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Global spillovers from multi-dimensional US monetary policy

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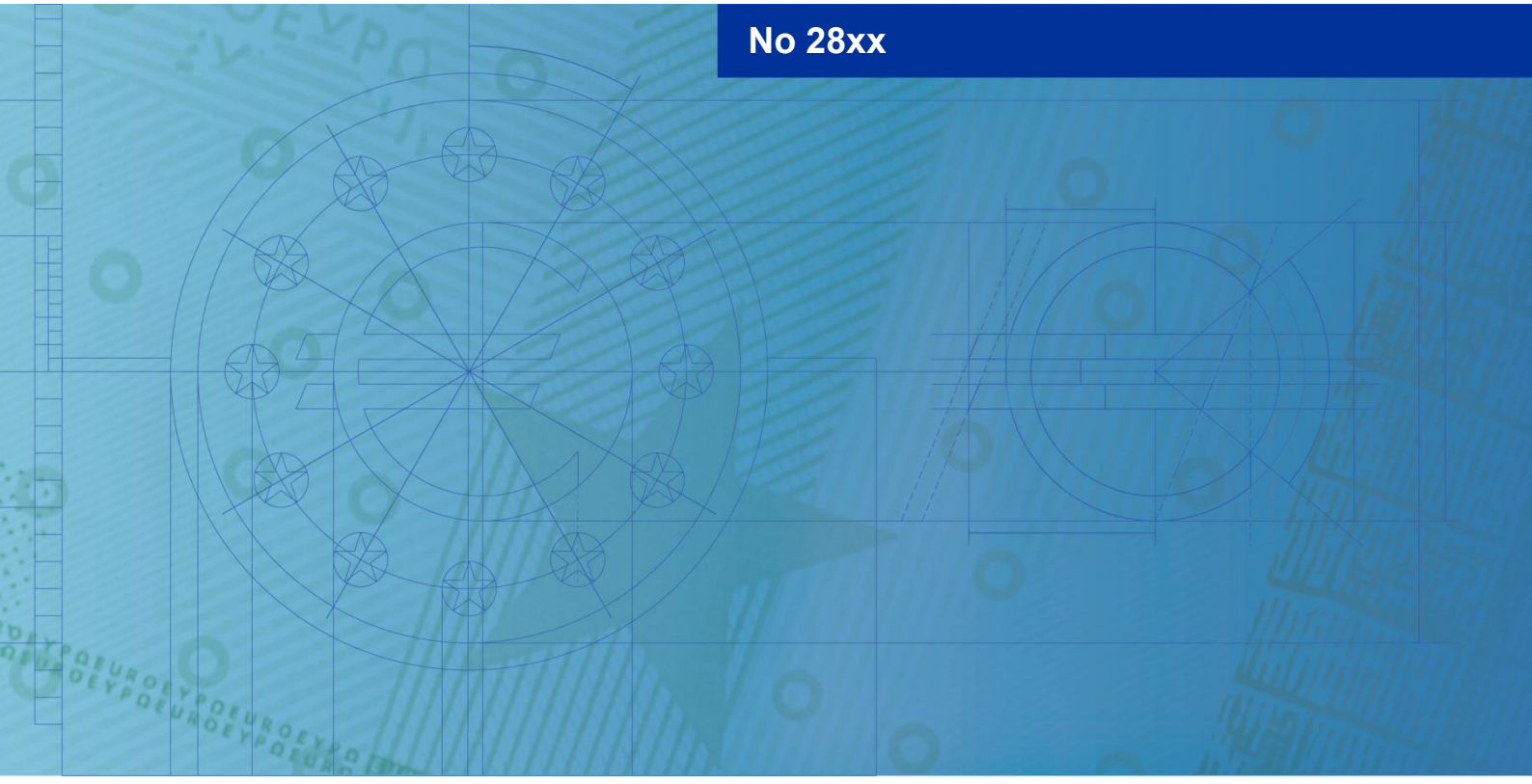


Abstract

We estimate spillovers from US monetary policy for different measures in the Federal Reserve's toolkit. We make use of novel measures of exogenous variation in conventional rate policy, forward guidance and large-scale asset purchases (LSAPs) based on high-frequency asset-price surprises around Federal Open Market Committee meetings. The identification relies on relatively weak assumptions and accounts for the possible presence of residual endogenous components—such as central bank information effects—in these monetary policy surprises. We find that: (i) forward guidance and LSAPs trigger much larger spillovers than conventional rate policy; (ii) spillovers transmit predominantly through financial channels centering on global investors' risk appetite and manifest in changes in equity prices, bond spreads, capital flows and the dollar exchange rate; (iii) LSAPs trigger immediate international portfolio re-balancing between US and advanced-economy bonds, but generally entail only rather limited term premium spillovers; (iv) both forward guidance and LSAPs entail trade-offs for emerging-market-economy central banks, either between stabilizing output and prices or between additionally ensuring financial stability in terms of capital inflows.

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

Non-technical summary

The dominant role of the dollar in global trade and finance has sparked a rich literature on the spillovers from Federal Reserve (Fed) monetary policy. However, despite a large amount of work, important gaps in our understanding remain. Examining the effects of Fed policy has become more complex due to the zero lower bound after the Global Financial Crisis and the increasing use of forward guidance about the future course of policy rates and large-scale asset purchases (LSAPs). Disentangling the implications of Fed policy normalization across these measures is critical as economies around the world emerge from the strains imposed by the COVID-19 pandemic and wrestle with the fallout of Russia's war on Ukraine. It is also critical because the Fed may resort to these different measures more frequently in the future, and because optimal policy responses may differ depending on the nature of the spillovers.

We study the global spillovers from Fed policy addressing these gaps in the literature. We make use of novel conventional rate policy, forward guidance and LSAP shocks identified in high-frequency asset-price surprises around Federal Open Market Committee announcements. The identification relies on relatively weak assumptions compared to existing literature. In particular, it exploits the non-Gaussianity of the observed surprises, namely that they are usually small but occasionally very large. The identification also accounts for the presence of confounding residual endogenous components in monetary policy surprises, such as central bank information effects. We estimate the effects of the different Fed policy measures on rest-of-the-world real activity, inflation, trade, exchange rates, asset prices and capital flows, and we explore whether they induce trade-offs for central banks in emerging market economies. We use the state-of-the-art smooth local projection estimator, which mitigates the excessive variability plaguing analyses of typical macroeconomic time-series samples and has been shown to outperform a wide range of alternative estimators in finite samples.

Our findings corroborate existing evidence but also uncover new stylized facts. Specifically, we confirm previous literature finding that Fed policy spillovers are large and that they transmit especially through financial channels centering on global investors' risk aversion. Our contribution is to provide evidence with greater resolution across the different Fed policy measures, to document that they entail trade-offs for emerging market economy monetary policy, and that it is critical to account for residual endogenous components in monetary policy surprises especially in case of forward guidance.

1 Introduction

The dominant role of the dollar in global trade and finance has sparked a rich literature on the spillovers from Federal Reserve (Fed) monetary policy (e.g. Miranda-Agrippino and Rey, 2020b). However, despite the large amount of work, important gaps in our understanding remain. In particular, examining the effects of Fed policy has become more complex due to the zero lower bound after the Global Financial Crisis, the increasing use of forward guidance about the future course of policy rates, and large-scale asset purchases (LSAPs).

A case in point is the monetary policy tightening in 2022, which involved Fed-funds rate hikes that were telegraphed well in advance by means of forward guidance as well as the unwinding of the stock of previously purchased assets on the Fed's balance sheet. Disentangling the implications of Fed policy normalization across these measures is critical as economies around the world emerge from the strains imposed by the COVID-19 pandemic and wrestle with the fallout of Russia's war on Ukraine (IMF, 2021). It is also critical because the Fed may resort to these different measures more frequently in the future (Reis et al., 2016), and because optimal policy responses may differ depending on the nature of the spillovers (IMF, 2020).

In this paper we study the global spillovers from Fed policy addressing these gaps in the literature. We make use of the novel conventional rate policy, forward guidance and LSAP shocks identified by Jarociński (2021) in high-frequency asset-price surprises around Federal Open Market Committee (FOMC) announcements. The identification relies on relatively weak assumptions compared to existing literature. In particular, it exploits the non-Gaussianity of the observed surprises, namely that they are usually small but occasionally very large. The identification also accounts for the presence of confounding residual endogenous components in high-frequency monetary policy surprises, such as central bank information (CBI) effects (Romer and Romer, 2000; Nakamura and Steinsson, 2018).

We estimate the effects of the different Fed policy measures on rest-of-the-world (RoW) real activity, inflation, trade, exchange rates, asset prices and capital flows, and we explore whether they induce trade-offs for central banks in emerging market economies (EMEs). We use the state-of-the-art smooth local projection estimator of Barnichon and Brownlees (2019), which mitigates the excessive variability plaguing analyses of typical macroeconomic time-series samples and outperforms alternative estimators in the extensive Monte Carlo simulations in Li et al. (2021).

Our findings corroborate existing evidence but also uncover new stylized facts. Specifically, we confirm previous literature finding that Fed policy spillovers are large and that they transmit especially through financial channels centering on global investors' risk aversion (e.g. Miranda-Agrippino and Rey, 2022; Degasperi et al., 2020). Our contribution is to provide evidence with greater resolution across the different Fed policy measures, to document that they all entail trade-offs for EME monetary policy, and that it is critical to account for residual endogenous components in high-frequency monetary policy surprises especially in case of forward guidance.

In more detail our findings are as follows. We first document that spillovers vary across the different Fed measures. In particular, forward guidance about the future path of policy rates and LSAPs entail large spillovers, while conventional policy managing the current Fed funds rate does not; this echoes the greater importance attributed to the "path factor" relative to the "target factor" by Gürkaynak et al. (2005a) in the context of the domestic transmission of US monetary policy. It is important to emphasize that this result does not mean that Fed interest-rate changes are inconsequential for the RoW. Instead, it should be interpreted as indicating that the most consequential interest-rate changes in our sample were telegraphed in advance, rather than being surprises about the short-term course of the policy.

Second, we provide new evidence on the key role of financial channels centering on global investors' risk aversion in the international transmission of Fed forward guidance. Consistently with a risk-off effect, a forward guidance tightening causes an immediate repatriation of foreign asset holdings that is concentrated in portfolio equity over debt, a decline in equity prices, an increase in corporate bond spreads, and an appreciation of the dollar exchange rate. These findings substantiate the transmission mechanisms centering on risk that underpin large Fed policy spillovers in structural models (e.g. Akinci and Queralto, 2019; Akinci et al., 2022; Jiang et al., forthcoming; Georgiadis et al., 2023).

Third, our findings also point to a key role of global investors' risk aversion for LSAP spillovers. In particular, we find that LSAPs have large effects on US and RoW equity prices, corporate bond spreads, the dollar exchange rate, and portfolio equity flows. In contrast to forward guidance, these effects are small on impact and only build up gradually over time. This may reflect that our LSAP shocks often reflect announcements of purchases that are executed only later, the difficulty for financial markets to quickly decipher their operational parameters (Bhattarai and Neely, 2022; Krishnamurthy, 2022), and the sluggish transmission of LSAPs through financial institutions' balance sheets.

We also find that contractionary LSAPs induce immediate portfolio re-balancing among similar safe assets as US investors shed AE but not EME portfolio debt, consistent with structural models featuring preferred-habitat investors in segmented markets linked by arbitrageurs (Gourinchas et al., 2022; Greenwood et al., 2023). At the same time, we find that effects on foreign term premia are generally small. This suggests that this specific portfolio re-balancing is not a key transmission channel for LSAP spillovers relative to other financial channels centering on global investors' risk aversion.

These findings for LSAP spillovers inform the design of structural models. For example, Alpanda and Kabaca (2020) and Kolasa and Wesołowski (2020) embed segmented markets for long and short-term bonds in two-country New Keynesian models. While in the model of Alpanda and Kabaca contractionary Fed LSAPs trigger a slowdown in RoW real activity because the contractionary effects of term premia spillovers dominate the expansionary effects of exchange rate depreciation and expenditure switching, in the model of Kolasa and Wesołowski the opposite is the case. As we find that the effect on foreign term premia is generally small, our result that contractionary LSAPs are nonetheless also contractionary for RoW real activity in the data suggests these spillovers must be transmitting through other

financial channels than the narrow portfolio re-balancing considered in Alpanda and Kabaca. Shedding light on the empirical relevance of these transmission channels is an important contribution as the literature is still far from consensus on how to integrate LSAPs in New Keynesian open-economy models (Krishnamurthy, 2022).

Fourth, we present evidence showing that both Fed forward guidance and LSAPs imply trade-offs for EME monetary policy. In particular, a Fed forward guidance tightening dampens EME real activity but puts upward pressure on consumer prices. The latter can be rationalized by the appreciation of the dollar against EME currencies and the pervasive dollar invoicing of global trade (Gopinath et al., 2020; Boz et al., 2022). Consequently, EME monetary policy cannot stabilize both output and prices in the face of changes in Fed forward guidance. Furthermore, contractionary LSAPs significantly depress both output and capital inflows. Hence, in the face of LSAPs EME monetary policy cannot stabilize the macroeconomy in terms of output and at the same time financial stability in terms of capital inflows.

Finally, similar to Jarociński and Karadi (2020) and Miranda-Agrippino and Ricco (2021) we document that estimates of the effects of Fed policy are puzzling at business-cycle horizons if residual endogenous components in monetary policy surprises are not accounted for. We move beyond existing evidence and show that accounting for such components is especially relevant in the context of forward guidance. In particular, we show that when residual endogenous components of monetary policy surprises are not accounted for the estimated business-cycle horizon effects of forward guidance are massively attenuated.

Related literature. The literature on US monetary policy spillovers is large. A first wave of work neither distinguishes between the different Fed measures nor accounts for residual endogenous monetary policy surprise components (Georgiadis, 2016; Dedola et al., 2017; Iacoviello and Navarro, 2019; Miranda-Agrippino and Rey, 2020b; Miranda-Agrippino et al., 2020; Dees and Galesi, 2021). Subsequent work distinguishes between different Fed measures, but does not account for residual endogenous monetary policy surprise components (Tillmann, 2016; Rogers et al., 2018; Miranda-Agrippino and Rey, 2020a; Bhattarai et al., 2021). Other work does account for such residual components, but does not distinguish between different Fed measures (Bräuning and Sheremirov, 2019; Degasperi et al., 2020; Camara, 2021; Cesa-Bianchi and Sokol, 2022; Gai and Tong, 2022; Jarociński, 2022; Arteta et al., 2022; Pinchetti and Szczepaniak, forthcoming).

To our knowledge only Miranda-Agrippino and Nenova (2022) distinguish between different Fed measures and at the same time account for residual endogenous monetary policy surprise components in estimating US monetary policy spillovers. The identification of Jarociński (2021) we use improves on that of Miranda-Agrippino and Nenova in two crucial directions: (i) it accounts for potentially confounding interactions between shocks to the different Fed measures; (ii) it is more parsimonious as it postulates fewer primitive exogenous innovations. Moreover, as our focus is on the Fed rather than on comparing spillovers across central banks we can study in more detail differences in the transmission across forward guidance and LSAPs, AEs and EMEs, and EME policy trade-offs.

Finally, our findings for LSAPs expand existing work based on identification approaches based on sign and zero restrictions in vector-autoregressive (VAR) models (Baumeister and Benati, 2013; Gambacorta et al., 2014; Weale and Wieladek, 2016; Bhattarai et al., 2021).

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 our results for US monetary policy spillovers and Section 4 for EME monetary policy trade-offs. Section 5 concludes.

2 Identification of US monetary policy shocks

2.1 High-frequency identification

Since the seminal work of Kuttner (2001), Cochrane and Piazzesi (2002) and Gertler and Karadi (2015), identifying policy shocks based on interest-rate surprises in narrow windows around central-bank announcements has become the industry standard in empirical monetary economics. In particular, under the assumption that financial markets price in the entire expected endogenous response of the central bank to the state of the economy, interest-rate surprises reflect exogenous variation that can be exploited to estimate the causal effects of monetary policy.

The basic high-frequency identification approach has been refined in two directions. The first refinement is to distinguish between conventional policy that focuses on setting the current Fed funds rate and unconventional measures such as forward guidance and LSAPs. Gürkaynak et al. (2005a,b) and Swanson (2021), among others, disentangle conventional and unconventional monetary policy shocks by imposing economically motivated restrictions on their relationship with observed interest-rate surprises along the yield curve.

The second refinement is to purge the asset-price surprises from residual endogenous monetary policy components. Among others, Cieslak and Schrimpf (2019), Jarociński and Karadi (2020), and Lewis (forthcoming) exploit the high-frequency co-movement between interest rates and equity prices to purge such a residual endogenous policy surprise that is due to the central bank's private assessment of the state of the economy. In an alternative approach, Miranda-Agrippino and Ricco (2021) account for such CBI effects by cleansing interest-rate surprises from non-publicly available, internal Fed forecasts. In a similar vein, Bauer and Swanson (2022) cleanse interest-rate surprises from publicly available information to account for a residual endogenous policy response that was not priced in by financial markets due to misperceptions about the central bank's reaction function.

2.2 Identification of structural shocks by fat tails

In this paper we use the novel identification proposed by Jarociński (2021) to distinguish between conventional and unconventional monetary policy shocks and at the same time account for residual endogenous monetary policy surprise components. Jarociński's approach starts from the observation that asset-price surprises around FOMC announcements are highly non-Gaussian with fat tails, i.e. that they are usually very small but occasionally very large.

Against this background, Jarociński postulates that the surprises in n observed financial market variables around FOMC announcement 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 n unobserved, structural—i.e. uncorrelated—shocks and $\mathcal{T}(\nu)$ indicates Student's t-distribution with ν degrees of freedom. Jarociński estimates $\boldsymbol{C}$ and ν by maximum likelihood using surprises in -10min/$+20$min windows around the 241 FOMC announcements from June 1991 to June 2019 in the dataset of Gürkaynak et al. (2005a) and the update of Gürkaynak et al. (2022). In the vector $\boldsymbol{y}_m$ Jarociński includes the expected Fed-funds rate after the FOMC announcement (the first Fed-funds future adjusted for the number of the remaining days of the month), the 2 and 10-year Treasury yields, and the S&P 500 Blue-Chip stock-market index. Upon estimation of $\boldsymbol{C}$, the implied shocks $\boldsymbol{u}_m$ can be recovered.

Notice that when the shocks $\boldsymbol{u}_m$ are Gaussian the model in Equation (1) is not identified, as orthogonal rotations of $\boldsymbol{u}_m$ fit the data equally well in terms of the likelihood function. By contrast, when the shocks are fat tailed and not too dependent—i.e. their distribution is non-spherical—the likelihood is not invariant to orthogonal rotations of $\boldsymbol{u}_m$, and so the model is identified up to re-ordering and changing signs. The intuition is that when the individual shocks in $\boldsymbol{u}_m$ are mutually independent with fat tails, it is likely that only one of them is large whenever unusually large asset-price surprises are observed around an FOMC meeting. Identification based on non-Gaussianity harks back to Comon (1994), and applications in macroeconomics include Lanne et al. (2017) and Brunnermeier et al. (2021).

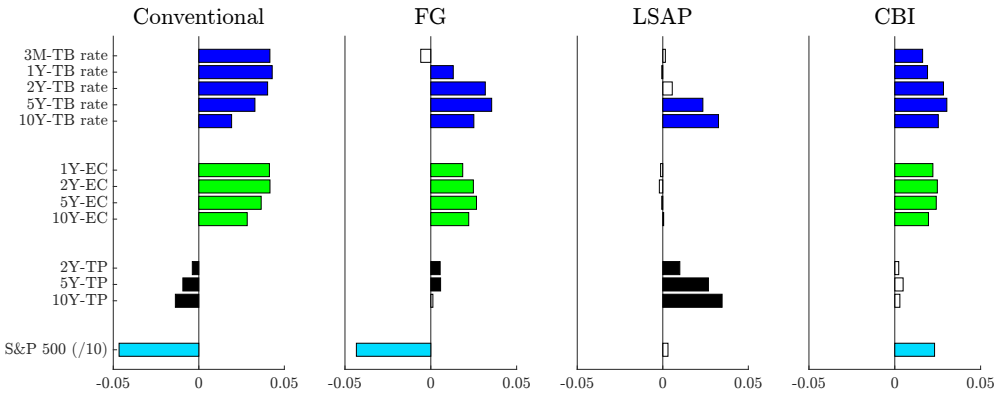
2.3 Structural interpretation of identified shocks

Since the structural shocks $\boldsymbol{u}_m$ are identified based on statistical rather than economic assumptions in Jarociński's approach, he labels them *ex post* based on the patterns in their estimated effects on financial market variables. Figure 1 presents the daily effects of one-standard-deviation shocks on Treasury yields with different maturities (blue), the corresponding expectations components (green) and term premia (black), as well as equity prices (cyan). The sample period is January 1991 to June 2019. Filled bars indicate that the estimate is statistically significantly different from zero at the 10% significance level.[1,2]

[1] One might object that there were arguably no LSAPs before the Global Financial Crisis. However, an appealing feature of Jarociński's non-Gaussian framework is that it accounts for this by design, as it allows shocks to be approximately zero over many consecutive periods. Indeed, Jarociński's LSAP shocks are quite small prior to 2008 (see Figure 8 in Jarociński, 2021). Nonetheless, results for an alternative specification of Jarociński's identification in which LSAP shocks are assumed to be zero until December 2008 and estimated only afterwards are similar (see Figure C.1). Because using these alternative LSAP shocks produces very similar estimates for macroeconomic effects (see Figure C.2), we stick to Jarociński's baseline LSAP shocks. One might also object that forward guidance was not an explicit Fed policy measure before the Great Recession. However, signals about the future path of policy rates have in fact been part of Fed announcements from as early as 2003 (Lunsford, 2020) and have been documented to be statistically and economically important in the data (Gürkaynak et al., 2005b).

[2] The shocks estimated based on Equation (1) are generated regressors in the regressions underlying the results in Figure 1. In general, one should account for the additional uncertainty due to the regressor being estimated in a first step when computing standard errors. However, Jarociński documents that the shocks

Figure 1: Impact-day US financial market effects of the monetary policy shocks of Jarociński (2021)



Note: Each bar depicts the daily impact response of a US monetary policy shock estimated from local projections. The shocks are taken from Jarociński (2021). We include one lag and no controls, but results hardly change for less parsimonious specifications, for example when we control for Bloomberg macro surprises/news. We include all four shocks simultaneously, but results are similar when we run the regressions separately for each shock. As in Curcuru et al. (2023) the expectation components and term premia are taken from Adrian et al. (2013). The sample period spans 1991m1 to 2019m6. Filled bars indicate estimates that are statistically significant at the 90% confidence level. Inference is based on Newey-West standard errors robust to heteroskedasticity and serial correlation.

Figure 1 shows that the first two shocks lift the Treasury yield curve through its expectations component and contract equity prices. The first shock raises the current Fed funds rate and its expected path over the short term, while the second shock raises the expected path of the Fed funds rate over the medium term. Given these patterns in the financial market effects we follow Jarociński and refer to the first as conventional rate policy shock and to the second as forward guidance shock (for a detailed discussion see Jarociński, 2021).

The third shock lifts only the long end of the Treasury yield curve, and does so exclusively through term premia. These patterns are consistent with the effects of LSAPs in models featuring segmented markets and limits to arbitrage as well as empirical evidence from event studies (see the surveys of Bhattarai and Neely, 2022, and Krishnamurthy, 2022). The response of equity prices is not estimated precisely, which, however, is a common finding in the empirical literature on the effects of LSAPs (Bhattarai and Neely, 2022).[3]

Finally, the financial-market effects of the fourth shock suggest that it captures a residual endogenous component in the interest-rate surprise: it induces a positive co-movement between interest rates along the Treasury yield curve and equity prices. The rationale is that

are estimated very tightly. Therefore, the additional uncertainty in subsequent regressions is unlikely to make much difference in practice.

[3]The results for the effects of Jarociński's LSAP shocks in Figure 1 are not consistent with a signalling channel of quantitative easing. This is in contrast to the findings for the LSAP shock of Swanson (2021) (see Figure B.2). However, when Jarociński's LSAP shocks are estimated only from December 2008 and assumed to be zero before in the spirit of Swanson's identification assumptions, the results are consistent with a signalling channel (see Figure C.1).

financial markets interpret the surprise interest-rate increase as indicating that the Fed is holding a more bullish view about the economy, and so they upgrade their earnings expectations by so much that equity prices rise; additionally, the interpretation as a more bullish Fed view may reduce investors' risk aversion and therefore the equity risk premium they require, inducing them to move into equity even for given earnings expectations, thereby raising prices. We show below that the estimated effects of the fourth shock are consistent with a CBI effect also at business-cycle horizons.

It is worthwhile emphasizing two issues concerning the labelling of Jarociński's fourth shock as a CBI effect. First, recall that in Jarociński's approach the estimation of the structural shocks is based on assumptions about their *statistical* properties rather than on assumptions about their economic nature and hence their financial-market effects. Therefore, the positive co-movement between interest rates and equity prices conditional on the fourth shock in Figure 1 is an *a posteriori* empirical finding and not an *a priori* identification assumption imposed in the estimation. Second, our reading of the literature is that the dominant interpretation of such a shock is that it reflects CBI effects (Romer and Romer, 2000; Campbell et al., 2012; Nakamura and Steinsson, 2018; Cieslak and Schrimpf, 2019; Jarociński and Karadi, 2020; Miranda-Agrippino and Ricco, 2021). Alternative, possibly complementary interpretations exist, such as that it reflects Neo-Fisherian effects (Uribe, 2022) or different variants of a 'Fed response to news' effect (Sastry, 2021; Bauer and Swanson, 2023, 2022). In the following, we refer to the fourth shock as CBI effect for simplicity. However, our point in this paper is not that it can only or exclusively be a CBI effect. Instead, our point is that, whatever it represents, if it is not accounted for then the estimates of the effects of some Fed measures are puzzling.

Jarociński documents that these shocks hardly change when the baseline model in Equation (1) is modified in several relevant ways. First, the shocks are robust to replacing the variables in $\boldsymbol{y}_m$ by the principal components of a larger set of financial variables. Second, the first four shocks hardly change when more shocks are allowed for as the dimensionality of $\boldsymbol{y}_m$ is increased by including additional asset price-surprises. And third, the shocks are robust to relaxing the assumption of mutual independence by allowing for a non-trivial, data-determined degree of common volatility.

2.4 Alternative identification approaches for multi-dimensional Fed policy shocks

We briefly outline the identification approaches of Swanson (2021) and Miranda-Agrippino and Nenova (2022) on which Jarociński improves.

The identification of Swanson (2021) is also based on the interest-rate surprises in −10min/+20min windows around the 241 FOMC announcements from June 1991 to June 2019 in the dataset of Gürkaynak et al. (2005a) and the update of Gürkaynak et al. (2022). Swanson uses the surprises in eight variables that represent different points on the yield curve: near-term term Fed funds futures, medium-term eurodollar futures and Treasury yields at the 2, 5 and

10-year maturities. He first calculates principal components in these asset-price surprises. Then, he rotates the principal components so that the first three satisfy economically intuitive restrictions and thereby lend themselves to being interpreted as conventional rate policy, forward guidance and LSAP surprises. In particular, the principal components are rotated so that: (i) only the conventional rate policy surprise—the first principal component—loads on the observed first Fed-funds-futures surprise; (ii) the variance of the LSAP surprise—the third principal component—is as small as possible before 2009, i.e. among the rotations that satisfy the zero restrictions under (i) the one that minimizes the variance of the LSAP surprise before 2009 is chosen. Importantly, Swanson's identification does not account for possible residual endogenous monetary policy surprise components.

The identification of Miranda-Agrippino and Nenova (2022) starts with Swanson's conventional rate policy, forward guidance and LSAP surprises and then cleanses them one-by-one from CBI effects based on the sign of the accompanying equity-price surprise in the spirit of Jarociński and Karadi (2020). For example, a surprise increase in Swanson's conventional rate policy surprise is re-labeled as a short-term CBI effect when the equity-price surprise is positive. A drawback of Miranda-Agrippino and Nenova's identification is that it processes the shocks one-by-one, disregarding possible interactions between different Fed measures. In the considered example, the positive equity-price surprise could also be due to e.g. an accompanying expansionary forward guidance or LSAP surprises dominating the conventional policy tightening. By contrast, Jarociński (2021) proceeds in one step accounting for such interactions. Moreover, Jarociński's approach is also more parsimonious in that it postulates—based on an extensive exploration of how many distinct dimensions can be robustly detected in the available data—that only four instead of six exogenous innovations drive the observed asset-price surprises.

2.5 Domestic macroeconomic effects

Before exploring spillovers we use the more familiar context of the US economy to illustrate key features of the Jarociński's conventional rate policy, forward guidance and LSAP shocks. We highlight three results. First, conventional rate policy has much smaller effects on the US economy than forward guidance and LSAPs. Second, the effects of LSAPs are small on impact, unfold gradually, and become large over time. Third, forward guidance is estimated to have negligible effects if residual endogenous monetary policy surprise components are not accounted for as in Swanson's identification, but strong effects if they are accounted for as in Jarociński's identification.

We estimate local-projection regressions

$$x_{t+h} - x_{t-1} = \boldsymbol{\gamma}^{(h)\prime}\boldsymbol{u}_t + \tau^{(h)} + \sum_{\ell=1}^{p} \alpha_j^{(h)\prime} x_{t-j} + \sum_{\ell=1}^{p} \boldsymbol{\beta}_j^{(h)\prime}\boldsymbol{w}_{t-j} + \epsilon_t^{(h)}, \quad h = 0, 1, \ldots, H, \quad (2)$$

where x_t is the response variable of interest, $\boldsymbol{w}_t$ are controls, $\boldsymbol{u}_t$ contains Jarociński's conventional rate policy, forward guidance, and LSAP shocks as well as CBI effects, and h is the

impulse-response horizon. 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 (EBP) of Gilchrist and Zakrajsek (2012). The sample period is again January 1991 to June 2019. Results are very similar if we include more lags, additional controls and a time trend.

Given the relatively short time series, we employ the smooth local projections (SLPs) proposed by Barnichon and Brownlees (2019). In particular, because ordinary least squares (OLS) regressions of Equation (2) are carried out separately across horizons h, in empirically relevant sample sizes such as ours the estimates often suffer from excessive variability. To mitigate this, Barnichon and Brownlees (2019) model the sequence of impulse responses $\{\boldsymbol{\gamma}^{(h)}\}_h$ in Equation (2) as a linear combination of parsimonious B-spline basis functions and use an estimator that shrinks them towards a polynomial. Using Monte Carlo simulations, Barnichon and Brownlees (2019) document that SLPs achieve substantial improvements over OLS LPs in terms of mean squared error. Similarly, comparing OLS LPs with penalized and Bayesian LPs as well as OLS, Bayesian, bias-corrected and model-averaged VAR models in extensive Monte Carlo experiments, Li et al. (2021, Figure 9) document that SLPs are optimal for most bias-variance weights and for short to medium-term impulse-response horizons.

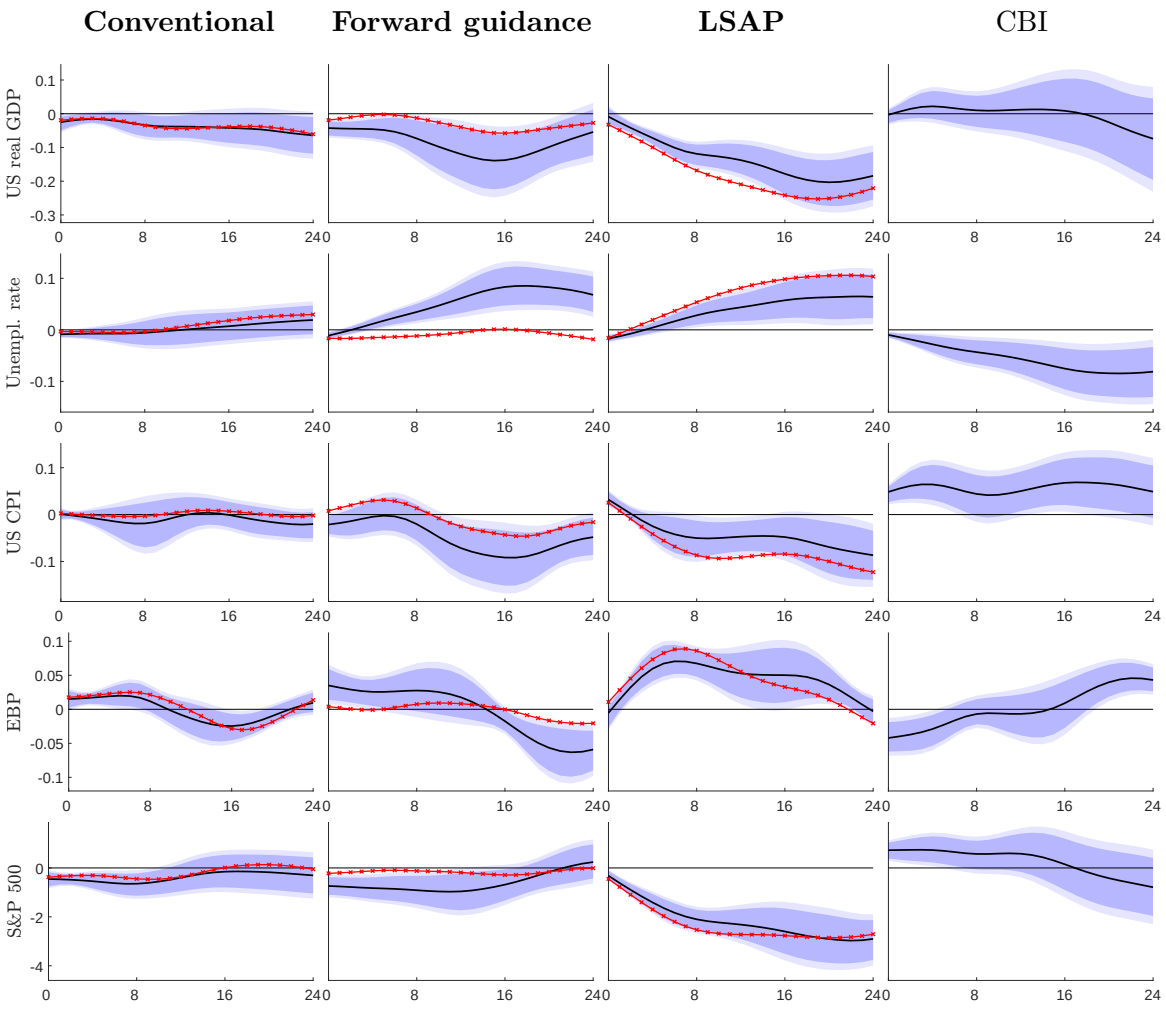
The black solid lines in Figure 2 depict the effects of Jarociński's (one-standard-deviation) Fed policy shocks over 24 months. Contractionary conventional rate policy, forward guidance and LSAP shocks are generally contractionary for real activity, consumer prices and financial conditions.[4] At the same time, there are several differences across Fed measures. First, the effects of conventional rate policy are small compared to those of forward guidance. This finding is not specific to Jarociński's conventional rate policy shock, as we obtain a similar result for Swanson's analogue (red crossed lines). The finding of small effects of conventional rate policy echoes the findings of Gürkaynak et al. (2005a), which highlight—in different data—the greater importance of their "path factor" relative to their "target factor".

Second, while forward guidance has significant effects on US equity prices and the EBP already on impact, the short-run effects of LSAPs are small and build up only gradually over time. Also this finding is not specific to Jarociński's LSAP shock, as it also holds for Swanson's analogue. This finding is consistent with limited portfolio re-balancing by arbitrageurs across segmented markets populated by preferred-habitat investors as long as the Fed has not yet started to carry out the announced purchases (Vayanos and Vila, 2021). Consistently with this, Krishnamurthy (2022) ascribes delays in the effects of LSAPs to the gradual adjustment in financial institutions' portfolio and lending decisions. Bhattarai and Neely (2022) discuss how delayed effects may also arise due to the complexity of LSAP announcements and the initial heterogeneity in financial-market interpretations.

Third, in contrast to contractionary forward guidance and LSAPs, in response to a surprise

[4]Results are similar for the alternative specification in which Jarociński's LSAP shocks are estimated only from 2008 and assumed to be zero before (see Figure C.2). Results are also similar for estimators that Li et al. (2021, Figure 9) document are optimal for somewhat less relevant bias-variance trade-offs and longer response horizons, namely (bias-corrected) OLS and Bayesian VAR models (see Figure C.3).

Figure 2: Effects of US monetary policy on US macroeconomic variables for the shocks of Jarociński (2021, black solid lines) and Swanson (2021, red crossed lines)



Note: Impulse responses depict deviations from baseline in percent or percentage points. Impulse responses are estimated using the SLPs of Barnichon and Brownlees (2019). The black solid lines depict the impulse responses of US monetary policy shocks of Jarociński (2021). The shocks are included simultaneously in the SLPs. The red crossed lines depict the responses to the shocks of Swanson (2021). The sample period is 1991m1 to 2019m6. Shaded areas indicate 68% and 90% confidence bands. Panels in a given row feature the same y-axis limits. The horizontal axes display months after the shock has hit.

Fed tightening due to CBI effects consumer prices increase and real activity accelerates, most visibly in the decline in the unemployment rate. Equity prices and the EBP also exhibit expansionary effects. These findings suggest it is important to account for residual endogenous components in monetary policy surprises when disentangling conventional and unconventional Fed policy shocks. In particular, while the effects of Jarociński's conventional rate policy and LSAP shocks (black solid lines) are very similar to the effects of Swanson's analogues (red crossed lines), they are noticeably different for forward guidance shocks, for which we do not estimate clear contractionary effects; Paul (2020), Miranda-Agrippino and Rey (2020a), and Miranda-Agrippino and Ricco (2023) report similar findings. One way to rationalize this is to think of Swanson's forward guidance shock as aggregating Jarociński's forward guidance shock and CBI effect and to recall that they affect the US economy with opposite signs (see Figure 2). In fact, results from a systematic comparison of Jarociński's and Swanson's shocks are consistent with this: Swanson's forward guidance shock is strongly correlated with Jarociński's CBI effect, even after controlling for Jarociński's forward guidance shock (see Table B.1 and Figure B.1).[5]

We conclude that it is critical to account for residual endogenous components in monetary policy surprises when disentangling conventional and unconventional Fed policy shocks, especially in the context of forward guidance. The approach of Jarociński (2021) is almost unique in its ability to achieve this.[6]

In recent work, Swanson (2023) also estimates the domestic effects of conventional monetary policy, forward guidance and LSAPs. In contrast to our findings based on the shocks of Jarociński (2021) and Swanson (2021) (see Figure 2), Swanson (2023) finds that conventional rate policy has had the *most* powerful effects on the US economy compared to forward guidance and LSAPs. This result could be due to the following methodological differences. First, while in Gürkaynak et al. (2005a), Swanson (2021), and Jarociński (2021) the conventional policy shock is based largely on very near-term interest rate expectations (the Fed funds future MP1, which matures at the end of the current *month*), in Swanson (2023) it is based on somewhat longer term interest-rate expectations (eurodollar futures ED1, which mature at the end of the current *quarter*), i.e. capture some of what these earlier papers assign to (near-term) forward guidance. Second, Swanson (2023) looks at a sample that goes further back (starting in 1988 for events for which surprises are compiled, and in 1973 for the reduced-form VAR estimation) when conventional policies were more important. Third, Swanson (2023) constructs high-frequency instruments for unconventional policy shocks from a much larger set of events, which in addition to FOMC announcements also includes other

[5]We have also verified that purging Swanson's shocks from the residual endogenous surprise component one-by-one as in Miranda-Agrippino and Nenova (2022) does not work well in our specification. In particular, the results remain quite close to those based on Swanson's original shocks (see Figure C.4).

[6]Lewis (forthcoming) identifies Fed policy shocks using intra-day heteroskedasticity in high-frequency financial variables on the days of FOMC announcements. Remarkably, despite exploiting a very different variation in the data, he finds similar types of monetary policy shocks and CBI effects. A practical advantage of the approach of Jarociński (2021) relative to that of Lewis is that the shock time series are available already from 1991 rather than 2007. A second practical advantage is that the shocks are defined uniformly across FOMC meetings, while the shocks of Lewis are announcement specific.

communication such as speeches, congressional testimonies and minutes releases. On the one hand, this results in stronger instruments. On the other hand, it opens the door for capturing more information effects, or for contamination by other shocks, which would attenuate the estimated effects of the unconventional policies.

3 Global spillovers

We first present results for daily effects in global financial markets and then for broader spillovers at business-cycle horizons.

3.1 Daily effects on global financial markets

Figure 3 presents impact-day effects on non-US 10-year sovereign-bond yields, the associated expectations components and term premia, equity prices and nominal bilateral dollar exchange rates estimated from panel regressions and data for six AEs (Australia, Canada, Germany/euro area, Japan, Sweden, UK).[7] The estimates point to large financial market spillovers from all Fed measures. This is consistent with anecdotal observations by policymakers in the RoW and their concerns about monetary autonomy, even in case of large economies (see for example Panetta, 2021).

In particular, in response to conventional rate policy tightenings AE long-term rates rise almost as much as their US analogue. In case of contractionary forward guidance and LSAPs AE interest rates also rise, but only by about half as much as in the US. LSAPs lift AE term premia along with those in the US, although again only by about half as much. AE equity prices move together with those in the US, especially in case of conventional rate policy and forward guidance. The dollar exchange rate appreciates in response to Fed policy tightenings. After a tightening due to a CBI effect AE interest rates also rise and the dollar exchange rate appreciates.

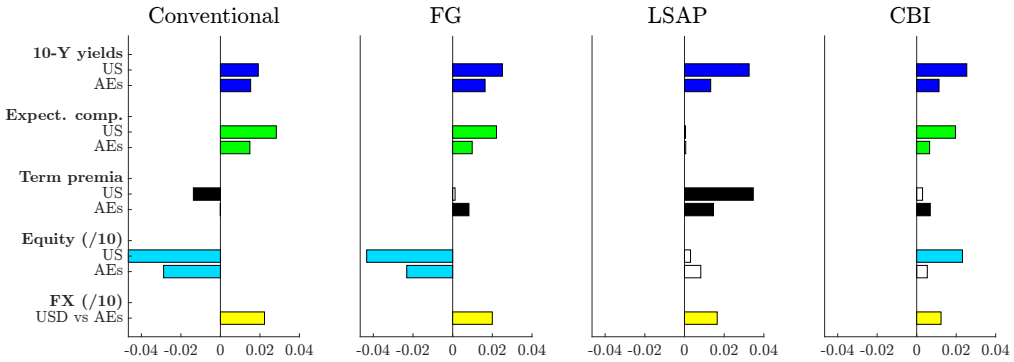
These findings for impact-day spillovers from LSAPs to foreign term premia and the exchange rate in Figure 3 are consistent with the empirical evidence based on event studies surveyed in Bhattarai and Neely (2022). Our findings are also consistent with theoretical predictions for the international transmission of LSAPs. In particular, in the models of Greenwood et al. (2023) and Gourinchas et al. (2022) arbitrageurs transmit the change in term premia required by domestic preferred-habitat investors in segmented markets in response to LSAPs across borders, causing an internationally synchronized increase in term premia of long-maturity sovereign bonds and an appreciation of the dollar. That the effect on US Treasury term premia is larger than on foreign analogues is consistent with the observation of Krishnamurthy (2022) that markets in which the announced LSAPs are carried out

[7] As in Curcuru et al. (2023) for countries other than Canada due to time differences in market closing hours relative to the US we adjust the timing of the variables so that x_t is the first local market close price after and x_{t-1} the last local market close price before the FOMC announcement. We also do this for the dollar exchange rates, including for Canada given that the data are taken from the BIS and feature the same fixing time for all countries.

are typically found to be affected most strongly. The results are very similar—if anything starker—when we use Jarociński's alternative LSAP shocks estimated only after 2008 and assumed to be zero before (see Figure C.5).

The finding of large impact-day effects on AE interest rates are consistent with Curcuru et al. (2018), who estimate spillovers from surprises in long-term US Treasury yields to German bond markets around notable FOMC announcements using intra-daily data. In turn, our finding that LSAPs have larger spillovers on foreign term premia than on expectations components while conventional rate policy and forward guidance have larger effects on foreign expectations components than on term premia is consistent with the analysis based on daily data in Curcuru et al. (2023).

Figure 3: Impact-day effects of US monetary policy shocks of Jarociński (2021) on global interest rates, equity prices and exchange rates



Note: The expectation components and term premia are taken from a dynamic Nelson-Siegel model. Inference is based on Driscoll-Kraay standard errors robust to heteroskedasticity, serial correlation and cross-section dependence. See also the notes from Figure 1.

3.2 Macroeconomic spillovers

Figure 4 presents results for Fed policy spillovers to RoW real activity and consumer prices at the monthly frequency. The effects of conventional rate policy are rather muted, consistently with their small domestic effects.[8] In contrast, contractionary forward guidance and LSAPs induce a contraction in RoW real activity and consumer prices (solid black lines), with magnitudes very similar to the domestic effects in the US (red crossed lines). Fed tightenings due to CBI effects are followed by an acceleration in RoW real activity, without an increase in RoW consumer prices.[9]

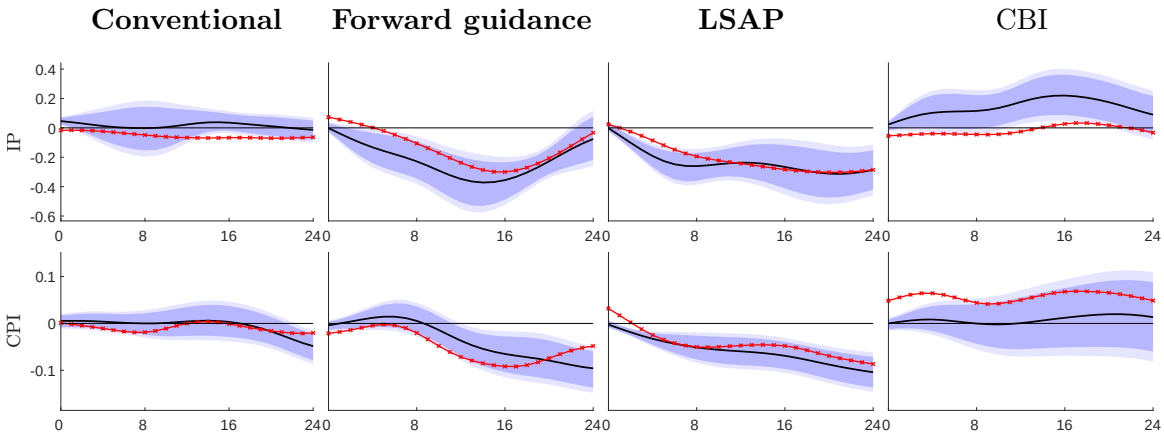
[8] We obtain similarly small estimates for the effects of conventional rate policy when we use the corresponding shocks of Swanson (2021) (see Figure C.6). Results are also similar when we estimate panel LPs on country-specific data for 62 AEs and EMEs instead of SLPs on aggregate RoW variables (see Figure C.7) and if we use Jarociński's alternative LSAP shocks estimated only after 2008 (see Figure C.2).

[9] That the acceleration in RoW real activity does not raise consumer prices is consistent with the rise in oil prices (see Figure C.8) being inconsequential for import prices as they are invoiced in dollars and the depreciation of the dollar in response CBI effects (see Figure 10 below).

Given the muted effects of conventional rate policy, as in Miranda-Agrippino and Nenova (2022) and Miranda-Agrippino and Rey (2022) in what follows we focus on forward guidance and LSAPs. We continue to present results for Jarociński's CBI effects in order to illustrate how failing to account for residual endogenous components in monetary policy surprises would attenuate the estimated effects of forward guidance.

We next discuss how forward guidance and LSAPs transmit to the RoW through trade and financial channels.

Figure 4: Effects of US monetary policy shocks on non-US RoW real activity and consumer prices



Note: Impulse responses depict deviations from baseline in percent. 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 Transmission through trade

We first review the role of the exchange rate, expenditure switching and demand effects in theory, and then present our empirical evidence. We find that the traditional Mundellian international transmission via expenditure switching, export demand and eventually bilateral US-RoW net exports is not important for Fed policy spillovers.

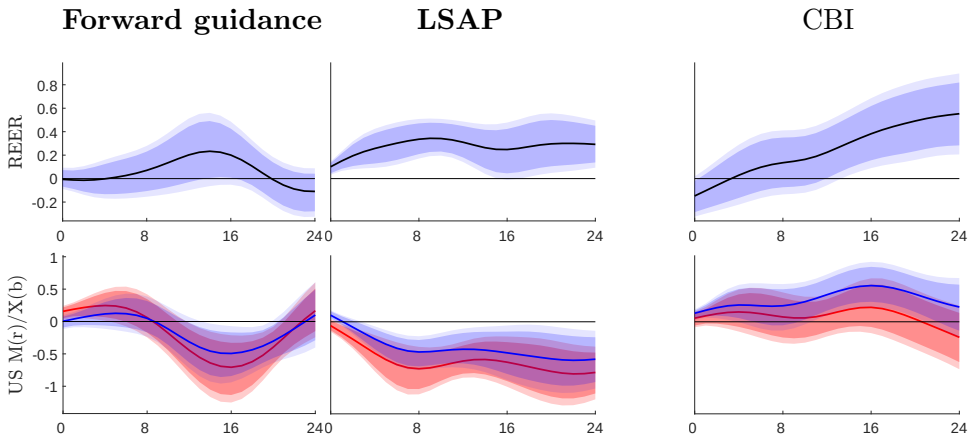
In theory, US monetary policy affects RoW real activity via bilateral trade through two channels. First, given the pervasive use of the dollar in the invoicing of global trade (Boz et al., 2022), dollar appreciation following a Fed tightening induces expenditure switching away from imports from the US to domestically produced goods in the RoW (Gopinath et al., 2020). This reduces US net exports, which bolsters RoW aggregate demand, at least all else equal. Theory thus predicts that the effect of a Fed tightening on the RoW through expenditure switching in bilateral US-RoW trade is expansionary.

Second, US-RoW trade is affected by a demand effect following a Fed tightening. For example, if the US and RoW economies slow down in response to a Fed tightening through other channels, demand for imports falls. However, since imports in general fall both in

the US and the RoW, the effect on US net exports—and thus aggregate demand in the RoW—is ambiguous, at least all else equal. Theory thus predicts that the effect of a Fed tightening on the RoW through the demand channel in bilateral US-RoW trade could be either expansionary or contractionary.

Against this background, *contractionary* real activity spillovers from Fed tightening through bilateral trade can only arise through the demand channel, and only if import demand in the US slows down more than in the RoW.[10]

Figure 5: Effects of US monetary policy shocks on the dollar real effective exchange rate and US real exports and imports



Note: Impulse responses depict deviations from baseline in percent. In the bottom row, impulse responses in red (blue) depict the effects on US imports (exports). See also the notes to Figure 2.

Recall that in the daily data in Figure 3 the dollar nominal effective exchange rate (NEER) appreciates on impact after Fed tightenings. However, exchange rates are highly volatile and most short-term movements fade fast. Indeed, Figure 5 shows that the real effective dollar exchange rate appreciates on impact and further over time in response to LSAPs, consistently with the mechanism in the models of Gourinchas et al. (2022) and Greenwood et al. (2023). Forward guidance also appreciates the dollar, though only with a delay. In contrast, in response to CBI effects the dollar initially depreciates for a few months before it appreciates.

Figure 5 indicates that US exports and imports move in tandem in response to all shocks. That associated US net exports hardly change implies that a demand channel in bilateral US-RoW trade cannot play a noteworthy role for the contractionary real activity spillovers from Fed policy shown in Figure 4.

[10] We do not consider here the possibility that Fed policy spillovers materialize through a slowdown in intra-RoW global value chain trade due to a tightening of borrowing conditions for dollar-denominated working capital as the dollar appreciates (Akinci et al., 2022; Bruno and Shin, 2023). We understand such spillovers as materializing through financial channels, which we discuss in Section 3.4 below.

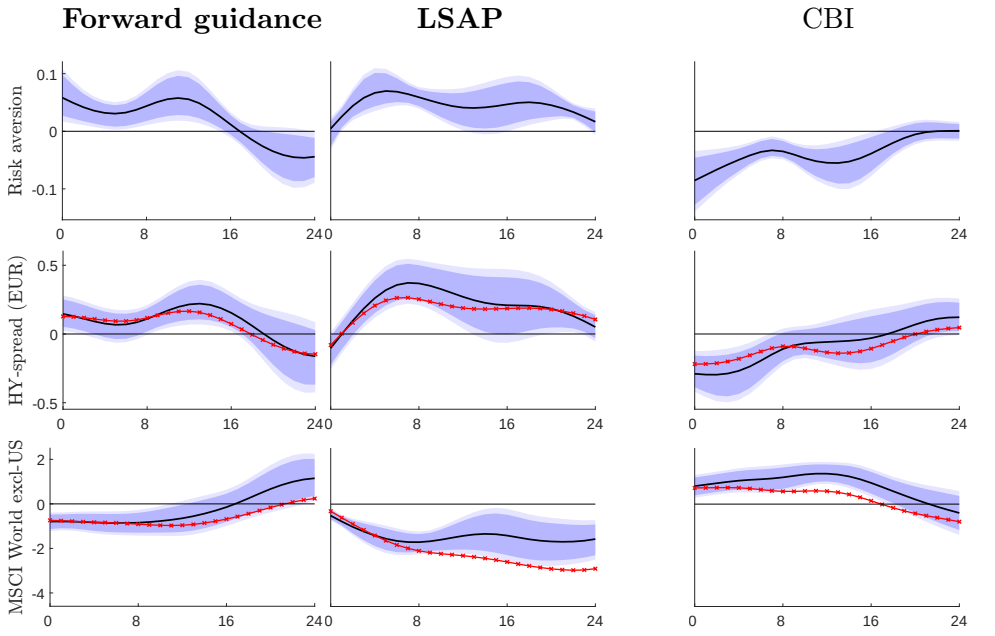
3.4 Transmission through financial channels

We find that financial channels centering on global investors' risk aversion are key for the transmission of US monetary policy to the RoW. Forward guidance affects global financial markets immediately on impact, while the effects of LSAPs unfold more gradually. US and RoW risky asset prices co-move strongly conditional on forward guidance and LSAP shocks.

Figure 6 presents our results for the global financial market effects of Fed policy at the monthly frequency; as in Figure 4, the red crossed lines depict the responses of the corresponding US variables.

A forward guidance tightening triggers an immediate increase in the measure of investors' risk aversion constructed by Bekaert et al. (2021), the ICE BofA option-adjusted high-yield euro corporate-bond spreads, and a contraction in RoW equity prices. Contractionary LSAPs also affect investors' risk aversion and foreign risky asset prices, but as in the US these effects build up gradually. The gradual build-up of the effects of LSAPs across global financial markets is consistent with the gradual execution of LSAPs upon their announcement and the mechanisms laid out the models of Greenwood et al. (2023) and Gourinchas et al. (2022).[11]

Figure 6: Effects of US monetary policy shocks non-US RoW financial variables



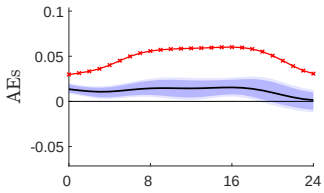
Note: Impulse responses of risk aversion depict deviations from baseline in levels and impulse responses of spreads in percentage points. Risk aversion is taken from Bekaert et al. (2021). See also the notes to Figure 2.

These findings inform the theoretical literature on the international transmission of LSAPs at the macroeconomic level. In particular, the two-country New Keynesian models of Al-

[11] Figure C.8 presents results for the effects on the global factor in risky asset prices originally introduced by Miranda-Agrippino and Rey (2020b) and extended in Miranda-Agrippino et al. (2020).

panda and Kabaca (2020) and Kolasa and Wesołowski (2020) highlight the role of term premia spillovers resulting from international portfolio re-balancing of sovereign-bond holdings. Consistently with this, Figure 7 shows that contractionary LSAPs raise AE term premia. However, compared to the effects on US term premia depicted by the red crossed lines, spillovers are muted. At the country level, they are large only in specific cases, such as the UK, Canada and Germany (see Figure C.9).[12] These results suggest term-premia spillovers due to international portfolio re-balancing of US sovereign-bond holdings and foreign close substitutes are unlikely to be the key transmission channel for the effects of LSAPs on the RoW. Instead, the findings in Figure 5 suggest that also for LSAPs changes in investors' appetite for risky assets play a key role in transmitting spillovers to the RoW.

Figure 7: Effects of LSAP shocks on AE term premia



Note: Impulse responses depict deviations from baseline in percentage points. Red crossed lines depict effects on US variables. The term premia refer to 10-year bonds and are taken from the estimation of the models of D'Amico et al. (2018) and Diebold et al. (2006). The AE term premium is calculated as a GDP-weighted average across Japan, Germany, Switzerland, the UK, Australia, Sweden, Canada and New Zealand.

The results in Figures 5 to 7 suggest that financial channels centering on investors' risk aversion play a key role in the global transmission of Fed forward guidance and LSAPs. This is consistent with the notion of a global financial cycle driven by US monetary policy (Miranda-Agrippino and Rey, 2020b; Jiang et al., forthcoming), the prominent role for transmitting US monetary policy to the RoW ascribed to the international risk channel (Kalemli-Özcan, 2019; Bruno and Shin, 2015), financial channels in general (Degasperi et al., 2020), and the evidence on the transmission of unconventional Fed policy in Miranda-Agrippino and Nenova (2022).

We next provide further evidence based on capital flows and the dollar exchange rate to corroborate the key role of global investors' risk aversion for the international transmission of Fed policy.

[12]The size of spillovers to foreign term premia varies across countries: UK term premia react the most, Japanese the least. This ranking is consistent with the analysis in Greenwood et al. (2023), who point out that the strength of term premia spillovers should be positively related to the correlation of short rates.

3.5 Capital flows

We next provide a comprehensive picture of effects on global portfolio investment flows across the different Fed measures. To do so we use two data sets. First, we study US investors' foreign portfolio equity and debt holdings from Treasury International Capital (TIC) with state-of-the-art adjustments for valuation effects (see e.g. Bertaut and Judson, 2022). Second, we study portfolio flows of non-US AE and EME investors from the IMF Balance of Payments Statistics. We find that contractionary forward guidance on impact induces US investors to reduce holdings of AE/EME equity and EME debt as opposed to arguably less risky AE debt, consistently with variation in investor risk aversion as a key transmission channel of Fed policy to the world economy. Contractionary LSAPs on impact induce US investors to reduce holdings of AE debt and non-US AE investors to reduce holdings of foreign—including US—debt, consistently with international portfolio re-balancing between US and AE bonds that are viewed as close substitutes and also as implied by state-of-the-art theory (Gourinchas et al., 2022; Greenwood et al., 2023). As time goes by, the effects of LSAPs on capital flows again become similar to those of forward guidance. The results are consistent with US monetary policy being a key driver of the Global Financial Cycle through variation in risk aversion (Miranda-Agrippino and Rey, 2020b; Miranda-Agrippino et al., 2020).

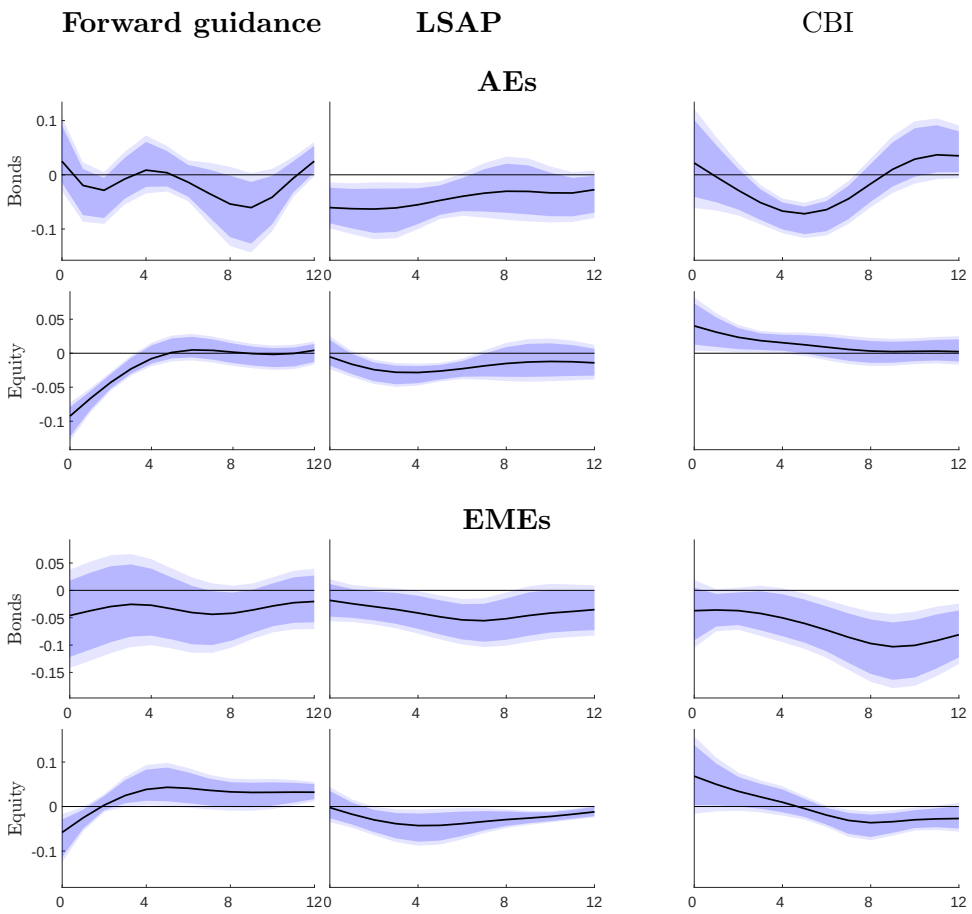
We first consider US capital flows given that the corresponding data are of relatively high quality and detail in terms of instruments/counterpart-country and available at monthly frequency. In particular, we consider US outflows defined as net purchases of foreign assets by US residents. We focus on portfolio equity and debt. The data are from Treasury International Capital (TIC) and adjusted for valuation effects by Bertaut and Tryon (2007) and Bertaut and Judson (2014, 2022).[13] Because capital flows at the country level and the monthly frequency are quite volatile, we consider effects only up to a horizon of one year. We scale US outflows by lagged stocks, but our findings are similar if we scale by lagged US GDP instead (see Figure C.10).

Figure 8 shows that forward guidance triggers an immediate drop in US outflows to AE/EME equity as well as EME debt, which is arguably more risky than AE debt. These patterns suggest that forward guidance spillovers transmit through risk-off effects: US investors shed their holdings of more risky instruments such as RoW equity and EME debt. These findings are economically important as US holdings of foreign assets are concentrated in equity instruments (see Figure C.11).

The second column of Figure 8 shows that after contractionary LSAPs only AE debt holdings fall immediately. In contrast, holdings of EME debt fall with a delay. As AE debt is arguably a closer substitute for the assets purchased by the Fed under the different QE

[13]The TIC system collects cross-border securities positions and transactions data based on surveys and is the primary source of information on foreign official and private demand for US Treasuries and other US securities (inflows) as well as for US investment in foreign securities (outflows). As advocated by Bertaut and Judson (2022), we analyze estimated flows that are calculated as changes in positions adjusted by estimates of valuation effects based on the TIC-SLT survey. We combine the estimated flows data based on the methodology of Bertaut and Judson (2014) for December 2011 to December 2019 and the estimated flows data based on the methodology of Bertaut and Tryon (2007) for December 1994 to December 2010.

Figure 8: Effects of US monetary policy shocks on US portfolio outflows by destination and instrument



Note: Impulse responses depict deviations from baseline in percentage points of lagged stocks. Data are taken from US TIC and Bertaut and Judson (2022). Outflows are defined as net increase in US foreign financial assets (or net purchases of foreign securities by US residents). See also the notes to Figure 2.

programs, these patterns are consistent with LSAPs triggering international portfolio re-balancing between Treasury securities and foreign sovereign bonds by US arbitrageurs across segmented markets populated by preferred-habitat investors as in the models of Gourinchas et al. (2022) and Greenwood et al. (2023): As the Fed is anticipated to shed Treasury securities after contractionary LSAP announcements, investors prepare to absorb these by shedding their holdings of foreign—especially closer AE—substitutes. Unfortunately, we cannot split US portfolio debt *outflows*—in contrast to inflows (see below)—across public and private bonds due to data availability in the TIC surveys.

While so far we have considered US investors' portfolio flows, we next turn to non-US, AE and EME investors' portfolio flows based on quarterly IMF Balance of Payments Statistics data, studied e.g. 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) and also linearly interpolate from quarterly to monthly frequency. Note that in this data we cannot distinguish whether outflows (inflows) are destined to (originate from) the US, other AEs or other EMEs, and we cannot distinguish between public and private debt instruments.

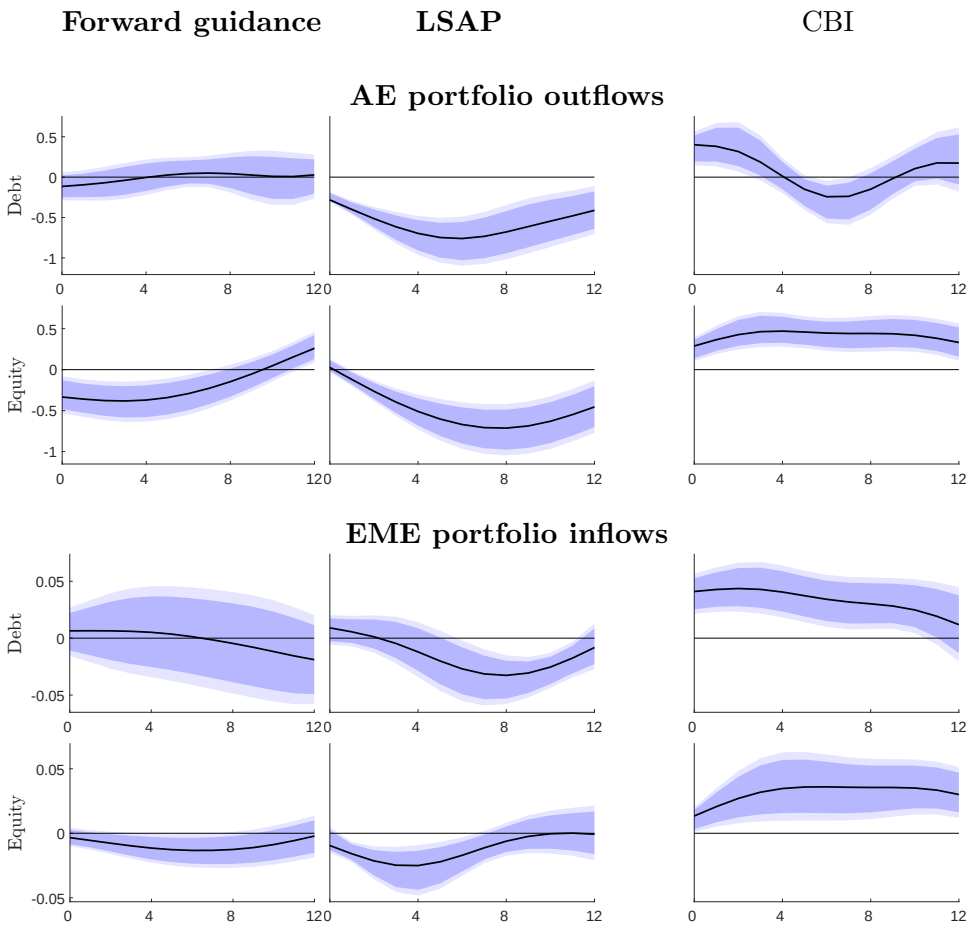
For AEs we again present results for portfolio outflows. For EMEs, we present results for inflows—defined as net purchases of domestic assets by foreigners—since they are more sensitive to variation in capital inflows than AEs due to their shallower and less developed financial markets and since they are only relatively small international investors. We estimate impulse responses using SLPs and data on cross-country averages of economies' ratio of portfolio flows to GDP; results are similar when we use panel LPs and country-level data in order to account for the different starting dates from which IMF Balance of Payments data is available across countries (see Figure C.12).

The results in Figure 9 are consistent with those for US portfolio outflows discussed above but provide additional insights. First, consistently with a risk-off effect AEs (EMEs) exhibit a drop in especially equity rather than debt outflows (inflows) in response to Fed forward guidance tightenings. These findings for AE and EME portfolio flows point to a pervasive reach of risk-off effects of Fed forward guidance across *global*—and thus beyond US—investors.

For LSAPs the results in Figure 9 are consistent with a gradually emerging broad portfolio re-balancing driven by variation in investors' risk aversion. One noteworthy finding is that AE portfolio debt outflows fall immediately on impact in response to contractionary LSAPs. This is consistent with the observation that foreign—especially AE—investors piled up Treasury securities as the Fed was carrying out LSAPs under the various QE programs (see Coeure, 2017, and Figure C.13); indeed, US portfolio *inflows* to public bonds from AEs also fall immediately and strongly in response to contractionary LSAPs (see Figure C.14). EME portfolio debt inflows also fall in response to LSAP shocks, but again the effect is delayed, as for equity inflows.

Our results for global portfolio flows improve existing evidence in terms of resolution regarding instruments, countries, policy measures, and identification: we distinguish between the US, non-US AEs and EMEs, and we compare effects of forward guidance and LSAPs while accounting for residual endogenous components in monetary policy surprises in the

Figure 9: Effects of US monetary policy shocks on non-US AE portfolio outflows and EME portfolio inflows



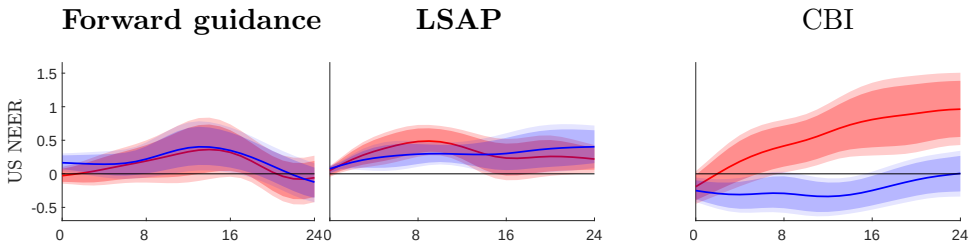
Note: Impulse responses depict deviations from baseline in percentage points of recipient-country nominal GDP. The first (second) row present results for AE portfolio equity (debt) outflows, and the third (fourth) row present results for EME portfolio equity (debt) inflows. The data are taken from the IMF Balance of Payments Statistic, are interpolated from quarterly to monthly frequency, and span 1996 to 2019. We use the cross-country mean of economies' ratio of flows to GDP. See also the notes to Figure 2.

identification. Miranda-Agrippino et al. (2020) consider IMF Balance of Payments data, do not account for endogenous surprise components, and do not distinguish between debt and equity flows and between conventional and unconventional measures. Dahlhaus and Vasishtha (2020) focus on the effects of forward guidance on bond and equity fund flows in Emerging Portfolio Funds Research (EPFR) data, but do not account for endogenous surprise components. Ciminelli et al. (2022) also consider EPFR data and do account for endogenous surprise components, but do not distinguish between conventional and unconventional measures. Chari et al. (2021) focus on the effects of LSAPs on US debt and equity flows in TIC data, but do not account for endogenous surprise components. Degasperi et al. (2020) and Pinchetti and Szczepaniak (forthcoming) study IMF Balance of Payments and International Institute of Finance data and account for endogenous surprise components, but do not distinguish between conventional and unconventional measures and between debt and equity flows.

3.6 The dollar exchange rate

Figure 10 presents the effects of Jarociński's Fed policy shocks on the dollar exchange rate separately for AEs (red) and EMEs (blue). While contractionary forward guidance and LSAPs strengthen the broad dollar NEER similarly against AE and EME currencies, CBI effects have opposite effects across AEs and EMEs after a very short-lived depreciation in the impact period. In particular, the dollar initially depreciates in response to a CBI effect against all currencies, but soon appreciates against AE currencies while remaining persistently depreciated against EME currencies.

Figure 10: Effects of US monetary policy shocks on the dollar NEER against AEs (red) and EMEs (blue)



Note: Impulse responses depict deviations from baseline in percent. Impulse responses in red represent estimates for AEs and impulse responses in blue represent estimates for EMEs. An increase in the dollar NEER indicates an appreciation. See also the notes to Figure 2.

These patterns in AE and EME exchange rate responses are consistent with existing evidence on the relationship between the dollar exchange rate and risk. First, consistent with standard uncovered interest rate parity (UIP) surprise interest-rate increases following forward guidance and LSAP shocks appreciate the dollar. At the same time, it is well known

that standard UIP does not hold and that currency-risk premia are important determinants of exchange rates. This means that in case of a risk-on shock—such as a CBI effect—currency-risk premia fall, reducing or even overturning the dollar's appreciation. In contrast, in case of a risk-off shock—such as contractionary Fed policy shocks—currency-risk premia rise and amplify the dollar's appreciation.

Interestingly, Kalemli-Özcan (2019) also finds that interest-rate differentials are the dominant driver for AE currencies while currency-risk premia dominate for EME currencies. Similarly, recent literature highlights the dollar's role as a 'barometer of risk appetite' especially vis-à-vis EMEs (Avdjiev et al., 2019; Erik et al., 2020; Hofmann et al., 2020). This is consistent with the divergence in the dollar NEER across AE and EME currencies in response to CBI effects in Figure 10.

4 Monetary policy trade-offs in EMEs

EME policymakers have repeatedly argued for more international monetary policy coordination in the sense that the Fed should internalize the spillovers it emits to the RoW even beyond associated spillbacks (Rajan, 2013, 2016). However, from a theoretical perspective Fed policy spillovers do not necessarily reduce welfare in EMEs. In order for spillovers to be a negative externality for EMEs they would have to induce policy trade-offs (for an overview see Engel, 2016). We document that both forward guidance and LSAPs entail trade-offs for EME monetary policy.

We explore two types of trade-offs for EME central banks conditional on changes in Fed policy: (i) between output and price stabilization; (ii) between macroeconomic stabilization in terms of real activity and consumer prices on the one hand and preserving financial stability in terms of capital inflows on the other hand.

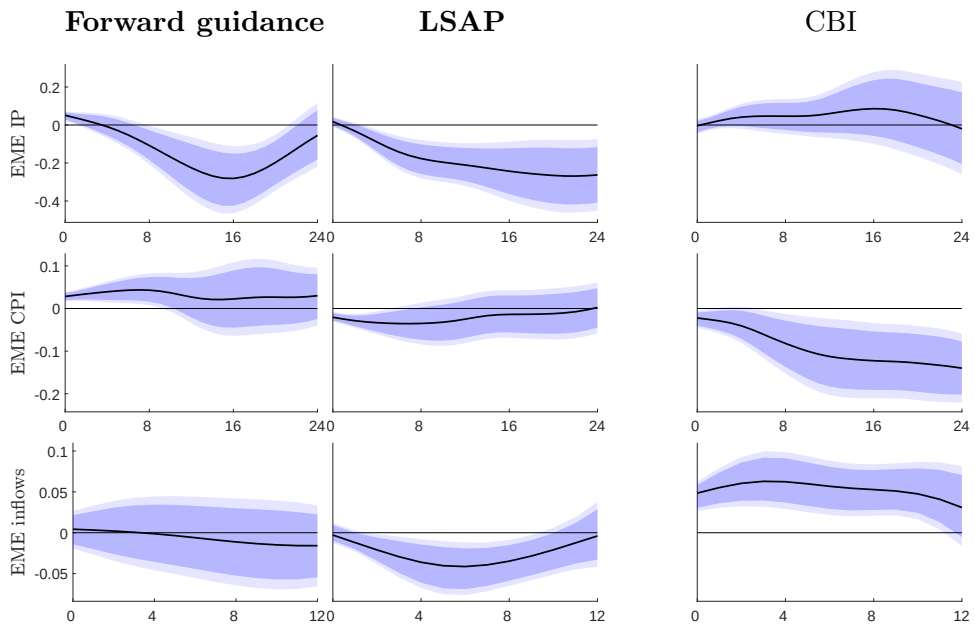
Figure 11 presents the effects of Fed policy on EME real activity, consumer prices and portfolio investment inflows. The first two rows inform about trade-offs between output and prices, and all three rows together about trade-offs between macroeconomic stabilization and preserving financial stability.

In response to a Fed policy tightening EME real activity declines strongly, while consumer prices respond little. The different effects of Fed policies on EME real actvity and consumer prices imply that EME monetary policy cannot stabilize both. For example, an EME monetary policy loosening would dampen the contractionary spillovers to real activity, but would put upward pressure on consumer prices.

In case of LSAPs there additionally is a significant trade-off between macroeconomic stabilization and preserving 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 exacerbate the drop in EME portfolio inflows.

We conclude that spillovers from both forward guidance and LSAPs give rise to trade-offs for EME monetary policy.

Figure 11: Effects of US monetary policy shocks on EME variables



Note: Impulse responses of industrial production and CPI depict deviations from baseline in percent, and impulse responses of inflows depict deviations from baseline in percentage points of recipient-countries' nominal GDP. See the notes to Figure 2.

5 Conclusion

We examine global spillovers from conventional and unconventional policy measures in the Fed's toolkit accounting for the possible presence of residual endogenous monetary policy components in high-frequency asset-price surprises used for identification. We contribute several findings to the literature: We find that: (i) forward guidance and large-scale asset purchases (LSAPs) trigger much larger spillovers than conventional rate policy; (ii) spillovers transmit predominantly through financial channels centering on global investors' risk appetite and manifest in changes in equity prices, bond spreads, capital flows and the dollar exchange rate; (iii) LSAPs trigger immediate international portfolio re-balancing between US and advanced-economy bonds, but generally entail only rather limited term premium spillovers; (iv) both forward guidance and LSAPs entail trade-offs for emerging market economy central banks, either between stabilizing output and prices or between additionally ensuring financial stability in terms of capital inflows

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A Additional tables

Table A.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 A.2: Data description for monthly time series

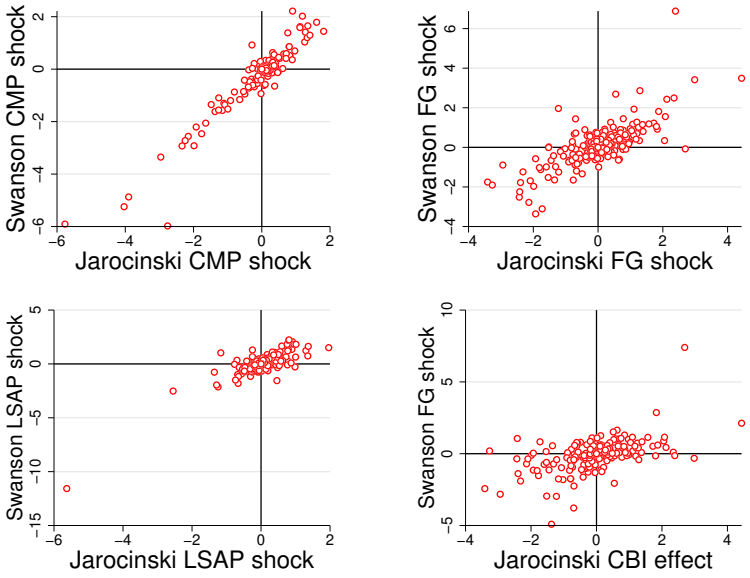
Variable	Description	Source	Coverage
US real GDP	IHS Markit's monthly GDP (SAAR, bil. chnd. 2012 US$)	Macroeconomic Advisors/Haver	1992m1 - 2019m12
US CPI	Consumer price index	BLS/Haver	1990m1 - 2019m12
US unemployment rate	Civilian unemployment rate (16yr+, SA)	BLS/Haver	1990m1 - 2019m12
US EBP	Excess 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
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
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.

B Comparison of the shocks of Jarociński (2021) and 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 and forward guidance shocks, respectively. It is interesting to note that there is also a similarity between Jarocinski's CBI effects and Swanson's forward guidance shocks. This is consistent with the possibility that Swanson's forward guidance shock represents a combination of Jarocinski's FG 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 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, forward guidance shocks and CBI effects. In turn, Jarocinski's conventional monetary policy shock is correlated only with Swanson's analogue (column (4)). Jarocinski's forward guidance and LSAP shocks are correlated both with Swanson's analogues, respectively, and Jarocinski's CBI effects only with Swanson's forward guidance 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 presents the results for the impact-day US financial market effects when we

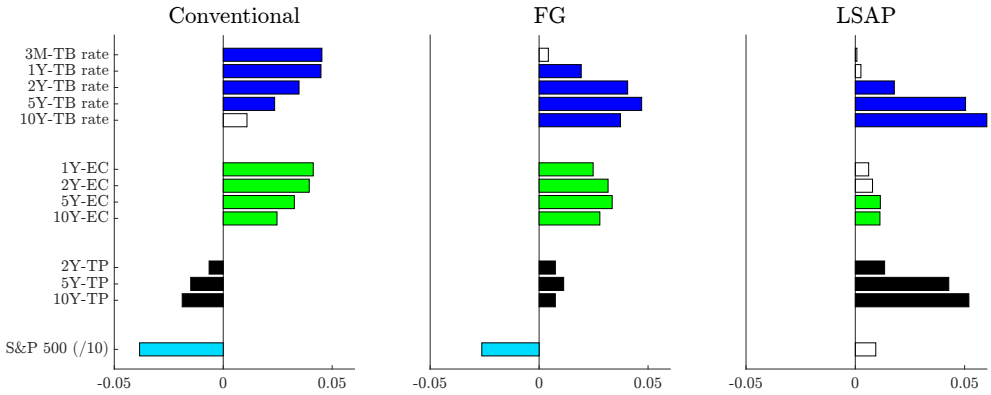
Table B.1: Results for regressions of the monetary policy shocks of Swanson (2021) on the analogues of Jarociński (2021) and vice versa

	Swanson shocks on LHS			Jarocinski shocks on LHS			
	(1) CMP	(2) FG	(3) LSAP	(4) CMP	(5) FG	(6) LSAP	(7) CBI
Jarocinski conventional MP shock	0.79***	0.25***	0.02				
	(0.00)	(0.00)	(0.54)				
Jarocinski 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 CBI effect	-0.01	0.53***	0.02				
	(0.50)	(0.00)	(0.60)				
Swanson conventional 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, forward guidance and LSAP shocks of Swanson (2021) in columns (1) to (3) and the conventional, forward guidance, LSAP and CBI effects 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.

use the conventional monetary policy, forward guidance and LSAP shocks of Swanson (2021). Overall, results are rather similar to those for the shocks of Jarociński (2021). One noteworthy difference is that the increase in long-term Treasury yields in response to Swanson's LSAP shocks 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 LSAPs in part operate through a 'signalling channel'. In contrast, for Jarociński'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, inconsistent with a 'signalling channel'. At the same time, note that when Jarociński's LSAP shock are estimated only after 2008, then also his shocks point to a signalling channel (see Figure C.5). In general, it again appears as if the responses to Swanson's forward guidance shock are a combination of the responses to Jarocinski's forward guidance shocks and CBI effects. Together with the discussion above this suggests that Swanson's forward guidance shocks might be contaminated by CBI effects. Interestingly, the counterintuitive findings in Campbell et al. (2012) that sparked the analysis of CBI effects are most pronounced for forward guidance shocks.

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

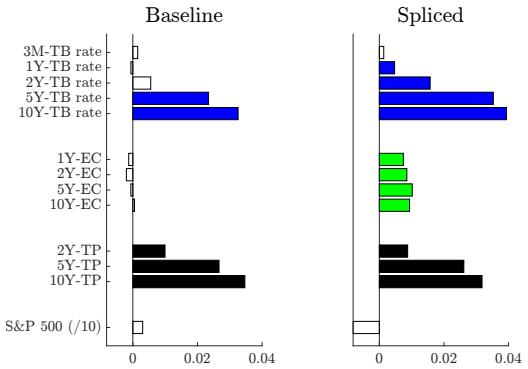


Note: The shocks are taken from Swanson (2021), and are included simultaneously in the regressions. See also the notes from Figure 1.

The seemingly contradictory finding that the shocks of Swanson (2021) entail impact-day estimates of financial market effects in Figure B.2 that are consistent with a 'pure' monetary policy 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.

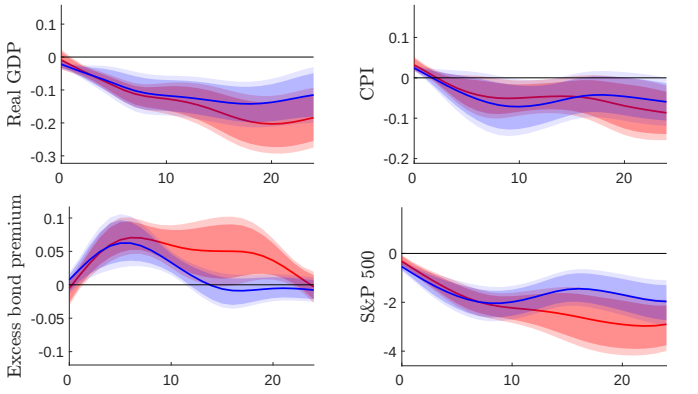
C Additional figures

Figure C.1: Daily US financial market impact effects of Jarociński's LSAP shocks



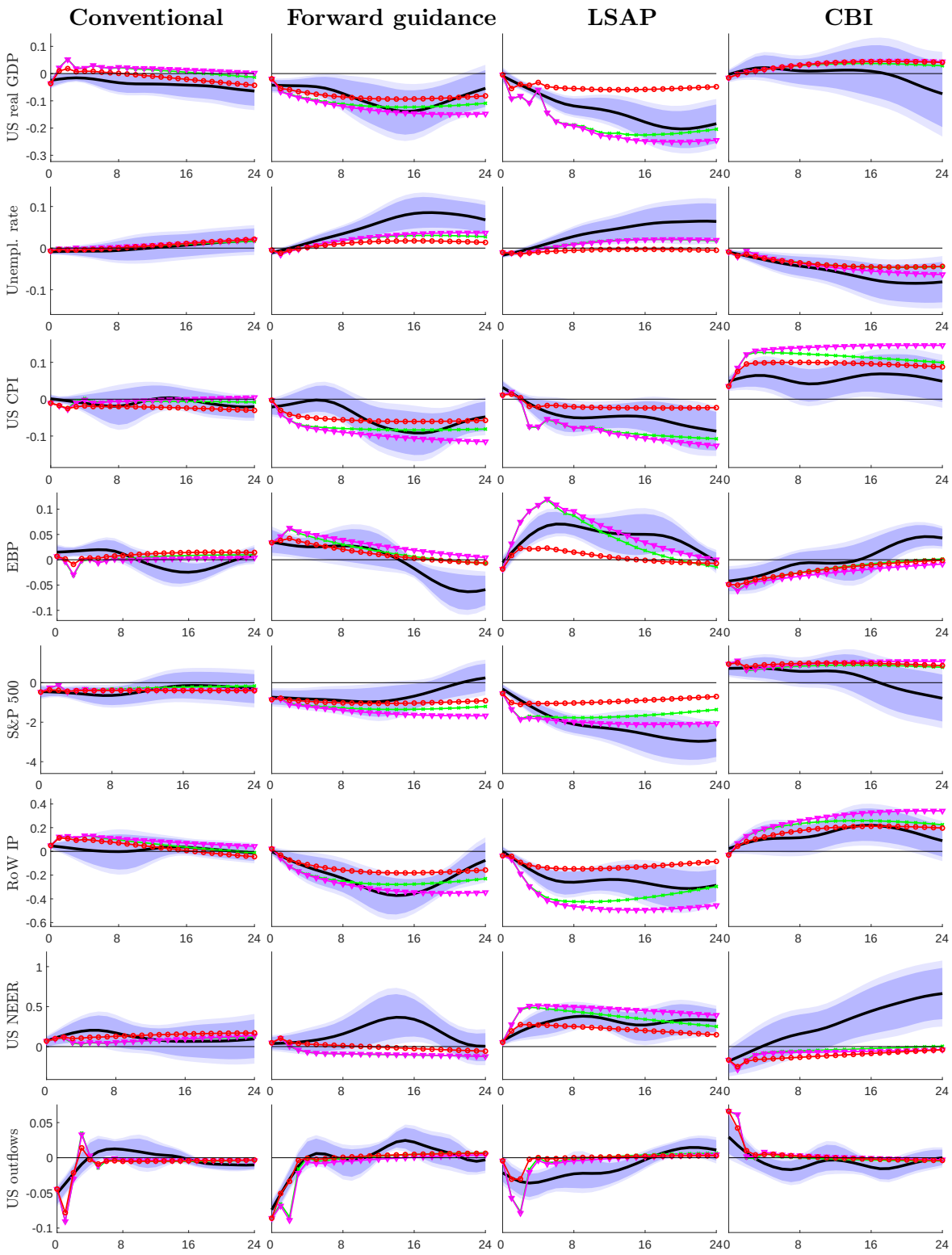
Note: The left panel depicts the baseline results from Figure 1 and the right panel those from an alternative specification in which LSAP shocks are estimated only for 2008 to 2019 and set to zero prior to 2008. See also the notes to Figure 1.

Figure C.2: Effects of US monetary policy shocks for alternative specifications with for the baseline (red) and LSAP shocks estimated only after 2008 and set to zero before (blue)



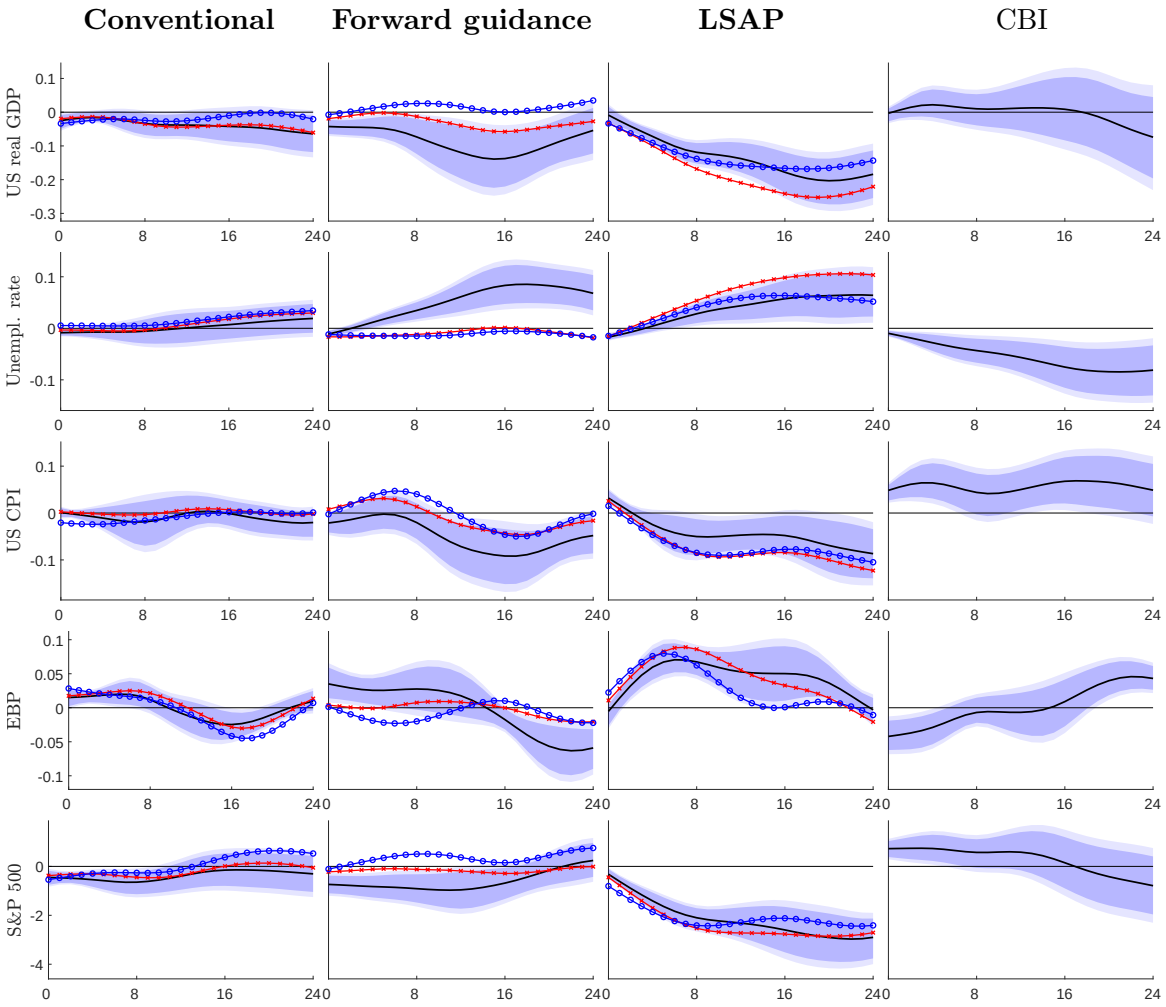
Note: Impulse responses in red depict the baseline. The impulse responses in blue depict the results from a specification in which the LSAP shocks are estimated only for the time period after 2008 and set to zero before. See also the notes to Figure 2.

Figure C.3: Comparison of effects of US monetary policy shocks of Jarociński (2021) estimated by SLPs (black solid), OLS VAR models (blue dashed-dotted), bias-corrected OLS VAR models (green crossed), and Bayesian VAR models (red circled)



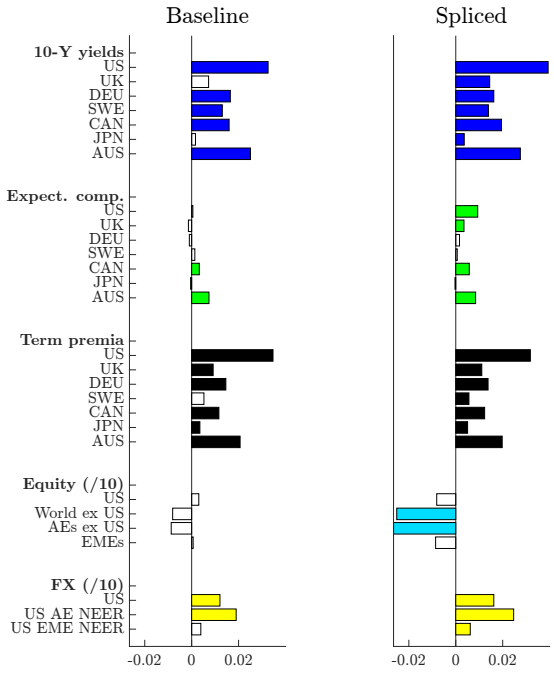
Note: The figure shows compares the baseline impulse responses estimated from SLPs with the specification discussed in Section 2.5 with those estimated from OLS, bias-corrected and Bayesian VAR models using the replication files of Li et al. (2021). We consider the specification with 'observed shocks' and generally adopt the other specification choices of Li et al. (2021). The only changes we make is to reduce the maximum lag order allowed in the optimal lag order selection from 20 to 12 and we use the Akaike instead of the Schwartz Bayesian information criterion.

Figure C.4: Effects of US monetary policy on US macroeconomic variables for the shocks of Jarociński (2021, black solid lines), Swanson (2021, red crossed lines) and Miranda-Agrippino and Nenova (2022, blue circled lines)



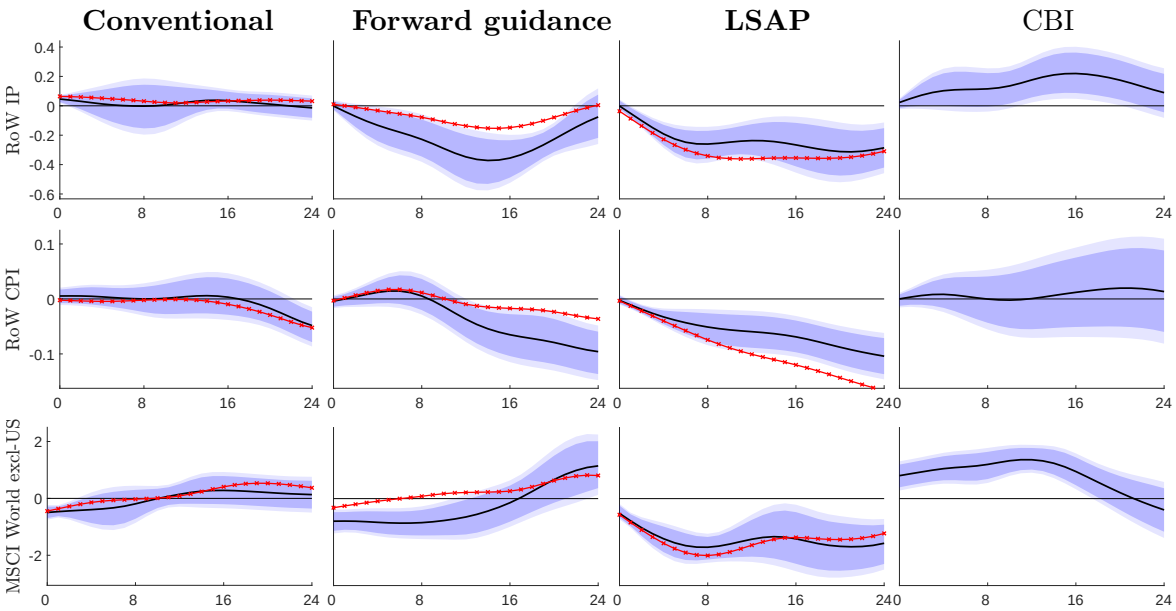
Note: Impulse responses depict deviations from baseline in percent. Impulse responses are estimated using the SLPs of Barnichon and Brownlees (2019). The black solid lines depict the impulse responses of US monetary policy shocks of Jarociński (2021). The shocks are included simultaneously in the regressions. The red crossed (blue circled) lines depict the responses to the monetary policy shocks of Swanson (2021) (Miranda-Agrippino and Nenova (2022)). The sample period is 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 months after the shock has hit.

Figure C.5: Daily impact effects of the LSAP shocks of Jarociński (2021) on global interest rates, stock prices and exchange rates



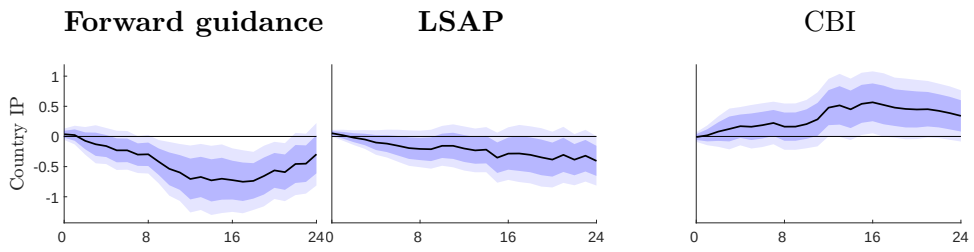
Note: See the notes to Figure C.1.

Figure C.6: Comparison of effects of US monetary policy shocks of Jarociński (2021) (black solid lines) and Swanson (2021) (red crossed lines) on non-US RoW variables



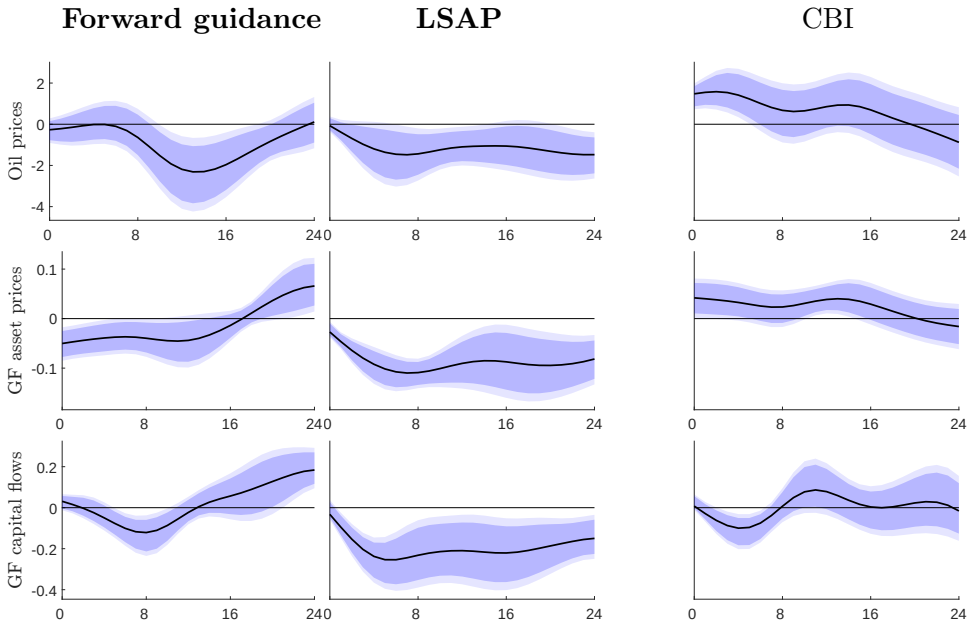
Note: The black solid lines indicate the impulse responses of US monetary policy shocks of Jarociński (2021) estimated from SLPs of Barnichon and Brownlees (2019). The shocks are included simultaneously in the regressions. The red crossed lines indicate the responses to the conventional monetary policy,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

Figure C.7: Effects of US monetary policy shocks of Jarociński (2021) estimated by panel LPs with country-level data



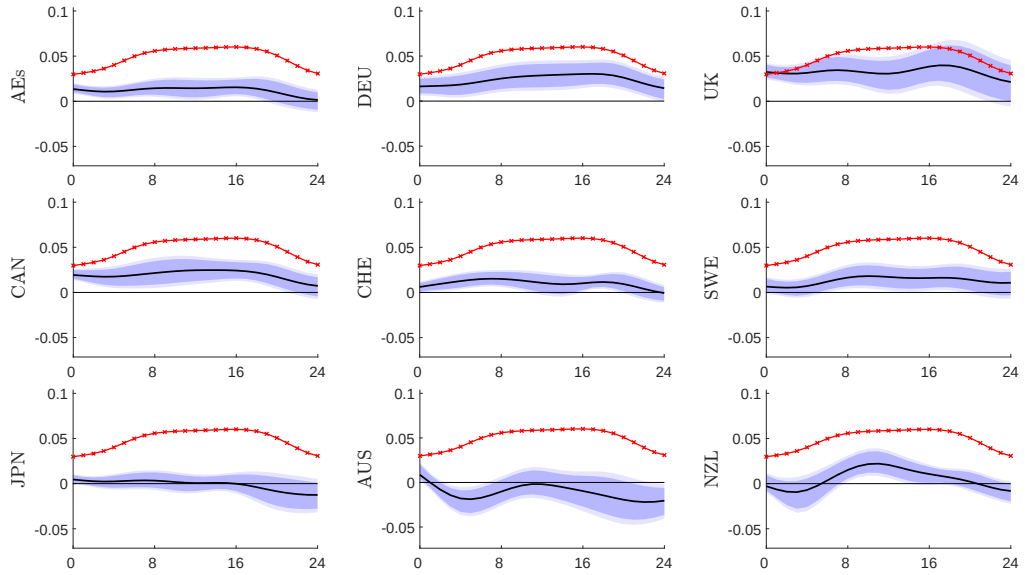
Note: The figure presents the results for the spillovers from US monetary policy shocks obtained from panel LPs estimated on country-specific data. The controls include RoW industrial production, the US excess bond premium and the 1-year Treasury bill rate. We set $p = 1$. The shaded areas represent 90% and 68% confidence bands based on Driscoll-Kraay robust standard errors.

Figure C.8: Effects of US monetary policy shocks of Jarociński (2021) on global factors and oil prices



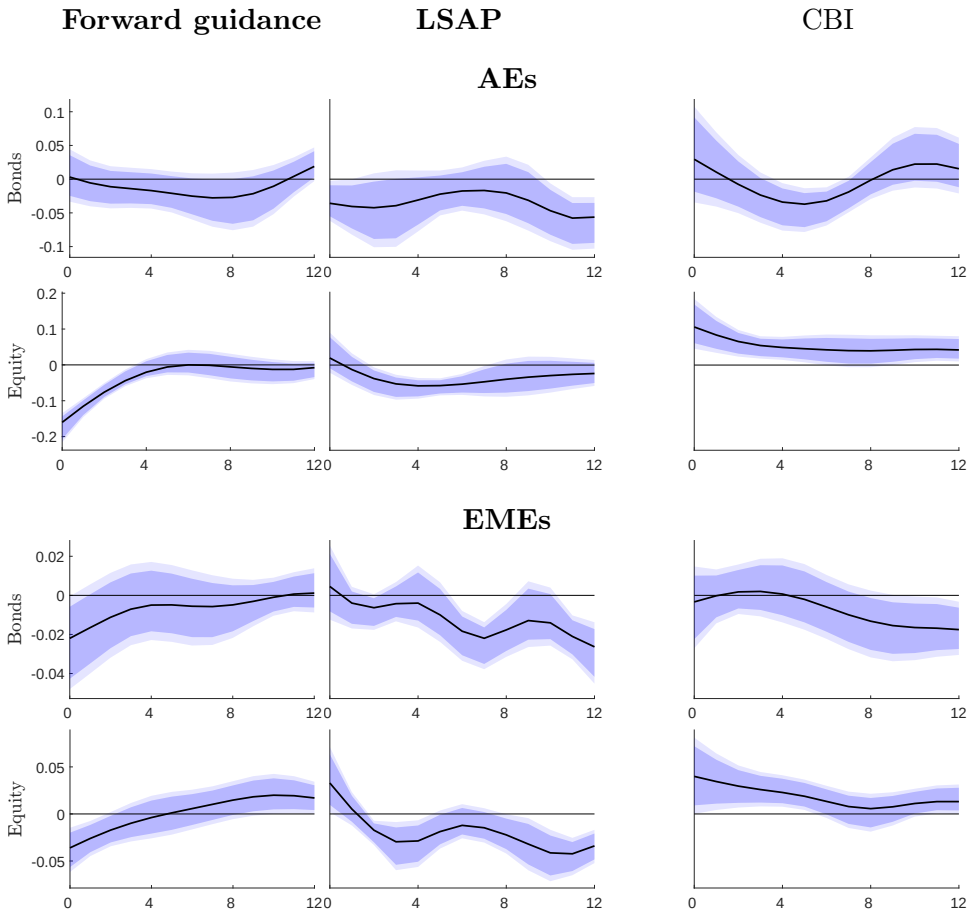
Note: The risk appetite index is taken from Bauer et al. (2023). The global factor ('GF') in risky asset prices were originally introduced by Miranda-Agrippino and Rey (2020b) and extended in Miranda-Agrippino et al. (2020), and the global factor in capital flows is taken from Miranda-Agrippino et al. (2020). See also the notes to Figure 2.

Figure C.9: Effects of LSAP shocks of Jarociński (2021) on foreign term premia



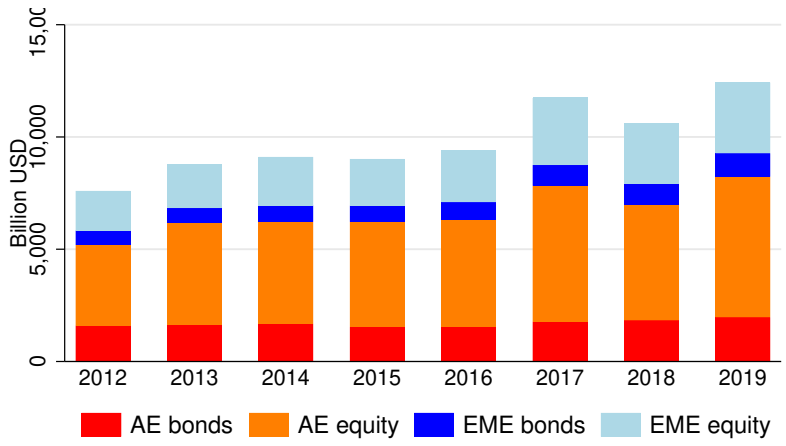
Note: Impulse responses depict deviations from baseline in percentage points. Red crossed lines depict effects on US variables. The term premia refer to 10-year bonds and are taken from the estimation of the models of D'Amico et al. (2018) and Diebold et al. (2006). The AE term premium is calculated as a GDP-weighted average across Japan, Germany, Switzerland, the UK, Australia, Sweden, Canada and New Zealand.

Figure C.10: Effects of US monetary policy shocks of Jarociński (2021) on US portfolio outflows by destination and instrument scaled by lagged US GDP



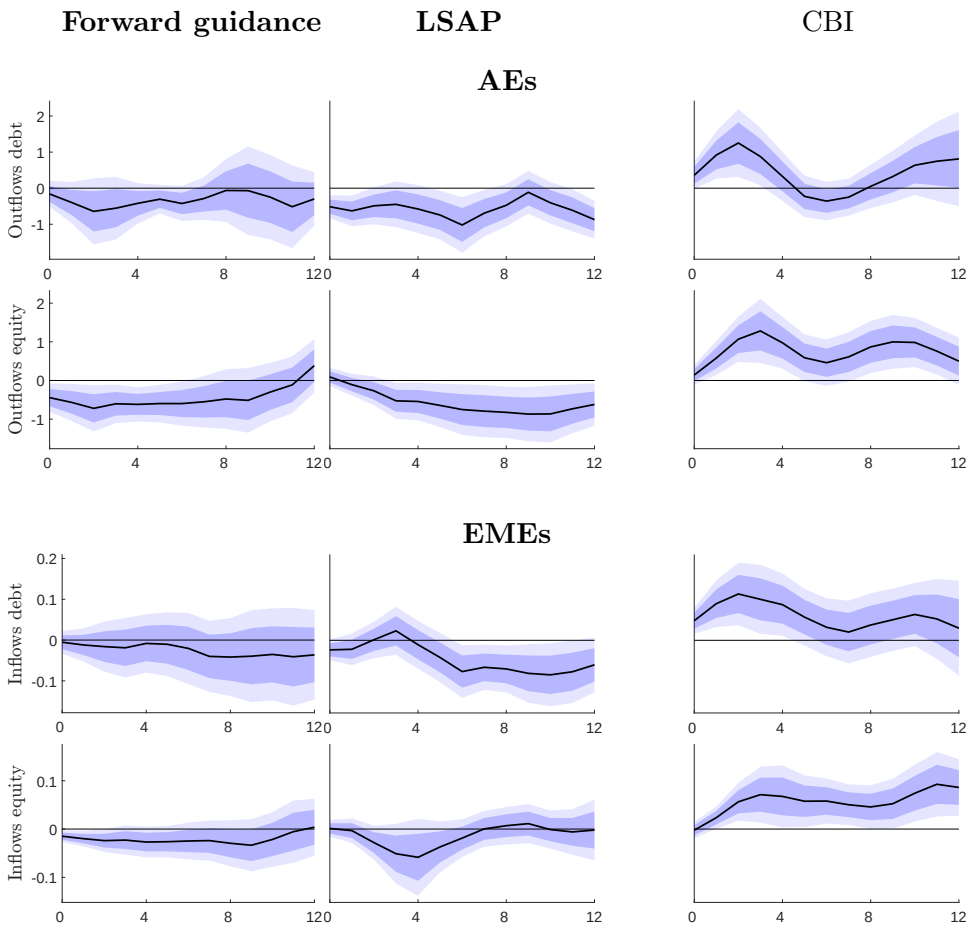
Note: See also the notes to Figure 8.

Figure C.11: Evolution of US holdings of foreign portfolio bond and equity



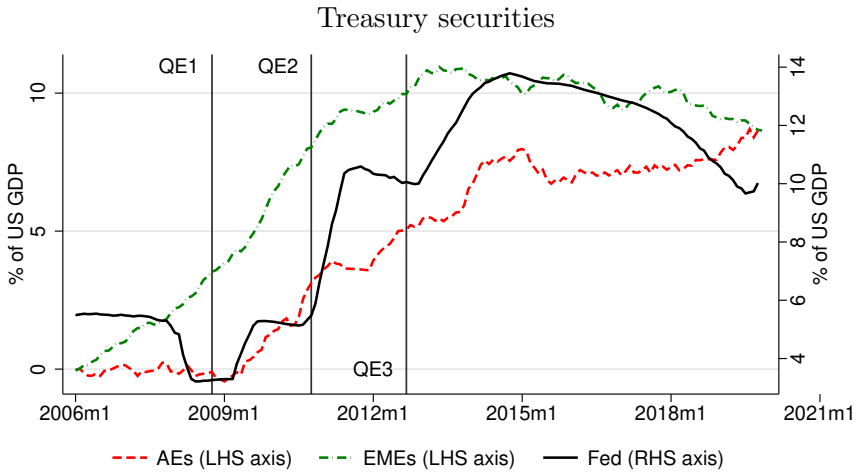
Note: Data are taken from US TIC and Bertaut and Judson (2022).

Figure C.12: Effects of US monetary policy shocks of Jarociński (2021) on non-US AE portfolio outflows and EME portfolio inflows estimated from panel LPs



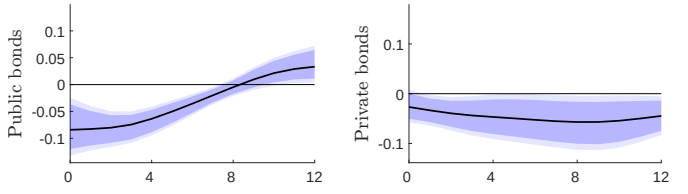
Note: Impulse responses depict deviations from baseline in percentage points of recipient-country nominal GDP. The data are taken from the IMF Balance of Payments Statistic, are interpolated from quarterly to monthly frequency, and span 1996 to 2019. See also the notes to Figure 2.

Figure C.13: Foreign and Fed holdings of Treasury securities



Note: The figure shows the evolution of AE (red dashed line) and EME (green dash-dotted line) cumulated purchases of US Treasury bonds and notes based on the compilation of Treasury Capital International data of Bertaut and Tryon (2007) and Bertaut and Judson (2014, 2022). All variables are scaled by US GDP. Under QE1, the Fed purchased $1.725 trillion of mortgage-backed securities (MBS), housing government-sponsored enterprise debt, and Treasury bonds.

Figure C.14: Effects of LSAP shocks of Jarociński (2021) on US portfolio inflows from AEs across debt instrument class



Note: See also the notes to Figure 8.

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