel dominates the demand-augmenting effect, $bd > ac$, and hence a tightening in the US is expansionary abroad in the baseline Mundell-Fleming model. In Figure 5, this corresponds to the blue dot in the bottom-left corner.

As the strength of financial channels, f, increases from that point, simple derivations show that there exists a threshold, $\bar{f}$, above which a US tightening causes a decline in domestic output, irrespectively of the classic channels. It can also be easily shown that there exists a threshold, $\bar{\bar{f}} > \bar{f}$, separating the standard case where a domestic tightening contracts domestic output (below the threshold) from the case where a tightening induces an expansion in the economy (above the threshold).[39] The two thresholds define the three horizontal regions of weak, intermediate, and strong financial spillovers in Figure 5 (see also Gourinchas, 2018).

If commodity price spillovers, h, are not too strong, a US tightening increases domestic inflation via the Phillips curve and the depreciation of the domestic currency. In particular, it can be shown that there exists a threshold, $\bar{h}(f)$, which is a monotonically decreasing function of f, separating the regions of weak and strong commodity price spillovers. Above this threshold, which is plotted in red in Figure 5, a tightening in the US creates deflationary pressure on domestic prices. Importantly, as the pass-through to domestic import prices, m, increases, the threshold $\bar{h}(f)$ shifts rightward. In other words, the stronger the pass-through, the larger the region of weak commodity price spillovers.[40]

The empirical results in the previous section show that the median AE and EM in our sample can be characterised as having intermediate financial spillovers and substantial commodity price effects. In other words, a tightening in the US induces a contraction of prices and output, with larger effects on the EMs than the advanced ones. On the contrary, the model predicts another response pattern for economies that are particularly fragile to US spillovers and particularly sensitive to exchange rate pass-through: a tight-

[39] Conditions for the existence of the two thresholds, $\bar{f}$ and $\bar{\bar{f}}$, and for their existence on the support $[0, \widehat{f}]$ are given in the Online Appendix, Section A. The Appendix also provides a discussion on the optimal monetary policy responses to spillovers.

[40] By assumption, m has to be smaller than 1.

ening in the US would generate a deep contraction of the domestic output accompanied by strong inflationary pressure. The policy rate would have to hike in response to financial spillovers in order to support the economy and stabilise the exchange rate. The median aggregation across economies is likely to mask the underlying heterogeneity of EMs in terms of their overall fragility, policy regimes, and other structural characteristics that may determine the exposure to the US dollar. In the next section, we explore in detail the responses of what can be thought of as fragile economies before inspecting the potential heterogeneity in policy regimes and other structural characteristics in the last chapter.

5 Asymmetric effects in the 'fragile five'

Emerging markets with pre-existing fragilities – heavy reliance on foreign capital and high exchange rate pass-through in particular – have been hit hard by sudden reversals of easing cycles in the US. Following US monetary loosenings, financial conditions in EMs ease, as foreign capital flows into local bonds and risky assets. When the policy stance reverses and becomes a tightening, however, it often leads to economic crises in EMs with abrupt outflows of capital, increase in risk premia, and sharp devaluations of the domestic currency that, in turn, cause hyperinflation and deep recessions. These sudden stops justify a policy stance informed by the 'fear of floating', whereby domestic central banks hike interest rates in response to a tightening in the US.

This story is inconsistent with the responses to US monetary shocks of the median EM in Figure 3b. However, those responses are averages across different economies with largely heterogeneous degrees of exposure to the US dollar. To further explore this point, we now zoom in on a set of so-called 'fragile' EMs – Turkey, Brazil, South Africa, Chile, and Mexico – to provide a more granular view of how policy regimes and country-specific fragilities may interact in shaping asymmetric responses to US policy shocks. This is an interesting pool of countries, with high exposure to the US dollar and potentially a high exchange rate pass-through, that either experienced currency crises (Mexico in 1994, Brazil in 1999, and Turkey in 2001) or conducted particularly prudent monetary policy (Chile, South Africa, Mexico) for fear of exposing themselves to global shocks.

In studying the transmission of US monetary policy to these countries, we divide our

monetary policy instrument into positive (tightening) and negative (loosening) surprises. Then, we identify the shock in the bilateral VARs by employing these two different external instruments.[41] For ease of comparison, in plotting the IRFs, we flip the loosening response and normalise both shocks to induce a 100bp increase in the US 1-year rate. For all five countries, we extend the sample back to the early 1990s.[42]

The responses of 'fragile five' countries uncover asymmetries and patterns of responses largely in line with the narrative evidence on sudden stop crises (Figure 6). Following a US tightening, all countries but Chile experience steep devaluations of the domestic currency that feed into a high rate of inflation, while output contracts and short-term interest rates spike up. The rise in inflation is particularly dramatic in Turkey and Brazil. For instance, following a tightening, Turkey's CPI increases by 5% on impact and the effect persists for 12 months. On the other hand, following a loosening, the response of prices is not significant, with a weaker effect on the exchange rate.

The dramatic surge in the short-term rate following a US tightening – which is particularly large on impact for Brazil, Turkey, and Chile – is due to the response of the policy rate and the increase in risk premia. Differently from the case of the median EM, the central banks reacts to plummeting exchange rates by hiking rates in the attempt of steadying the economy, as is visible in the response of the policy rates, where available.[43] This in turn exacerbates the contraction in domestic economic conditions.

These responses bear the pattern of the currency crises experienced by EMs (see, for example, Eichengreen et al., 2007).[44] Our results confirm both the narrative on currency crises and intuition provided by our model, whereby fragile economies can be

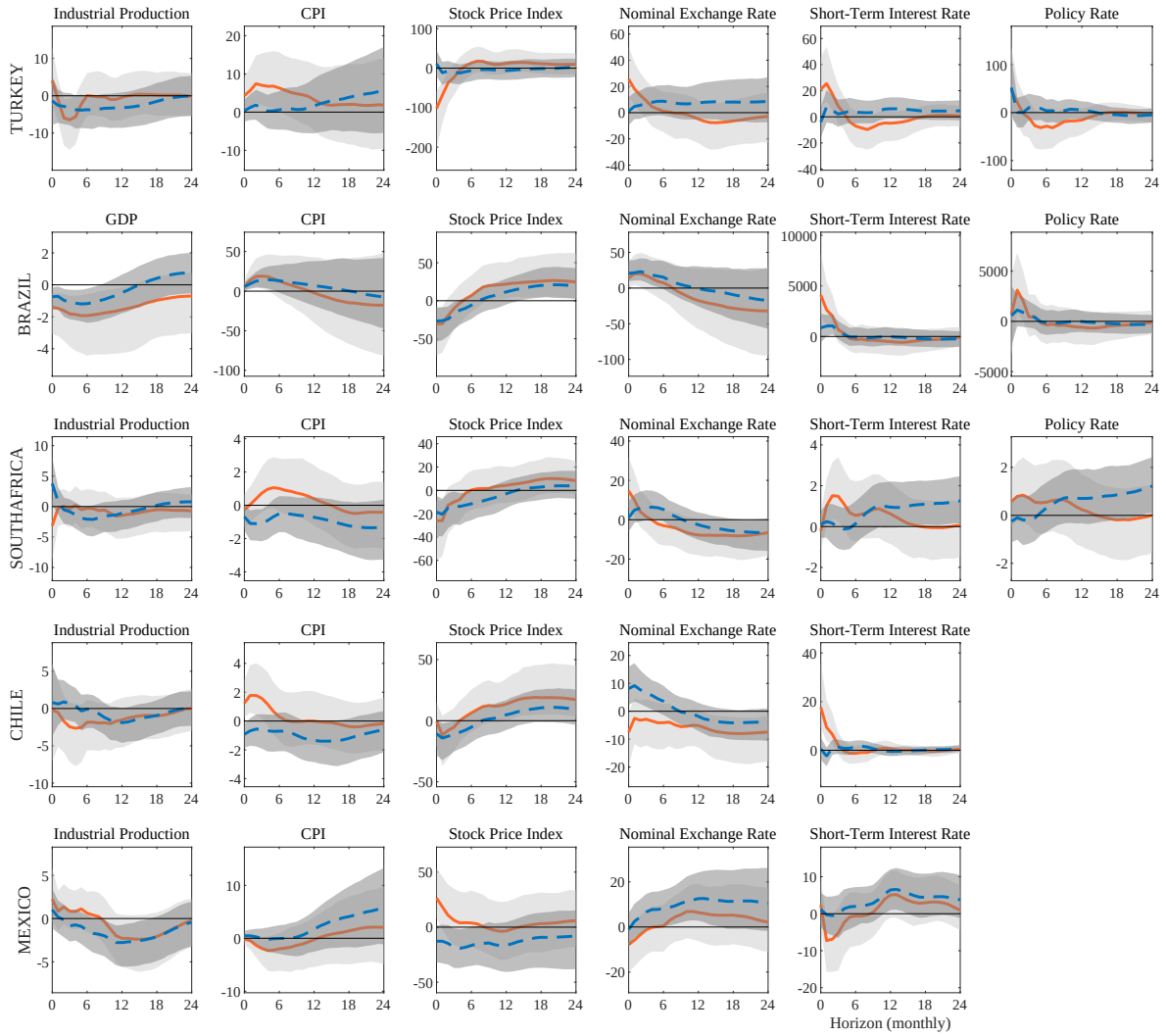
[41]This amounts to assuming that while the system is still linear, tightenings and loosenings are two different types of shock with distinct transmissions. It can be seen as a stylised way to gauge the extent of the different impacts of tightenings and loosenings while maintaining large information sets. Alternatively, one could explore the same effects using a Local Projections approach. The two approaches are largely equivalent. Importantly, when regressing the VAR residuals on the modified instruments to identify the shocks, we drop the observations for which the sign of the surprise was incompatible with the shock. Replacing it with a zero would bias the estimates (Kilian and Vigfusson, 2011).

[42]See Table E.9 in the Online Appendix for details on the sample, the interpolation method used to reconstruct some of the series, and the estimation set.

[43]The policy rate series are available from the BIS policy rate database. For Chile and Mexico, they start late relative to our sample (in 1995:5 for Chile and 1998:11 for Mexico).

[44]For instance, Brazil suffered various hyperinflationary spells during the 1980s and 1990s. The annualised policy interest rate (SELIC) grew exponentially since the early 1980s and peaked in February 1990 at 355,085.6%. By May 1990, various reforms, among which a redenomination of the currency, brought the SELIC annual rate down to 65%. In June 1994, however, the SELIC was at a new annual high of 15,405.6%. After the introduction of the Real in July 1994, Brazil managed to rein in inflation and stabilise interest rates. The average policy rate from 1995 to 2018 is around 17%.

Figure 6: Asymmetric Effects in the 'Fragile Five'



Note: Orange line – median responses of each EM to a contractionary US monetary policy shock. Dashed blue line – median responses of each EM to an expansionary shock. Shocks are normalised to induce a 100bp rise in the US 1-year treasury constant maturity rate. Informationally robust high-frequency identification. Sample reported in Table E.9 in the Online Appendix. For Brazil, we replace IP by monthly GDP interpolated backwards from 1996:01 to 1990:01. BVAR(12) with asymmetric conjugate priors. Shaded areas are 90% posterior coverage bands.

characterised by strong financial spillovers and large exchange rate pass-through to prices. The monetary policy is forced to tighten in response to a US monetary tightening in order to stabilise the economy against capital flights and hyperinflation.

6 Exchange rate regimes and capital flows

Since the wave of financial crises in the EMs 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 in an effort to create a buffer against external shocks, and a shift in government borrowing from foreign to national currencies. How effective are these policies in insulating countries from US monetary policy spillovers?

We now explore the role of different policy regimes. We group countries by their (i) exchange rate regimes (as defined by Ilzetzki et al., 2019) and (ii) degree of openness to capital (based on Chinn and Ito, 2006's index). These are two key dimensions of the classical Trilemma. We also briefly discuss the role of (iii) dollar trade invoicing (see Gopinath, 2015) and (iv) dollar gross exposure (see Bénétrix et al., 2015) in the transmission of US monetary policy.

6.1 Exchange rate regimes

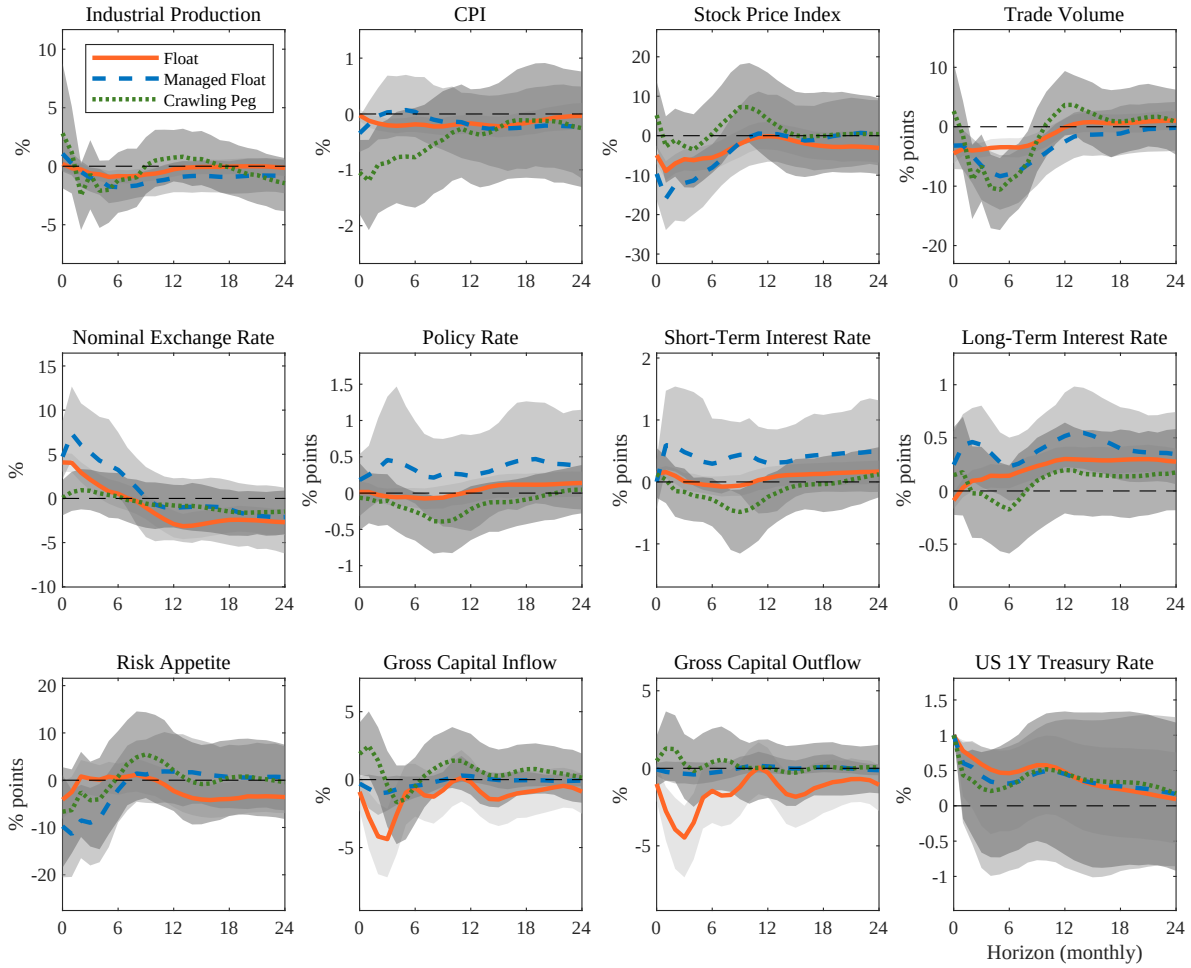
To explore the role of exchange rate regimes, we classify countries into three different groups: (i) floaters, (ii) managed floaters, and (iii) crawling peggers. We assign each country to the regime corresponding to its median value of Ilzetzki et al. (2019)'s classification over the sample period.[45] In our sample, there are 17 floaters (all AEs except Canada, plus the Czech Republic, Hungary, and Poland), 7 managed floaters (Brazil, Canada, Chile, Colombia, Mexico, South Africa, and Turkey), and 6 crawling peggers (China, India, Malaysia, Philippines, Russia, and Thailand). As before, we obtain median group responses by aggregating IRFs from the countries' bilateral models. To provide a thorough picture of capital movements, we use measures of gross inflows and outflows constructed from the official IMF balance of payments data.[46]

A few important results emerge when comparing the median responses of the three different exchange rate groups (Figure 7). First, the exchange rate response validates our classification: it depreciates for the first two groups but does not react for the crawling pegs. The stronger depreciation of the exchange rate in the managed float group reveals

[45] We use Ilzetzki et al. (2019)'s 'fine' classification to construct the three exchange rate regimes. Table E.8 in the Online Appendix contains more information about these criteria.

[46] The IMF BOPS series are not sufficiently long for Belgium and China, as they start respectively in 2002 and 2005. For Belgium, we use BIS data, while for China we extend the IMF series back to 1999 using capital flows data for Hong Kong.

Figure 7: Exchange rate regimes



Note: Orange line – median responses of 17 floaters (15 AEs except Canada, plus Czech Republic, Hungary, and Poland), Dotted blue line – median responses of 7 managed floaters (Brazil, Canada, Chile, Colombia, Mexico, South Africa, and Turkey), Green dash-dotted line – median responses of 6 crawling peggers (China, India, Malaysia, Philippines, Russia, and Thailand). Data on exchange rate regimes are from Ilzetzki et al. (2019). The shock is normalised to induce a 100bp increase in the US 1-year treasury constant maturity rate. BVAR(12) with asymmetric conjugate priors. Shaded areas are 90% posterior coverage bands.

the relative weakness of this group as compared to the free floaters, which are mainly AEs. Second, US monetary policy spillovers affect all regimes – output, CPI, stock prices, and risk appetite contract in all three groups – but the overall recessionary effects are somewhat more muted for the floaters. Crawling peggers 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.

Floaters, mostly AEs, suffer from a significant fall in both inflows and outflows, while managed floaters experience only a mild drop in inflows and no reaction in outflows.

Peggers face some outflows and contraction in inflows with a delay, but responses are insignificant. Both floaters and peggers loosen monetary conditions in response to the shock. This is not surprising once we notice that our group of peggers are the least open in terms of capital control management. Importantly, managed floaters have to hike rates, 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. The policy rate seems to stabilise capital flows: cross-border flows remain steady for this group. Conversely, floaters experience significant swings in capital flows in the absence of the capital controls that shield the peggers. Overall, responses corroborate our findings: consistent with the 'fear of floating' argument, managed floaters seem to target capital flow stability by mimicking US monetary policy. Hence, compared to floaters, they are exposed to larger real and nominal spillovers.

6.2 Openness to capital flows

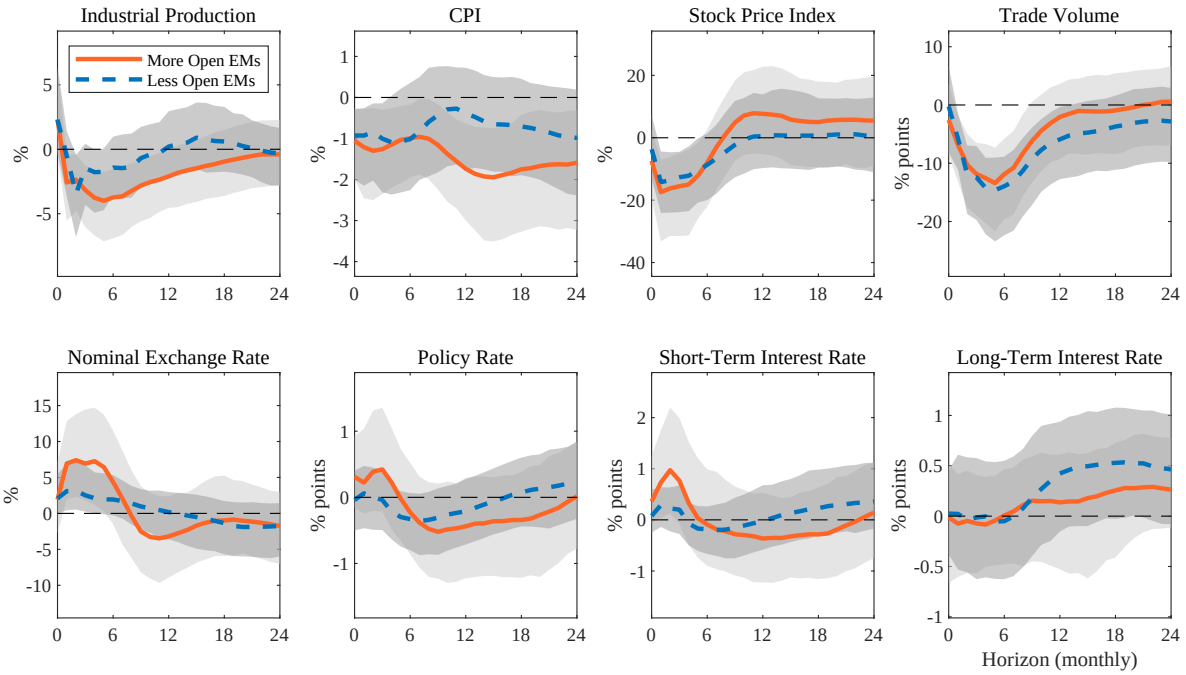
We now explore the role of capital flow management in the transmission of US monetary spillovers by comparing more- and less-open markets. To construct more- and less-open country groups, we calculate the arithmetic average over the sample period of the Chinn-Ito index, which measures the degree of *de jure* capital market openness of a country.[47] Then, we classify countries in the top tercile as more-open capital markets and countries in the bottom tercile as less-open ones.

Differences in spillover effects between more and less open EMs are stark (Figure 8).[48] While the response of industrial production in more-open markets is significantly negative, remaining below trend for almost two years, the same response in less-open countries is mostly insignificant and quickly reverts back to trend. The response of CPI for the two groups is negative and overlaps for the first six months, after which it turns insignificant for less-open EMs, while it strengthens for more-open ones. Moreover,

[47] We use the *ka_open* index, a continuous measure that ranges between 0 and 1. The higher the number is, the more open a country's capital markets are. Table E.5 in the Online Appendix contains more information about the classification.

[48] The average value of the Chinn-Ito index for more and less open EMs is 0.469 and 0.354, respectively. Chile, the Czech Republic, Hungary, Mexico, and Poland have more open capital markets, while China, India, South Africa, Thailand, and Turkey have relatively closed capital markets. It is worth highlighting that the two groups differ not only in terms of capital openness but also in terms of other structural features. For instance, we find a prevalence of floaters among more-open markets and a prevalence of peggers among less-open ones.

Figure 8: Emerging Economies with more v. less Openness to Capital

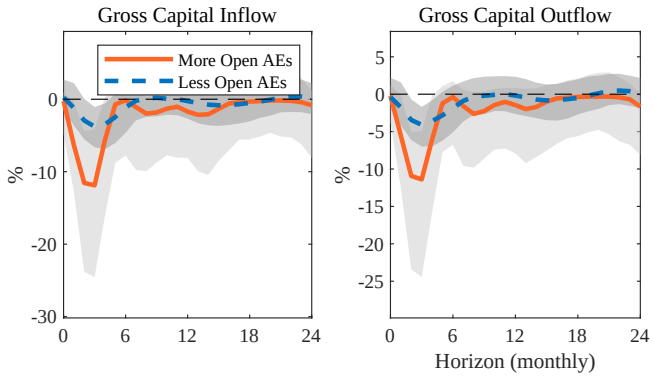


Note: Orange line – median responses of 5 EMs (Chile, Czech Republic, Hungary, Mexico, and Poland), whose overall degree of capital openness corresponds to the top 1/3 among 15 EMs. Dotted blue line – median responses of 5 EMs (China, India, South Africa, Thailand and Turkey), whose overall degree of capital openness corresponds to the bottom 1/3. Data on capital restrictions are from Chinn and Ito (2006). The shock is normalised to induce a 100bp increase in the US 1-year treasury constant maturity rate. BVAR(12) with asymmetric conjugate priors. Shaded areas are 90% posterior coverage bands.

although the nominal exchange rate depreciates for both groups, it depreciates more for the open markets. The response of policy rates suggests that less-open EMs can afford more policy space relative to more open markets. Finally, we find almost no difference in the responses of stock prices, trade volume, and long-term rates.

We repeat the exercise by comparing more- and less-open AEs and focusing on gross capital flows (Figure 9). Notably, all countries in both groups adopt a flexible exchange rate regime during the sample period 1990–2018. The two sides of flows drop and mirror each other for both groups of AEs due to the contraction of global financial activities, but the magnitude is larger for the more-open capital markets. This result indicates that even marginal differences in the degree of openness to capital can result in large spillover

Figure 9: AEs Openness to Capital: Inflows and Outflows



Note: Orange line – median responses of 5 AEs (Canada, Denmark, Germany, Netherlands, and UK), whose overall degree of capital openness corresponds to the bottom 1/3 among 15 AEs. Dotted blue line – median responses of 6 AEs (Australia, France, Italy, Norway, Spain, and Sweden), whose overall degree of capital openness corresponds to the top 1/3. Data on capital flow management are from Chinn and Ito (2006). The shock is normalised to induce a 100bp increase in the US 1-year treasury constant maturity rate. BVAR(12) with asymmetric conjugate priors. Shaded areas are 90% posterior coverage bands.

effects via capital flows.[49]

6.3 Trade and financial exposure to the US dollar

We conclude this section by focusing on EMs to explore the role of (i) the share of trade invoiced in dollars and (ii) gross dollar exposure as determinants of US monetary policy spillovers. We use data from Gopinath (2015) to classify countries based on their share of dollar trade invoicing, while we follow Bénétrix et al. (2015) to divide countries based on their exposure to the dollar.[50]

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 (Figures F.9 and F.10, in the Online Appendix). We also conduct a robustness check on our capital flow management

[49]EMs are more heterogeneous than AEs in terms of capital openness. The group of more-open capital markets consists of five countries: Canada, Denmark, Germany, Netherlands, and the UK. The relatively less-open markets are Australia, France, Italy, Norway, Spain, and Sweden. The full set of responses for AEs is reported in Figure F.12.

[50]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). Similarly to what we do 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. See Tables E.6 and E.7 in the Online Appendix for details about the classifications.

results, where we classify EMs into less- and more-open countries based on Fernández et al. (2016). Results in Figure F.11 in the Online Appendix are consistent with those in Figure 8 reported above.

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 with more open capital markets. Crucially, neither the 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. However, it is important to notice that different policy dimensions and country characteristics – the exchange rate regime, openness of capital markets, dollar trade invoicing, and gross dollar exposure – appear to be related, and the choice of the regime is likely to be endogenous and determined by country-specific deeper structural features.

7 Conclusion

This paper provides novel estimates of the spillover effects of US monetary policy shocks and delivers a number of novel findings. First, a tightening of the Fed policy stance triggers a global contraction in real activity, a risk-off scenario with the repricing of risky assets, capital outflows and, on average, downward pressure on prices. The pattern is robust and fairly homogeneous at the country level, especially across advanced economies. A detailed analysis of emerging economies shows that structural features, such as monetary policy regimes and capital flow management policies, explain part of the heterogeneity in the responses of exchange rates, policy rates, and capital flows.

Second, commodity prices are central in the transmission of the shock to headline inflation across different economies. The synchronised reduction in global activity puts downward pressure on commodity and oil prices and, in turn, on headline inflation. This mechanism operates differently in fragile emerging markets with strong financial exposure to the US dollar and a high pass-through of imported prices, where the US tightening causes upward pressure on prices.

Third, the transmission to real variables largely operates via financial variables. A key mechanism is the repricing of risk premia that steepens the term structure, with the long

end of the yield curve moving against the policy impulse and partially neutralising the response of the local central banks. Flexible exchange rates provide a substantial degree of insulation. However, they cannot entirely prevent spillovers via financial variables and risk premia that limit the ability of a central bank to stabilise the economy fully. The depth and reach of the international spillovers of US monetary policy indicate the need for a rich policy toolkit, including ex-ante macro-prudential policies and the ex-post activation of multiple monetary policy tools to mitigate the shocks.

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