Global implications of multi-dimensional US monetary policy normalization[*]

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September 16, 2022

Work in progress

Abstract

At least since the Global Financial Crisis US monetary policy spans several dimensions and has been documented to involve (Delphic) information effects. This multi-dimensional nature of US monetary policy is not adequately accounted for by existing work on spillovers. We explore spillovers, associated trade-offs and non-linearities, simultaneously accounting for the different dimensions of the Federal Reserve's toolkit and information effects. Findings novel to the literature are: (i) forward guidance and asset purchases entail large spillovers to the rest of the world, while conventional monetary policy is essentially inconsequential; (ii) for emerging market economies Delphic forward guidance is expansionary as risk-on effects reduce spreads and induce capital inflows, while for advanced economies it is contractionary as globally active banks reduce cross-border credit and as commodity import bills rise; (iii) forward guidance and large-scale asset purchases induce trade-offs for emerging market economy policymakers; (iv) the effects of forward guidance are amplified by recipient-economy macro-financial vulnerabilities and recessions; (v) spillovers are generally small when US monetary policy tightenings occur in US business cycle expansions.

Keywords: US monetary policy shocks, central bank information shocks, monetary policy spillovers, high-frequency identification.
JEL-Classification: F42, E52, C50.

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[*] We would like to thank, without implying endorsement, our discussants Ambrogio Cesa-Bianchi and Peter Tillmann, and for their comments Martin Schmitz, seminar participants at Bank of Canada, IW Halle, University of Tübingen and the ECB, as well as conference participants at the ADB-BIS-HKIMR Workshop on Monetary Policy Spillovers and the 2022 Annual Central Bank Research Association Meeting. Silvia Miranda-Agrippino kindly shared her data on global factors in risky asset prices and capital flows. Jonas Bagola and Francesca Verga provided excellent research assistance. The views expressed in the paper do not reflect those of the ECB, the Eurosystem and should not be reported as such.

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1 Introduction

The dominant role of the dollar in the international monetary and financial system has sparked a rich literature on the global implications of Federal Reserve (Fed) monetary policy. Nonetheless, important gaps in our understanding of the global implications of Fed monetary policy remain, and new gaps keep emerging. In particular, examining the effects of US monetary policy has become more complex due to the zero lower bound since the Global Financial Crisis (GFC). The Fed's toolkit now extends from the conventional Fed funds rate to forward guidance and asset purchases. In addition, recent work suggests that surprise tightenings may not necessarily reflect monetary policy shocks in terms of deviations from a feedback rule, but instead central bank information (CBI) effects.[1]

As we discuss in more detail below, existing empirical work on the spillovers from US monetary policy that addresses these challenges either accounts for the multi-dimensional nature of the Fed's toolkit *or* for CBI effects. To our knowledge no work exists that accounts for these two aspects *simultaneously* in a—as we explain below—coherent manner. This is an important gap, as when only a subset of the true shocks in the data related to monetary policy is identified their estimates could be contaminated by those shocks that are ignored. Our paper fills this gap. We estimate the global spillovers from the different dimensions of US monetary policy while simultaneously accounting for CBI effects.

In particular, we consider the novel conventional monetary policy, Odyssean and Delphic forward guidance as well as large-scale asset purchase (LSAP) shocks identified by Jarociński (2021). The identification exploits the non-Gaussianity of high-frequency asset price surprises around Federal Open Market Committee (FOMC) meetings, namely that in the few cases in which they are meaningfully different from zero they are rather large. Other approaches to identify shocks to the different dimensions of US monetary policy exist (Rogers et al., 2018; Lewis, 2019; Bu et al., 2021; Inoue and Rossi, 2021; Swanson, 2021; Kaminska et al., 2021). However, the approach of Jarociński (2021) relies on relatively weak identification assumptions and produces shocks that simultaneously distinguish between 'pure' conventional and unconventional monetary policies *and* account for CBI effects.

We estimate the effects of US monetary policy on global financial markets, real activity, and capital flows by local projections with daily and monthly data for 1991–2019. As recommended by the extensive Monte Carlo analyses of Li et al. (2021), for the monthly regressions we adopt the smooth local projections of Barnichon and Brownlees (2019) to address the excessive variability plaguing estimates in typical macroeconomic time-series samples.

Our results echo existing findings that spillovers from US monetary policy are large, that

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[1] Throughout this paper by 'central bank information effect' we mean an unexpected monetary policy tightening that is followed by more bullish financial markets and an economic expansion. This pattern can be rationalized by a 'CBI effect' as agents update their beliefs about the economy based on the observed monetary policy stance (e.g. Romer and Romer, 2000; Campbell et al., 2012; Melosi, 2017; Nakamura and Steinsson, 2018; Cieslak and Schrimpf, 2019; Jarociński and Karadi, 2020; Miranda-Agrippino and Ricco, 2021). It can also be rationalized by Neo-Fisherian effects (e.g. Uribe, 2022). It might also reflect the 'Fed response to news' (Bauer and Swanson, 2020) or mechanisms related to the disagreement about the state of the economy (Sastry, 2021). For the sake of brevity we refer only to 'CBI effects' in the rest of the paper.

they transmit through variations in global investors' risk aversion, global financial conditions and capital flows, and that economies that exhibit macro-financial vulnerabilities and are in recessions are more susceptible. Our main contribution compared to existing work is to provide new evidence with greater resolution regarding the different dimensions of the Fed's toolkit and CBI effects.

Our key findings are as follows. We first document that the different dimensions of US monetary policy transmit differently to the global economy. Forward guidance and LSAP shocks elicit large spillovers to the rest of the world, while conventional shocks to the Fed funds target rate do not induce meaningful spillovers. Especially forward guidance shocks are amplified by local macro-financial vulnerabilities. And we show that estimates of spillovers from forward guidance are counterintuitive if one does not account for CBI effects.

We furthermore provide new evidence on the global transmission of CBI effects. In particular, in response to a Delphic forward guidance tightening the dollar depreciates against emerging market economy (EME) currencies, consistent with a 'risk-on' effect that depresses currency risk premia; at the same time, the dollar appreciates against advanced economy (AE) currencies, consistent with divergences between foreign and US policy rates. Moreover, on the one hand, the 'risk-on' sentiment reflected in the dollar depreciation vis-à-vis EMEs is associated with an increase in capital inflows and a compression of credit spreads, consistent with the mechanism centering on risk premia discussed in Akinci and Queralto (2019) and Ahmed et al. (2021). On the other hand, the dollar appreciation vis-à-vis AEs is associated with a contraction in cross-border credit, consistent with the mechanism centering on currency mismatches on globally active banks' balance sheets discussed in Bruno and Shin (2015b). Additionally, as the dollar appreciates against the currencies of AEs, they are subject to contractionary effects stemming from rising commodity prices, which are largely invoiced in dollar; in contrast, as the dollar depreciates against the currencies of EMEs, they are shielded from commodity price increases. As a result, real activity spillovers from CBI effects are expansionary in EMEs but contractionary in AEs.

We also provide new evidence for differences in the transmission of US monetary policy through capital flows across types of instruments and AEs versus EMEs. In particular, contractionary Odyssean forward guidance shocks cause a drop in equity and private bond inflows to the US, as well as a repatriation of US holdings of foreign equity. Equity inflows indeed drop markedly in AEs and EMEs. At the same time, US inflows to safe Treasury securities and agency bonds increase. These patterns are consistent with a risk-off effect conditional on a contractionary Odyssean forward guidance shock. In contrast, LSAP shocks elicit patterns that are consistent with the observation that foreign investors piled up US Treasury securities during the QE2 and QE3 programs (Coeure, 2017): in response to LSAP shocks foreign investors buy (sell) US Treasuries when the Fed is buying (selling) them, with US investors on the other end of these transactions. Finally, Delphic forward guidance shocks induce an increase in global equity inflows in the US, AEs and EMEs, as well as inflows to EME bonds. At the same time, US inflows to Treasury securities and agency bonds fall. These patterns following a Delphic forward guidance shock are again consistent with a risk-on effect. Overall, our findings support the notion of US monetary policy driving a global financial cycle through variation in risk aversion (Bruno and Shin, 2015a; Miranda-Agrippino and Rey, 2020b).

We additionally provide new evidence that spillovers from US monetary policy imply trade-offs for policymakers in EMEs, either between output and price stabilization and/or between macroeconomic stability in terms of output and prices on the one hand and financial stability in terms of capital inflows on the other hand. In particular, Odyssean forward guidance shocks dampen real activity but put upward pressure on consumer prices; the latter can be accounted for by the appreciation of the dollar against EME currencies in the presence of pervasive dollar invoicing of global trade (for evidence on this dominant-currency paradigm see Boz et al., 2022). Delphic forward guidance shocks stimulate real activity and put downward pressure on consumer prices, hence also move output and prices in opposite directions. And while LSAP shocks put downward pressure on EME consumer prices and real activity, they also induce a drop in capital inflows. For LSAP shocks policymakers thus face a trade-off between leaning against capital inflows and stabilizing consumer prices.

Finally, we document that spillovers from US monetary policy tightenings are generally small when these occur during US or local business cycle expansions, but large during recessions. Moreover, we document that especially—both Odyssean and Delphic—forward guidance entails larger spillovers to economies with greater macro-financial vulnerabilities.

Our empirical evidence on the transmission of the different dimensions of US monetary policy and CBI effects to the global economy also informs the theoretical literature on the spillovers and transmission channels of US monetary policy as well as CBI effects. First, Alpanda and Kabaca (2020) and Kolasa and Wesołowski (2020) consider multi-country structural models with segmented asset markets for long and short-term bonds within and across countries to study the cross-border effects of LSAPs. Both show that expansionary LSAP shocks generate reductions in term premia and exchange rate depreciations vis-à-vis the dollar. However, regarding the real activity spillovers the model of Alpanda and Kabaca (2020) predicts that the former effect dominates, while in Kolasa and Wesołowski (2020) the latter is predicted to be stronger. In our empirical analysis we find that expansionary LSAP shocks also have expansionary real activity spillovers to the rest of the world. Second, Ahmed et al. (2021) consider a structural two-country model with financial frictions, partly-dollarized balance sheets and imperfectly anchored inflation expectations. They show that a US monetary policy tightening driven by stronger-than-expected US aggregate demand entails an increase in corporate bonds spreads and expansionary spillovers to EMEs only when these exhibit solid fundamentals. In contrast, in our empirical analysis we find that US CBI effects are actually followed by a decline in credit spreads and expansionary real activity effects especially in economies with greater macro-financial vulnerabilities.

In terms of policy implications, our analysis speaks to the challenges faced by the global economy associated with the normalization of US monetary policy as the COVID-19 pandemic fades, the Russia-Ukraine war unfolds, and inflationary pressures mount. Discussions in this context revolve around the normalization across the different dimensions of the Fed's toolkit and the communication necessary to avoid markets deeming a tightening to be excessive given their views on fundamentals (Powell, 2019). Our analysis also speaks to the demands for new 'rules of the monetary game' voiced repeatedly by EME policymakers since the GFC (Rajan, 2013, 2016). Our findings for trade-offs for EME policymakers suggest that a necessary condition for the desirability of international monetary policy coordination in which the Fed internalizes spillovers in its decision-making is satisfied (Engel, 2016).

Related literature. The literature on spillovers from US monetary policy is large and growing. Early work focuses on the effects of conventional monetary policy and does not distinguish between 'pure' monetary policy (PMP) shocks and CBI effects (Georgiadis, 2016; Dedola et al., 2017; Iacoviello and Navarro, 2019; Miranda-Agrippino and Rey, 2020b; Dees and Galesi, 2021). More recent work distinguishes between the different dimensions of monetary policy in the context of spillovers, but does not account for CBI effects (Tillmann, 2016; Rogers et al., 2018; Miranda-Agrippino and Rey, 2020a; Bhattarai et al., 2021). And some work distinguishes between PMP shocks and CBI effects when estimating macroeconomic spillovers, but does not distinguish between the different dimensions of US monetary policy (Bräuning and Sheremirov, 2019; Degasperi et al., 2020; Jarociński, 2020; Pinchetti and Szczepaniak, 2021; Camara, 2021; Gai and Tong, 2022).

Some work on spillovers that distinguishes between the different dimensions of US monetary policy and *simultaneously* accounts for CBI effects exists, but may be subject to important pitfalls. In particular, Miranda-Agrippino and Nenova (2022) and Miranda-Agrippino and Rey (2022) use the conventional, FG and LSAP shocks constructed by Swanson (2021) as external instruments in a VAR model. They cleanse the shocks one at a time from CBI effects based on the sign of the stock market surprise. This approach might be problematic because the sign of the stock market surprise has to identify CBI effects in *three*—conventional, FG and LSAP—shocks. Our contribution is to document that it is important to distinguish between the different dimensions of US monetary policy and *simultaneously* account for CBI effects.

Our paper is also related to the literature on non-linearities in the effects of US monetary policy. One strand of this literature studies asymmetries in the domestic effects of monetary policy across tightenings and loosenings, without distinguishing between conventional, FG and LSAP shocks and accounting for CBI effects (Angrist et al., 2018; Barnichon and Matthes, 2018; Debortoli et al., 2020). Other work on non-linearities studies asymmetries in the domestic effects of US monetary policy over the business cycle, again without distinguishing between conventional and unconventional shocks and accounting for CBI effects (Barnichon and Matthes, 2016; Tenreyro and Thwaites, 2016; Jorda et al., 2020; Bruns and Piffer, 2021). Our contribution to this literature is to provide evidence for non-linearities in *spillovers* rather than domestic effects as well as for non-linearities in the effects of *unconventional* US monetary policy; we are not aware of any work that studies these two issues.

The paper is organised as follows. Section 2 discusses the identification of US monetary policy shocks we use in the empirical analysis. Section 3 presents the results for the global spillovers from US monetary policy. Section 4 concludes.

2 Identification of US monetary policy shocks

2.1 High-frequency identification

Prompted by the seminal work of Kuttner (2001), Cochrane and Piazzesi (2002) and Gertler and Karadi (2015), identifying monetary policy shocks based on high-frequency interest rate surprises around central bank policy announcements has become the industry standard in empirical monetary economics. When financial markets price in the expected endogenous response of central banks to the state of the economy, interest rate surprises are useful for isolating the exogenous variation in monetary policy. The latter can then be treated as an exogenous intervention and used to estimate the causal effects of monetary policy.

The basic high-frequency identification approach has been refined in two directions. The first is to distinguish between current interest rate policy and unconventional monetary policies, namely FG and LSAPs (see, for example, Gürkaynak et al., 2005a,b; Swanson, 2021; Inoue and Rossi, 2021). The second is to address the concern that high-frequency surprises might be contaminated by some residual endogenous monetary policy component. Cieslak and Schrimpf (2019), Lewis (2019), and Jarociński and Karadi (2020), among others, exploit the high-frequency co-movement between interest rates and stock prices to distinguish PMP shocks and CBI (Delphic) effects associated with the central bank's endogenous response to the state of the economy. An alternative approach is pursued by Miranda-Agrippino and Ricco (2021) as they cleanse interest rate surprises by non-publicly available, internal Fed forecasts. In a similar vein, Bauer and Swanson (2022) cleanse high-frequency interest rate surprises by publicly available data to purge from a combination of a 'Fed response to news' effect and the financial markets' learning about the Fed's reaction function.

The existence of CBI effects helps explain a number of puzzling patterns in monetary policy spillovers, often related to unconventional measures. For example, Gürkaynak et al. (2021) and Stavrakeva and Tang (2018) document that the dollar exchange rate moves in counterintuitive directions on several FOMC announcement dates given the signs of the high-frequency interest rate surprises. Lakdawala (2019) uses the path factor surprises of Gürkaynak et al. (2005b) as an external instrument in a VAR model and finds they are followed by increases in US output and prices. Similarly, Jarociński (2020) documents counterintuituive spillovers from ECB interest rate surprises. Lakdawala (2019), Lewis (2019), Jarociński and Karadi (2020), Miranda-Agrippino and Ricco (2021), Miranda-Agrippino and Rey (2022) and Bauer and Swanson (2022) find that accounting for CBI effects eliminates these puzzles.

2.2 Identification by fat tails

In this paper we use the novel identification of monetary policy shocks proposed by Jarociński (2021). The approach simultaneously distinguishes between (i) conventional and unconventional monetary policy and (ii) PMP shocks and CBI effects. It picks up the most salient dimensions of Fed policy announcements in a data-driven way by exploiting the fat-tailed distribution of the high-frequency surprises for identification.

The approach of Jarociński (2021) starts from the observation that the high-frequency interest rate surprises around FOMC meetings are highly non-Gaussian with fat tails. Intuitively, this means that the surprises are very small for most FOMC meetings, and those few meetings where they are meaningfully different from zero they tend be rather large. Motivated by this observation, Jarociński postulates that the surprises in n observed financial market variables around FOMC meeting m and collected in the vector $\boldsymbol{y}_m$ are generated by

$$\boldsymbol{y}_m = \boldsymbol{C}\boldsymbol{u}_m, \qquad u_{j,m} \overset{i.i.d.}{\sim} \mathcal{T}(\nu), \tag{1}$$

where $\boldsymbol{u}_m$ are unobserved, structural—i.e. uncorrelated—shocks and $\mathcal{T}(\nu)$ indicates Student's t-distribution with ν degrees of freedom. Jarociński then estimates $\boldsymbol{C}$ and ν in Equation (1) by maximum likelihood using surprises in -10min/$+20$min windows around 241 FOMC meetings from June 1991 to June 2019 from the dataset of Gürkaynak et al. (2005a). $\boldsymbol{y}_m$ includes the expected Fed funds rate after the FOMC meeting $MP1$ (the first Fed funds future adjusted for the number of the remaining days of the month), the 2 and 10-year Treasury yields $ONRUN2$ and $ONRUN10$, and the S&P 500 bluechip stock market index. Upon estimation of $\boldsymbol{C}$, the implied shocks $\boldsymbol{u}_m$ can be recovered.[2]

Since the shocks are pinned down by a statistical criterion rather than economic assumptions, Jarociński labels them *ex post* based on their effects on the financial markets; this is the same as in the identification-through-heteroskedasticity approach of Rigobon (2003). Figure 1 presents estimates of the daily effects of one-standard deviation-sized shocks on the Effective Fed funds rate and yields of Treasury securities with different maturities (blue), the expectations component of the Treasury yield curve (green), Treasury term premia (black), and stock prices (cyan).[3] Filled bars indicate that the estimate is statistically significantly different from zero at the 10% significance level. The sample period spans January 1991 to June 2019 and is determined by the availability of the shock time series of Jarociński (2021).[4]

As can be seen in Figure 1, the first three shocks of Jarociński (2021) can be readily labelled as 'conventional monetary policy', 'Odyssean FG' and 'LSAP' shocks based on their estimated effects on financial market variables (for a detailed discussion see Jarociński, 2021).[5]

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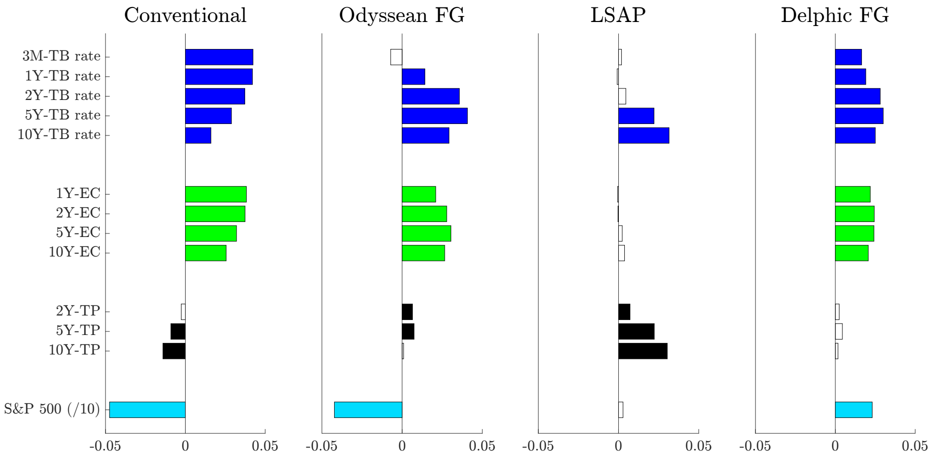
[2] The identification of the model in Equation (1) depends crucially on the distribution of the shocks. For example, when the shocks are Gaussian the model is not identified and there are infinitely many different $\boldsymbol{u}$ and $\boldsymbol{C}$ that fit the data equally well. By contrast, when the shocks are independent and fat tailed $\boldsymbol{u}$ and $\boldsymbol{C}$ are identified up to reordering and changing the signs.

[3] The New York Fed publishes the Effective Fed funds rate for the previous business day at 9.00am, and the exchange rates reported by the Fed are Certified Noon New York City Buying Rates. For these two variables the reference period thus precedes the FOMC meeting windows from 1.50-2.30pm around which the interest rate surprises used in the estimation of the shocks in Jarociński (2021) are calculated. For the daily regressions we therefore take the respective values of the Effective Fed funds rate and dollar exchange rates from the day after the FOMC meeting.

[4] One might object that there were arguably no LSAP shocks before the GFC. However, the non-Gaussian framework of Jarociński (2021) accounts for this and allows shocks to be approximately zero over many periods. Although FG was not an explicit policy before the Great Recession, signals about the future path of policy rate have long been part of Fed policy announcements from as early as 2003 (Lunsford, 2020) and are statistically and economically important in the data (Gürkaynak et al., 2005b).

[5] Swanson (2021) also finds that his LSAP shock does not have a statistically significant effect on stock prices in his full sample. When splitting the sample, Jarociński (2021) shows that in the second half the third

Figure 1: Daily financial market impact effects of the US monetary policy shocks of Jarociński (2021)



Note: Each bar depicts the daily impact response of a US monetary policy shock estimated from the local projections in Equation (2). The shocks are taken from Jarociński (2021), and are included simultaneously in the regressions. We include one lag and no controls, but results hardly change for less parsimonious specifications. We include all four shocks simultaneously, but results are very similar if we run the regressions separately for each shock. The expectation components and term premia are taken from Adrian et al. (2013) as in Curcuru et al. (2018b). The sample period spans 1991m1 to 2019m6. Filled bars indicate estimates that are statistically significant at the 90% confidence level. Standard errors are robust to heteroskedasticity and serial correlation.

The fourth shock is consistent with a 'Delphic' CBI effect: it induces a positive co-movement between interest rates and stock prices. Figure D.3 in the Appendix presents financial market effects estimated for up to 20 business days.

Figure D.1 in the Appendix depicts the shocks over time. Two observations are worth emphasizing. First, conventional monetary policy shocks have been muted since the GFC, consistent with the zero lower bound and the role of FG and LSAPs in the Fed's monetary policy since then. Second, LSAP shocks have been particularly prevalent between the GFC and 2015 after which the Fed started to taper. Note that none of these patterns in the shocks are imposed *ex ante* as identification assumptions.

Jarociński (2021) documents that the estimated shocks hardly change when the baseline model in Equation (1) is modified in various plausible ways. First, he shows that the results are robust to replacing the variables in $\boldsymbol{y}_m$ by the principal components of a larger set of financial market variables. Second, results are robust to identifying more shocks: the baseline four shocks change little, and the additional shocks reflect additional Delphic or uncovered interest parity shocks. And third, results are robust to relaxing the assumption of mutual independence of the shocks by allowing for some (data-determined) common volatility.

Finally, it is worthwhile to briefly discuss the notion of CBI effects in the context of

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shock elicits the same financial market effects as the LSAP shock in the full sample but causes a contraction in stock prices. In the first half of the sample the third shock elicits patterns that are consistent with a second Delphic shock on the current monetary policy stance.

our paper. The identification of Jarociński (2021) relies on assumptions about *statistical* properties of shocks rather than about their economic nature and their effects on financial and macroeconomic variables. This is worth stressing in the context of the Delphic FG shock that generates a positive co-movement of interest rates and stock prices. The presence of this shock in market reactions to FOMC announcements is an empirical finding, not an assumption. According to our reading of the literature, the dominant interpretation of such a shock is that it reflects CBI effects (Romer and Romer, 2000; Campbell et al., 2012; Melosi, 2017; Nakamura and Steinsson, 2018). An alternative, complementary interpretation is that it reflects Neo-Fisherian effects (see for example Uribe, 2022). Bauer and Swanson (2020), Sastry (2021) and Bauer and Swanson (2022) question the evidence for CBI effects, at least in survey expectations, arguing for different variants of a 'Fed response to news' effect. In this paper we refer to the CBI effect interpretation given our estimates for its financial and macroeconomic effects, but we are open to other interpretations, such as the Neo-Fisherian effects of Uribe (2022) or 'Fed response to news' effects of Bauer and Swanson (2020, 2022). Whatever the economic mechanism behind this shock, our point in this paper is that if this shock is not accounted for then the estimates of the effects to monetary policy shocks display counterintuitive patterns.

2.3 Benchmarking against industry-standard shocks

We next compare the shocks of Jarociński (2021) with several alternative sets of shocks identified from high-frequency surprises around FOMC meetings. We draw three main conclusions. First, identifications that separate conventional monetary policy centering around the current Fed funds rate from policies that affect longer term interest rates imply that the latter have much larger effects (when comparing one standard deviation shocks). This finding echoes Gürkaynak et al. (2005a), who highlight the greater importance of the "path factor" relative to the "target factor". Second, the identification of Jarociński (2021) that separates Odyssean from Delphic FG implies these have large and qualitatively different macroeconomic effects. In contrast, the identification of Swanson (2021) that pins down only a single FG shock implies small macroeconomic effects. We argue this might be the result from averaging the expansionary effects of Delphic FG and contractionary effects of Odyssean FG. Third, the identification approaches of Jarociński and Karadi (2020), Miranda-Agrippino and Ricco (2021) and Bauer and Swanson (2022) that disentangle CBI effects and PMP shocks imply macroeconomic effects that are qualitatively similar to those of the Delphic FG shock of Jarociński (2021).[6]

In order to arrive at these conclusions, we estimate the medium-term effects based on local projection regressions

$$y_{t+h} - y_{t-1} = \boldsymbol{\gamma}^{(h)\prime}\boldsymbol{\epsilon}_t + \tau^{(h)} + \sum_{\ell=1}^{p} \alpha_j^{(h)\prime} y_{t-j} + \sum_{\ell=1}^{p} \boldsymbol{\beta}_j^{(h)\prime} \boldsymbol{x}_{t-j} + u_t^{(h)}, \tag{2}$$

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[6] In Appendix A we present a comparison of estimates of the daily financial market effects of the shocks of Jarociński (2021), Jarociński and Karadi (2020) and Bauer and Swanson (2022).

where y_t is the response variable of interest, $\boldsymbol{x}_t$ are controls, and $\boldsymbol{\epsilon}_t$ is the four-dimensional vector containing the conventional monetary policy, Odyssean FG, LSAP, and Delphic FG shocks of Jarociński (2021).[7] We set $p = 3$ in Equation (2) and include as controls the 1-year Treasury yield, the logarithms of US CPI and monthly US real GDP, and the excess bond premium of Gilchrist and Zakrajsek (2012). Results are very similar if we include more lags and controls.

Given the relatively short time series at the monthly frequency, we employ the smooth local projections (SLPs) proposed by Barnichon and Brownlees (2019) instead of ordinary least squares (OLS) regressions of Equation (2) as for the daily financial market effects. Intuitively, as OLS estimation of the local projection regressions is carried out independently across horizons $h = 0, 1, \ldots, H$, in empirically relevant sample sizes the estimates of the impulse responses $\boldsymbol{\gamma}^{(h)}$ often suffer from excessive variability. To avoid this, Barnichon and Brownlees (2019) model the sequence of impulse responses $\{\boldsymbol{\gamma}^{(h)}\}_{h=0,1,\ldots,H}$ as a linear combination of more parsimonious B-spline basis functions and obtain the associated coefficients using an estimator that shrinks $\{\boldsymbol{\gamma}^{(h)}\}_{h=0,1,\ldots,H}$ toward a polynomial. The SLP approach of Barnichon and Brownlees (2019) is one in a class of strategies aimed at obtaining regularized estimates of impulse responses (Barnichon and Matthes, 2018; Miranda-Agrippino and Ricco, 2021). Using Monte Carlo simulations Barnichon and Brownlees (2019) document that SLPs achieve substantial improvements over standard LPs in terms of mean squared error for a range of data generating processes. Indeed, comparing OLS with penalized and Bayesian local projections or VAR models in extensive Monte Carlo experiments, Li et al. (2021) document that SLPs are among the class of shrinkage estimators that are optimal for most combinations of a researcher's bias/variance weights and response horizons.[8]

Figure 2 presents estimates of the effects on domestic real GDP and consumer prices over 24 months. The black solid lines represent the estimates of the impulse response to one-standard-deviation US monetary policy shocks. The conventional, Odyssean FG and LSAP shocks of Jarociński (2021) are generally contractionary for US real activity and consumer prices. Similarly, Figure 3 documents that over short to medium-term horizons the US excess bond premium rises and stock prices fall in response to US PMP shocks.

One interesting observation in Figures 2 and 3 is that the effects of conventional US monetary policy—in terms of one-standard deviation shock effects—are small compared to those from Odyssean FG and LSAP, echoing the findings of Gürkaynak et al. (2005a). This finding obtains also when we use the conventional, FG and LSAP shocks of Swanson (2021), as indicated by the impulse responses depicted by the red crossed lines in Figures 2 and 3.

Figure 2 also shows that Delphic FG shocks are expansionary for consumer prices, while they only have a very small and short-lived expansionary effect on US real activity. The findings for financial variables in Figure 3 also show an expansionary effect. These findings

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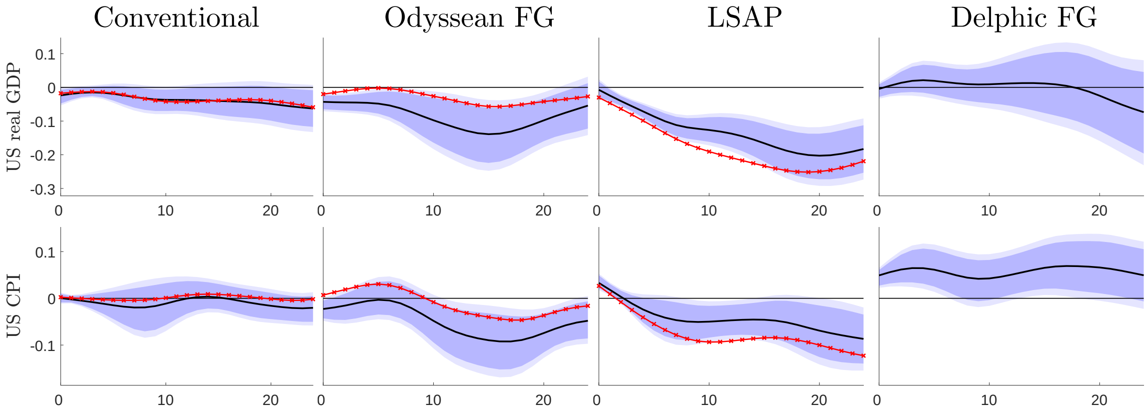
[7] Note that using a local projection framework is appealing because the shocks of Jarociński (2021) are non-Gaussian by assumption, which would require departures from standard VAR methods.

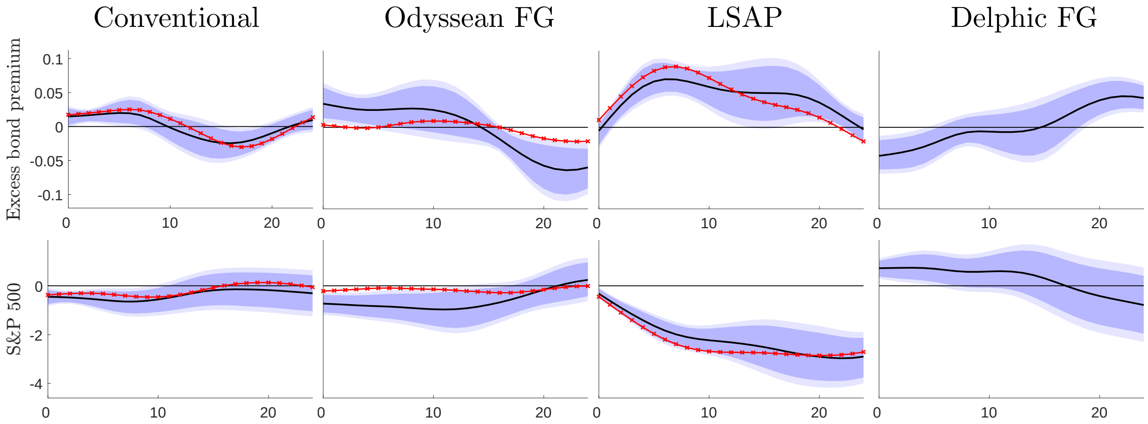
[8] We use the replication files of Barnichon and Brownlees (2019) and, given that they also estimate the effects of US monetary policy shocks at the monthly frequency over a similar sample, adopt their settings for the shrinkage parameter λ, its cross-validation, and the polynomial order r.

Figure 2: Effects of US monetary policy shocks on US macroeconomic variables



Note: The black solid lines indicate the impulse responses of US monetary policy shocks of Jarociński (2021) estimated from SLPs of Barnichon and Brownlees (2019). The shocks are included simultaneously in the regressions. The red crossed lines indicate the responses to the conventional monetary policy, FG and LSAP shocks of Swanson (2021). The sample period spans 1991m1 to 2019m6. Shaded areas indicate 68% and 90% confidence bands. Panels in a given row feature the same limits on the vertical axis. The horizontal axes display horizons in terms of months after shock has hit.

Figure 3: Effects of US monetary policy shocks on US financial variables



Note: See the notes of Figure 2.

for Delphic FG shocks are consistent with Jarociński and Karadi (2020) in that a PMP shock is contractionary while a CBI effect is expansionary.

While results displayed in Figures 2 and 3 are similar for conventional monetary policy and LSAP shocks of Swanson (2021) and Jarociński (2021), they are noticeably different for Odyssean FG shocks. In particular, we do not observe clear contractionary effects on real activity, consumer and equity prices as well as a rise in the excess bond premium in response to Swanson's FG shock; especially the estimated responses of the financial variables in Figure 3 seem to be attenuated. Interestingly, Paul (2020) and Miranda-Agrippino and Ricco (forthcoming) also do not find contractionary effects in response to Swanson's FG shock. And Miranda-Agrippino and Ricco (forthcoming) find that Swanson's FG shock is associated with output and price puzzles when used as external instrument in a VAR model.

One possibility to rationalize this finding is to think of Swanson's FG shock as a combination of Jarocinski's Odyssean and Delphic FG shocks. In fact, results from a direct, regression-based comparison of Jarocinski's and Swanson's shocks in Table B.1 in the Appendix is consistent with this possibility (see also Figure B.1 in the Appendix): Swanson's FG shock is clearly correlated with Jarocinski's Delphic FG shock, even when controlling for Jarocinski's Odyssean FG shock.[9]

Interestingly, when Miranda-Agrippino and Ricco (forthcoming) study theoretically the conditions for consistent causal inference with external instruments in VAR models and LPs they find that Swanson's FG shock is associated with counterintuitive impulse response estimates. In line with this, against the background of their analysis of the conditions for consistent causal inference with external instruments in VAR models and LPs Miranda-Agrippino and Ricco (forthcoming) argue the counterintuitive impulse response estimates suggests Swanson's FG shock is not only correlated with the corresponding PMP shock but also with contemporaneous CBI effects.

Finally, Figure 4 compares the estimated effects of the Delphic FG shock of Jarociński (2021) on US real GDP, consumer and equity prices depicted by the red crossed lines with impulse responses obtained using alternative non-PMP shock components of Jarociński and Karadi (2020, J&K), Bauer and Swanson (2022, B&S), Bu et al. (2021, B&R&W), and Miranda-Agrippino and Ricco (2021, MA&R). These alternatives are also constructed based on intra-daily surprises around FOMC meetings, but obtained using different approaches. While there are some differences in the effects of these alternative non-PMP shocks in Figure 4, they all tend to be expansionary.[10] That the estimated effects are similar for the Delphic FG shock of Jarociński (2021) and these alternative non-PMP shocks despite the differences in their identification corroborates the evidence for non-PMP shocks in narrow windows around FOMC meetings.

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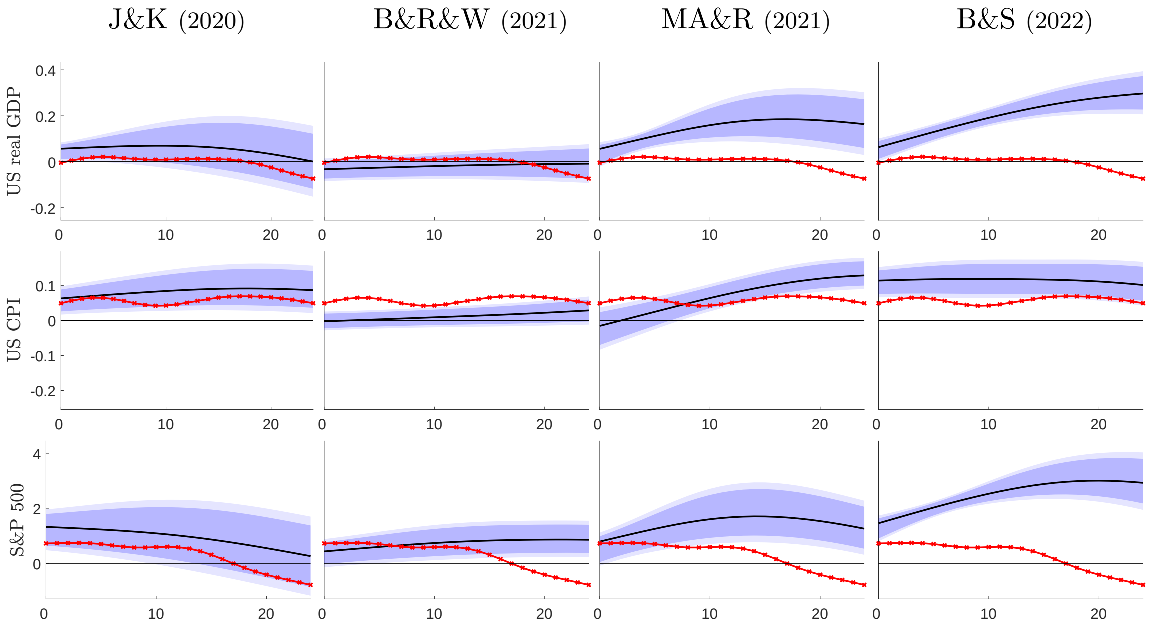
[9] The seemingly contradictory finding that the shocks of Swanson (2021) entail estimates of *daily* financial market effects in Figure B.2 that are with a PMP shock but at least in part implausible estimates of macroeconomic effects at *medium-term* horizons in Figure 2 is consistent with the argument in Bauer and Swanson (2022) that the shocks are contaminated by a CBI or—their preferred interpretation—a 'Fed response to news' effect.

[10] Figure D.2 in the Appendix documents that the associated PMP shocks are all contractionary.

Figure 4: Effects of alternative US non-PMP shocks on US variables



Note: The black solid lines indicate the impulse responses of US real GDP to the US non-PMP shocks of Jarociński and Karadi (2020, J&K, 1991-2019), Bu et al. (2021, B&R&W, 1994-2019), Miranda-Agrippino and Ricco (2021, MA&R, 1990-2015), and Bauer and Swanson (2022, B&S, 1991-2019) estimated from SLPs of Barnichon and Brownlees (2019). For the shock of Bauer and Swanson (2022) we take the difference between their baseline and orthogonalised monetary policy surprises. For the shock of Bu et al. (2021) we take the information component from Ciminelli et al. (2022). And for the shock of Miranda-Agrippino and Ricco (2021) we take the difference between the three-months Fed funds futures surprises and their 'informationally-robust' monetary policy surprise; the data are originally available until 2009, but we update them until 2015. The red crossed line depicts the impulse response of the Delphic FG shock of Jarociński (2021) shown in Figure 2. See also the notes of Figure 2.

We conclude that distinguishing *simultaneously* between the different dimensions of US monetary policy *and* between PMP shocks and CBI effects matters for estimating spillovers, especially in the context of FG. The approach of Jarociński (2021) is unique for practical purposes in its ability to do so.[11] We next explore the global spillovers from US monetary policy.

3 Global spillovers from US monetary policy

3.1 Daily effects on global financial variables

We start examining spillovers by looking again at the daily financial market impact effects of US monetary policy shocks. Figure 5 presents estimates for spillovers to global long-term interest rates, the associated expectations components and term premia, stock prices and effective exchange rates.[12] The estimates point to large financial market spillovers from all dimensions of US monetary policy, consistent with anecdotal observations by policymakers in the RoW and their concerns about monetary autonomy (see for example Panetta, 2021) as well as corresponding evidence put forth in academic research (Rey, 2016).

In particular, long-term rates rise essentially in tandem with those in the US; the domestic impact of US monetary policy is systematically larger than the spillover effect only in case of the expectations component. LSAP shocks lift term premia in other AEs systematically along with those in the US; this is consistent with theoretical predictions for the international transmission of LSAP through portfolio rebalancing (Alpanda and Kabaca, 2020; Kolasa and Wesołowski, 2020). Both AE and EME stock prices move together with those in the US, especially in case of conventional monetary policy and Odyssean FG shocks. Figures D.6 to D.9 in the Appendix present the full impulse responses, which point to a generally high degree of co-movement between US and RoW financial variables conditional on US monetary policy shocks also over longer horizons.

The finding of large effects of US monetary policy shocks on AE interest rates are consistent with Curcuru et al. (2018a), who estimate spillovers between US and German bond

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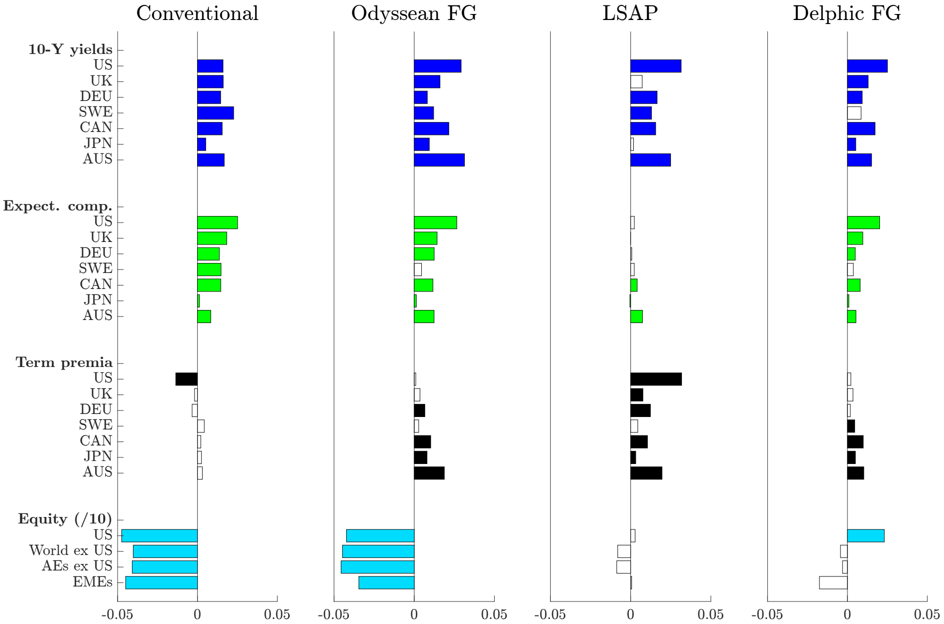
[11] The only other identification approach that achieves both in a coherent manner is Lewis (2019), who exploits the heteroskedasticity in high-frequency intra-daily financial market data on the days of FOMC announcements. Remarkably, in spite of exploiting a very different variation in the data, Lewis ends up finding similar types of monetary policy shocks. An advantage of the approach of Jarociński (2021) relative to that of Lewis (2019) is that the shock time series are available already from 1991 rather than 2007, which is helpful for the estimation of the macroeconomic effects. Moreover, while Lewis (2019) provides FOMC announcement-specific shocks to, say, 2-year or 3-year FG that are difficult to use in a time-series exercise, the shocks of Jarociński (2021) are defined consistently over meetings. We have also tried cleansing Swanson's shocks one a time from CBI effects based on the sign of the accompanying high-frequency stock market surprise, as done in Miranda-Agrippino and Nenova (2022) and Miranda-Agrippino and Rey (2022). The problem with this approach is that, for a given FOMC announcement, the sign of the stock market surprise has to identify the CBI effects in *three* shocks (conventional, FG and LSAP), which may be problematic if the three shocks do not have the same signs. In any case, in our application this approach did not yield economically plausible effects of the FG shock (see Figure D.5 in the Appendix).

[12] For countries other than Canada, due to time differences in market opening/closing hours, as in Curcuru et al. (2018b) we use the observation from the following day relative to the US monetary policy shock in the regressions.

Figure 5: Daily impact effects of US monetary policy shocks of Jarociński (2021) on global interest rates and stock prices



Note: The expectation components and term premia are taken from a dynamic Nelson-Siegel model. See also the notes from Figure 1.

markets around notable FOMC and ECB monetary policy communications using intra-daily data. In turn, the result that LSAP shocks have larger spillovers on foreign term premia than on expectations components while conventional monetary policy and Odyssean FG shocks have larger effects on foreign expectations components than on term premia is consistent with Curcuru et al. (2018b).

3.2 Medium-term effects on the global real activity and prices

Figure 6 presents results for non-US, RoW real activity and consumer prices at the monthly frequency obtained from the estimation of SLPs. The results for spillovers to the RoW (solid black lines) are overall similar to those for the domestic effects in the US (red crossed lines). Unconventional PMP shocks induce a contraction in RoW real activity and consumer prices, mirroring the findings for the domestic effects. Only spillovers from conventional monetary policy shocks are rather muted, consistently with their small domestic effects.[13] Therefore, in the following we focus on unconventional PMP shocks. In contrast to PMP shocks, Delphic FG shocks cause an acceleration in RoW real activity.

The first row in Figure D.12 shows that results are very similar when we estimate panel

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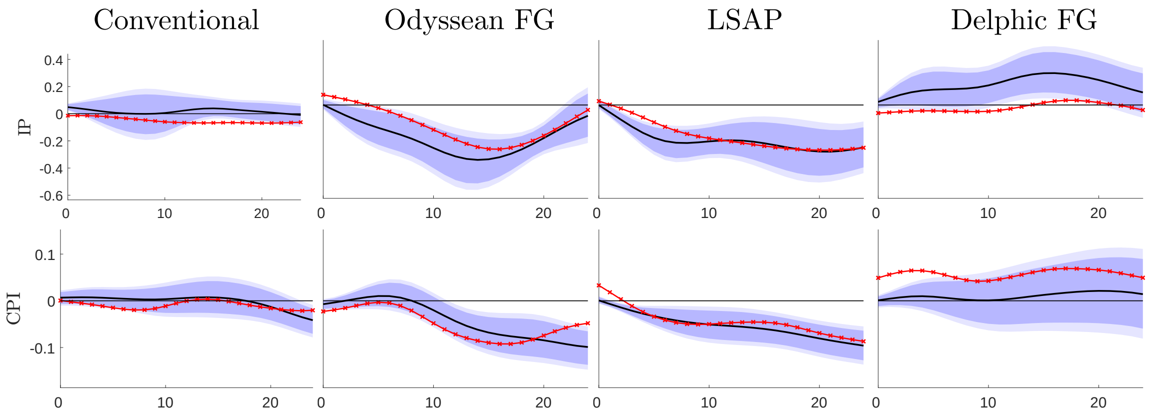
[13] This finding is not specific to the real activity measure we use or the shocks of Jarociński (2021). Figure D.10 in the Appendix presents impulse responses for alternative measures of global real economic activity. Figure D.11 compares the estimates for spillovers in Figure 6 to those based on the shocks of Swanson (2021), and shows that these alternative shocks also imply small spillovers of conventional monetary policy.

LPs on country-specific data for up to 62 AEs and EMEs starting in 1990, depending on data availability.[14] And the second row in Figure D.12 shows the distribution of country-specific SLPs estimates for these 62 economies. Results are similar to the those for the SLP estimations using RoW aggregate variables in Figure 6. The results in the second row indicate that the dispersion of spillovers across countries is not different across dimensions of US monetary policy.[15]

Figure 6: Effects of US monetary policy shocks on non-US RoW real activity and consumer prices



Note: The black solid lines depict spillovers to the Row, and red crossed lines the domestic effects in the US. See also the notes to Figure 2.

3.3 Medium-term effects on global financial markets

Figure 7 presents results for the effect of US monetary policy on RoW financial variables. Odyssean FG and LSAP shocks induce a contraction in RoW equity prices, an increase in the Bekaert et al. (2021) measure of investors' risk aversion, an increase in the spread of the J.P. Morgan Emerging Markets Sovereign Bond Index (EMBI) over US Treasury securities, a delayed/persistent appreciation of the dollar nominal effective exchange rate (NEER), and a decline in oil prices. In contrast, Delphic FG shocks induce an increase in RoW equity prices, a decline in investors' risk aversion and the EMBI spread, a short-lived depreciation of the dollar that is subsequently reversed, and an increase in oil prices.

Next we explore the effects of US monetary policy on capital flows. Unfortunately, for most countries capital flows data is not available at the monthly frequency. Therefore, we focus mostly on US capital inflows—i.e. net purchases of US portfolio securities by foreign residents—and outflows—i.e. net purchases of foreign securities by US residents. Moreover,

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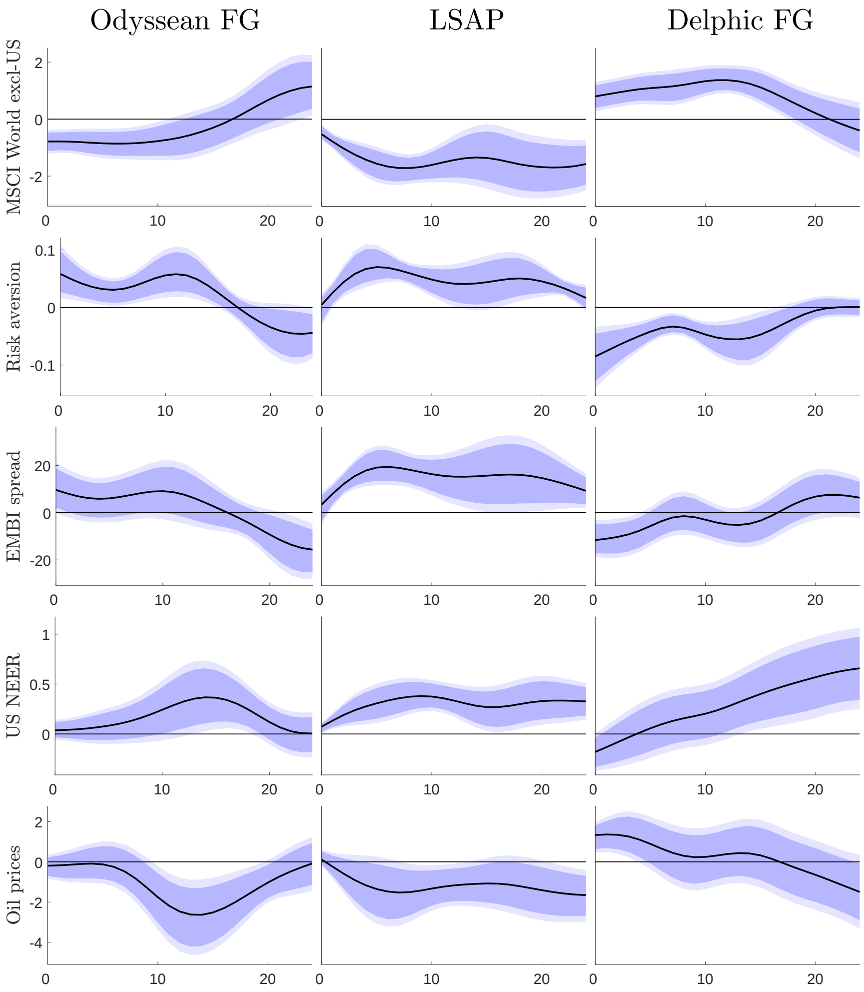
[14] The controls $\boldsymbol{x}_{it}$ again include RoW industrial production, the US excess bond premium and the 1-year Treasury bill rate. We set $p = 1$. Results hardly change for specifications with more lags or different controls.

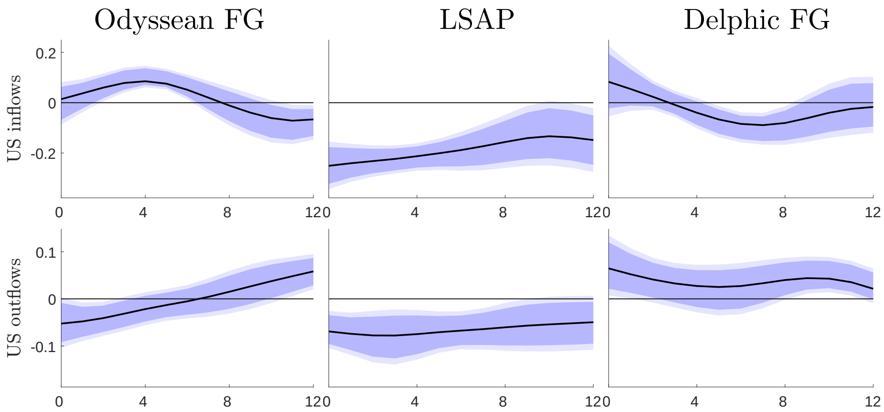
[15] Figure D.13 documents that non-US RoW trade contracts in response to PMP shocks but expands in response to a CBI effect.

Figure 7: Non-US RoW financial variables impulse responses to US monetary policy shocks



Note: Risk aversion is taken from Bekaert et al. (2021). The dollar NEER is defined so that an increase reflects an appreciation. See also the notes to Figure 2.

Figure 8: Effects of US monetary policy shocks on US portfolio flows



Note: The figure presents the effects of US monetary policy shocks on inflows/outflows of portfolio debt and equity scaled by US GDP taken from US TIC. Inflows are defined as net increase in US foreign financial liabilities (or net purchases of domestic assets by foreigners), and outflows as net increase in US foreign financial assets (or net purchases of foreign securities by US residents). Impulse responses in the top row are obtained using SLPs. See also the notes to Figure 2.

we focus on the most volatile component of the balance of payments, namely portfolio equity and debt flows. We use transactions data from Treasury International Capital (TIC), and we drop transactions related to foreign official entities as well as financial centers as defined in Bertaut et al. (2019).[16] Because capital flows are quite volatile, we consider only effects up to a horizon of one year.

The first row in Figure 8 presents the results for US portfolio inflows and outflows scaled by US GDP. The results suggest that Odyssean FG shocks are followed by an increase in inflows to the US as well as a drop in outflows from the US. LSAP shocks are followed by a persistent fall in inflows and outflows, while Delphic FG shocks are followed by an increase in inflows and outflows.[17]

Figure 9 provides additional resolution by splitting flows across country groups and instruments. The results deliver several important insights. In particular, the increase in inflows to the US observed in response to Odyssean FG shocks in Figure 8 is driven by an increase in AE and EME investors' purchases of safe US public bonds (US Treasury securities and agency bonds). In contrast, AE investors shed risky US corporate bonds; EME investors increase their holdings of risky bonds, but this is quantitatively small. In turn, Figure 10

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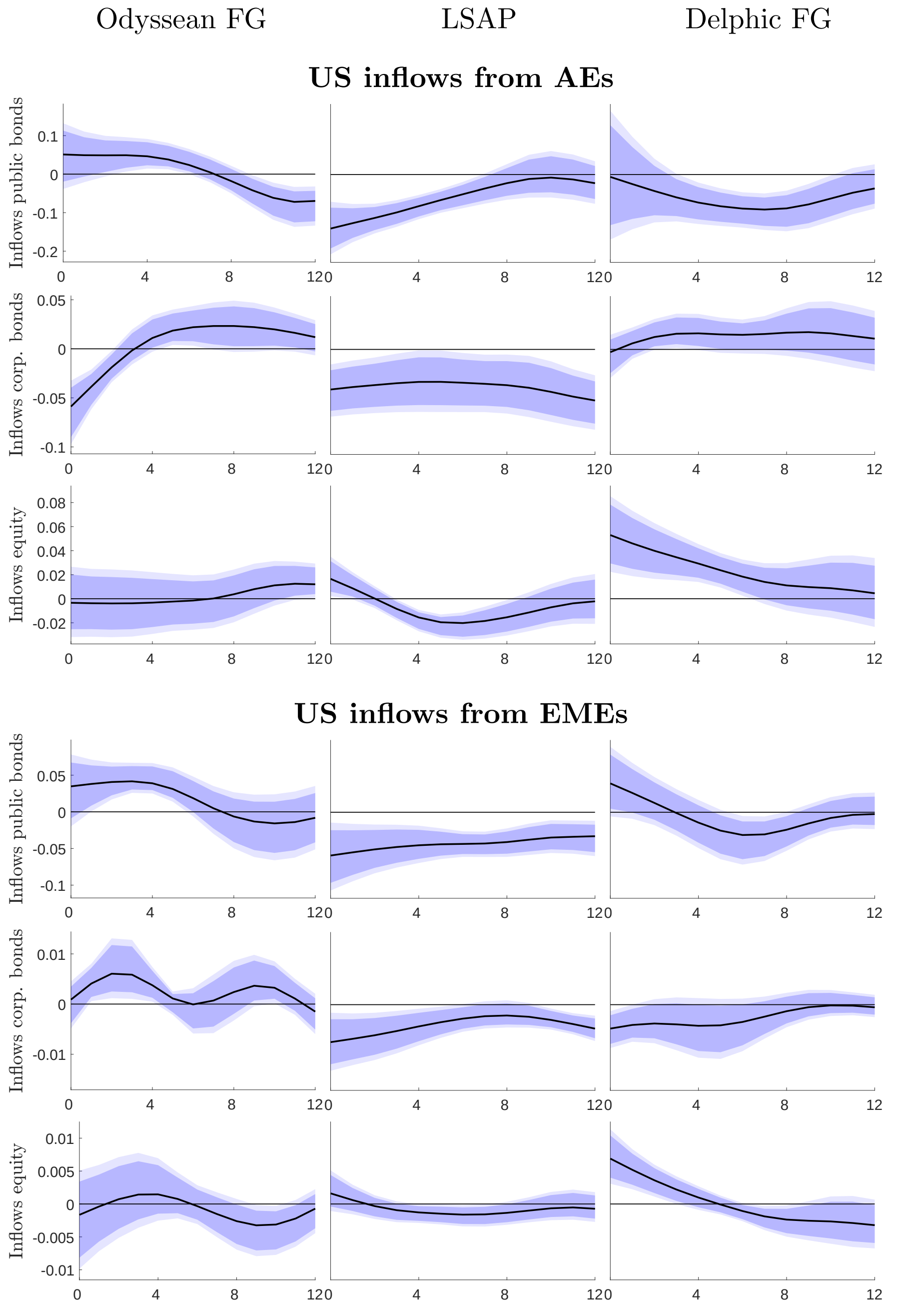
[16] Bertaut and Judson (2022) present estimates of US cross-border transactions based on the TIC form SLT that address several technical pitfalls of the data we use based on the TIC form S, including "sales bias" of transactions related to official entities and "transactions bias" due to financial centers. However, the TIC-SLT-based transaction estimates are only available from 2012.

[17] Figure D.13 presents results for the effects of US monetary policy on the global factors in risky asset prices and capital flows originally introduced by Miranda-Agrippino and Rey (2020b) and extended in Miranda-Agrippino et al. (2020).

Figure 9: Effects of US monetary policy shocks on US portfolio inflows across country groups and instruments



Note: The country classification for AEs and EMEs is taken from Miranda-Agrippino et al. (2020). See the notes to Figure 8.

shows that US investors repatriate foreign equity investments from both AEs and EMEs, as well as bond investments from EMEs. These patterns are consistent with a general risk-off effect triggered by Odyssean FG shocks, especially for US investors and US corporate debt, as US equity inflows appear hardly affected.

In contrast, the increase in inflows and outflows in response to Delphic FG shocks in Figure 9 is consistent with a risk-on effect. In particular, Figure 9 shows that both AE and EME investors increase their holdings of especially US equity; there even seems to be some re-balancing by foreign investors from US corporate bonds to riskier equity. Also consistent with a risk-on effect triggered by Delphic FG shocks, Figure 10 shows that US investors increase their holdings of especially AE and EME equity and EME bonds.

Figures 9 and 10 suggest that the drop in inflows and outflows in response to LSAP shocks in Figure 8 is not related to changing risk aversion but reflects a general re-balancing of foreign to domestic bond holdings. In particular, Figure 9 shows that AE and EME investors shed in particular safe US public bonds. In fact, it has been noted before that foreign investors piled up US Treasury securities during the (expansionary) QE2 and QE3 programs (Coeure, 2017), when the RoW's share in the US Treasury market increased (Carpenter et al., 2015). Consistent with these observations, our results suggest that foreign investors buy US Treasury securities when the Fed is buying (and sell when it is selling), with US investors on the other side of these transactions. Indeed, Figure 10 shows that US investors shed foreign bonds as well as foreign equity in response to LSAP shocks.

While so far we consider only US capital flows because these are available at monthly frequency, Figure 11 presents results for inflows from the perspective of (non-US) AEs and EMEs based on quarterly IMF Balance of Payments Statistics data as in Miranda-Agrippino et al. (2020) and Degasperi et al. (2020); we consider the broad sample of 81 countries of Miranda-Agrippino et al. (2020). Note that we cannot distinguish in this data whether inflows stem from the US, other AEs or other EMEs, or between public and private bonds. The results in Figure 11 are in line with those for US inflows and outflows in Figure 10, but some interesting additional insights emerge. First, in contrast to the US in Figure 9, AEs and EMEs both experience a drop in equity inflows in response to Odyssean FG shocks, consistent with a risk-off effect; to the extent driven by safe bonds also the increase in AE bond inflows is consistent with a risk-off effect, but unfortunately we cannot disaggregate these flows further. Second, consistent with a risk-on effect EMEs experience a persistent increase in debt and equity inflows in response to Delphic FG shocks, starker than when focusing on US investors' outflows only in Figure 10. Third, as for the US in Figure 9 for AEs we obtain a drop in debt inflows but an increase in equity inflows in response to Delphic FG shocks, again consistent with a risk-on effect.[18] Figure 11 in the Appendix presents results for outflows, which suggest the persistent increase in equity and debt inflows in response to Delphic FG shocks in Figure 11 is driven by non-US AE and EME investors. This points to a global reach of risk-on effects in the context of US Delphic FG.

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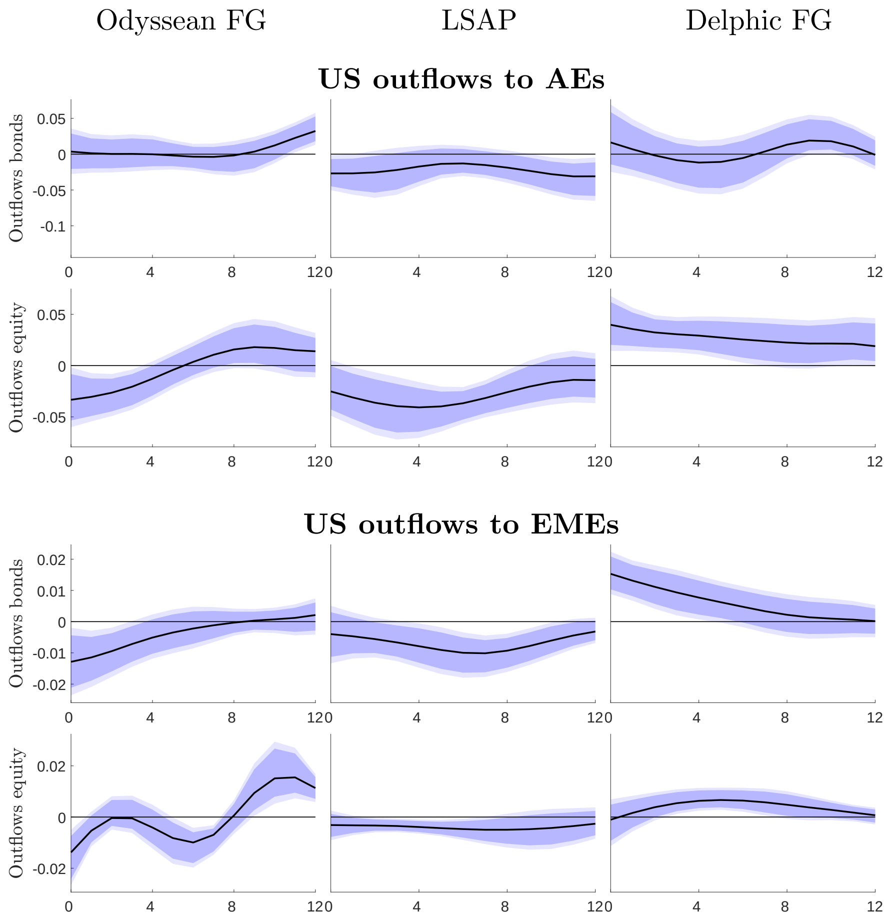
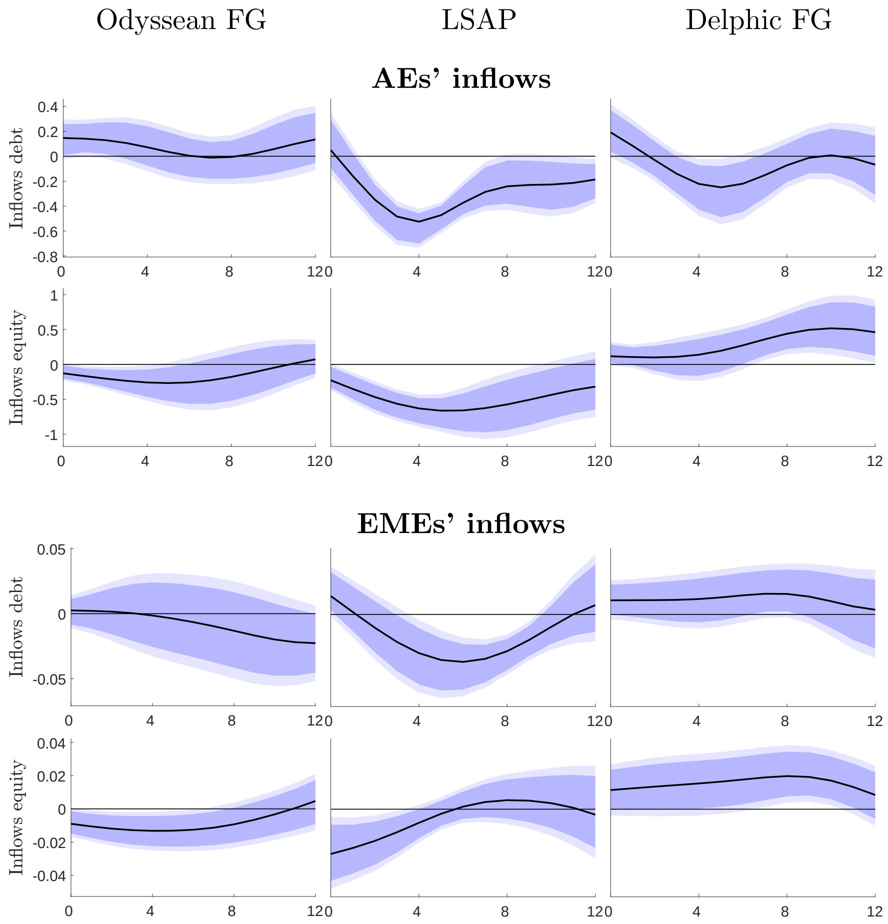
[18] Results are very similar when we use panel LPs instead of SLPs in order to account for the different starting dates from which IMF Balance of Payments data is available across countries.

Figure 10: Effects of US monetary policy shocks on US portfolio outflows across country groups and instruments



Note: The country classification for AEs and EMEs is taken from Miranda-Agrippino et al. (2020). See also the notes to Figure 8.

Figure 11: Effects of US monetary policy shocks on IMF Balance of Payments AE and EME portfolio inflows



Note: The first (last) two rows present results for AE (EME) portfolio equity and debt inflows, respectively. The data are taken from the IMF Balance of Payments Statistic, are interpolated from quarterly to monthly frequency, and span 1996 to 2019. We use the cross-country average of economies' ratio of inflows to recipient-country GDP. See also the notes to Figure 2.

Our results for global portfolio flows expand in terms of resolution relative to existing literature regarding types of flows, PMP versus CBI effects and/or FG versus LSAP shocks. For example, examining weekly investment-fund-level data from Emerging Portfolio Funds Research (EPFR) Ciminelli et al. (2022) find that a US PMP shock leads to a decline in net flows to bond and equity funds investing in EMEs while a CBI effect does the opposite. Our findings extend those of Ciminelli et al. (2022) as we show that this pattern emerges both for Odyssean FG and LSAP shocks. Dahlhaus and Vasishtha (2020) also consider EPFR data, but do not distinguish between PMP shocks and CBI effects. Our findings also extend those of Miranda-Agrippino et al. (2020) consider IMF Balance of Payments data, but only look at total inflows, do not distinguish between PMP shocks and CBI effects as well as between conventional and unconventional monetary policy. Chari et al. (2021) use US TIC data and focus on bond and equity flows to study the effect of QE based on high-frequency interest rate surprises, but do not distinguish between PMP shocks and CBI effects. And while Degasperi et al. (2020) and Pinchetti and Szczepaniak (2021) do distinguish between PMP shocks and CBI effects, they do not distinguish between FG and LSAP shocks and they only examine total portfolio inflows or cross-border bank credit.

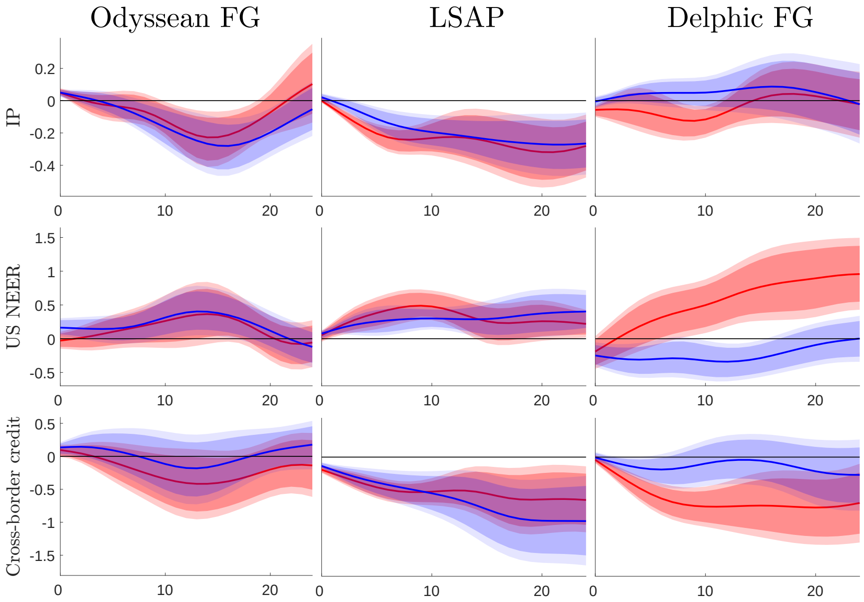
3.4 More differences across AEs and EMEs

Figure 12 presents separate results for AEs (red) and EMEs (blue). In particular, the first row shows that while Odyssean FG and LSAP shocks have similar effects across AEs and EMEs in terms of real activity spillovers, Delphic FG shocks are expansionary in EMEs but contractionary in AEs. A possible explanation for this pattern is that the risk-on effects triggered by Delphic FG shocks discussed in the context of capital flows above benefit in particular EMEs.

A test of the hypothesis that Delphic FG shocks benefit EME real activity because of their greater sensitivity to risk-on effects can be devised given recent work on the drivers of exchange rate variation. In particular, Kalemli-Özcan (2019) shows that while currency risk premia play a key role in driving EME exchange rates, for AEs interest rate differentials are more important. The second row in Figure 12 shows that Delphic FG shocks indeed have starkly different effects on the NEER against AE and EME currencies: The dollar eventually appreciates against AE currencies, but persistently depreciates against EME currencies; similar findings are obtained by Franz (2020) and Jarociński (2020). That the dollar appreciates against AE currencies due to interest rate differentials is consistent with the finding in the first row that in response to a Delphic FG shock AE real activity diverges from US real activity as shown in Figure 2. Additional evidence supporting the notion of a risk-on effect in EMEs triggered by Delphic FG shocks is the decline in the EMBI spread shown in the third row in Figure 7.

So far we account for the expansion in EMEs in response to Delphic FG shocks. But why are real activity spillovers to AEs contractionary? While the exchange rate vis-à-vis the dollar may not be a relevant measure of risk sentiment for AEs, it may still induce contractionary

Figure 12: AE (red) and EME (blue) impulse responses to US monetary policy shocks



Note: Impulse responses in red represent estimates for AEs and impulse responses in blue represent estimates for EMEs. See also the notes to Figure 2.

financial spillovers. In particular, Bruno and Shin (2015b) construct a model in which global banks intermediate dollar funds raised in the US to borrowers in the RoW. When the dollar appreciates, global banks' net worth is reduced due to the currency mismatch on their balance sheet: The dollar value of their assets ultimately reflecting cash flows in local currency falls while the value of their dollar-denominated liabilities is unchanged. The model of Bruno and Shin (2015b) then predicts that as a result of the decline in net worth global banks reduce lending. Indeed, the last row in Figure 12 shows that cross-border bank credit to AEs drops markedly in response to Delphic FG shocks; in contrast, cross-border bank credit to EMEs hardly drops, consistent with their currencies not depreciating against the dollar. The findings for AEs echo the 'triangular relationship' between the dollar exchange rate, cross-border bank credit and real activity established by Avdjiev et al. (2019).

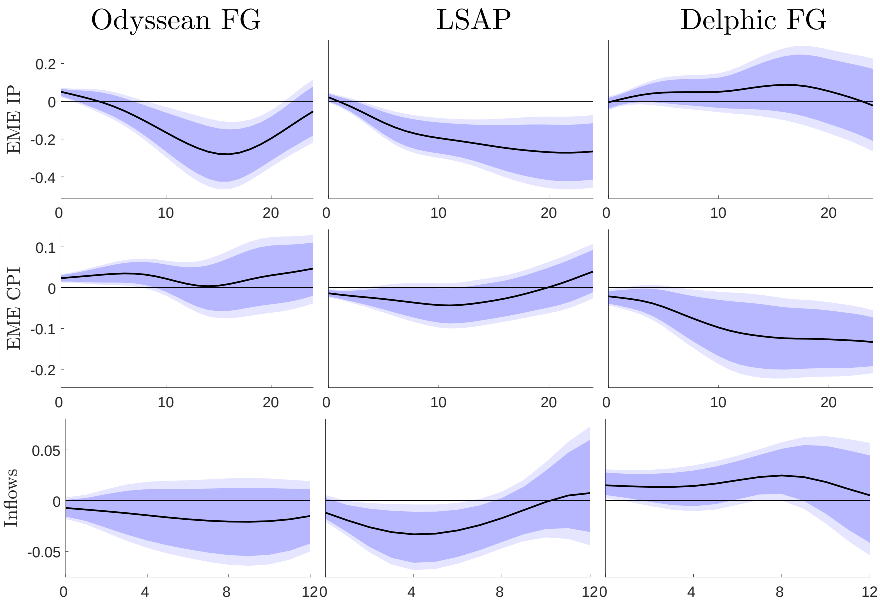
Finally, the financial channel of exchange rates alone may not be sufficiently strong to generate the contraction in AE real activity in response to a Delphic FG shock shown in the first row in Figure 12. However, recall that Figure 7 shows that oil prices rise in response to a Delphic FG shock, which is contractionary for real activity (Känzig, 2021; Degasperi, 2022). In general this would impact EMEs as much—and potentially even more strongly due to higher energy import shares—as AEs. However, this effect is dampened for EMEs as oil and other commodities are almost exclusively invoiced in dollar and as EME currencies appreciate against the dollar as shown in Figure 12. In fact, the local effect of the rise in oil prices is *de facto* amplified for AEs as their currencies depreciate against the dollar.

3.5 Monetary policy trade-offs in EMEs

Spillovers from US monetary policy do not necessarily reduce welfare in the RoW. A necessary condition for spillovers to be a negative externality is that RoW monetary policy faces trade-offs conditional on US shocks. The presence of trade-offs is critical for the desirability of international monetary policy coordination (for an overview see Engel, 2016). Against this background, we look for evidence for two types of trade-offs for RoW monetary policy: (i) between output and price stability; (ii) between macroeconomic stability in terms of real activity and consumer prices on the one hand and financial stability in terms of capital inflows on the other hand. We focus on EMEs as these have been most vocal in calling for US monetary policy to internalize its spillovers (Rajan, 2013, 2016).

Figure 13 presents the effects of US monetary policy shocks on EME real activity, consumer prices and portfolio inflows. The first two rows inform about the presence of trade-offs between output and prices, and all three rows together about trade-offs between macroeconomic stability and financial stability. First, in response to Odyssean and Delphic FG shocks EME real activity and consumer prices move in opposite directions, implying that EME monetary policy cannot stabilize both. For example, in case of an Odyssean FG shock, an EME monetary policy loosening would dampen the contractionary spillovers to real activity, but would put further upward pressure on consumer prices. Thus, spillovers from Odyssean and Delphic FG imply trade-offs between output and price stability in EMEs. In contrast, LSAP shocks do not imply trade-offs in EMEs, as they have qualitatively identical effects on real activity and consumer prices.

Figure 13: EME monetary policy trade-offs



Note: See the notes to Figure 2.

Considering the last row in Figure 13 showing the effects of US monetary policy on total portfolio debt and equity IMF Balance of Payments Statistics inflows together with the first two informs about the presence of trade-offs between macroeconomic stability and financial stability. In particular, while in case of LSAP shocks there is no trade-off between output and prices, there is a trade-off between macroeconomic stability and financial stability: If EME monetary policy were to loosen in order to dampen the contractionary effects on real activity and consumer prices, this would discourage foreign investors and further reduce negative inflows. In case of Delphic FG shocks—and to the extent that inflows drop also in case of Odyssean FG shocks—the trade-off between output and prices is exacerbated by the presence of an additional trade-off between macroeconomic stability and financial stability. We conclude that spillovers from all dimensions of US monetary policy give rise to at least some trade-off that in general reduces welfare in EMEs.

3.6 Non-linearities in global spillovers from US monetary policy

We now explore non-linearities to speak more specifically to the challenges implied by the normalization of US monetary policy in 2022. In particular, in this section we explore non-linearities with respect to the sign of the US monetary policy shock and to the phase of the US business cycle; we discuss how the business cycles position in an individual non-US economy affects the spillovers from US monetary policy it receives in the next section. We measure the phase of the US business cycle based on the Fed monetary policy cycle. In particular, the left panel in Figure 14 depicts the evolution of the Fed monetary policy stance reflected by its target rate, a shadow short rate that is not constrained by the zero lower bound and that incorporates the effects of unconventional policy measures, the corresponding *ex ante* real policy rate as calculated using the University of Michigan inflation expectations, and the gap between the latter and the natural rate estimate of Holston et al. (2017). The right panel plots the Congressional Office's output gap as well as personal consumption expenditure (PCE) inflation. We narratively date the US business cycle reflected in the Fed tightening cycles based on whether the real policy rate (gap) is increasing. The relevant periods are indicated by the grey shaded areas. The dating based on the (real) policy rate gap aligns reasonably well with the evolution of the US business cycle as summarized by the output gap and inflation.[19]

We explore non-linearities in spillovers from US monetary policy using a modified version of Equation (2) given by

$$\begin{aligned} y_{t+h} - y_{t-1} =& \boldsymbol{\gamma}^{(h)\prime}\left[\boldsymbol{\xi}_t \circ \boldsymbol{\epsilon}_t\right] + \boldsymbol{\delta}^{(h)\prime}\left[(\boldsymbol{\iota} - \boldsymbol{\xi}_t) \circ \boldsymbol{\epsilon}_t\right] \\ &+ \tau^{(h)} + \sum_{\ell=1}^{p} \alpha_j^{(h)\prime} y_{t-j} + \sum_{\ell=1}^{p} \boldsymbol{\beta}_j^{(h)\prime} \boldsymbol{x}_{t-j} + u_t^{(h)}, \end{aligned} \tag{3}$$

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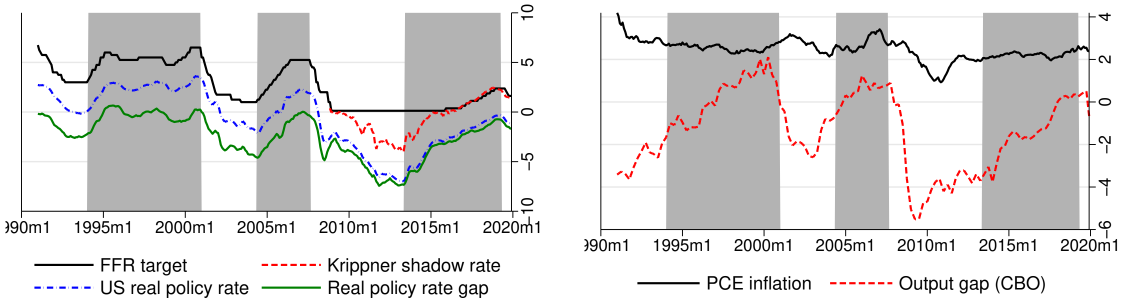
[19] An alternative for slicing the business cycle would be to use the NBER's recession dates. However, doing so results in much less than 10% of the sample being classified as a recession, and so only very few observations remain to estimate non-linearities across business cycle stages.

Figure 14: US monetary policy cycles



Note: In the left panel, the black solid line represents the Fed Funds target rate, the red dashed line the shadow short rate of Krippner (2013), the blue dashed-dotted line the implied ex ante real policy rate based on the University of Michigan inflation expectations, and the green solid line the real policy rate gap defined as the difference between the latter and the natural rate estimate of Holston et al. (2017) linearly interpolated from quarterly to monthly frequency. Grey shaded areas indicate narratively dated US tightening cycles. In the right panel, the black solid line depicts the Cleveland Fed median PCE inflation and the red dashed line the Congressional Budget Office's output gap.

where $\circ$ indicates element-wise multiplication, $\boldsymbol{\xi}_t$ is a 4×1 vector of indicator variables and $\boldsymbol{\iota}$ a 4×1 vector of ones. For example, to investigate non-linearities with respect to the sign of the monetary policy shocks we specify $[\xi_t]_{j1} \equiv 1(\epsilon_{jt} > 0)$. To explore non-linearities across business cycle stages we additionally consider $[\xi_t]_{j1} \equiv 1(\text{expansion})$, where $1(\text{expansion})$ is a scalar indicator variable that equals unity for periods in which the US economy was in a business cycle expansion and the Fed was in a tightening cycle as indicated by the shaded regions in Figure 14.[20]

In order to benchmark our analysis against existing literature, we again first consider the domestic effects in the US. We focus on the effects on real activity to limit the dimensionality of the analysis. A caveat to be kept in mind is that the results for LSAP shocks should be taken with caution, as they are arguably inferred from a single expansion/monetary policy tightening cycle that started in 2013 (see Figure 14).

The first row in Figure 15 presents estimates of the domestic real GDP effects of contractionary shocks in business cycle expansions and recessions, respectively. Note that Figure 15 does not only display impulse responses to a shock normalized to be contractionary; it displays results estimated using only contractionary shocks. The second row in Figure 15

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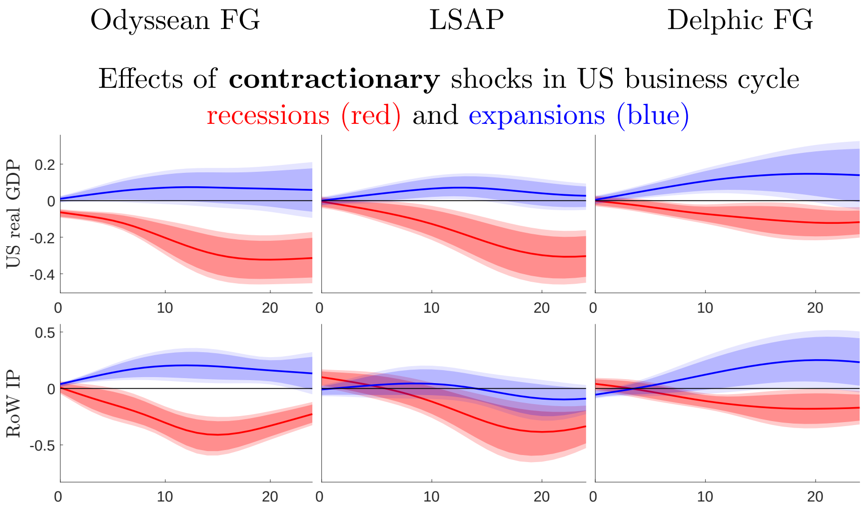
[20] Goncalves et al. (2022) show that a sufficient condition for the consistency of state-dependent LPs as in Equation (3) is that the first and second-order conditional moments of the structural shocks are independent of current and future states. This rules out models in which the state is a function of current or future realizations of the outcome variable. Thus, for our estimations to be consistent we need to assume that US monetary policy *shocks* do not induce a transition from a business cycle expansion to a recession and vice versa. We believe this is a plausible assumption given that US monetary policy shocks are usually found to account only for a small share of the variance of real activity and inflation. For example, Plagborg-Moller and Wolf (forthcoming) find that "monetary shocks are of limited importance for post-1990 aggregate dynamics, especially for inflation". While the state variable and the shock are by construction correlated in our application when we condition on the sign of the monetary policy shock, this correlation disappears by construction for $h > 0$. Thus, at most there might be a bias in the *impact* response estimates.

Figure 15: US and RoW real activity impulse responses to US monetary policy shocks across US business cycle expansions and recessions



Note: See the notes to Figure 2.

depicts results for RoW real activity spillovers analogous to the domestic effects in the US in the first row. Results for the domestic and spillover effects on real activity are broadly similar: Spillovers from contractionary shocks in US business cycle *expansions* are weaker than in recessions; Figure D.16 in the Appendix suggests these findings apply equally to AEs and EMEs.

Figure D.15 in the Appendix suggests that monetary policy cycles—at least as measured using real policy rates—are rather synchronized across the RoW and the US. This synchronicity of business cycles at the level of the US and the aggregate RoW may explain the similarity in the domestic and spillover effects of US monetary policy we estimate over the domestic, US business cycle.

The finding of limited spillovers from contractionary US monetary policy shocks during business cycle expansions is particularly relevant for the juncture in 2022 after the Fed started to normalize. Our findings suggest that—keeping in mind the above discussion on trade-offs in EMEs—for the average economy in the RoW real activity spillovers are likely to be limited.

3.7 The role of macro-financial vulnerabilities

The implication that spillovers from US monetary policy normalization in 2022 may be limited overall contrasts with historical experiences in which the start of a tightening cycle triggered financial crises abroad, as in Mexico's in 1994, in South-East Asia in 1998, or—although a crisis eventually did not erupt—the 'taper tantrum' in 2013; for systematic evidence on the role of US monetary policy for financial crisis in the RoW see Durdu et al. (2020). While our findings indicate that US monetary policy tightening does not entail adverse spillovers to the average economy in the RoW, it may well be that this does not apply to economies exhibiting macro-financial vulnerabilities. For example, Iacoviello and Navarro (2019) find that economies with large external debt positions, high inflation rates, current account deficits and low foreign exchange reserves experience larger output spillovers from US monetary policy shocks measured by Taylor-rule deviations. Ahmed et al. (2017) document that financial markets in EMEs with vulnerabilities in these dimensions exhibited greater volatility during the 'taper tantrum'. And Hoek et al. (2022) document that economies with vulnerabilities exhibit larger financial market spillovers on the day a US PMP shock occurs.

To explore non-linearities rooted in heterogeneities in spillover-recipient economies we introduce interaction terms in panel LPs

$$\begin{aligned} y_{i,t+h} - y_{i,t-1} = \;& \gamma_1^{(h)} \epsilon_t^{(s)} + \gamma_2^{(h)} \epsilon_t^{(s)} \times vuln_{i,t-1} \\ & + \tau_i^{(h)} + \sum_{\ell=1}^{p} \alpha_j^{(h)\prime} y_{i,t-j} + \sum_{\ell=1}^{p} \boldsymbol{\beta}_j^{(h)\prime} \boldsymbol{x}_{i,t-j} + u_{i,t}^{(h)}, \end{aligned} \tag{4}$$

where y_{it} is economy i's industrial production, $\tau_i^{(h)}$ a country fixed effect, $\boldsymbol{x}_{it}$ controls, $vuln_{it}$ country's i's macro-financial vulnerability measure described below, and ϵ_t^s the s-th component of the four-dimensional vector $\boldsymbol{\epsilon}_t$ containing the Odyssean FG, LSAP, and Delphic FG shocks.[21]

In contrast to Figure 15, we restrict the analysis to the interaction between economies' macro-financial vulnerabilities on the one hand and *all*—i.e. both positive and negative—monetary policy shocks over the *entire* US business cycle on the other hand.

A large body of work documents that macro-financial vulnerabilities are shaped in particular by weakly anchored inflation expectations, a persistently overvalued exchange rate, and large stocks of dollar-denominated external liabilities (Gourinchas and Obstfeld, 2012; Durdu et al., 2020; Hoek et al., 2022; Ahmed et al., 2021). Against this background, we construct a country-time-specific vulnerability index $vuln_{it}$ based on data for economies' inflation rates, real effective exchange rates and their stocks of dollar-denominated foreign debt liabilities. The vulnerability index is given by the average of three component series that reflect vulnerabilities measured by high inflation rates, pronounced exchange rate misalignments, and large stocks of dollar-denominated foreign liabilities.[22] Figure D.17 in the Appendix presents the

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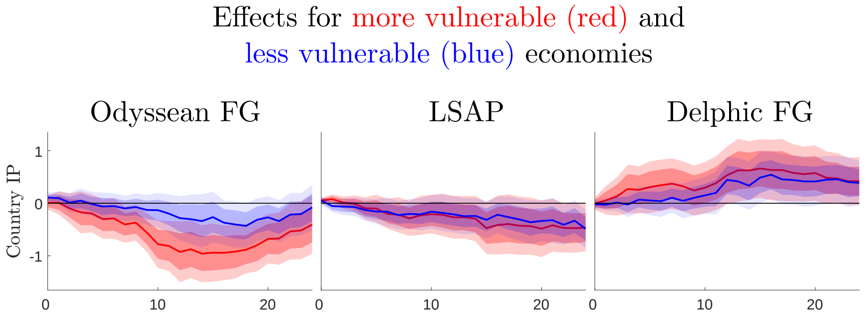
[21] It is more restrictive to assume that the state is not affected by the structural shocks in Equation (4) than in Equation (3), and so the sufficient condition for the consistency of state-dependent LPs established by Goncalves et al. (2022) might not be met. Intuitively, suppose (i) US PMP shocks had a greater impact on the RoW the more pronounced vulnerabilities, and (ii) a US PMP shock would cause vulnerabilities in the RoW to improve over time. Then, in response to a US monetary policy shock the RoW would experience a large spillover if it started out with more pronounced vulnerabilities; at the same time, its vulnerabilities would also start to improve over time. Because Equation (4) conditions the effect of US PMP shocks only on vulnerabilities in t and not $t + h$ with $h > 0$, this would then induce an overestimation of the spillovers for $h > 0$. However, we believe assumption (ii) that US monetary policy shocks *improve* RoW vulnerabilities is implausible at least for contractionary US PMP shocks.

[22] In more detail, we proceed in six steps. First, we gather data for inflation from the IMF World Economic Outlook database, for the real effective exchange rate from the IMF International Financial Statistics database, and for the dollar-denominated foreign debt liabilities from Benetrix et al. (2015, 2020). Second, we linearly interpolate annual data to monthly frequency. Third, we calculate real effective exchange rate misalignments

evolution of the cross-country distribution of the index over time, showing that vulnerability were most pronounced in the early/mid-1990s as well as in the run-up to the GFC, and that economies have generally improved over time. This is especially driven by the better anchoring of inflation expectations as well as the reduction in dollar exposures. After 2009 the top-five most vulnerable economies in our sample were Argentina, Ukraine, Brazil, Turkey, and Russia.

Figure 16 presents the estimates of the panel LPs with interactions between the monetary policy shocks and the vulnerability index. The results suggest that macroeconomic and financial vulnerabilities produce heterogeneities in the spillovers from Odyssean and Delphic FG shocks. In particular, for more vulnerable economies at the 90% percentile of the distribution of the index spillovers are larger—i.e. more negative—in case of Odyssean FG shocks and—i.e. more positive—than for less vulnerable economies at the 10% percentile in case of Delphic FG shocks. The first row in Figure D.18 in the Appendix shows that results are similar when instead of a vulnerability *index* we use a vulnerability *score* constructed as the sum of three indicator variables each equalling unity if the value of the country-time-specific component variable exceeds the median of the cross-country-time distribution. And the second row shows that results are similar when we additionally consider the share of economies' total exports that is destined to the US and their current account deficit in the index, although these variables seem to shape heterogeneities in spillovers somewhat less.

Figure 16: Real activity spillovers from US monetary policy shocks across dimensions of non-linearities estimated from panel LPs and country-level data



Note: The figure presents the results for the estimates of the spillovers from US monetary policy shocks obtained from the panel LPs in Equation (4). Impulse responses in red indicate spillovers for more vulnerable economies at the 90% percentile of the distribution of the index and the impulse responses in blue for less vulnerable economies at the 10% percentile. Shaded areas represent 90% and 68% confidence bands. Inference is based on Driscoll-Kraay robust standard errors.

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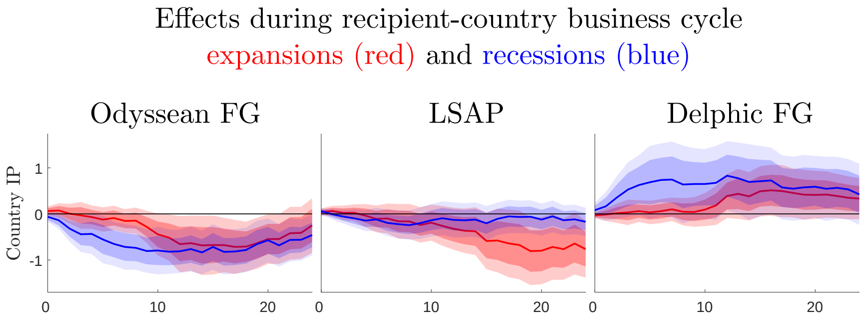
as deviations from trend using the Hodrick-Prescott filter to account for the Balassa-Samuelson effect. Fourth, we winsorise the data to remove extreme observations; for inflation we winsorise at the 95% percentile, and for the stock of dollar-denominated foreign debt liabilities and the real effective exchange rate gap at the 99% percentile. Sixth, we take the unweighted average of the three component series; in this step we set the dollar liabilities exposure for AEs and small financial centers such as Singapore and Hong Kong to zero.

Finally, we explore how recipient-country business cycles affect the spillovers from US monetary policy. To do so, we define expansions as positive deviations of an economy's two-quarter backward moving average (log) industrial production from its two-year backward moving average, assuming additionally that expansions and recessions last at least two quarters. Figure 17 presents the results from panel LPs as in Equation (4) in which we interact the US monetary policy shocks with this recipient-country business cycle expansion indicator variable. The results suggest that spillovers from US Odyssean and Delphic FG shocks tend to be greater during recipient-country recessions, consistent with the findings conditional on the US business cycle in Figure 15. While the results for LSAP shocks are less clear cut, recall the caveat that these should be taken with caution as they are based on a much smaller effective sample.

Figure 17: Real activity spillovers from US monetary policy shocks during recipient-country business cycle expansions (red) and recessions (blue) estimated from panel LPs and country-level data



Note: The figure presents the results for the estimates of the spillovers from US monetary policy shocks obtained from the panel LPs in Equation (4). Impulse responses in red indicate spillovers during recipient-country business cycle expansions and the impulse responses in blue during recessions. See also the notes to Figure 16.

4 Conclusion

At least since the Global Financial Crisis US monetary policy manifests in several dimensions that have not been accounted for comprehensively in the empirical literature on its global spillovers. Against this background, in this paper we examine global spillovers from US monetary policy simultaneously accounting for the multi-dimensional nature of the Fed's toolkit in terms of the short-term policy rate, forward guidance and asset purchases, as well as for central bank information effects. The paper contributes several findings to the literature: First, spillovers are larger for forward guidance and asset purchase shocks than for conventional policy shocks; second, not accounting for central bank information effects in particular in the context of forward guidance entails counterintuitive estimates of domestic and spillover effects; third, while spillovers from US monetary policy tightenings during US business cycle expansions are generally small, economies with macro-financial vulnerabilities or in recession exhibit greater spillovers. Our results confirm the findings in the existing literature that spillovers from US monetary policy are large, that they transmit in particular through variations in global financial conditions rather than trade, that they affect EMEs more strongly than AEs and give rise to policy trade-offs in EMEs, and that economies exhibiting macro-financial vulnerabilities are more susceptible to adverse spillovers. Read against the background of a track record of financial crises in EMEs triggered by the start of Fed tightening cycles, our findings thus underline the importance of careful monitoring of economies' external vulnerabilities.

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A Comparing estimates of the financial market effects for different high-frequency shocks

We benchmark the shocks of Jarociński (2021) with the shocks considered in Jarociński and Karadi (2020) and Bauer and Swanson (2022). The latter also build on interest rate surprises in narrow windows around FOMC meetings and distinguish between PMP shocks and CBI effects, but not between the conventional and unconventional US monetary policy.[23] Analogous to Figure 1, the fourth and fifth columns in Figure A.1 present the estimated financial market effects for these alternative shocks. Both cause an increase in US interest rates (with the biggest effect at medium-term maturities), an increase in the expectations component, a flattening in the slope of the yield curve, and a drop in equity prices. Overall, this pattern is most similar to that obtained for the conventional monetary policy shocks of Jarociński in Figure 1 and reproduced in column (1) in Figure A.1 for convenience.

In contrast, the effects of Jarociński's Odyssean FG and LSAP shocks reproduced in columns (2) and (3) in Figure A.1 exhibit patterns that are *qualitatively* different compared to those of the alternative shocks for at least one set of financial market variables. In particular, in case of Odyssean FG shocks the slope of the yield curve *steepens*; and in case of LSAP shocks in addition only interest rates at *longer* maturities increase, the slope of the yield curve *steepens*, and term premia *increase*. The differences in the patterns of the effects of the alternative shocks of Bauer and Swanson (2022) and Jarociński and Karadi (2020) on the one hand and the Odyssean FG/LSAP shocks on the other hand suggests that only the shocks of Jarociński (2021) allow us to disentangle the effects of unconventional monetary policy in terms of Odyssean FG and LSAP from those of conventional monetary policy.

Having said that, recall that the shocks of Swanson (2021) are designed to capture the different dimensions of US monetary policy. Indeed, Figure B.2 in Appendix B shows that their estimated daily financial market effects are very similar to those in Figure 1; one exception is the LSAP shock of Swanson (2021), which seems to transmit additionally through a signalling channel. Overall, Figure B.2 suggests the shocks of Swanson (2021) may be as useful as those of Jarociński (2021) for capturing the multi-dimensional nature of US monetary policy when estimating short-term financial market effects.

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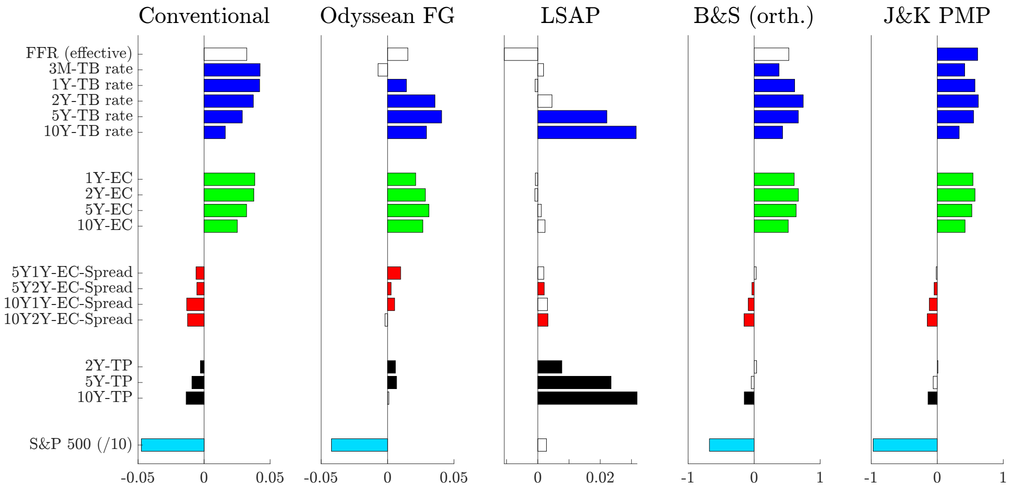
[23] The PMP shocks of Miranda-Agrippino and Ricco (2021) and the PMP extension of the shocks of Bu et al. (2021) by Ciminelli et al. (2022) could be additional alternatives but are available only at the monthly frequency.

Figure A.1: Comparison of daily financial market impact effects of the US monetary policy shocks of Jarociński, Bauer and Swanson (2022) and Jarociński and Karadi (2020)

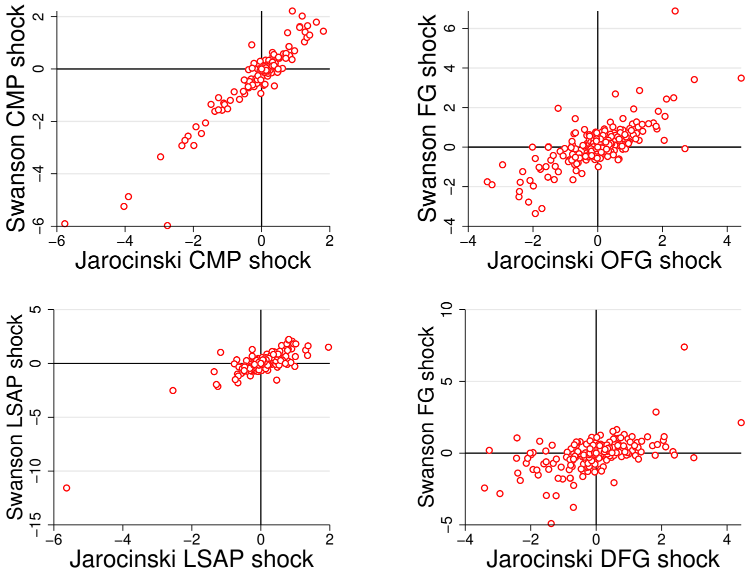


Note: The first three columns depict results for the shocks of Jarociński, the fourth column for the shocks of Bauer and Swanson (2022, B&S (orth.)), and the last column for the shocks of Jarociński and Karadi (2020, 'J&K PMP'). 'B&S (orth.)' is the suspsise in the first principal component of $ED1$ *to* $ED4$*, i.e. the first four quarterly euro-dollar futures cleansed from publicly available Bluechip forecasts from prior to the respective FOMC meeting; 'J&K PMP' is the PMP shock obtained from the rotational approach and based on surprises in* $FF4$ *and the* $S\&P500$*. See also the notes from Figure 1.*

B Comparison to the shocks of Swanson (2021)

Figure B.1 presents a comparison of the monetary policy shocks of Jarociński (2021) and Swanson (2021). There is a great degree of similarity between Jarocinski's and Swanson's conventional monetary policy and LSAP shocks, as well as between Jarocinski's Odyssean FG and Swanson's FG shocks. It is interesting to note that there is also a similarity between the Jarocinski's Delphic FG shocks—reflecting CBI effects—of and Swanson's FG shocks. This may indicate that Swanson's FG shock represents a combination of Jarocinski's Odyssean and Delphic FG shocks, meaning a combination PMP shocks and CBI effects. This is also suggested by the results from regressions of Swanson's monetary policy shocks on those of Jarocinski reported in Table B.1 in columns (1) to (3). In particular, Swanson's conventional monetary policy shock is (conditionally) correlated only with Jarocinski's analogue. Similarly, Swanson's LSAP shock is only correlated with Jarocinski's analogue. In contrast, Swanson's FG shock is correlated with Jarocinski's conventional monetary policy, Odyssean and Delphic FG shocks. In turn, Jarocinski's conventional monetary policy shock is correlated (conditionally) only with Swanson's analogue (column (4)). Jarocinski's Odyssean FG and LSAP shocks are correlated both with Swanson's FG and LSAP shocks, and Jarocinski's Delphic FG shock only with Swanson's FG shock.

Figure B.1: Comparison between the monetary policy shocks of Jarociński (2021) and Swanson (2021)



Note: The figure compares the monetary policy shocks of Jarociński (2021) depicted on the horizontal axes with those of Swanson (2021) depicted on the vertical axis. The units on the axes are basis points.

Figure B.2 and the red lines in the panels in the first three columns in Figure D.3 in the Appendix present the results for the daily US financial market effects when we use the

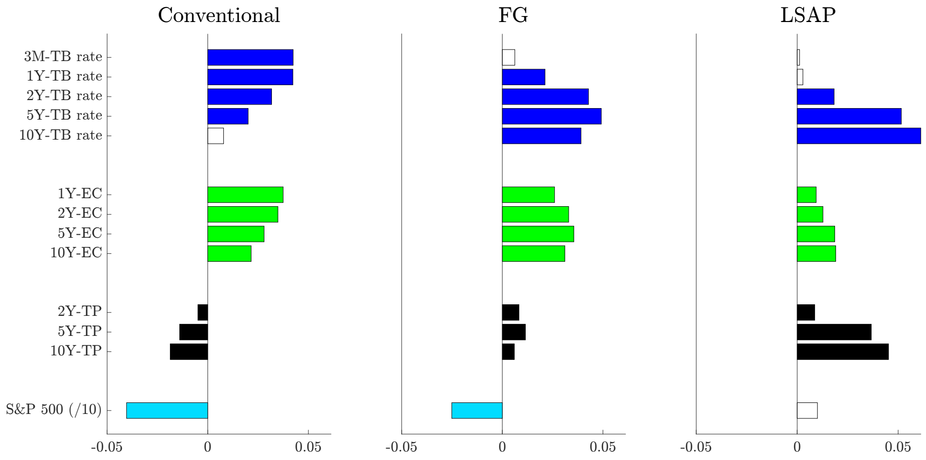
Table B.1: Results for regressions of the monetary policy shocks of Swanson (2021) on the analogues of Jarociński (2021) and vice versa

	Swanson shocks on LHS			Jarocinski shocks on LHS			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	CMP	FG	LSAP	CMP	OFG	LSAP	DFG
Jarocinski conventional MP shock	0.79***	0.25***	0.02				
	(0.00)	(0.00)	(0.54)				
Jarocinski Odyssean FG shock	0.06	0.79***	-0.02				
	(0.19)	(0.00)	(0.61)				
Jarocinski LSAP shock	0.01	-0.01	0.50***				
	(0.68)	(0.82)	(0.00)				
Jarocinski Delphic FG shock	-0.01	0.53***	0.02				
	(0.50)	(0.00)	(0.60)				
Swanson sonventional MP shock				1.16***	-0.21	-0.05	-0.14
				(0.00)	(0.13)	(0.36)	(0.43)
Swanson FG shock				0.00	0.74***	0.11**	0.52***
				(0.90)	(0.00)	(0.05)	(0.00)
Swanson LSAP shock				-0.03	0.18*	1.41***	0.06
				(0.43)	(0.07)	(0.00)	(0.66)
R-squared	0.91	0.86	0.70	0.91	0.58	0.71	0.29
Observations	240	240	240	240	240	240	240

Note: The dependent variable across columns is the daily conventional, FG and LSAP shocks of Swanson (2021) in columns (1) to (3) and the conventional, Odyssean FG, LSAP and Delphic FG shocks of Jarociński (2021) in columns (4) to (7), respectively. Inference is based on robust standard errors. *p*-values are reported in parentheses below the point estimates, and * (**) [***] indicates statistical significance at the 10% (5%) [1%] significance level.

conventional monetary policy, FG and LSAP shocks of Swanson (2021). Overall, results are rather similar to those for the conventional monetary policy, Odyssean FG and LSAP shocks of Jarociński (2021). One noteworthy difference is that the increase in long-term Treasury yields in response to Swanson's LSAP shocks shown in the third column in Figure B.2 is not only driven by an increase in term premia but also by an upward shift in the expectations component. This is consistent with the notion that QE in part operates through a 'signalling channel'. In contrast, for Jarocinski's LSAP shock the results in the third column in Figure 1 suggest that the rise in long-term Treasury yields is exclusively driven by term premia, that is due to portfolio re-balancing, convenience yields and preferred habitat effects. A second noteworthy difference is that the interest rate responses to Swanson's FG shock shown in the second column in Figure D.3 in the Appendix are larger than those to the Odyssean FG shock of Jarociński (2021). In general, it appears as if the responses to Swanson's FG shock are a combination of the responses to Jarocinski's Odyssean and Delphic FG shocks. This and the discussion above suggest that—although implying impulse response estimates that are *qualitatively* consistent with a PMP shock—Swanson's FG shocks might be contaminated by CBI effects.[24]

Figure B.2: Daily impact effects of US interest rates and stock prices to the US monetary policy shocks of Swanson (2021)



Note: The shocks are taken from Swanson (2021), and are included simultaneously in the regressions. See also the notes from Figure 1.

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[24] Interestingly, the counterintuitive findings in Campbell et al. (2012) that sparked the analysis of CBI effects are most pronounced for FG shocks.

C Tables

Table C.1: Data description for daily time series

Variable	Description	Source	Coverage
Federal funds rate	Effective Federal funds rate	Federal Reserve Board/Haver	1/1/1990 - 31/12/2019
Treasury yields	Treasury Bill/Note yields, constant maturity	Federal Reserve Board/Haver	1/1/1990 - 31/12/2019
Treasury expectations components	Risk-neutral yield	Adrian et al. (2013), Haver	1/1/1990 - 31/12/2019
Treasury term premia	Term premium	Adrian et al. (2013), Haver	1/1/1990 - 31/12/2019
S&P 500	S&P 500 Composite	S&P/Haver	1/1/1990 - 31/12/2019
US dollar NEERs	Nominal broad/AFE/EME trade-weighted dollar index	Federal Reserve Board/Haver	1/1/1990 - 31/12/2019
Germany 10Y yield	10Y government bold yield	Refinitiv/Haver	10/1/1994 - 31/12/2019
UK 10Y yield	10Y government securities Par yield	Bank of England/Haver	1/1/1990 - 31/12/2019
Sweden 10Y yield	10Y government securities yield	Sveriges Riksbank/Haver	1/1/1990 - 31/12/2019
Canada 10Y yield	10Y benchmark bond yield	Bank of Canada/Haver	1/1/1990 - 31/12/2019
Japan 10Y yield	10Y benchmark government bond yield	Ministry of Finance/Haver	1/1/1990 - 31/12/2019
Australia 10Y yield	10Y Treasury bond	Reserve Bank of Australia/Haver	1/1/1990 - 31/12/2019
Non-US 10Y expectations components	Dynamic-Siegel model decomposition	ECB calculations	4/9/1990 - 31/12/2019
Non-US 10Y term premia	Dynamic-Siegel model decomposition	ECB calculations	4/9/1990 - 31/12/2019
Germany equity prices	Frankfurt Xetra DAX	Deutsche Boerse/Haver	1/1/1990 - 31/12/2019
UK equity prices	London Financial Times All share	Financial Times/Haver	1/1/1990 - 31/12/2019
Sweden equity prices	Stockholm Affersvalden	OMX Nordic Exchange/Haver	1/1/1990 - 31/12/2019
Canada equity prices	S&P TSX Composite Index	Toronto Stock Exchange/Haver	1/1/1990 - 31/12/2019
Japan equity prices	Nikkei 225 Average	Financial Times/Haver	1/1/1990 - 31/12/2019
Australia equity prices	Stock Price Index All Ordinaries	S&P/Haver	1/1/1990 - 31/12/2019

Notes: The table provides information on the daily data used in the estimations.

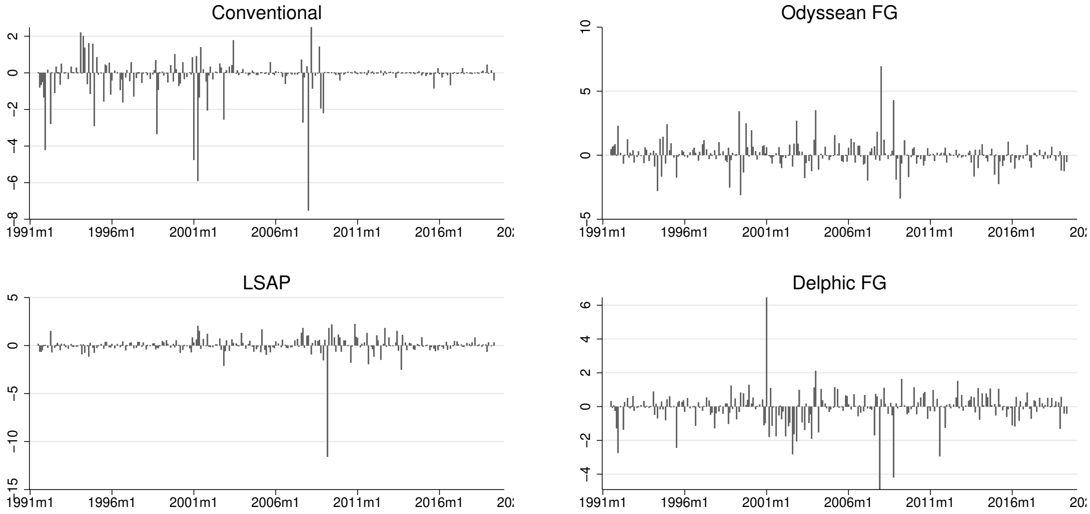
Table C.2: Data description for monthly time series

Variable	**Description**	**Source**	**Coverage**
US real GDP	IHS Markit's monthly GDP (SAAR, bil. chnd. 2012 US$)	Macroeconomic Advisors/Haver	1992m1 - 2019m12
US CPI	Consumer price index	BLS/Haver	1990m1 - 2019m12
US EBP	Excess bond premium	See Favara et al. (2016)	1990m1 - 2019m12
S&P 500	S&P 500 Composite (eop)	S&P/Haver	1990m1 - 2019m12
US dollar NEERs	Nominal broad/EME/AFE trade-weighted dollar index	FRB/Haver	1990m1 - 2019m12
RoW/AE/EME IP	Production-weighted world/AE/EME industrial production (swda)	NBEPA/Haver	1991m1 - 2019m12
RoW/AE/EME CPI	RoW/AE/EME consumer price index	Dallas Fed Global Economic Indicators/Haver (Martínez-García et al., 2015)	1990m1 - 2019m12
MSCI World excl. US	MXWOU Index: MSCI World excluding US (eop)	MSCI/Bloomberg	1990m1 - 2019m12
MSCI AEs	MSCI AEFE Index: Developed markets in Europe, Australasia, Israel and the Far East	MSCI/Bloomberg (eop)	1990m1 - 2019m12
MSCI EMEs	MSCI MXEF Index: Emerging markets with mid to large cap (eop)	MSCI/Bloomberg	1990m1 - 2019m12
AE/EME inflows	Inflows, portfolio investment flows, Interpolated	IMF BoP	1995q1-2019q4
US inflows, outflows	Net purchases of US/foreign securities by foreign/US residents	US TIC	1990m1-2019m12
EMBI spread	EMBI Global Brady Bonds sovereign spread (eop)	JP Morgan Emerging Markets Bond Indexes/Haver	1993m12-2019m12
Non-US cross-border bank credit	Banks' external liabilities of banks owned by the world less external liabilities of banks owned by US nationals	BIS Locational Banking Statistics, Table A7/Haver	1990q1 -2019q4, interpolated to monthly frequency
World non-US trade	World excl. US trade volume (sa)	NBEPA/Haver	1991m1 - 2019m12
GF risky asset prices	Global factor in risky asset prices	Miranda-Agrippino et al. (2020)	1990m1 - 2019m4
GF capital flows	Global factor in total inflows	Miranda-Agrippino et al. (2020)	1990q1 - 2018q4, interpolated to monthly frequency
Oil prices	Brent crude oil, European Free Market price	Financial Times/Haver	1990m1 - 2019m12

Notes: BLS stands for Bureau of Labour Statistics, FRB for Federal Reserve Board, NBEPA for Netherlands Bureau for Economic Policy Analysis, and TIC for Treasury International Capital.

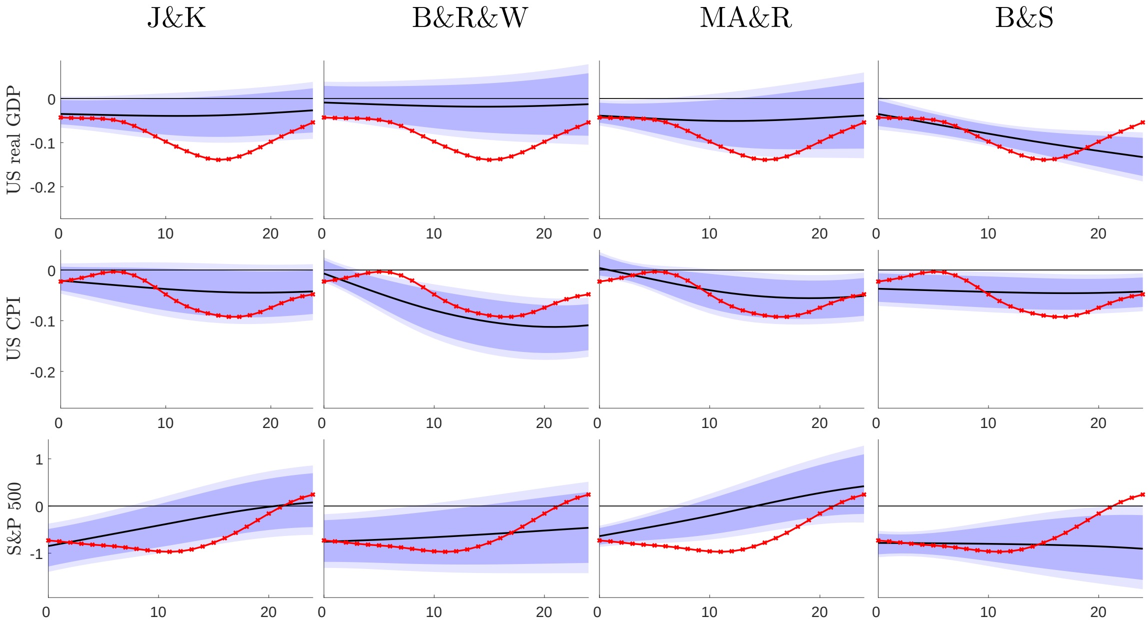
D Figures

Figure D.1: Time series of the US monetary policy shocks of Jarociński (2021)



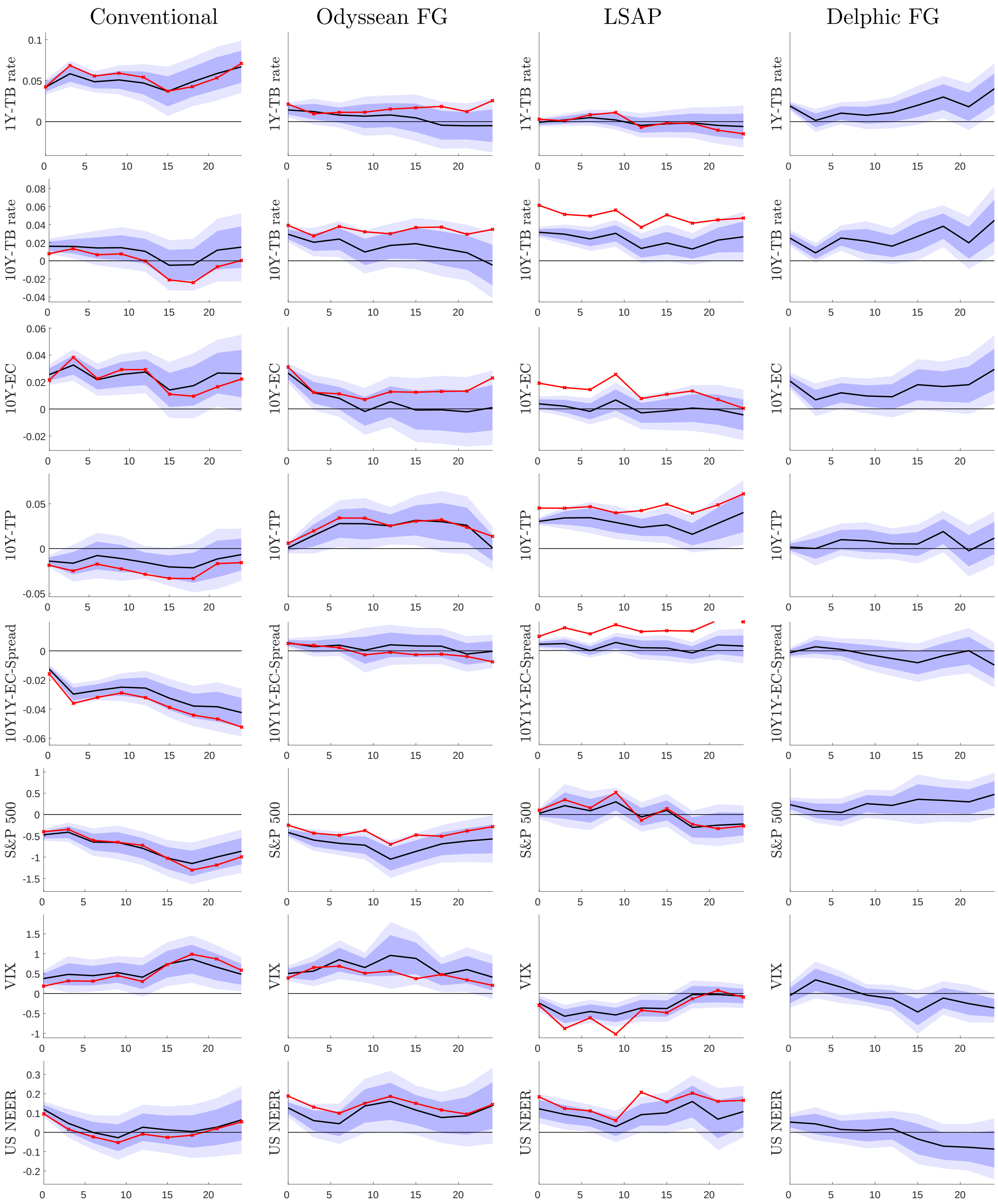
Note: The figure shows the incidence of the monetary policy shocks of Jarociński (2021) over time. Daily shocks are temporally aggregated by summing them up within a month.

Figure D.2: Effects of alternative PMP shocks on US variables



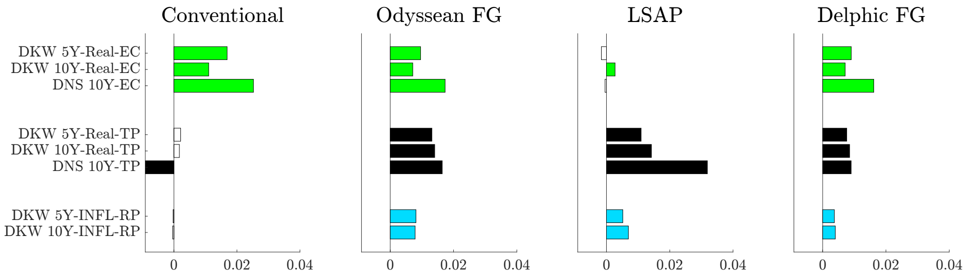
Note: The black solid lines indicate the impulse responses of US real GDP to the US PMP shocks of Jarociński and Karadi (2020, J&K, 1991-2019), Bu et al. (2021, B&R&W, 1994-2019), Miranda-Agrippino and Ricco (2021, MA&R, 1990-2015), and Bauer and Swanson (2022, B&S, 1991-2019) estimated from SLPs of Barnichon and Brownlees (2019). The data for the shock of Miranda-Agrippino and Ricco (2021) are originally available until 2009, but we update them until 2015. In a given column the shocks are included simultaneously in the regressions. See the notes of Figure 2.

Figure D.3: Daily US financial market responses to US monetary policy shocks



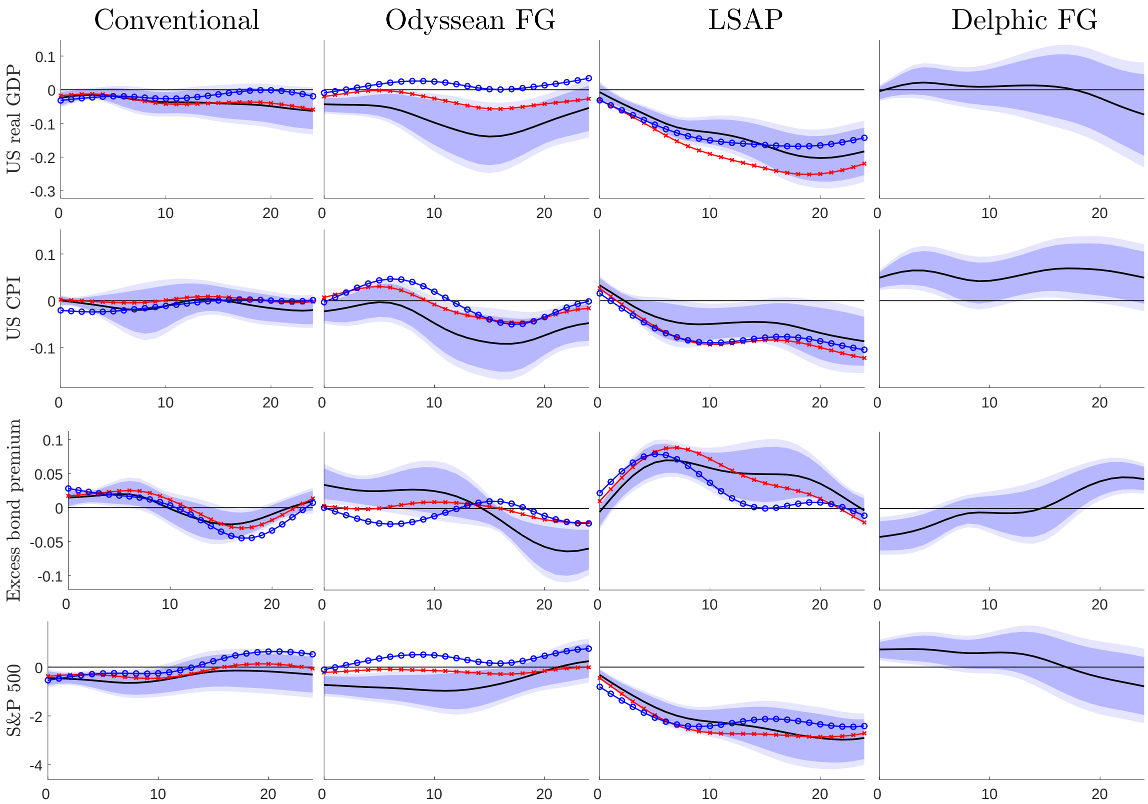
Note: The black solid lines indicate the daily impulse responses of US monetary policy shocks of Jarociński (2021) estimated from the LPs in Equation (2). The shocks are included simultaneously in the regressions. The red crossed lines indicate the responses to the shocks of Swanson (2021). The sample period spans 1991m1 to 2019m6. Shaded areas indicate 68% and 90% confidence bands. Panels in a given row feature the same limits on the vertical axis.

Figure D.4: Daily impact effects of the US monetary policy shocks of Jarociński (2021) on alternative expectations components and term premia taken from D'Amico et al. (2018) and Diebold et al. (2006)



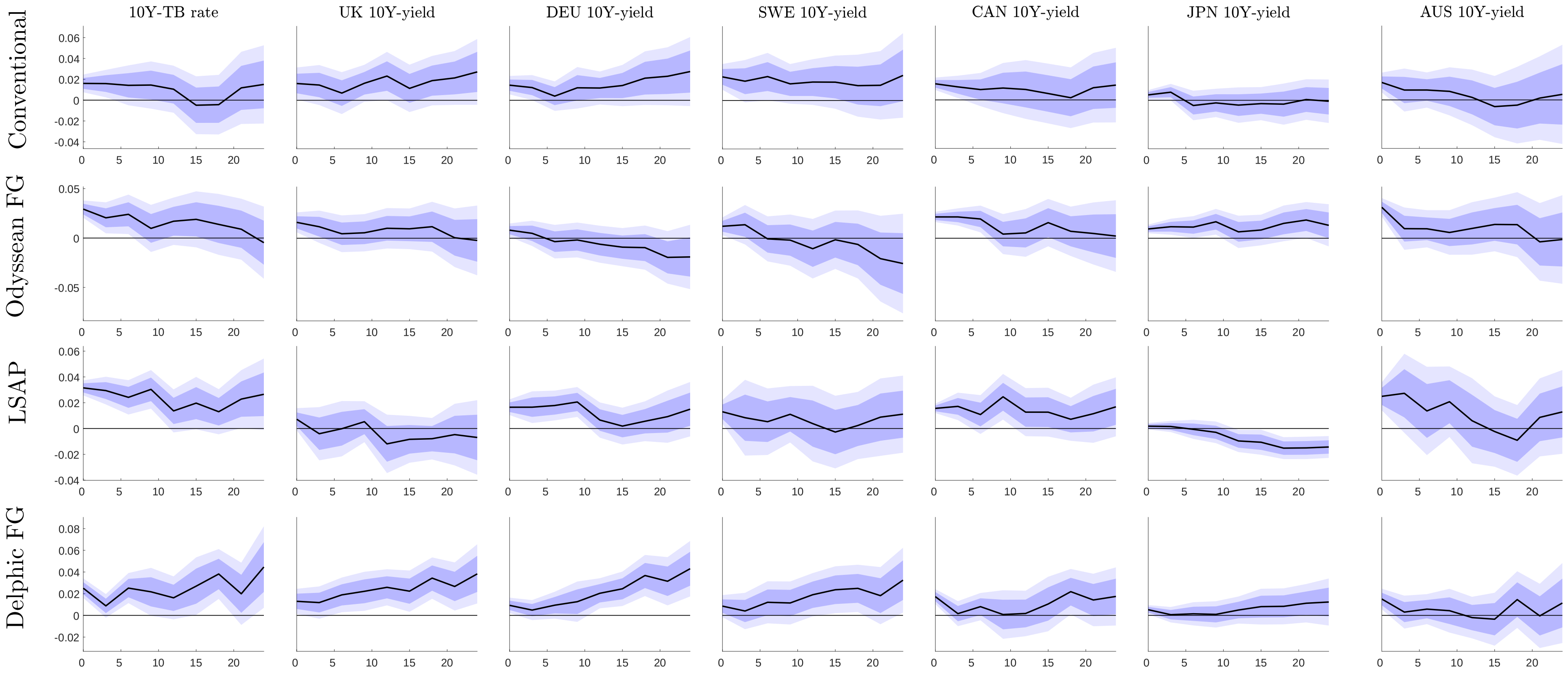
Note: The expectation components and term premia are taken from D'Amico et al. (2018, DKW) and Diebold et al. (2006, DNS). The figure depicts the effects on the real expectations components, real term premia, and inflation risk premia. See also the notes from Figure 1.

Figure D.5: Effects of US monetary policy shocks on US macroeconomic and financial variables



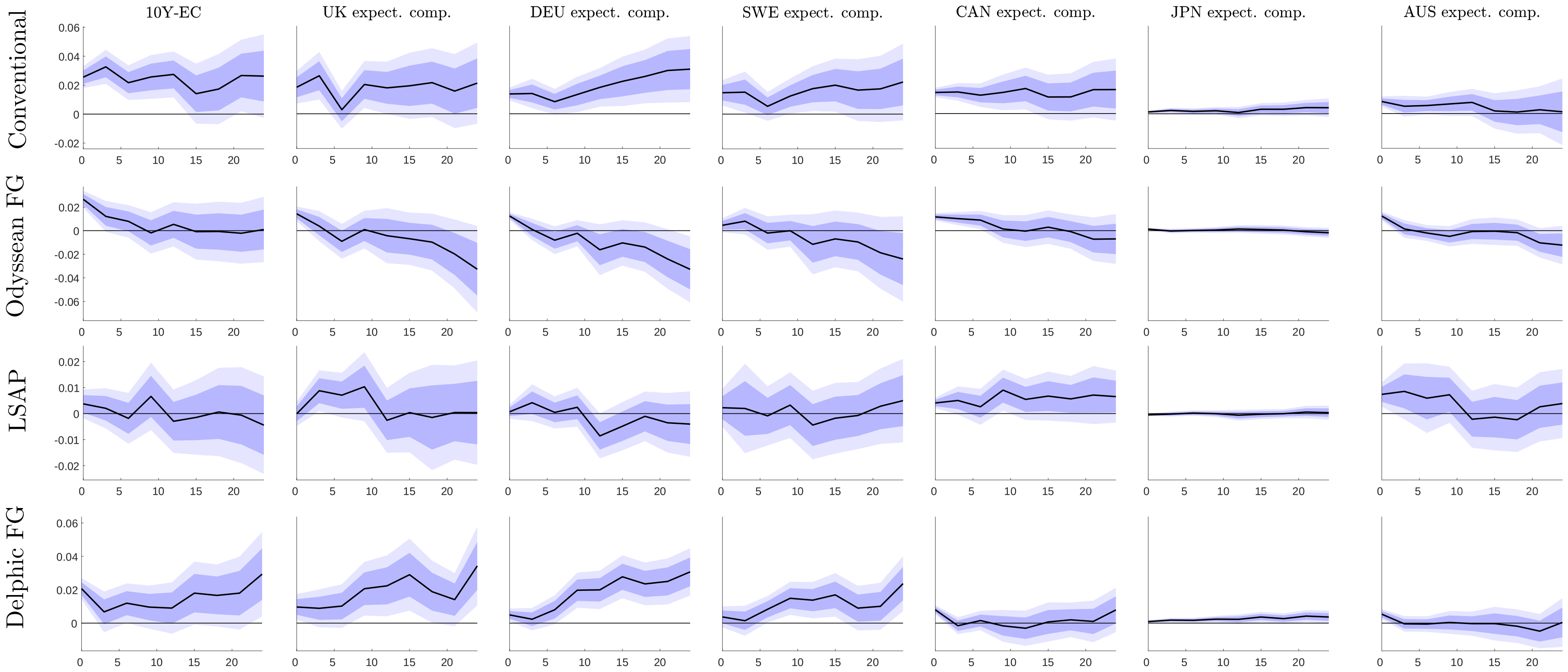
Note: The red crossed lines indicate the responses to the conventional monetary policy, FG and LSAP shocks of Swanson (2021). The blue plus lines indicate the responses to the conventional monetary policy, FG and LSAP shocks of Swanson (2021) cleansed one a time from CBI effects based on the sign of the accompanying high-frequency stock market surprise, as done in Miranda-Agrippino and Nenova (2022). See also the notes of Figure 2

Figure D.6: Daily global interest rate effects of US monetary policy shocks



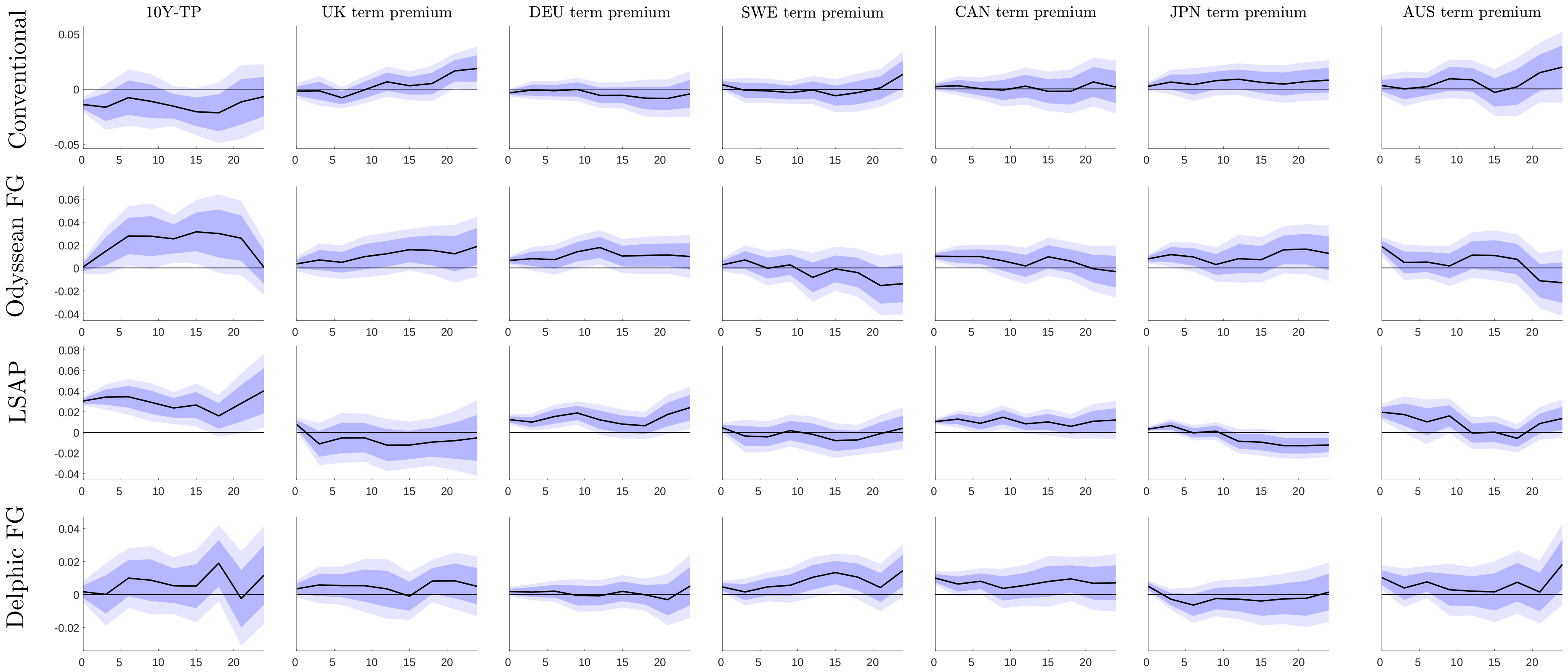
Note: The black solid lines indicate the daily impulse responses of global 10-year sovereign yields to the monetary policy shocks of Jarociński (2021) estimated from the LPs in Equation (2). The shocks are included simultaneously in the regressions. The sample period spans 1991m1 to 2019m6. Shaded areas indicate 68% and 90% confidence bands. Panels in a given row feature the same limits on the vertical axis.

Figure D.7: Daily global expectations component effects of US monetary policy shocks



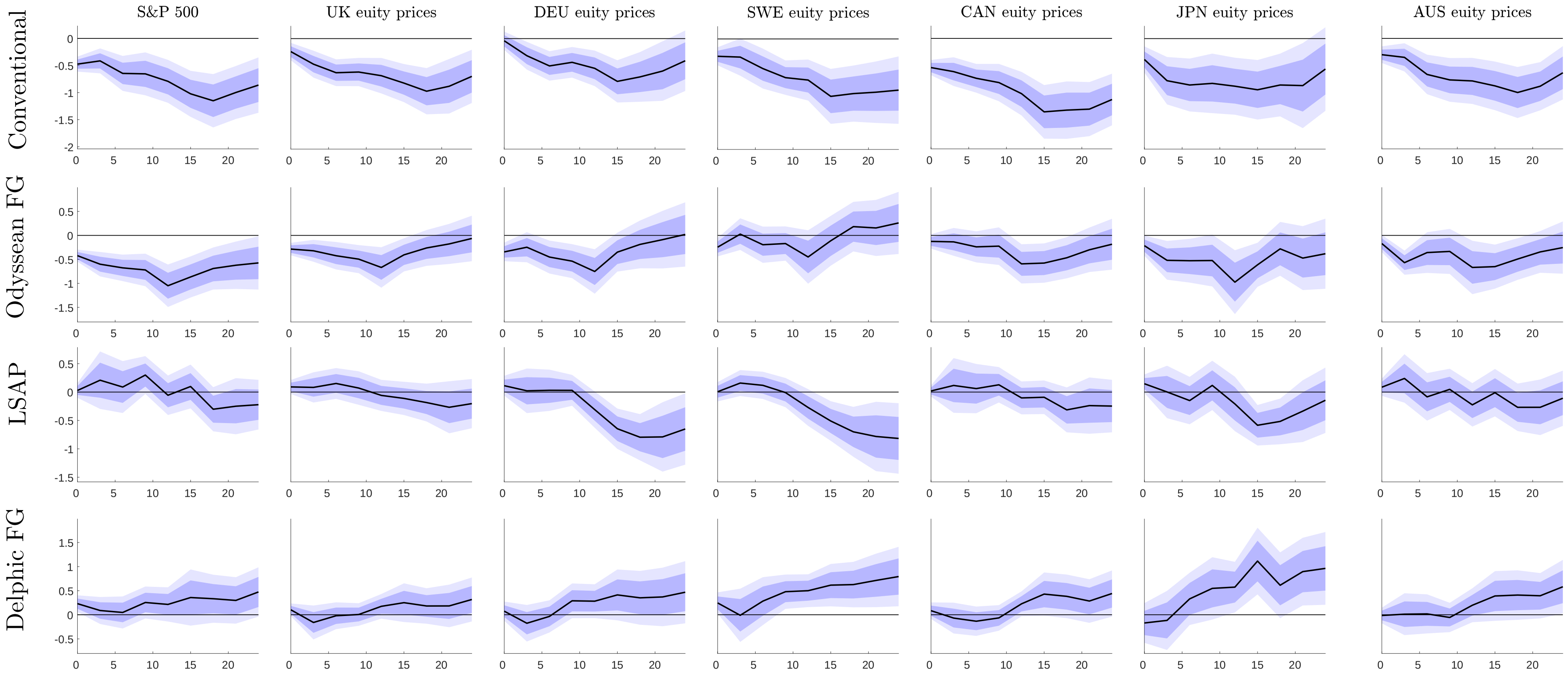
Note: The black solid lines indicate the daily impulse responses of global 10-year risk-free expectations components to the monetary policy shocks of Jarociński (2021) estimated from the LPs in Equation (2). The shocks are included simultaneously in the regressions. The sample period spans 1991m1 to 2019m6. Shaded areas indicate 68% and 90% confidence bands. Panels in a given row feature the same limits on the vertical axis.

Figure D.8: Daily global term premia effects of US monetary policy shocks



Note: The black solid lines indicate the daily impulse responses of global 10-year risk-free expectations components to the monetary policy shocks of Jarociński (2021) estimated from the LPs in Equation (2). The shocks are included simultaneously in the regressions. The sample period spans 1991m1 to 2019m6. Shaded areas indicate 68% and 90% confidence bands. Panels in a given row feature the same limits on the vertical axis.

Figure D.9: Daily global equity price effects of US monetary policy shocks

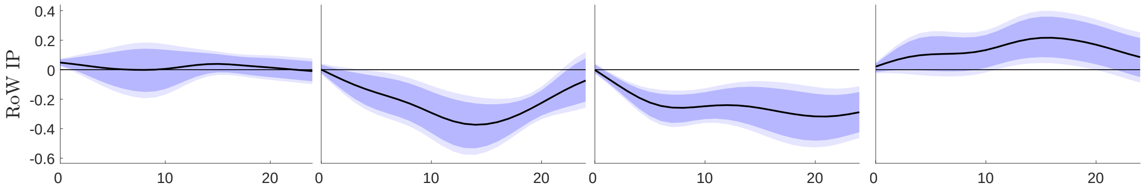


Note: The black solid lines indicate the daily impulse responses of global 10-year risk-free expectations components to the monetary policy shocks of Jarociński (2021) estimated from the LPs in Equation (2). The shocks are included simultaneously in the regressions. The sample period spans 1991m1 to 2019m6. Shaded areas indicate 68% and 90% confidence bands. Panels in a given row feature the same limits on the vertical axis.

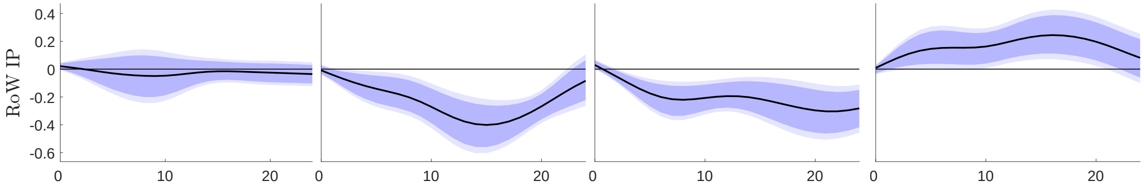
Figure D.10: Effects of US monetary policy shocks on non-US RoW/world real activity measures

Conventional Odyssean FG LSAP Delphic FG

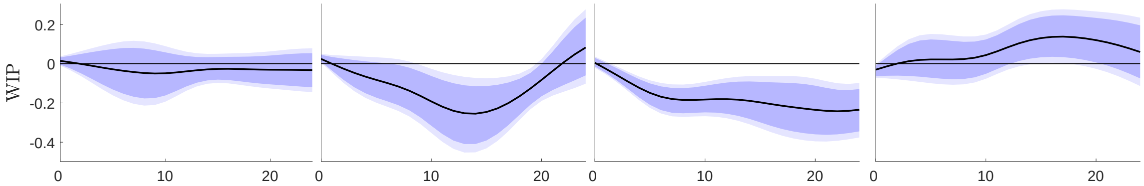
Baseline RoW industrial production



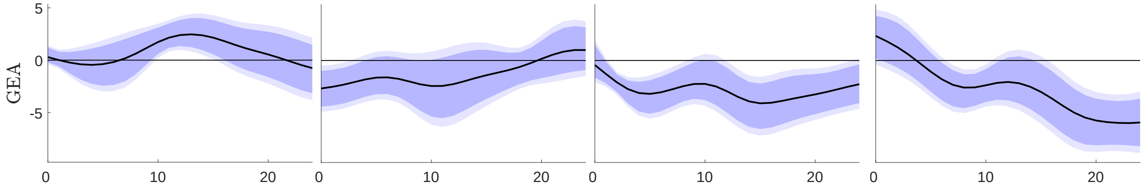
Dallas Fed RoW industrial production
(Martínez-García et al., 2015)



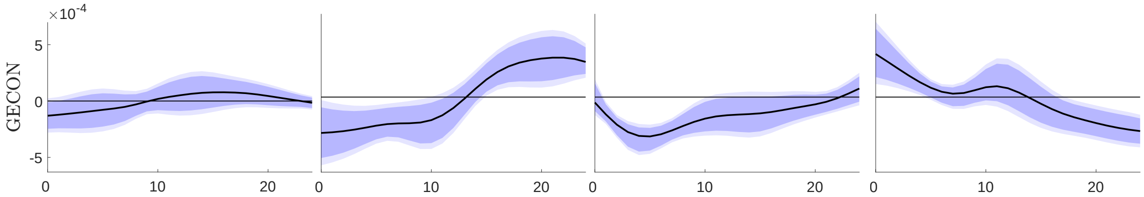
World Industrial Production index (WIP)
(Baumeister and Hamilton, 2019)



Global Economic Activity Index in Industrial Commodity Markets (GEA)
(Kilian, 2009; Kilian and Zhou, 2018)

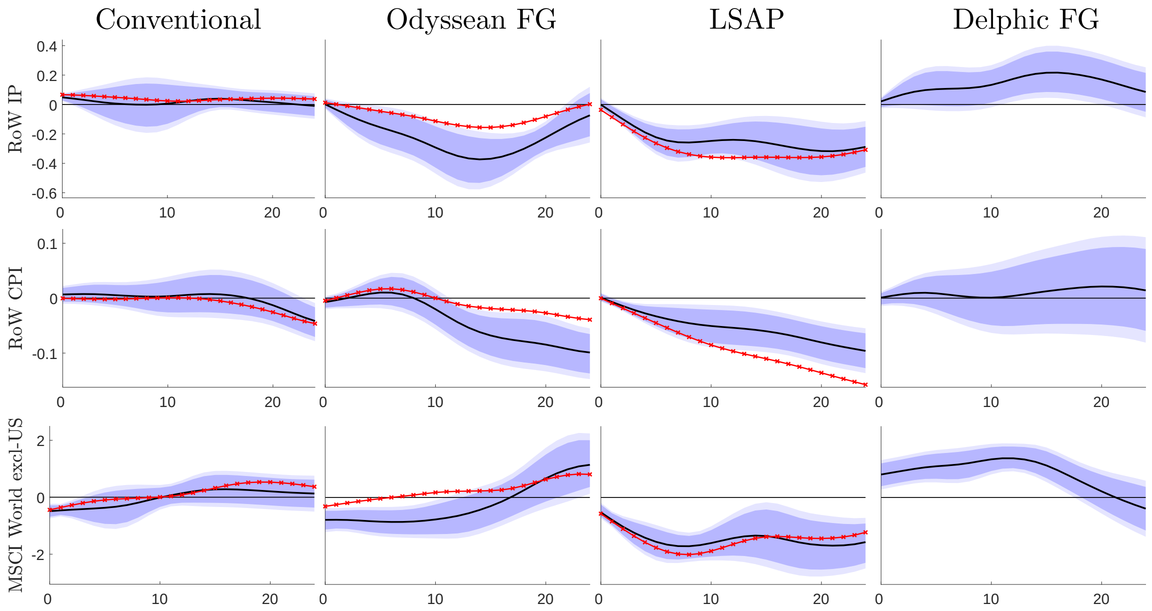


Global Economic Conditions indicator (GECON)
(Baumeister et al., 2020)



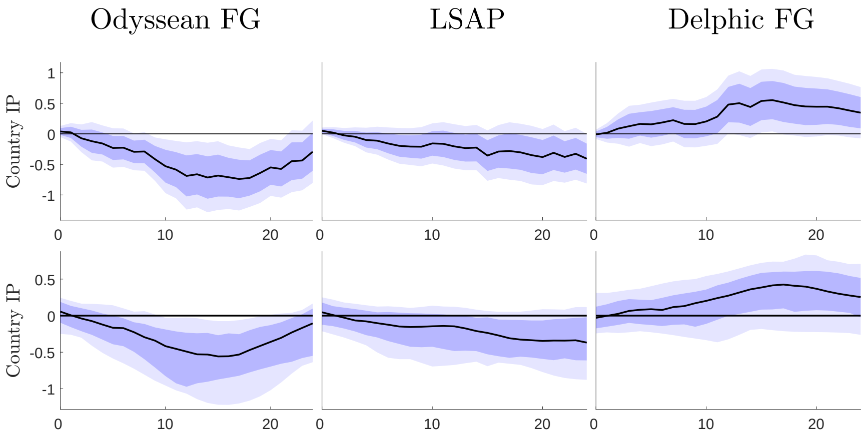
Note: The Dallas Fed RoW industrial production (Martínez-García et al., 2015) is an average of 40 non-US economies' industrial production indices calculated using US trade weights. The World Industrial Production index (WIP; Baumeister and Hamilton, 2019) is an extension of the OECD's index of monthly industrial production in OECD and six additional major other economies. The remaining indicators are all tied to predicting energy and/or commodity demand. The Global Real Economic Activity Index in Industrial Commodity Markets (GEA; Kilian, 2009; Kilian and Zhou, 2018) is derived from a panel of dollar-denominated global bulk dry cargo shipping rates and may be viewed as a proxy for the volume of shipping in global industrial commodity markets and is expressed in percent deviations from trend. Finally, the Global Economic Conditions indicator (GECON; Baumeister et al., 2020) is a combination of 16 indicators covering a broad range of variables including real economic activity, commodity prices, financial indicators, transportation, uncertainty, expectations, weather, and energy-related measures. See also the notes to Figure 2.

Figure D.11: Effects of US monetary policy shocks of Swanson (2021) on non-US RoW variables



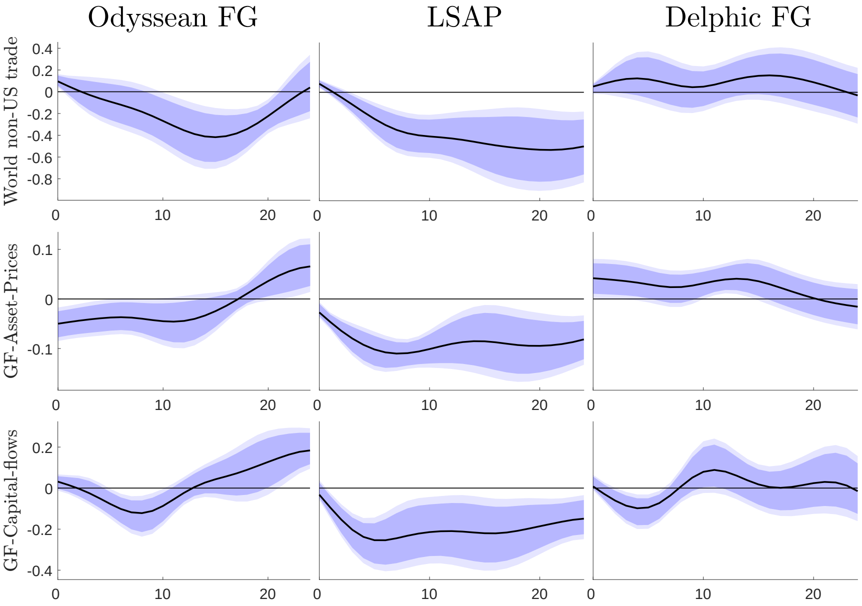
Note: The black solid lines indicate the impulse responses of US monetary policy shocks of Jarociński (2021) estimated from SLPs of Barnichon and Brownlees (2019). The shocks are included simultaneously in the regressions. The red crossed lines indicate the responses to the conventional monetary policy, FG and LSAP shocks of Swanson (2021). See also the notes to Figure 2

Figure D.12: Comparison of spillover estimates of US monetary policy shocks obtained from country-specific SLPs with country-level data (top row), and panel LPs with country-level data (bottom row)



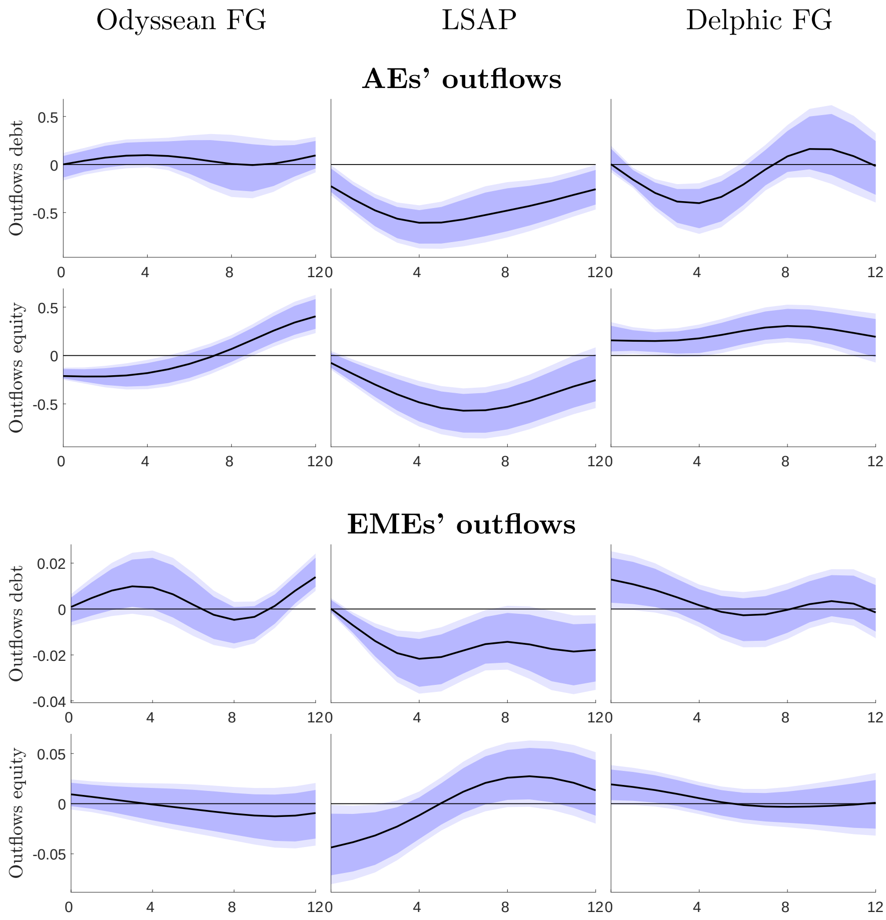
Note: The figure presents the results for the spillovers from US monetary policy shocks obtained from panel LPs estimated on country-specific data (middle row) and mcountry-specific SLPs (bottom row). For the panel LPs in the top row the shaded areas represent 90% and 68% confidence bands based on Driscoll-Kraay robust standard errors. For the country-specific SLPs in the bottom row the solid line represents the median and the shaded areas the 90% and 68% point-wise percentiles of the distribution of the country-specific estimates.

Figure D.13: Responses of global factors to US monetary policy shocks



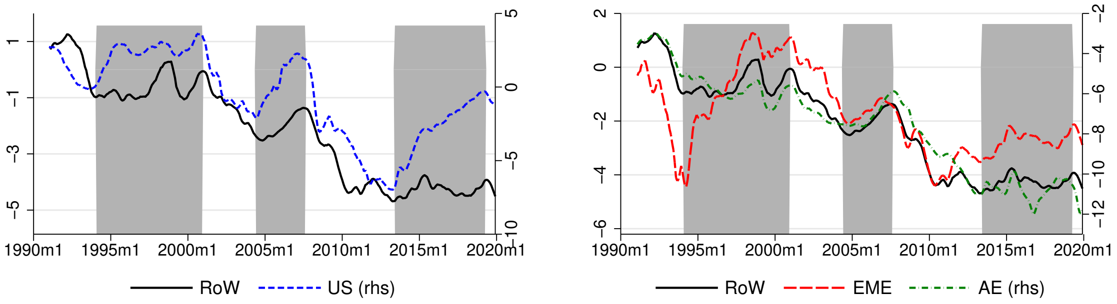
Note: The global factor ('GF') in risky asset prices were originally introduced by Miranda-Agrippino and Rey (2020b) and extended in Miranda-Agrippino et al. (2020), and the global factor in capital flows is taken from Miranda-Agrippino et al. (2020). See the notes to Figure 2.

Figure D.14: Effects of US monetary policy shocks on IMF Balance of Payments Statistics AE and EME portfolio outflows



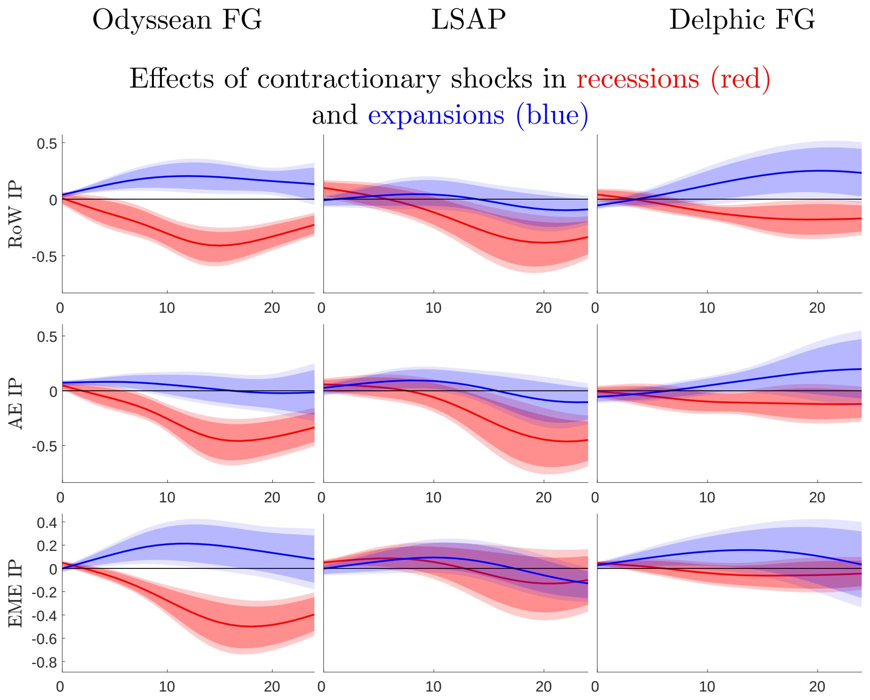
Note: The first (last) two rows present results for AE (EME) portfolio equity and debt outflows, respectively. The data are taken from the IMF Balance of Payments Statistic, are interpolated from quarterly to monthly frequency, and span 1996 to 2019. We use the cross-country average of economies' ratio of outflows to recipient-country GDP. See also the notes to Figure 2.

Figure D.15: US and RoW real policy rates and US monetary policy cycles



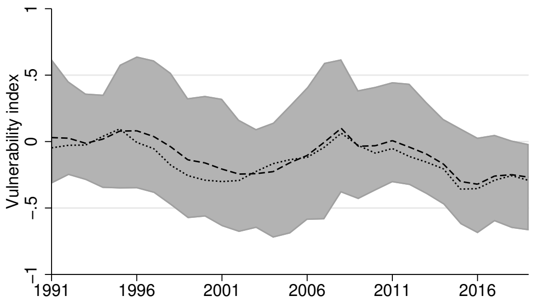
Note: In the left-hand side panel, the black solid line represents the RoW (AEs and major EMEs) GDP-weighted average of implied ex ante real policy rates based on Consensus Economics inflation expectations and the blue dashed the implied ex ante US real policy rate based on the University of Michigan inflation expectations. For the RoW we cumulate GDP-weighted averages of first-differences in country-specific real policy rates in order to avoid jumps due to changes in the availability of data across countries. We convert the Consensus Economics fixed-event next-year forecasts to fixed-horizon 12-months ahead forecasts through weighted linear combinations of the relevant nowcasts and forecasts. In the right-hand side panel, the black solid line depicts the ex ante real policy rate for the RoW as in the top panel, the red dashed line for major EMEs and the green dash-dotted line for AEs. Grey shaded areas indicate US tightening cycles. We do not plot a real policy rate gap as in Figure 14 as unfortunately the estimates for global r-star of Del Negro et al. (2019) are only available until 2016, and Holston et al. (2017) provide estimates beyond the US for the euro area, Canada and the UK.

Figure D.16: RoW, AE and EME real activity impulse responses to US monetary policy shocks across US business cycle expansions and recessions



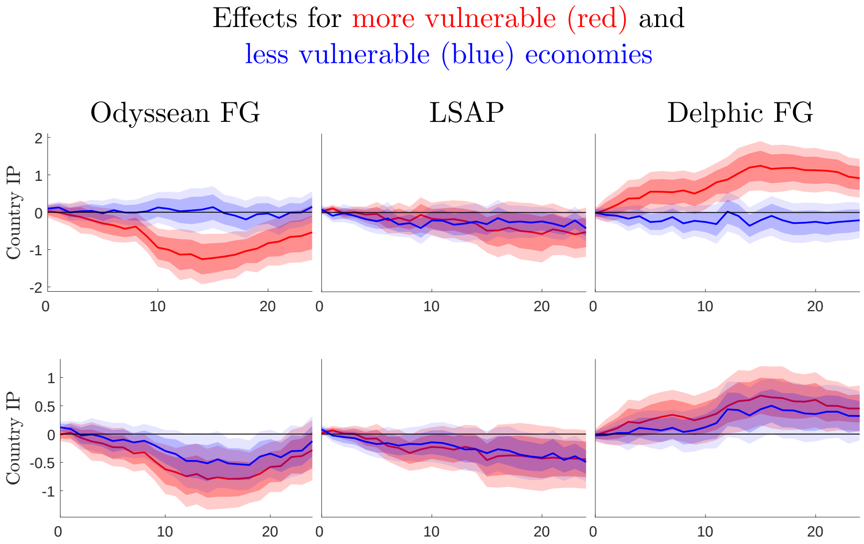
Note: See the notes to Figure 15.

Figure D.17: Evolution of financial and macroeconomic vulnerability in non-US economies



Note: The figure presents the evolution of the financial and macroeconomic vulnerability index summarizing developments in inflation, exchange rate misalignments and foreign dollar liability stocks as discussed in the main text. The shaded area is bounded by the 10% and 90% percentiles of the yearly cross-country distribution, and the dashed (dotted) line indicates the mean (median).

Figure D.18: Real activity spillovers from US monetary policy shocks to more (red) and less (blue) vulnerable economies estimated from panel LPs and country-level data



Note: In the first row we consider a vulnerability score constructed as the sum of three indicator variables each equalling unity if the value of the country-time-specific component variable exceeds the median of the cross-country-time distribution. In the second row we consider economies' total exports that is destined to the US and their current account deficit as additional variables in the construction of the vulnerability index. See also the notes to Figure 16.