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JEL Classification: F42, E52, G15

Keywords: Unconventional Monetary Policy, High-Frequency Identification, International spillovers, Fed, ECB

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1 Introduction

The conduct of monetary policy is mostly a national matter. Modern independent central banks typically operate within a mandate that is solely focused on domestic objectives, and set their monetary strategies accordingly. However, when it comes to evaluating the consequences of monetary policy actions of the largest central banks, domestic borders become less relevant. Particularly in a world of increasingly integrated and synchronised global macroeconomic and financial activity.

The international spillovers of US monetary policy have received a lot of attention in both academic and policy circles. A large and growing body of literature documents how US monetary policy decisions reverberate strongly at the global level. The transmission channels that enable these spillovers are several, potentially all simultaneously at play. Traditional explanations rest on classic trade balance effects, and international business cycle synchronisation (e.g. Obstfeld and Rogoff, 2004, 2007). Monetary policy, by affecting aggregate domestic demand and the value of the domestic currency, can have significant effects on world balances through current account adjustments. The relative shares that countries contribute towards global output and trade determine the strength of these channels, and the extent to which countries are vulnerable to such types of spillovers. Standard trade channels have dominated historically. More recently, the unprecedented integration of financial markets and of worldwide financial activity – that have consolidated the position of the US and the US dollar at the centre of the international monetary and financial systems –, have unlocked further channels for the international transmission of monetary policy in general, and of US monetary policy in particular. The risk-taking channel of monetary policy – where the investors' risk profile takes centre stage, first introduced in Bernanke and Kuttner (2005) –, has been shown to operate internationally as well (e.g. Bruno and Shin, 2015; Miranda-Agrippino and Rey, 2020; Kalemli-Ozcan, 2019). By affecting asset prices, monetary policy relaxes investors' balance sheet/leverage constraints, and can play an important role in shaping their risk aversion. In turn, variations in risk aversion feed back into asset prices and cross-border capital flows (Adrian and Shin, 2010, 2014; Borio and Zhu, 2012). The existence of a Global Financial Cycle (GFC, see Rey, 2013) – characterised by the co-

movement of risky asset prices, leverage of financial intermediaries, credit growth, and gross capital flows around the world – acts as a facilitator and amplifier for this channel (see Miranda-Agrippino and Rey, forthcoming, for a review). Currency also plays a role. The US dollar is by far the most traded currency, it is the primary reserve currency, and the currency of choice for trade invoicing and the pricing of financial transactions (Rey, 2013; Gopinath, 2016; Ilzetzki, Reinhart and Rogoff, 2019; Maggiori, Neiman and Schreger, 2020). Fluctuations in the value of the anchor currency compound valuation effects to real ones, with important consequences for balance sheets, external foreign asset positions, debt sustainability, as well as for standard trade balance considerations (e.g. Gourinchas and Rey, 2007). These latter mechanisms can be very powerful. The dominant role of the dollar, coupled with the large degree of integration of international financial markets confer a special role to US monetary policy as an important driver of the GFC (Miranda-Agrippino and Rey, 2020; Jorda, Schularick, Taylor and Ward, 2018; Habib and Venditti, 2018).

In a world that is becoming gradually more multipolar, an important question is whether we should continue to think of these channels as unique to US monetary policy. Or whether instead other major central banks are also potentially capable of generating international spillovers through the same mechanisms. This is the question that we explore in this paper. Understanding these mechanisms and transmission channels is important for the conduct of domestic monetary policy in small open economies whose financial conditions can be largely determined by global factors. But it is also important in order to frame the contours of the current equilibrium of the international monetary and financial systems. To address this question, we conduct a comprehensive empirical investigation, and compare the international financial spillovers of the Fed and ECB monetary policies on asset prices as well as on global macro and financial aggregates, by focusing specifically on the unconventional monetary policy tools deployed by both central banks following the financial crisis of 2008.

ECB policy spillovers can be large, and equally powerful irrespective of the recipient country's exchange rate regime (Corsetti, Kuester, Müller and Schmidt, 2021). Dedola, Georgiadis, Gräb and Mehl (2021) showed that ECB balance sheet policies can have strong and persistent effects on the €/$ exchange rate. However, earlier studies, such as

e.g. Ca' Zorzi, Dedola, Georgiadis, Jarociński, Stracca and Strasser (2020) and Jarociński (2020), documented that conventional interest rate ECB monetary policy propagates internationally mostly through trade channels.

Since the financial crisis, with most countries shaken largely by the same shocks, and with many short-term rates at or near the zero/effective lower bound, the degree of interdependence in financial markets has arguably become stronger than ever. The two major central banks have intervened with massive relief programmes, aimed at reestablishing correct market functionings, restoring liquidity conditions, and providing the necessary stimulus to satisfy the needs of their slowly recovering economies. These programmes were similar in nature and size.[1] In addition, while still a relatively young currency, the euro is increasingly consolidating its role as an international safe currency. And taken together, the US dollar and the euro essentially saturate the currency denomination of virtually all international transactions, including international debt and loans, foreign exchange reserves and turnover, and global payments (ECB, 2020). Hence, at least in principle, the conditions should be there for the monetary policies of the two central banks to operate both domestically and internationally along very similar dimensions. Particularly since the crisis.

Our results show that indeed this is the case. The international macroeconomic and financial spillovers of the unconventional monetary policies of the Fed and the ECB are similar to a very large extent. A monetary policy tightening in either of the two areas – whether enacted through forward guidance, or asset purchases programmes, or a combination of the two –, triggers a contraction in global output and trade, a fall in global stock markets, and a retrenchment of global capital flows. The domestic currency appreciates, both in bilateral terms, and against a broader basket of currencies. Credit costs rise, domestically and internationally. While equivalent in sign and significance, however, the magnitude of the ECB monetary policy spillovers is sensibly smaller relative to the Fed's, particularly when analysing the effects on world aggregates. What explains these findings? We find strong evidence in favour of an international risk-taking channel

[1]The ECB started asset purchases several years later than the Fed, but its balance sheet quickly caught up and as of end-2021 exceeds that of the Fed both in absolute terms and as a percentage of national output (https://www.federalreserve.gov/monetarypolicy/bst_recenttrends.htm and https://sdw.ecb.europa.eu/quickview.do?SERIES_KEY=123.ILM.W.U2.C.T000000.Z5.Z01).

for the policies of both central banks. Following a monetary policy contraction in either area, market-based measures of aggregate risk aversion rise very significantly, and to essentially the same degree, irrespective of the proxy used. Thus, this channel is enabled in both cases, and equally strong. With the two areas accounting for similar shares of output and trade globally,[2] we postulate that the difference in the strength of the spillovers can be traced back, at least in part, to the relative importance of the US dollar and the euro in the international monetary and financial systems. In order to provide some qualification for this claim, we identify the largest euro users in terms of both trade invoicing and the pricing of financial assets and liabilities using the data in Boz, Casas, Georgiadis, Gopinath, Mezo, Mehl and Nguyen (2020) and Benetrix, Gautam, Juvenal and Schmitz (2020) respectively, and find that there is some evidence of countries with largest euro exposure experiencing somewhat stronger spillovers from ECB policies. This latter section of the paper is admittedly more speculative in nature. Countries with strongest economic and financial ties with the Eurozone may be naturally more prone to adopting the euro as their currency of choice. But, while not conclusive, our findings speak to a growing body of evidence that the currency in which trade and financial transactions are settled plays an important role in the international transmission of shocks, both due to the economic links that it reflects and proxies for, and in its own right (Lane and Shambaugh, 2010; Gopinath, 2016; Gopinath and Stein, 2017; Gopinath, Boz, Casas, Díez, Gourinchas and Plagborg-Møller, 2020). Disentangling the relative contribution of the currency channel is a complex but fascinating problem. More research in this direction is certainly needed, particularly as more global currencies surface to share a primacy that until very recently had been exclusively a feature of the US dollar.

Our empirical analysis proceeds as follows. We start by constructing high-frequency factors to summarise unconventional monetary policy in the two areas, building on the work of Gürkaynak, Sack and Swanson (2005) and Altavilla, Brugnolini, Gürkaynak, Motto and Ragusa (2019), and using the intuition in Swanson (2021). We separate monetary policy news from information effects as in Jarociński and Karadi (2020). We then

[2]The US accounts for a larger share of global output – 25% compared to 15% for the euro area (output as of 2020, valued at market exchange rates, IMF World Economic Outlook Database, October 2021). When it comes to global merchandise trade, their roles are reversed, with the EA accounting for 26%, compared to 8.1% for the US as of 2020 (trade valued at current US dollars, UNCTAD).

evaluate spillovers in global markets on the days that follow the respective monetary policy announcements using event-studies. Here we study the response of yield curves, credit spreads, stock markets and exchange rates. Finally, we use the factors as instrumental variables to study the dynamic transmission of unconventional policy at horizons and frequencies that are more relevant from a macro perspective. In this part of the paper we focus on the response of aggregates, such as output, trade, inflows, and asset prices, both at global level and in bilateral terms.

The paper is organised as follows. In Section 2 we extract high-frequency unconventional monetary policy instruments for the Fed and ECB; we then study the propagation to financial markets using daily projections in Section 3. Section 4 collects the VAR results on the bilateral spillovers of ECB and Fed monetary policies, and on their international propagation to global aggregates. Section 5 focuses on the role of euro exposure in the transmission of the monetary policy of the ECB. Section 6 concludes. Additional details are reported in the Appendix.

2 Unconventional Monetary Policy Surprises and their Information Content

We start our analysis by looking at the sequence of monetary policy surprises both in the Euro Area (EA) and United States (US). Following the tradition initiated by Kuttner (2001) and Gürkaynak et al. (2005), we use high-frequency price revisions around the monetary policy announcements to measure the extent to which the decision was interpreted as a surprise, or news, by market participants. Absent other contemporaneous events, the narrow measurement window guarantees that if a price revision occurs, the monetary announcement was its only trigger.

However, whether that price revision can be used to proxy for a monetary policy shock is a different matter. Indeed, it has become apparent how market participants also extract non-monetary news from monetary policy announcements (Miranda-Agrippino, 2016; Melosi, 2017; Nakamura and Steinsson, 2018; Cieslak and Schrimpf, 2019). A

phenomenon known in the literature as the central bank information effect.

The literature has identified two complementary ways to deal with the consequences of such an effect. Miranda-Agrippino and Ricco (2021) propose to tackle the source of the confounding effect, and explicitly control for central bank official forecasts. Jarociński and Karadi (2020) instead propose to act directly on its consequences, and identify monetary policy news on the basis that they should induce a negative contemporaneous comovement between stock prices and bond yields. The two approaches lead to equivalent results. The latter, while more reduced-form, has the advantage of being very simple to implement, and is the one we follow in this paper. Differently from these previous contributions, here we extend the decomposition into monetary and non-monetary news also to unconventional policy, summarised using appropriately rotated principal components, in the spirit of Gürkaynak et al. (2005) and Swanson (2021).

Swanson (2021) identifies three orthogonal dimensions of US monetary policy that summarise movements in the entire term structure of interest rates: a Federal Funds rate/Target factor, that loads predominantly on the overnight rate, and dominates in the pre-ZLB (zero-lower-bound) sample; a communication/Path factor that has higher loadings on 1 to 2-year maturity rates; and an LSAP/QE factor that mostly captures the variation at the long end of the curve, and is constrained to be negligible in the pre-ZLB sample.

The Target factor captures monetary policy shocks that act predominantly on the short-term policy rate. Naturally, this factor has minimal variation when short-term rates are at or near the zero lower bound, i.e. throughout most of the post 2009 sample.

The Path factor proxies for shocks that affect markets expectations of future medium-term interest rates. Given that the typical horizon of implicit and explicit forward guidance announcements roughly matches the maturity of the interest rates that mostly load on this factor, it quite naturally lends itself to being interpreted as identifying the effects of forward guidance. However, to the extent that the announcement and implementation of QE can have an impact also on expectations of interest rates at maturities other than 10 years, it is important to bear in mind that this factor effectively combines the effects of forward guidance with those of this "signalling channel" of the QE transmission mechanism (see Krishnamurthy and Vissing-Jorgensen, 2011).

Similarly, we interpret the QE factor as identifying the combination of primitive shocks that, prompted by the FOMC announcements, lead market participants to revise their expectations about future long-term rates. In essence, it captures residual ways in which FOMC announcements alter long-term rates expectations beyond those that result from direct transmission of changes in shorter-maturity rates.

To suit the international context of this paper, we refer to these three factors as a Target/Policy Rate Factor, a Path/Forward Guidance Factor, and a QE/Asset Purchases Factor respectively.

We extract both sets of factors from contracts with comparable maturities for both currency areas. For the US, we replicate Swanson (2021)'s setup, and extract the factors from Federal Funds rate futures (the current- and next-month contract rate), Eurodollar futures (the next-quarter rate and the contract rates for each of the following two quarters), and Treasury bond yields (2-, 5-, and 10-year maturities). The sample covers all announcements from January 1991 to June 2019. For the EA, we use an equivalent set of contracts, namely, OIS rates at 1- and 3-month, and at 1-, 2-, 5- and 10-year maturities. The sample covers all announcements from January 1999 to March 2021, and we take the data from Altavilla et al. (2019).

Tables 1 and 2 report the loadings of the three factors on the contracts respectively used for their estimation.[3] In both cases we normalise them such that the Target factor has a loading of 1 on the shortest-maturity contract, the Path factor has a loading of 1 on 1-year rates, and the QE factor has loading of 1 on the 10-year rate. The factors behave very similarly across the two currency areas. The loadings of the Target factor decline monotonically as the maturity increases, while those of the QE factor increase as one moves along the yield curve. The Path factor isolates changes primarily in medium-range maturities. The zero loadings of both the Path and QE factors on the shortest maturity contracts is imposed by construction to identify the three components.

Consistently with the original estimates in Swanson (2021), the largest observations for the US Path factor correspond to the FOMC signalling an extension of the LSAP scheme in September 2009, the intention to keep the Federal Funds rate low "until mid-2013" of August 2011, and the extension of that guidance to mid-2014 in January 2012.

[3]Summary statistics and plots of the estimated factors are reported in the Appendix.

Table 1: Loadings of Monetary Policy Factors, US

	MP1	MP2	ED2	ED3	ED4	ONR2	ONR5	ONR10
Target Factor	1	0.93	0.75	0.65	0.54	0.55	0.32	0.15
Path Factor	0	0.25	0.77	0.91	1	0.98	1.06	0.91
QE Factor	0	-0.14	-0.25	-0.24	-0.20	0.02	0.49	1

Notes: Factors extracted as in Swanson (2021). The sample includes all FOMC announcements from Jan-1991 to Jun-2019.

Table 2: Loadings of Monetary Policy Factors, EA

	OIS-1M	OIS-3M	OIS-1Y	OIS-2Y	OIS-5Y	OIS-10
Target Factor	1	0.91	0.57	0.42	0.22	0.09
Path Factor	0	0.44	1	1.13	0.68	0.56
QE Factor	0	-0.16	-0.27	-0.20	0.90	1

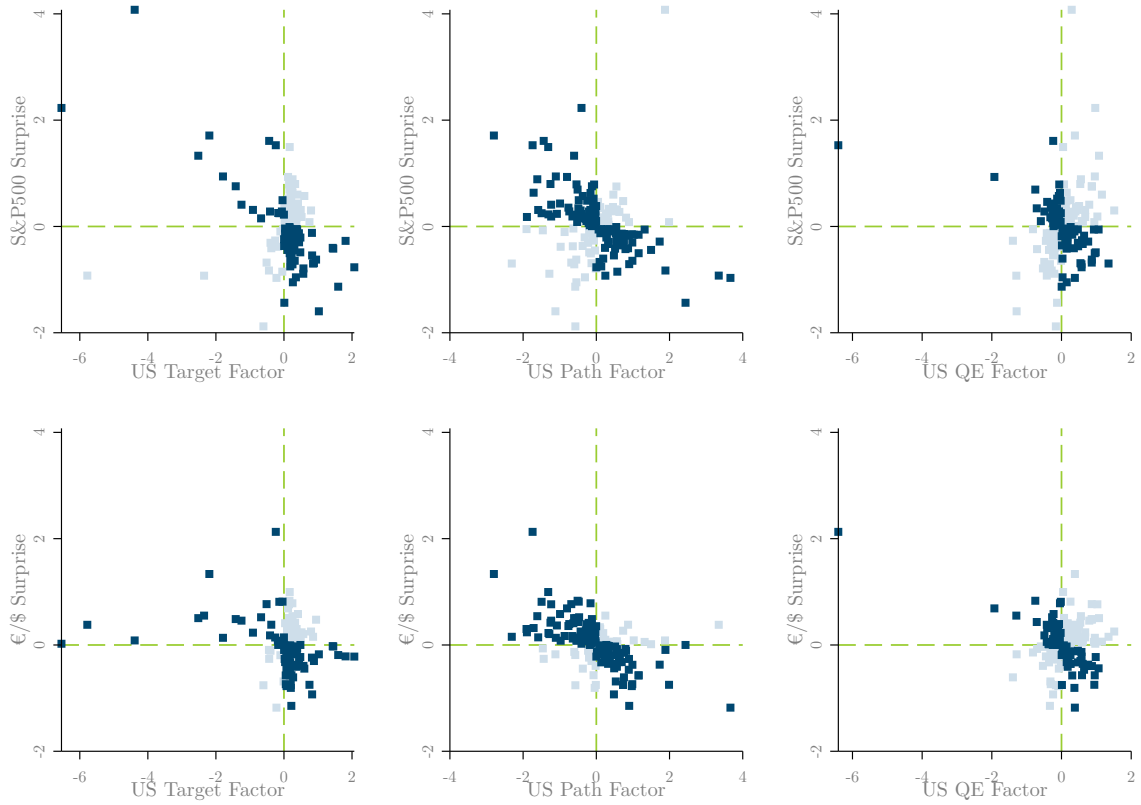
Notes: Factors extracted as in Swanson (2021). The sample includes all ECB Governing Council (GC) announcements from Jan-1999 to Mar-2021.

Interestingly, the latest points in the sample suggest successive easing surprises in the spring and summer of 2019, preceding three consecutive rate cuts at the FOMC meetings in July, September and October of that year. For US QE, and again consistent with Swanson's estimates, the largest surprise is undoubtedly the announcement of the first round of QE in 2009.

For the EA, the largest Path surprises are clustered around the European sovereign debt crisis, and the positive surprise of December 2015 corresponds to the ECB cutting the deposit facility rate by 10bps, less than anticipated by market participants. For what concerns the QE factor instead, the largest surprises are registered in January 2015, which corresponds to the announcement of the ECB's Asset Purchase Programme (APP), June 2015, when the ECB decided not to counter rising yields in European bond markets through further unconventional easing, and December 2015, coinciding with the announcement of an extension to asset purchases at a pace slower than prevailing market expectations.

Figures 1 and 2 report scatter plots of the high-frequency reaction of financial markets to policy announcements in the two areas. In both figures, the top row compares the reaction of the relevant stock market index with that of the monetary policy surprises, while the bottom row reports the reaction of the bilateral €/$ exchange rate. The two

FIGURE 1: MONETARY POLICY SURPRISES IN THE US

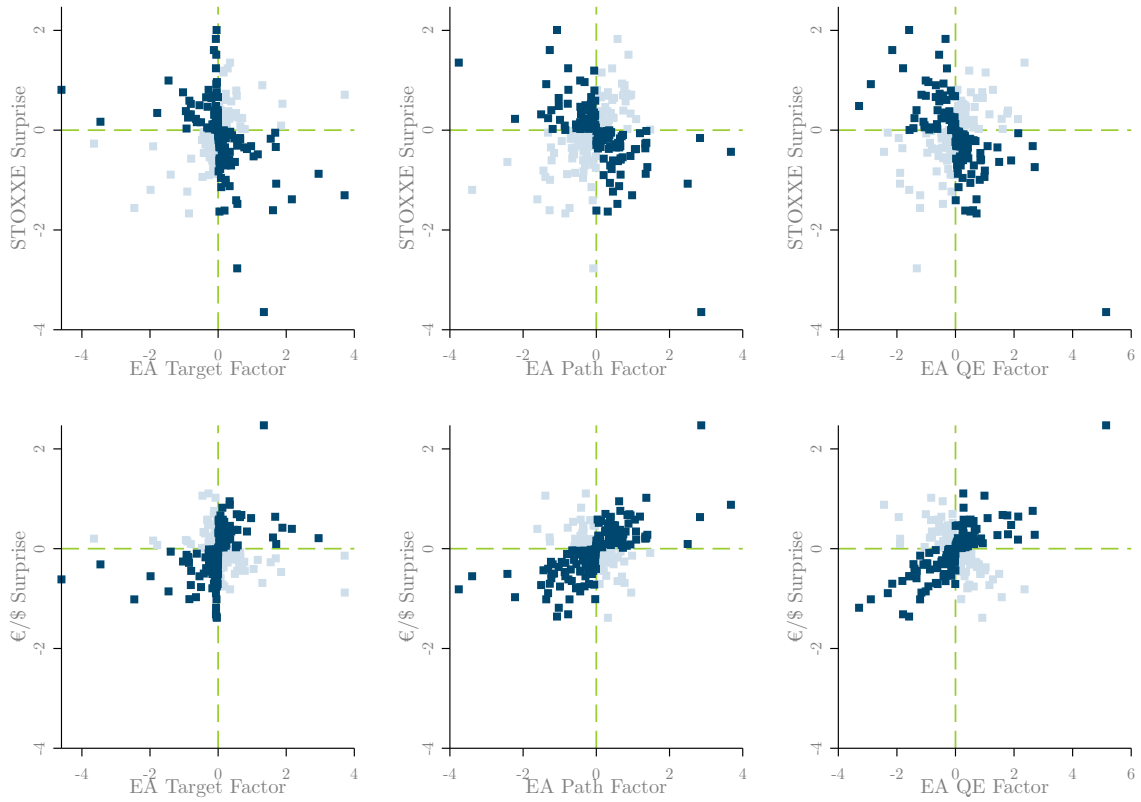


Notes: [Top Panels:] Intraday reactions of monetary policy surprises and the stock market (S&P 500) around FOMC announcements. [Bottom Panels:] Intraday reactions of monetary policy surprises and the bilateral €/$ exchange rate around FOMC announcements. [Across Columns:] Target factor, Path factor, QE factor.

figures confirm the pervasiveness of confounding effects, such as central bank information, across the whole of the maturity spectrum. Classic economic theory would have the stock market reacting negatively to tightening surprises, and the local currency appreciating. As is visible in the two sets of charts, this only occurs in a fraction of all the available announcements (dark markers), and there is a substantial share of cases in which the empirical comovement instead seems to invalidate the theory (light markers). As also noted in Gürkaynak et al. (2020), information effects also affect exchange rates.

In the analysis that follows, we isolate monetary news using the "poor man's" identification of Jarociński and Karadi (2020). This corresponds to identifying monetary policy news using sign restrictions, based on the high-frequency negative comovement between stock prices and bond yields as predicted by economic theory. In practical terms, this is

FIGURE 2: MONETARY POLICY SURPRISES IN THE EA



Notes: [Top Panels:] Intraday reactions of monetary policy surprises and the stock market (EuroSTOXX) around ECB GC announcements. [Bottom Panels:] Intraday reactions of monetary policy surprises and the bilateral €/$ exchange rate around ECB GC announcements. [Across Columns:] Target factor, Path factor, QE factor.

equivalent to using only the observations that correspond to the darker markers in each of the top panel charts of Figures 1 and 2.

While information effects characterise a sizeable portion of both central banks' announcements, we note they are more prevalent for the ECB. Of the 278 announcements included in Figure 2, this approach classifies around half of the high-frequency changes in each factor as monetary policy news. For the US, the share of monetary policy events is somewhat higher, at almost a third for the Path factor and just over half for the other two factors. This conforms with what observed in Jarociński and Karadi (2020), who note that the larger prevalence of "information days" is consistent with the ECB adopting a more transparent communication strategy with the public, relative to the Fed. For example, while the Fed introduced press conferences only in 2011, these were part of

the communication strategy of the ECB since 1999. Moreover, the ECB publishes staff forecasts promptly after they are produced, whereas Fed's staff forecasts are typically only released with a five-year lag. Another reason for why information effects are more prevalent for the ECB may reside in the fact that information aggregation across the different countries in the Eurozone is more challenging, and better handled by expert ECB staff than the public. This may confer to the ECB a considerable informational advantage in forecasting European macroeconomic aggregates.

An important final point relates to the correlation of monetary policy factors across the two areas. Jarociński (2020) uses a setup equivalent to ours to study the spillovers from ECB and Fed conventional policies and reports that the correlation between ECB and Fed short-rate surprises is not significant. We confirm this result also using the factors. The correlation between the two Target factors is equal to -0.14 (p-value 0.128) and to 0.067 (p-value 0.465) when only the monetary policy news component is isolated. Table 3 reports the correlation among the Fed and ECB Path and QE factors calculated over the sample 2009:01-2019-06. Results in the table show that also for what concerns unconventional monetary policy instruments, we do not find any evidence of significant correlation across countries and policy tools. This is important, as it will allow us to use the factors in isolation in the analysis that follows (as in Jarociński, 2020).[4]

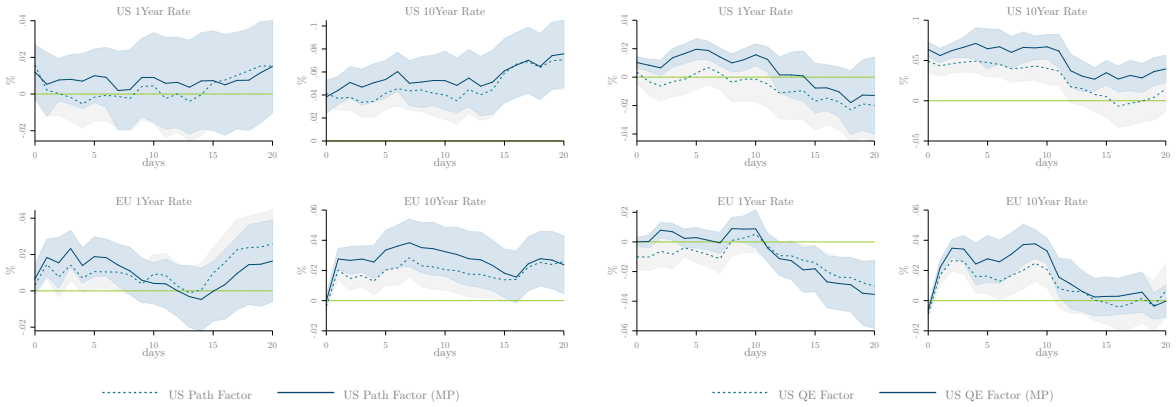
Table 3: Cross-Country Correlation in Monetary Policy Factors

	US Path	US QE	US Path (MP)	US QE (MP)
EA Path	0.121 (0.178)	0.122 (0.174)		
EA QE	-0.022 (0.808)	0.005 (0.959)		
EA Path (MP)			-0.041 (0.646)	0.074 (0.413)
EA QE (MP)			-0.104 (0.247)	-0.003 (0.972)

Notes: Pairwise correlation coefficients. P-values reported in parentheses. Sample: 2009:01-2019-06 (n=126 observations).

[4]Moreover, we do not find any evidence of Granger causality among the factors across countries. Results are available upon request.

FIGURE 3: RESPONSE OF US & EA YIELD CURVE TO UNCONVENTIONAL US MP



(A) Fed Path Shocks (B) Fed QE Shocks

Notes: Daily projections. Sample 1999-01:2019-06. Responses to full announcement (dotted lines), and to monetary news only (solid lines). Shaded areas are one standard deviation bands.

3 Financial Markets Spillovers

In this section we analyse the way in which Fed and ECB policies affect global financial markets in the days that follow the announcements. Fed policies have been proven to affect global financial markets in a number of different studies. However, the evidence relative to the ECB is more mixed. Here we intend to characterise the extent to which any differences in the transmission of the monetary policies of the two largest central banks materialise, and if they do, in what way do they differ.

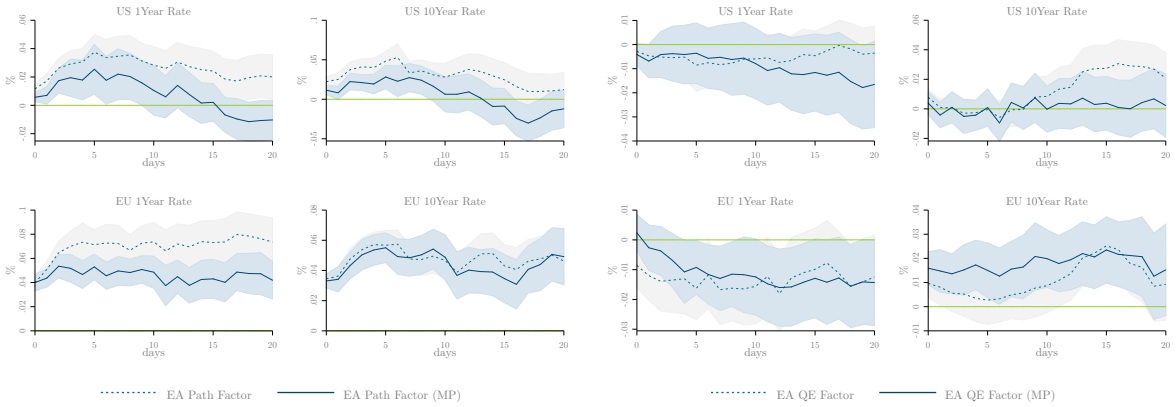
We evaluate the spillovers of the two monetary policies on the same set of asset prices, and over the same sample. We consider the overlapping sample across the two sets of factors, that is, from January 1999 to June 2019. Following Jarociński (2020), we also drop from the sample the three joint Fed and ECB announcements that occurred on the 13 and 17 September 2001, and on 8 October 2008. We quantify the spillovers by using daily projections (Jordà, 2005) of the following form

$$y_{t+h} - y_{t-1} = \alpha_h + \beta_h mps_t + \nu_{t+h} \tag{1}$$

$$y_{t+h} - y_{t-1} = \alpha_h + \beta_h^* mps_t \mathbb{1}_- + \nu_{t+h} \tag{2}$$

where $y_{t+h} - y_{t-1}$ is the cumulated daily change in asset prices, mps_t denotes the value of

FIGURE 4: RESPONSE OF US & EA YIELD CURVE TO UNCONVENTIONAL EA MP



(A) ECB Path Shocks

(B) ECB QE Shocks

Notes: Daily projections. Sample 1999-01:2019-06. Responses to full announcement (dotted lines), and to monetary news only (solid lines). Shaded areas are one standard deviation bands.

the relevant factor at the announcement date, and $\mathbb{1}_{-}$ is an indicator function that isolates only those announcements in which the high-frequency stock market response is in line with economic theory (corresponding to the "poor man's" identification of Jarociński and Karadi, 2020). We report results for the cases in which mps_t is either the Path or the QE factor.[5] The figures that follow report the estimated β_h (response to full announcement, dotted lines) and β_h^* (response to monetary policy news only, solid lines) for horizons covering the first 20 business days following the announcements, which corresponds to a one-month horizon. Shaded areas are one standard deviation bands. All factors are interpretable as tightening surprises.

We focus on two sets of asset prices. In Figures 3 and 4 we evaluate the response of the two yield curves, summarised by the interest rates at maturities equal to 1 and 10 years. In Figures 5 and 6 we look at the response of the stock market indices (S&P 500 and EuroSTOXX), of volatility indices (VIX and VSTOXX), of corporate bond spreads ($- and €-denominated investment-grade and high-yield spreads), and of currencies ($ and € broad indices excluding the bilateral exchange rate and, separately, the bilateral €/$ rate). Variables definitions and sources are reported in the Online Data Appendix.

[5]Results for conventional monetary policy align with those in the previous literature and are not reported.

We start by discussing the responses of the two yield curves in Figures 3 and 4. A number of results emerge. First, both types of unconventional policies are very effective at moving the relevant interest rates domestically. Unsurprisingly, most of the reaction is concentrated at the longer end of the curve. While the persistence of the effects is different, the 10-year US rate is significantly higher after both Fed policies (Figure 3). Similarly, long term rates in the Eurozone are significantly and persistently higher following both Path and QE ECB shocks (Figure 4). Second, there are some asymmetries in the spillovers to the yield curves. European long-term rates respond significantly to both types of Fed policies. Again, most of the action is concentrated at the long end of the curve, but there is some evidence of US Path shocks significantly affecting the whole EA yield curve.[6] On the contrary, ECB QE shocks seems not to have strong effects on 10-year Treasury rates. However, importantly, the US yield curve shifts up significantly following a contractionary ECB Path shocks.

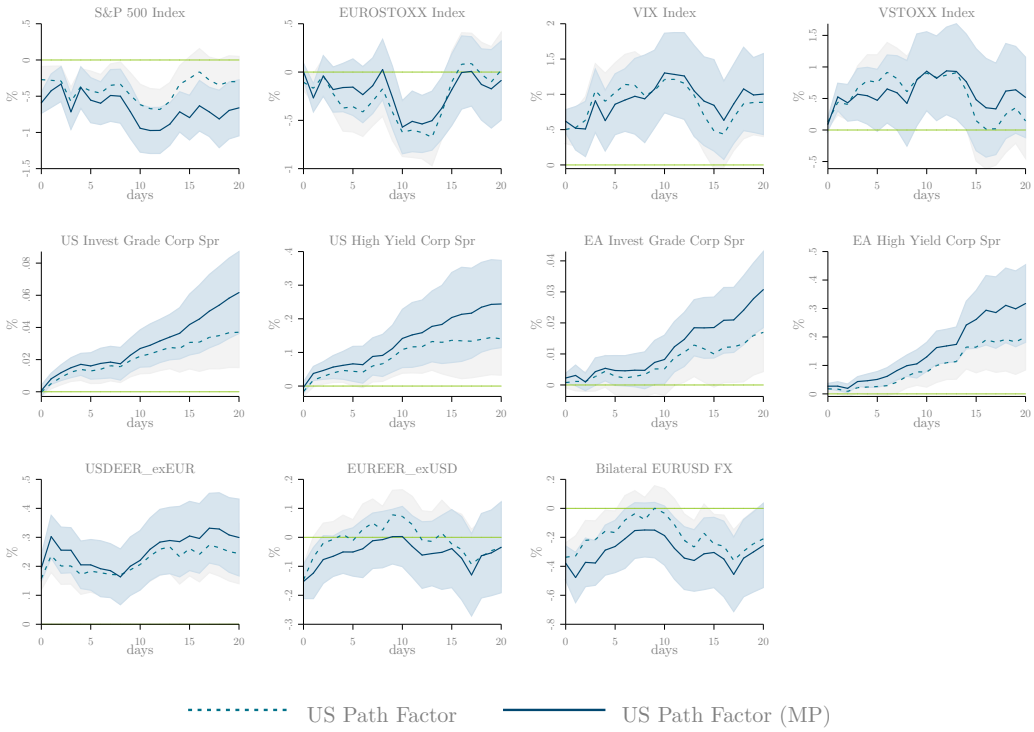
This is where the interpretation of the factors becomes relevant. As noted in the previous section, the QE Factor only captures residual ways in which the central bank announcements move long-term rates, once all the action at shorter maturities has been filtered out. The Path factor, on the other hand, picks up a combination of implicit communication of future intentions when the main policy instrument is the overnight rate, explicit forward guidance when this is used as a policy tool in its own right, and QE signalling, i.e. asset purchases signalling an intention to keep shorter term rates lower going forward. Hence, the results in Figure 4 should not be interpreted as indicating that there are no spillovers from ECB QE to the US curve; rather, that the Path factor is more effective at summarising the combination of ECB policy shocks, including QE, that are relevant for the US yield curve. Interestingly, it is in the responses of the US curve to ECB Path shocks that controlling for information effects is most important. Failing to account for this effect would produce even stronger spillovers. This result aligns with and extends the findings in Jarociński (2020) on the transatlantic interest rate spillovers of ECB information effects to unconventional policy as well.

Previous results in the literature have shown how US monetary policy shocks spill

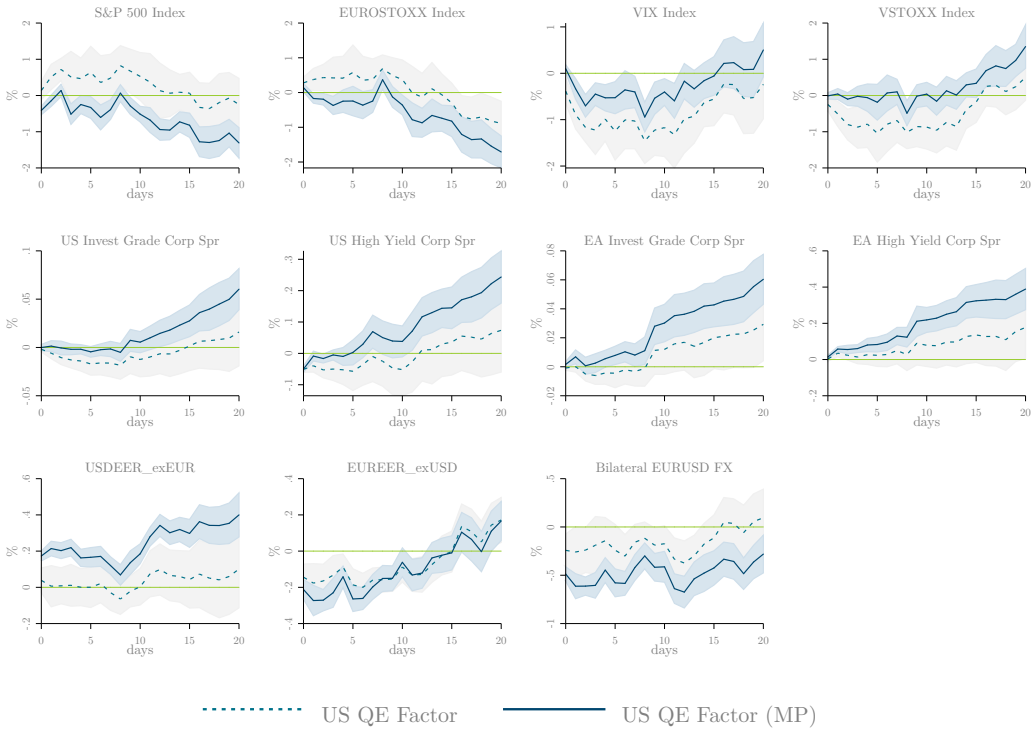
[6]The zero impact responses are mechanically induced by the different time zones at which decisions take place. The effects of Fed policies on European markets are visible from the day following that of FOMC announcements.

Figure 5: Response of Asset Prices to Unconventional US MP

(A) Fed Path Shocks



(B) Fed QE Shocks

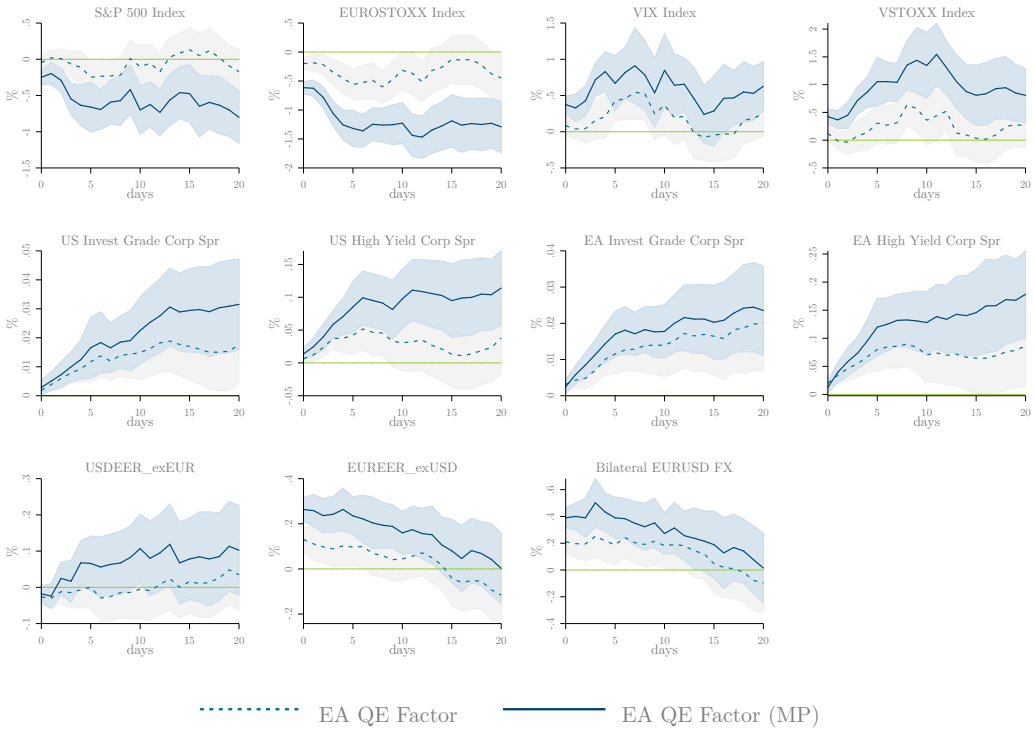


Notes: Daily projections. Sample 1999-01:2019-06. Shaded areas are one standard deviation bands.

Figure 6: Response of Asset Prices to Unconventional EA MP

(a) ECB Path Shocks

(b) ECB QE Shocks



Notes: Daily projections. Sample 1999-01:2019-06. Shaded areas are one standard deviation bands.

over to international financial markets by affecting global risk aversion and global stock markets. We confirm these results also for unconventional policies. Tighter US monetary policy, as captured by either factor, generally leads to a fall in global stock markets – both the S&P 500 and the EuroSTOXX fall –, and a rise of both $- and €-denominated corporate bond spreads (Figure 5). Not surprisingly, financial conditions tighten more for more financially constrained firms, with high-yield spreads responses being an order of magnitude larger than the corresponding investment-grade ones. The dollar appreciates significantly; a result that is consistent with findings in Inoue and Rossi (2019). This is the case both in bilateral terms against the euro, and generally relative to a broader basket of currencies. These results hold for both dimensions of unconventional policy; however, some important differences emerge. US asset purchases (as captured by the factor) generally do not lead to an increase in risk perceptions, suggesting they may be associated with a re-pricing of corporate debt through portfolio rebalancing, without affecting market risk attitudes per se. Instead, surprises to the US Path factor (capturing forward guidance and QE signalling) lead to higher risk perceptions (as captured by the implied volatility indices), consistent with the tightening of financial conditions. In Section 4 we dig deeper into this point and show that the response of the volatility indices is driven by a rise in risk aversion, as captured by a number of proxies proposed in the literature.

Figure 6 reports the responses of the same set of asset prices to ECB policies.[7] The first strong result that emerges is that ECB policies spill over to global financial conditions in similar ways to Fed policies. But that, as noted in the previous section, information effects are also much stronger for the ECB than they are for the Fed, and therefore, these results can only be appreciated once the confounding factors have been appropriately controlled for. ECB monetary policy tightenings, whether as captured by Path or QE shocks, lead to a contraction in global stock market indices (both the S&P 500 and the EuroSTOXX fall), and to a broad-based appreciation of the euro. The magnitude of the responses is also very similar to that elicited by equivalent Fed shocks.

US monetary policy contractions lead to a broad-based depreciation of the euro. In

[7]The ECB Governing Council switched to monthly meetings in 2002. Our results are robust to starting the sample after this date, see Appendix.

contrast, ECB tightening shocks are associated with a modest broad-based appreciation of the US dollar, beyond that in the bilateral FX. Coupled with the increase in risk perceptions, as captured by the rise in both the VIX and the VSTOXX, this points to the role of the dollar as a barometer of risk-taking by global financial intermediaries (Bruno and Shin, 2015; Avdjiev, Du, Koch and Shin, 2019; Georgiadis, Müller and Schumann, 2021), and further reinforces the potency of ECB policy spillovers via global risk attitudes (see also Dilts Stedman, 2019). The VIX and the VSTOXX increase substantially, and to a very similar degree.

ECB QE policies also lead to sustained tightening of international financial conditions. All corporate spreads rise, and the effects have equivalent magnitudes whether one considers either $-denominated or €-denominated debt. In contrast, ECB Path shocks have very modest and only marginally significant effects on risk and spreads. This suggests that it is the movements at the longer end of the European curve that are accounting for much of the rise in risk aversion globally. A point that we return to in the next section.[8]

Taking stock, the results in this section suggest that there is evidence of ECB and Fed unconventional monetary policy transmitting to international financial markets in very similar ways. That is, by affecting global risk perceptions, global assets valuations, and global financing costs. In the event-studies that we have discussed, also the magnitude of these spillovers is comparable to a very large extent. This suggests that the international risk-taking channel of monetary policy may be an active transmission channel for the policies of both central banks, a claim that we explore more in detail in the next section. One important source of asymmetry remains. The US dollar clearly displays the properties of a safe haven currency, and appreciates when risk perceptions rise, whereas this is not the case for the euro. In the next section we explore to what extent these spillovers extend to global macroeconomic and financial aggregates.

[8]The differential response of credit spreads may also be related to other differences in the liquidity and structure of corporate bonds markets in the two currency areas.

4 Global Spillovers of ECB and Fed Unconventional Monetary Policy

The literature on the spillovers of US monetary policy is large. Studies that have focused on conventional Fed Funds rate policies have found that global macroeconomic and financial aggregates significantly respond to US monetary policy shocks. The evidence is consistent with the spillovers operating through an international risk-taking channel, amplified and facilitated by the Global Financial Cycle, as well as through more standard trade channels (see e.g. Ha, 2016; Georgiadis, 2016; Dedola, Rivolta and Stracca, 2017; Degasperi, Hong and Ricco, 2020; Miranda-Agrippino and Rey, 2020; Miranda-Agrippino, Nenova and Rey, 2019).

The literature on the spillovers of ECB conventional policies is considerably sparser, and more mixed. In a recent paper, Ca' Zorzi et al. (2020) note how conventional ECB policies transmit mainly through trade channels, while the effects on global financial variables are less pronounced. Jarociński (2020) shows that transatlantic spillovers from ECB conventional policy to US aggregates goes mainly through information effects.

The evidence collected in the previous section, however, suggests that the financial crisis of 2008 may have marked an important break point, and that unconventional policies implemented by both the Fed and the ECB do indeed affect international asset prices in a very similar way and to a very similar extent. In this section we extend the analysis to global macroeconomic and financial aggregates and study to what extent these spillovers are similar also from a macro perspective.

In particular, as done in the previous section, we compare the spillovers of unconventional monetary policy shocks in the two areas on the same set of variables and over the same sample.[9] We estimate the spillovers using monthly VARs and identify monetary policy shocks in the two areas using the factors extracted in Section 2 as instrumental variables for the shocks. Given the absence of correlation among the factors (see Table 3), we use them each in isolation. As in Section 3, we distinguish between the total announcement effect (dotted lines in the figures that follow), and that due to monetary policy news only (solid lines) using the identification in Jarociński and Karadi (2020).

[9]The spillovers of conventional policies are equivalent to those in the literature and not reported.

The setup is identical for the US and EA. The VAR includes global output and global trade, global capital flows as a share of global GDP, the global factor in asset prices of Miranda-Agrippino et al. (2019), the VIX index, the bilateral €/$ exchange rate, and the domestic term structure slope, measured as the spread between the 10-year and 2-year rates. Variables definitions and sources are reported in the Online Data Appendix. Both VARs are estimated with six lags over the sample 2000-01:2018-12 with standard macroeconomic priors. We report results based on median impulse response functions, and normalised such that all shocks induce a steepening of the domestic yield curve that rises by 1% on impact.

The estimated spillovers of US and EA monetary policy shocks identified using the QE factors are reported in Figure 7, while those elicited by shocks to the Path factors are in Figure 8.[10]

The spillovers elicited by unconventional Fed policies are in line with what documented by Miranda-Agrippino and Rey (2020), and indicate that the global transmission channels of US monetary policy were not altered by the global financial crisis, or indeed by the introduction of unconventional monetary tools. A US monetary policy tightening operated via either type of policy depresses global activity and global trade and has dramatic effects on the variables that characterise the GFC: global asset prices fall, risk perceptions rise, and there is a strong retrenchment in global capital flows. The dollar appreciates against the euro.[11]

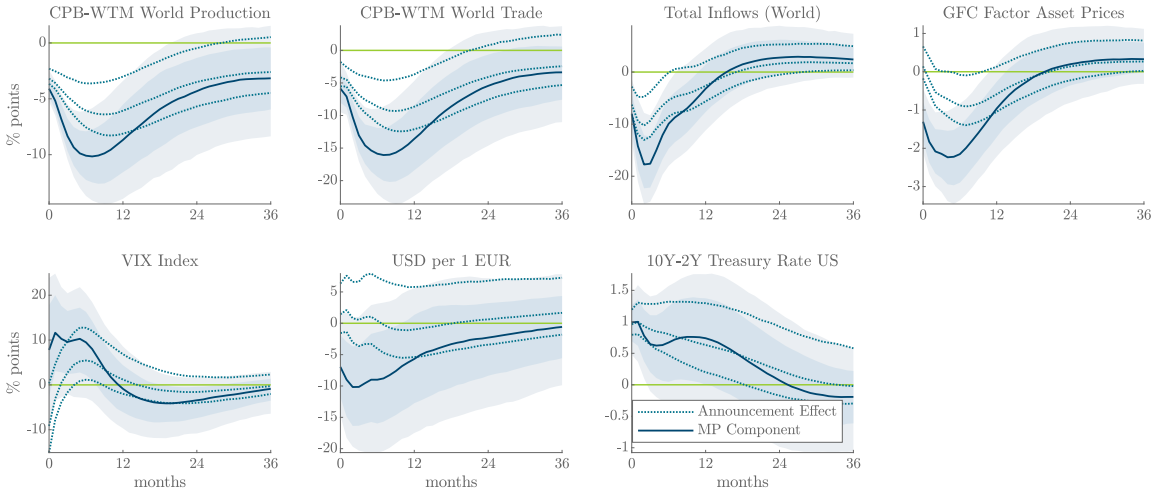
Importantly, however, the responses indicate that ECB monetary policy tightenings induce the same type of global spillovers, consistent with what was noted in the previous section. Namely, global production and trade contract and so do gross capital flows, global asset prices fall, and the VIX rises very significantly. The euro appreciates strongly. While the sign of the spillovers is equivalent to a very large extent, the magnitudes are sensibly

[10]Results are robust to starting the identification sample for ECB shocks in 2002 when the ECB Governing Council switched from bi-monthly to monthly meetings, see Appendix.

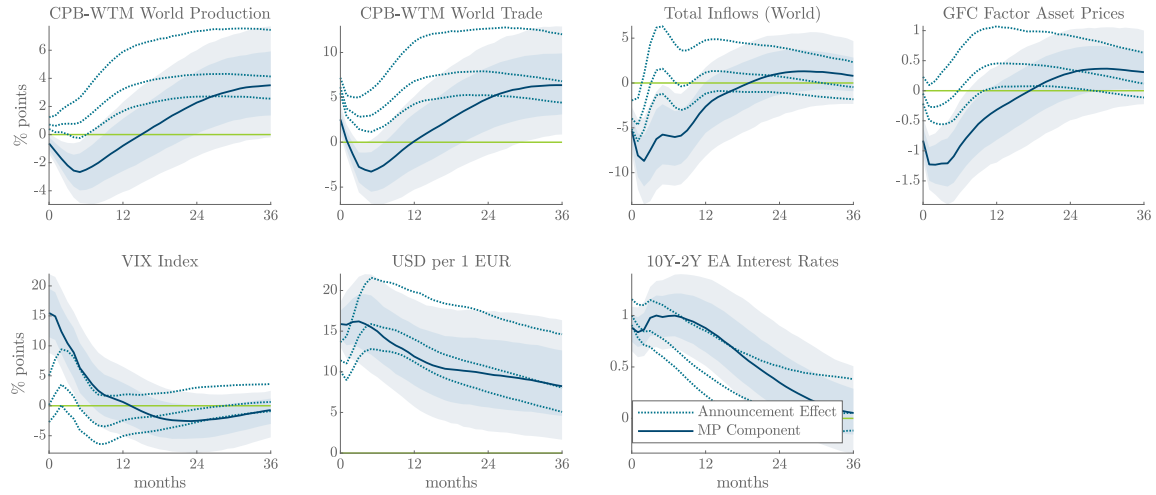
[11]Recent literature has noted that during some episodes Fed unconventional policies have led to counterintuitive responses of asset prices, including a depreciation of the US dollar after a Fed tightening (Stavrakeva and Tang, 2019; Gürkaynak et al., 2020; Cesa-Bianchi and Sokol, 2022; Jarociński, 2020). The counterintuitive responses are typically interpreted as due to information effects, an intuition consistent with what reported in Figure 7. The wider confidence bands around the exchange rate response to Fed QE shocks could be a manifestation of the time-variation documented in Stavrakeva and Tang (2019), but the short sample period since the introduction of the euro leaves us with too few observations to formally test for this in our set-up.

FIGURE 7: GLOBAL SPILLOVERS OF FED AND ECB QE SHOCKS

(A) Fed QE Shocks.



(B) ECB QE Shocks.

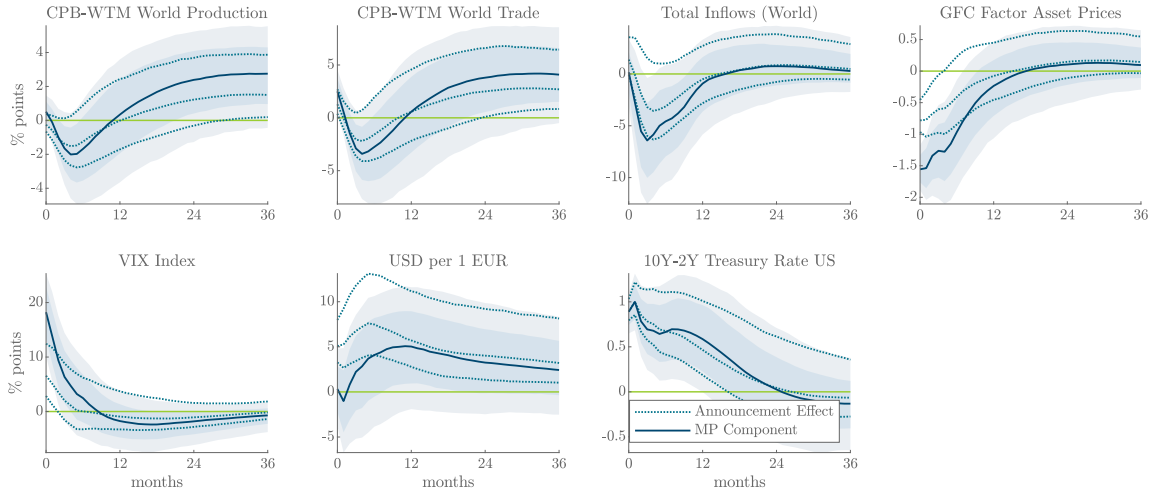


Notes: Median IRFs with 68% and 90% posterior credible sets. All announcements (dotted lines), monetary policy news (solid lines). BVAR(6). 2000:01-2018:12.

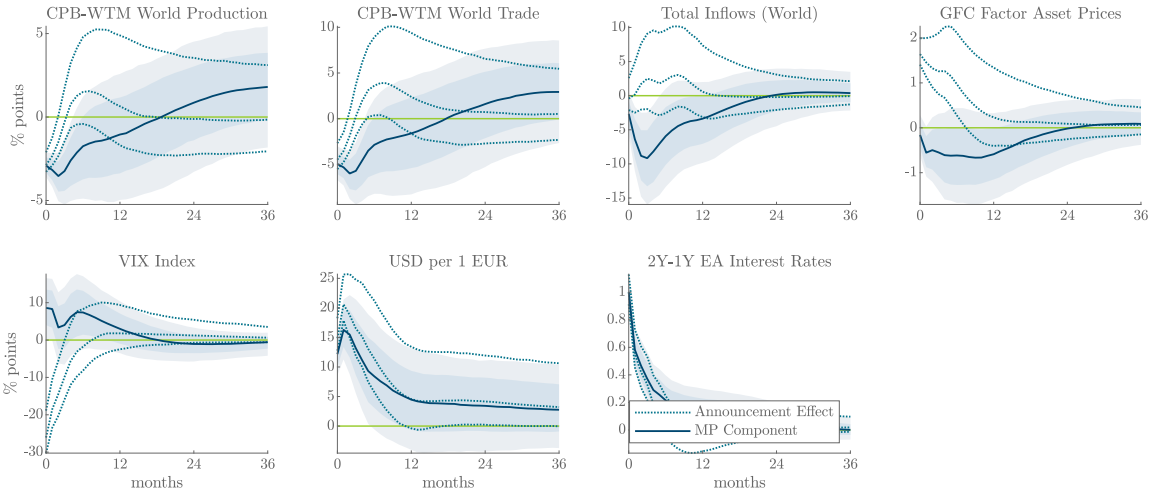
smaller in some cases. For QE shocks (Figure 7), the peak decline in global output and trade is about a third of the size of that elicited by equivalent Fed shocks. Similarly, the contraction in global inflows and asset prices is only about half the size relative to the US case. This does not hold across the board; for the VIX and the bilateral exchange rate the peak responses are in fact larger following ECB QE shocks. The effects of forward guidance and other policies affecting the Path factor elicit qualitatively similar spillovers

FIGURE 8: GLOBAL SPILLOVERS OF FED AND ECB PATH SHOCKS

(A) Fed Path Shocks.



(B) ECB Path Shocks.



Notes: Median IRFs with 68% and 90% posterior credible sets. All announcements (dotted lines), monetary policy news (solid lines). BVAR(6). 2000:01-2018:12.

relative to QE (Figure 8). However, the magnitudes are smaller and the effects tend to die out more quickly. Again, we note how confounding factors are more pervasive for ECB policies.[12]

We examine more in detail the extent to which global spillovers reflect bilateral con-

[12]For ECB Path shocks we instrument a 'mini-slope' constructed as the spread between 2 and 1 year yields. The first-stage F statistics reveal that the Path ECB factor is a weak instrument for the standard slope (F-stat=5.393 with 10Y-2Y slope, vs F-stat=10.181 with 2Y-1Y). The opposite holds true for Fed Path shocks (F-stat=9.432 with 10Y-2Y, vs F-stat=0.016 with 2Y-1Y).

tamination between the two areas in Figure 9. To this end we replace some of the global variables in the VAR with their domestic counterparts for both the US and EA. Namely, industrial production, trade, capital inflows (as % of domestic GDP), and the two implied volatility measures as proxies for risk aversion.[13] As in the baseline global VARs, we also include the global factor in asset prices, the bilateral exchange rate, and the relevant yield curve slope.

Following a US monetary policy contraction, US and EA production and trade contract to a very similar degree. Gross inflows in the Eurozone contracts strongly – more so than global inflows depicted in Figure 7 – suggesting that cross-border investment into the EA is especially sensitive to US monetary policy. There is however large uncertainty around the estimated response functions to Fed QE shocks.

In response to an ECB monetary policy tightening global production falls by about 3pp at peak, while global trade by as much as 4pp (Figure 7). The bilateral spillovers from ECB policies in Figure 9 reveal that the magnitude of the response of US variables is comparable to that of global aggregates. ECB QE shocks have much stronger effects on domestic variables, with peak effects more than double those in the US. Similarly, the peak effect of global inflows is of the order of 10pp. This magnitude is comparable to the peak effect of US inflows, and half the size of the peak response of EA inflows. In all, our results are consistent across specifications, and indicate that the bilateral spillovers of ECB monetary policy to the US are a significant component of the global ones. But that the domestic responses are much stronger, pointing to potential significant heterogeneity in the response of equivalent variables in other countries.

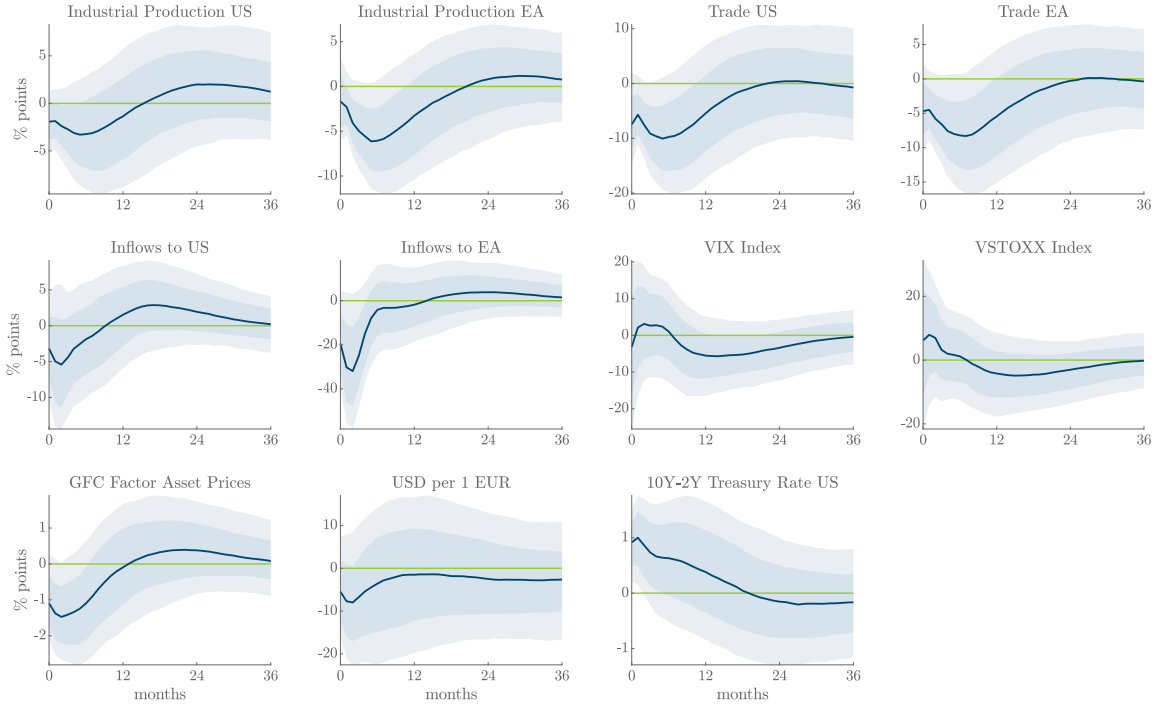
In order to shed more light on the likely transmission mechanisms behind our results, we analyse more in detail the role that both monetary policies play in shaping risk aversion in global markets. As noted, ECB shocks tend to be less powerful than Fed ones when considering the spillovers to real aggregates. Conversely, the response of financial markets is at least as strong as, if not more so, when considering ECB shocks, such as for example in the case of the VIX.[14] This points to the presence of a powerful international risk-taking channel for both Fed and ECB policies.

[13] We discuss the responses of alternative proxies of risk aversion in Figure 10.

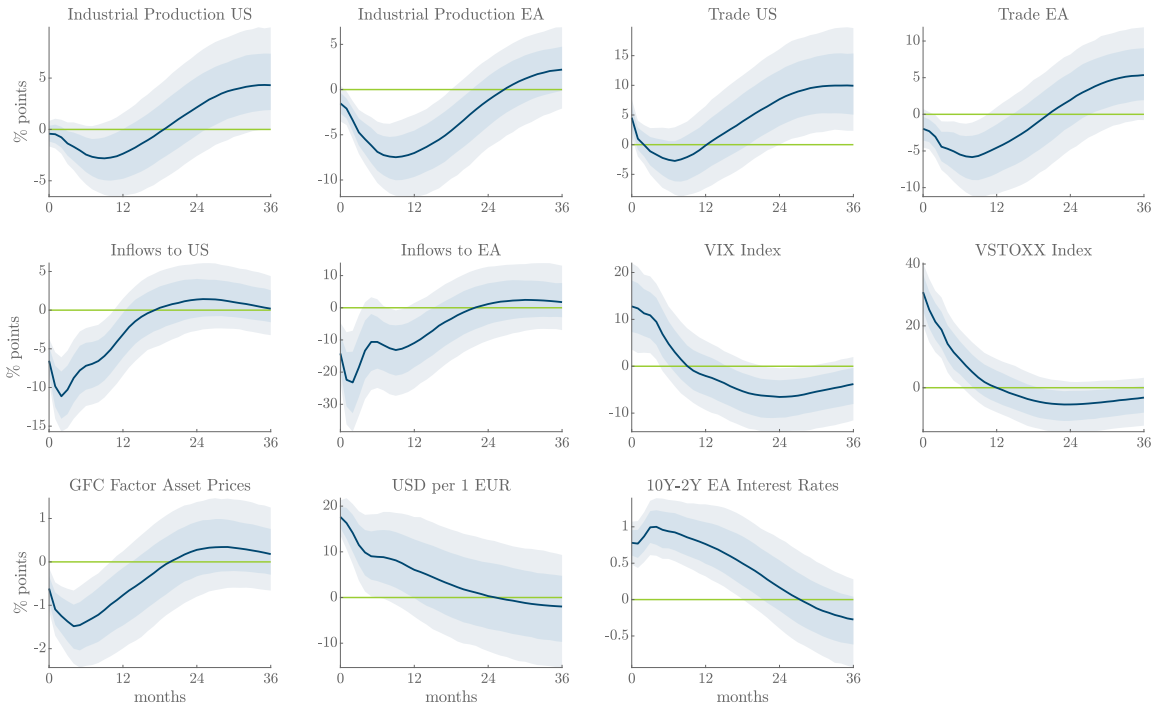
[14] Equivalent response are obtained when the VIX and VSTOXX are substituted by the Goldman Sachs financial conditions indices for the US and EA, see the Appendix.

Figure 9: Bilateral EA/US Spillovers to QE Shocks

(a) Fed QE Shocks.



(b) ECB QE Shocks.



(c) *Notes:* Median IRFs to monetary policy shocks with 68% and 90% posterior credible sets. BVAR(6). 2000:01-2018:12.

We explore this channel more in detail in Figure 10. While implied volatility measures such as the VIX are routinely used to proxy for risk aversion, they also embed a concept of physical risk. Bekaert, Hoerova and Lo Duca (2013) and Bekaert, Engstrom and Xu (2019) separate these components of the VIX empirically, by using estimates of realised market variance to capture physical risk. Along similar lines, Miranda-Agrippino and Rey (2020) estimate a proxy for global risk aversion using their estimates of the global component of asset prices. In their baseline estimate, they control for global markets realised variance only; but they also provide a refined measure that also controls for future expected global GDP growth and discount rates. The figure reports the response to Fed and ECB QE shocks of a number of different proxies for risk aversion. The impulse response functions are obtained by sequentially substituting a different risk aversion variable in place of the VIX in the same VAR, the composition of which is equal to our benchmark global VARs (i.e. those of Figure 7). The measures we consider are: the proxies for risk aversion in Bekaert et al. (2013) and Bekaert et al. (2019), those in Miranda-Agrippino and Rey (2020), and a measure of global risk appetite distributed by Cross-Border Capital Ltd and calculated as the difference between global equity and bond balance sheet exposures across all investors.

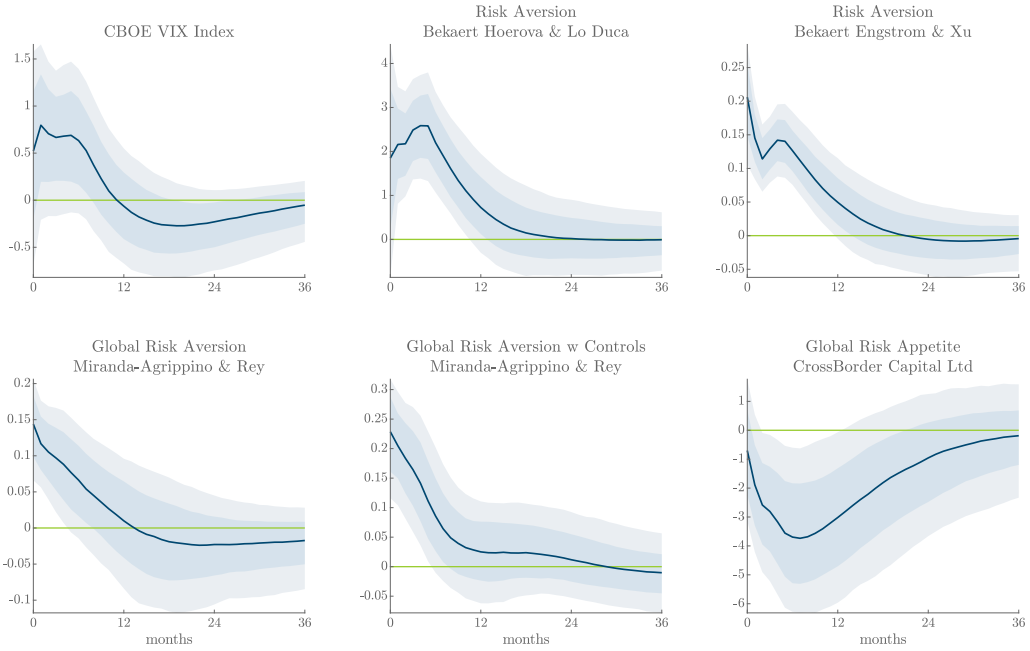
The charts in Figure 10 paint a consistent picture throughout. Monetary policy tightenings in the two areas significantly raise risk aversion (reduce global risk appetite), and this finding is robust to using different measures and samples.[15] Very importantly, while the existence of an international risk-taking channel had been documented only for US monetary policy, we show that this is indeed an active channel for the international transmission of ECB monetary policy shocks as well. This finding helps to rationalise our results on the global financial spillovers of ECB monetary policy.

To summarise, Fed unconventional monetary policy shocks spill over significantly to global financial and real variables. Controlling for central bank information effects helps us to better characterise these spillovers. Our estimates lead to the novel finding that unconventional policies by the ECB also affect global financial conditions and real variables

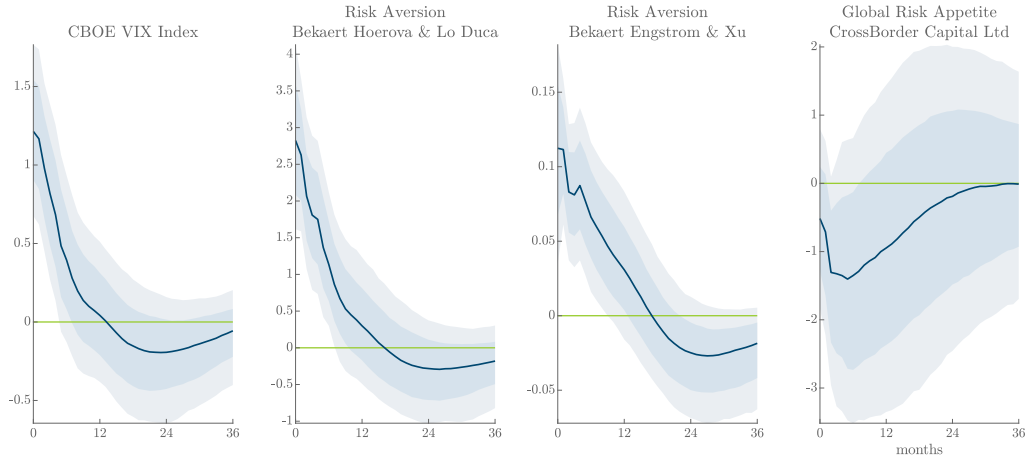
[15]The sample over which the responses are calculated varies, and is dictated by data availability. We do not report the response of the risk aversion proxies of Miranda-Agrippino and Rey (2020) to ECB QE shocks due to the fact that these are only available until December 2012, which is incompatible with the timing of ECB QE announcements.

FIGURE 10: RESPONSE OF RISK AVERSION AND RISK APPETITE

(A) Fed QE Shocks.



(B) ECB QE Shocks.



(C) *Notes:* Median IRFs to monetary policy shocks with 68% and 90% posterior credible sets. BVAR(6) with baseline specification as in Figure 7 and each risk aversion measure substituted in turn. 2000:01-2018:12.

in a similar manner as Fed policies, albeit to a more moderate degree for real variables such as output and trade. An important share of the global spillovers of the policies of either central bank is accounted for by the bilateral ones. Finally, and importantly, ECB

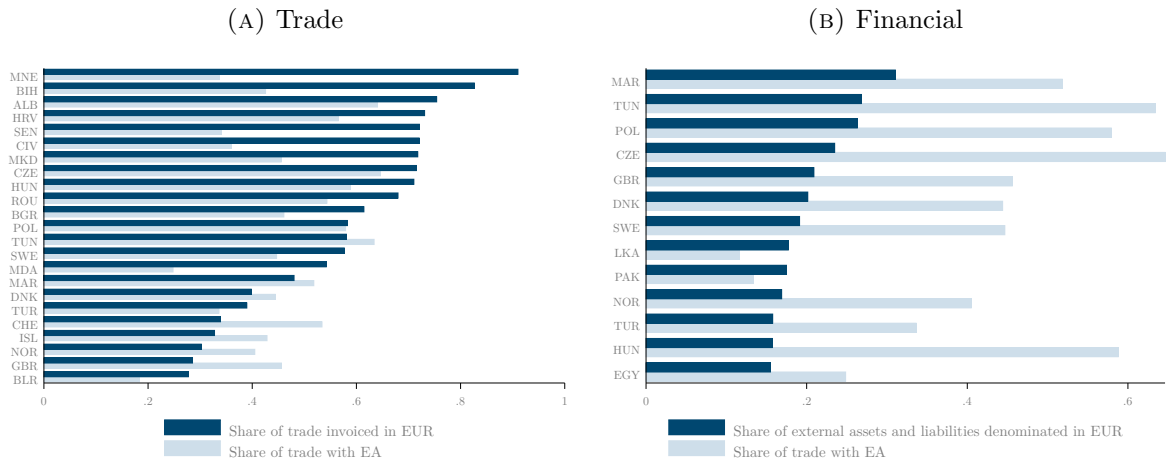
policy spillovers to financial markets and aggregates are powerful. Risk aversion rises robustly and to an equivalent extent following a monetary policy tightening in either area; this is consistent with the implications of an international risk-taking channel for the transmission of the monetary policies of both the Fed and the ECB.

5 The International Role of the Euro and ECB Monetary Transmission

In the previous sections we have shown how ECB and Fed spillovers transmit internationally through both risk-taking and more standard trade channels. On the balance, the spillovers to macroeconomic and financial aggregates of the monetary policies of the two central banks are equivalent in terms of sign and significance to a very large extent. However, we have noted how ECB spillovers to global output, trade and gross inflows tend to be about half or even a third of the size of those elicited by equivalent Fed shocks. Given the relatively similar size of the US and EA in terms of world output and trade, we postulate that a potential explanation for the different magnitude of the spillovers can be found in the relative positioning of the US dollar and the euro in the international monetary and financial systems (see e.g. ECB, 2020, and Appendix).

Building on intuitions developed in an influential strand of the literature (Gopinath et al., 2020; Ilzetzki et al., 2019; Gopinath, 2016; Lane and Shambaugh, 2010), in this section we explore more in detail the role that € invoicing and financial exposures play in the international transmission of ECB monetary policy shocks. In particular, we evaluate the response of output, trade, and capital flows in the countries that use the euro as an invoicing currency, or have external assets and liabilities denominated in euros, and compare them with the responses of the global variables estimated in Section 4. In order to identify the largest euro users we rely on the information in two new datasets that collect historical information on the currency usage for trade and financial transactions by a large and diverse sample of countries. In particular, we use the data on currency pricing of external trade of Boz, Casas, Georgiadis, Gopinath, Mezo, Mehl and Nguyen (2020), and data on the currency denomination of cross-border assets and liabilities of

FIGURE 11: SHARES OF € EXPOSURE



Notes: [Left] Weighted average of the share of imports and exports invoiced in euro (dark bars) for top tercile of € exposure relative to share of trade with EA (light bars). [Right] Weighted averages of the share of external assets and liabilities denominated in euros (dark bars) for top tercile of € exposure relative to share of trade with EA (light bars). All shares calculated as simple averages over all years with available data for each country.

Benetrix, Gautam, Juvenal and Schmitz (2020).

Figure 11 reports the top international € users for what concerns trade invoicing (left panel), and the denomination of external assets and liabilities (right panel). Invoicing shares are constructed as weighted averages of the share of imports and exports invoiced in euros, as reported in Boz et al. (2020). Similarly, financial exposures are calculated as weighted averages of the share of external assets and liabilities denominated in euros, as reported in Benetrix et al. (2020). The shares are relative to all other currencies used. The average use of the euro for trade invoicing falls short of that of the US dollar. However, the euro is the dominant currency for invoicing in a significant subset of countries. And in many cases it well exceeds the share of trade with EA counterparts. These heavy euro users are primarily European countries outside of the EA, as well as countries in nearby North and Western Africa. We note that while the share of external trade invoiced in euros can be sizeable, and up to 80% of the total, the share of external assets and liabilities denominated in euros barely reaches 30% of the total even for the 'heavy' euro users.

A note of caution is in order. The choice of currency is intimately connected to both trade and financial linkages, such that it reasonable that countries that have stronger ties

with the Eurozone may be more prone to use the euro to price their transactions. For each of the top euro users, Figure 11 also reports the share of that country's external trade with counterparts in the EA (light bars). As expected, there exists a positive correlation between these measures. In the case of trade invoicing, the correlation with the share of trade with the EA is 0.404 but not significant at conventional levels. For the pricing of financial transactions instead the correlation is significant at 5% level, but relatively weak in magnitude (equal to 0.165). Thus, while the euro usage can proxy for the strength of trade and financial linkages, the weak correlations suggest that there is scope for a currency channel that operates above and beyond these standard ones to exist. It is also possible that other forms of business cycles synchronisation may be picked up by our analysis, also due to the geographical location of the euro users. Ideally, we would like to isolate the role played by currency use once all these confounding factors are accounted for. Equally, our data only covers currency use partially. Other dimensions that we cannot account for due to data availability are, for example, the euro's role in bilateral payments as well as in derivatives transactions.[16] With these caveats in mind, we turn to analyse how ECB monetary policy shocks affect these heavy euro users, relative to the rest of the world.

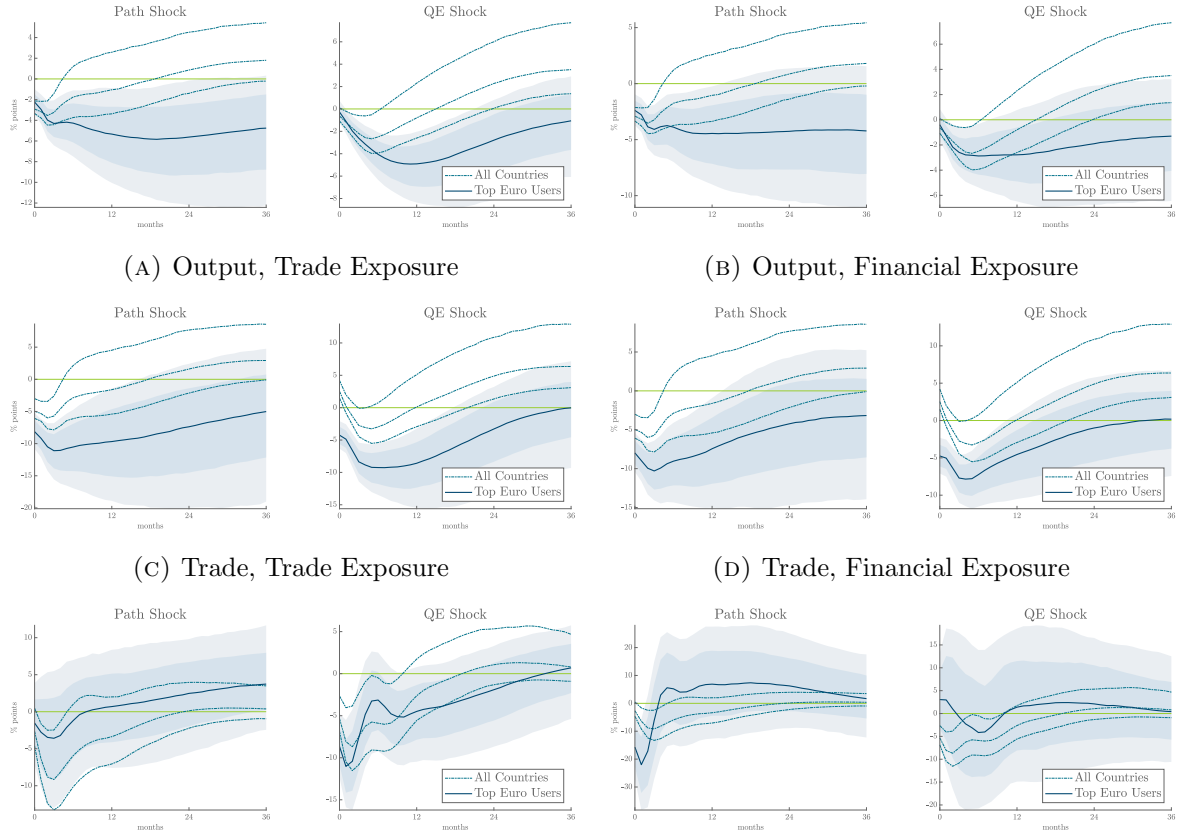
Figure 12 reports the results. We construct aggregates for the top euro users as weighted sums of individual country series, where the weights denote the relative euro exposure; for countries where invoicing or denomination shares are provided for multiple periods, we use the average share over all available periods to construct the weights.[17] All details on the construction of the data are reported in the Online Data Appendix.

The composition of the VARs is the same as in the previous section, with the exception that world aggregates are replaced with those computed for the subsets of heavy euro users. The dash-dotted lines are the responses estimated in Section 4, and IRFs are only reported for the announcements classified as monetary policy events.

[16] We use the currency shares reported for total assets and liabilities, which include foreign direct investment, international portfolio debt and equity holdings, cross-border bank lending as well as official foreign exchange reserves.

[17] We follow the approach in Boz et al. (2020), as the sparser time coverage for some countries would restrict the cross section considerably. Boz et al. (2020) note that the shares are exceptionally stable from 2000 onwards, with the exception of some European countries in the neighbourhood of the EA, for which they have increased considerably. All these countries are included in our sample of top euro invoicers.

FIGURE 12: € EXPOSURE AND ECB MP SPILLOVERS



(A) Output, Trade Exposure

(B) Output, Financial Exposure

(C) Trade, Trade Exposure

(D) Trade, Financial Exposure

(E) Capital Inflows, Trade Exposure

(F) Capital Inflows, Financial Exposure

Notes: Median IRFs with 68% and 90% posterior credible sets. All countries (dash-dotted lines), top € users (solid lines with shaded areas). BVAR(6). 2000:01-2018:12.

The responses in the figure suggest that countries that rely more on the euro tend to be more sensitive to ECB monetary policy shocks relative to world aggregates. This is particularly visible in the response of external trade and could reflect the positive association between euro exposure and trade shares with EA counterparts that we noted at the onset. Similarly, the heavy euro users tend to experience more persistent falls in output relative to the rest of the world.

Consistently, countries that have larger financial exposure to the euro experience a significantly more severe contraction in capital inflows relative to the rest of the world following ECB Path shocks. However, in general the responses for this subset of countries do not deviate significantly from world aggregates in most cases. This is likely a consequence of the relatively low share of international financial exposures denominated

in euros, even for the heavy euro users.

Overall, our results are consistent with the intuition that currency usage in international transactions could be one important channel for the international transmission of monetary policy shocks, and could help us understand the different magnitudes of monetary policy spillovers from the Fed and the ECB. The analysis presented here is, of course, not a formal test of the role of one channel of transmission over all others. As noted, currency usage and economic links often go hand-in-hand. But our results speak to a growing body of evidence that the currency of trade and financial transactions plays an important role in the international transmission of shocks both due to the economic links that currency choice reflects, and in its own right.

6 Conclusions

In this paper we have compared the international spillovers of ECB and Fed unconventional monetary policies. We find that monetary policy tightenings in either area are followed by a fall in global activity and trade, global retrenchments in capital flows, a fall in global stock market indices, and a rise in global risk aversion. The local currency appreciates strongly, and credit spreads rise, both domestically and internationally. Global spillovers reflect in large part bilateral ones. However, ECB global spillovers are smaller in magnitude, particularly when considering the response of real aggregates.

Having documented the existence of an equally powerful international risk-taking channel for the transmission of both monetary policies, and provided that the US and the EA contribute to global output and trade roughly in equal measure, we postulate that the difference in the magnitude of the spillovers is to be found, at least in part, in the different positioning of the US dollar and the euro in the international monetary and financial systems. In line with recent literature, we provide tentative evidence that links the strength of ECB spillovers to countries' exposure to the euro, for both trade invoicing and the pricing of international financial transactions.

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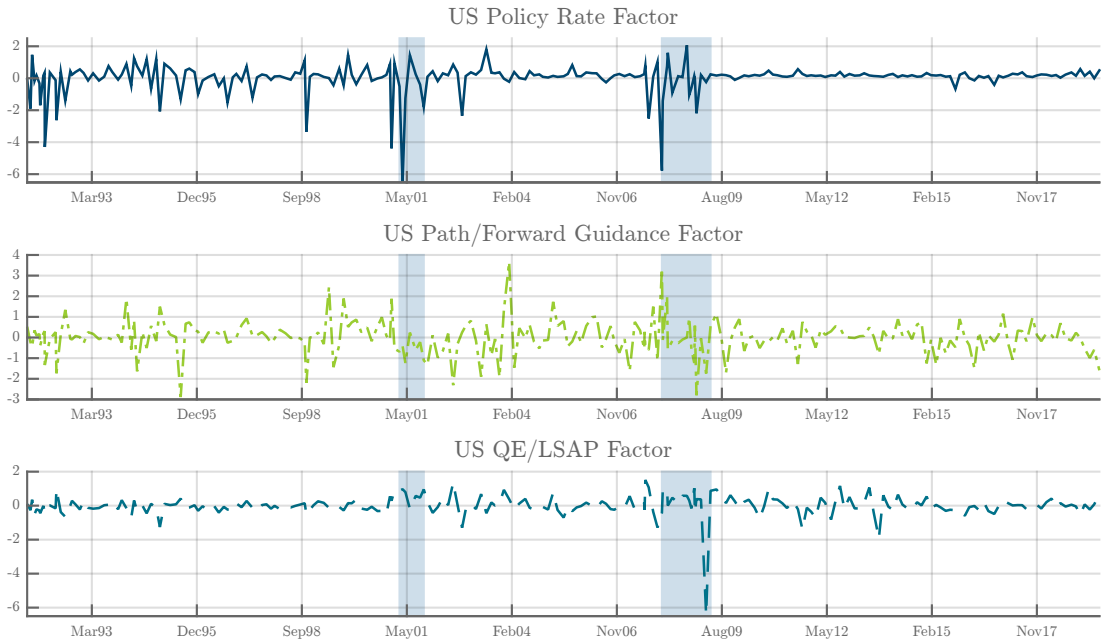
A Additional Results

Table A.1: Summary Statistics

	N	Mean	Std. Dev	Min	Max
US Sample					
Target Factor	172	0.041	0.934	-6.538	2.068
Path Factor	172	-0.014	0.880	-2.798	3.664
QE Factor	172	0.035	0.697	-6.406	1.514
EA Sample					
Target Factor	261	0.026	0.782	-4.600	3.720
Path Factor	261	-0.019	0.780	-3.757	3.678
QE Factor	261	-0.011	0.858	-3.291	5.145

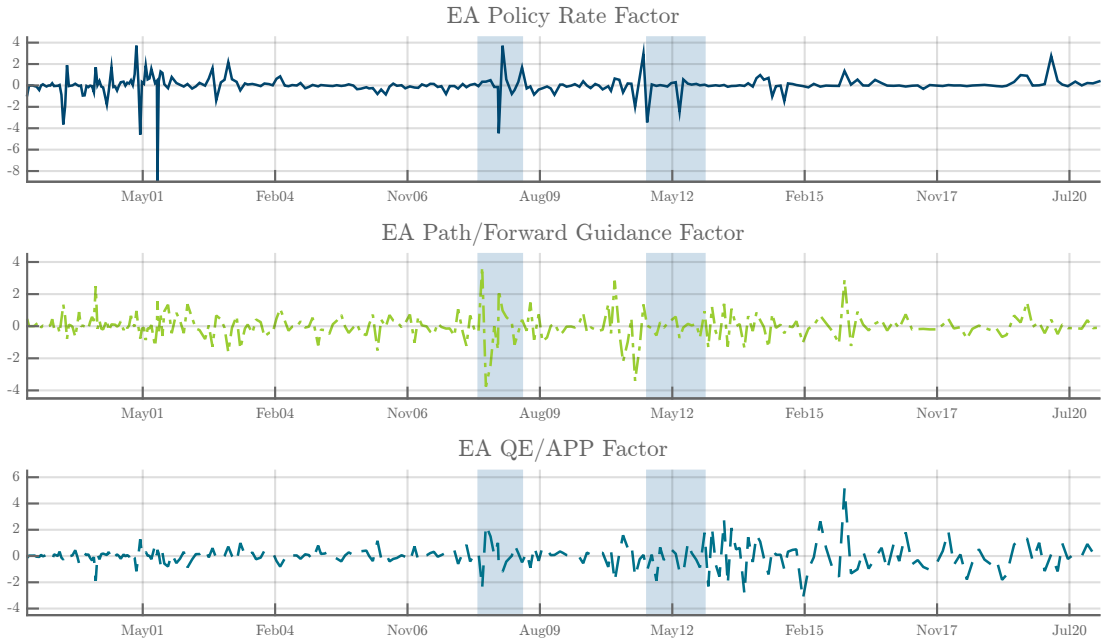
Notes: Factors extracted as in Swanson (2021). The sample includes all FOMC and ECB Governing Council (GC) announcements from Jan-1999 to Jun-2019.

Figure A.1: Monetary Policy Factors, US



Notes: Dimensions of Fed monetary policy. Estimation follows Swanson (2021).

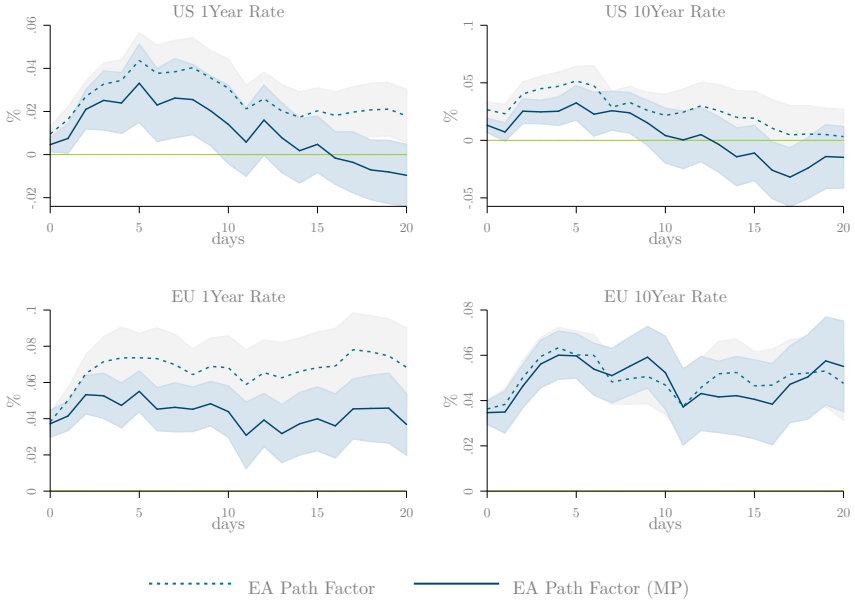
Figure A.2: Monetary Policy Factors. EA



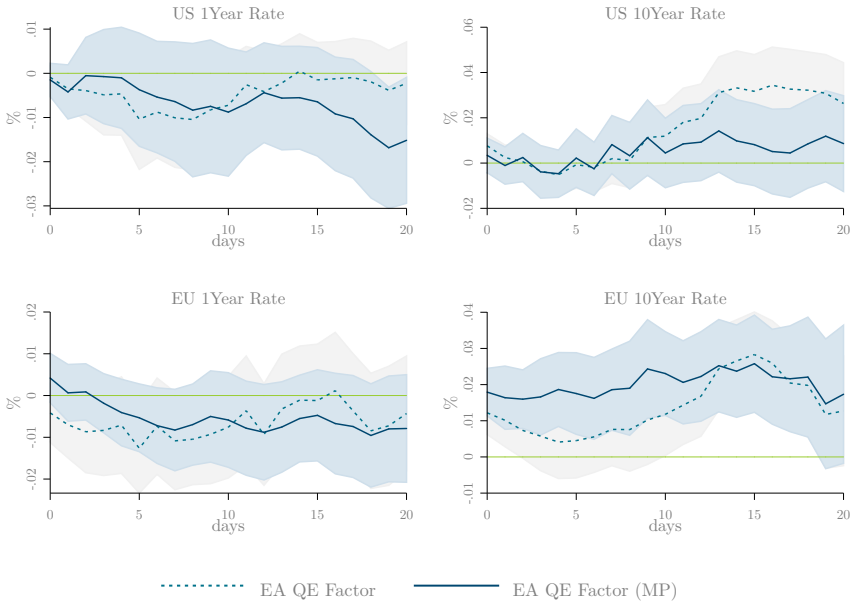
Notes: Dimensions of ECB monetary policy. Estimation follows Swanson (2021).

Figure A.3: Response of US & EA Yield Curve to ECB Shocks – post-2002

(a) EA Path Shocks.



(b) EA QE Shocks.

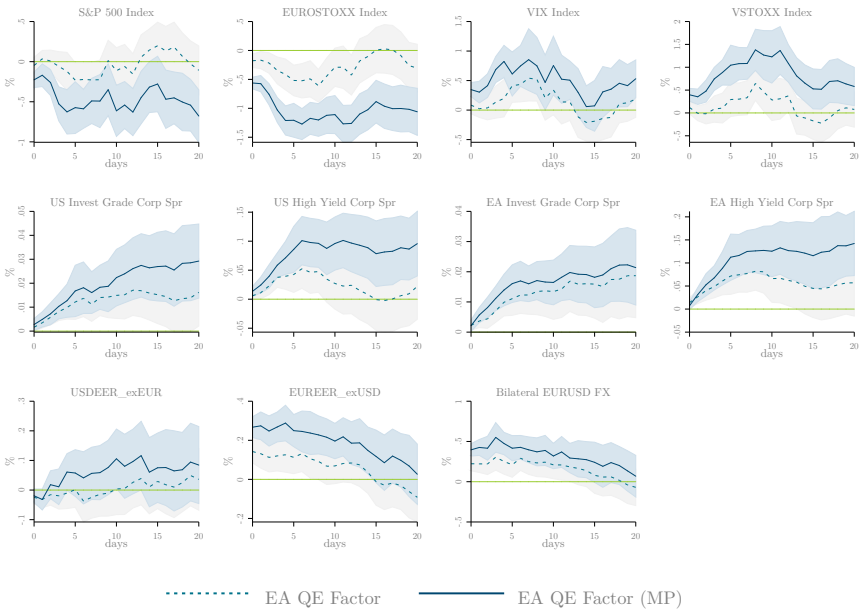


Notes: Daily projections. Sample 1999-01:2019-06. Responses to full announcement (dotted lines), and to monetary news only (solid lines). Shaded areas are one standard deviation bands.

FIGURE A.4: RESPONSE OF ASSET PRICES TO ECB SHOCKS – POST-2002

(A) EA Path Shocks.

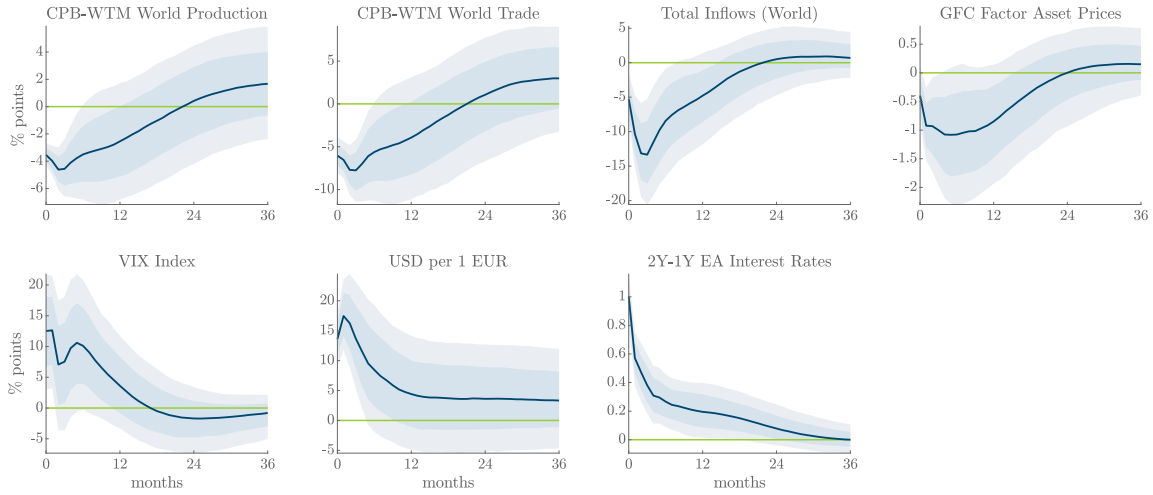
(B) EA QE Shocks.



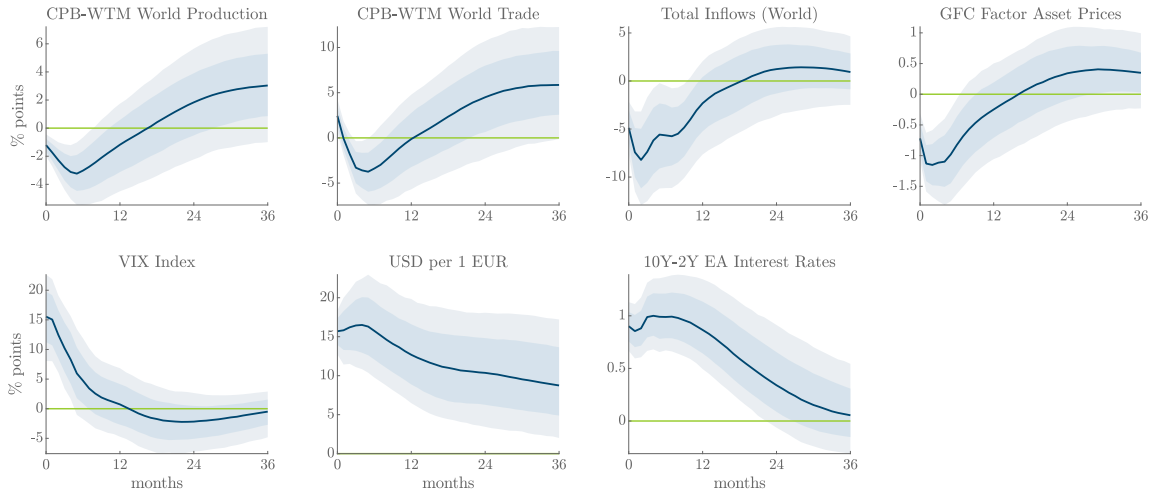
Notes: Daily projections. Sample 1999-01:2019-06. Responses to full announcement (dotted lines), and to monetary news only (solid lines). Shaded areas are one standard deviation bands.

Figure A.5: Spillovers of ECB Shocks – post-2002

(a) ECB Path Shocks.



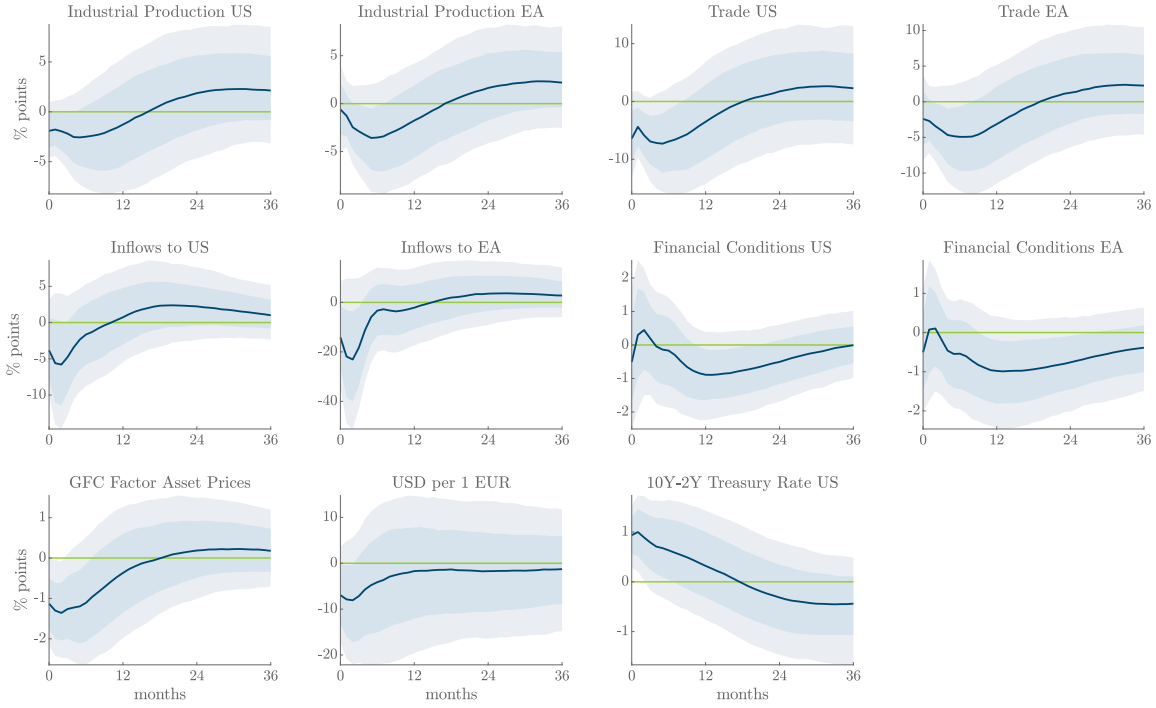
(b) ECB QE Shocks.



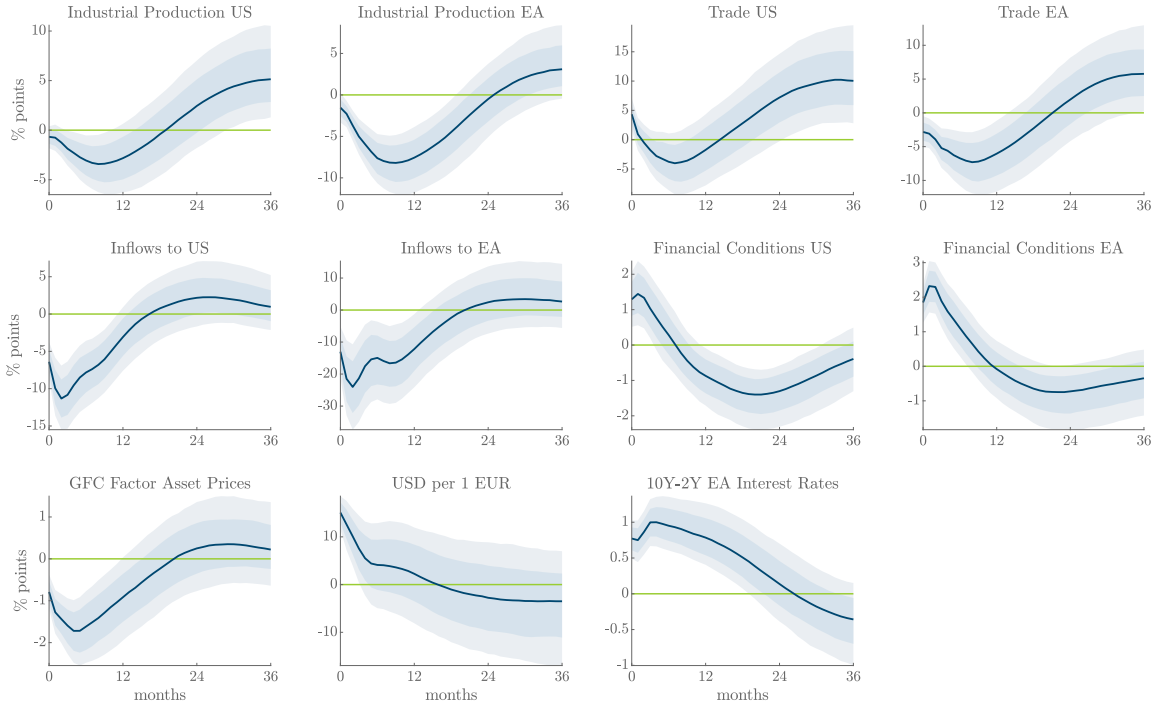
Notes: Median IRFs with 68% and 90% posterior credible sets. All announcements (dotted lines), monetary policy news (solid lines). BVAR(6). 2002:01-2018:12.

Figure A.6: Bilateral EA/US Spillovers – Financial Conditions

(a) Fed QE Shocks.

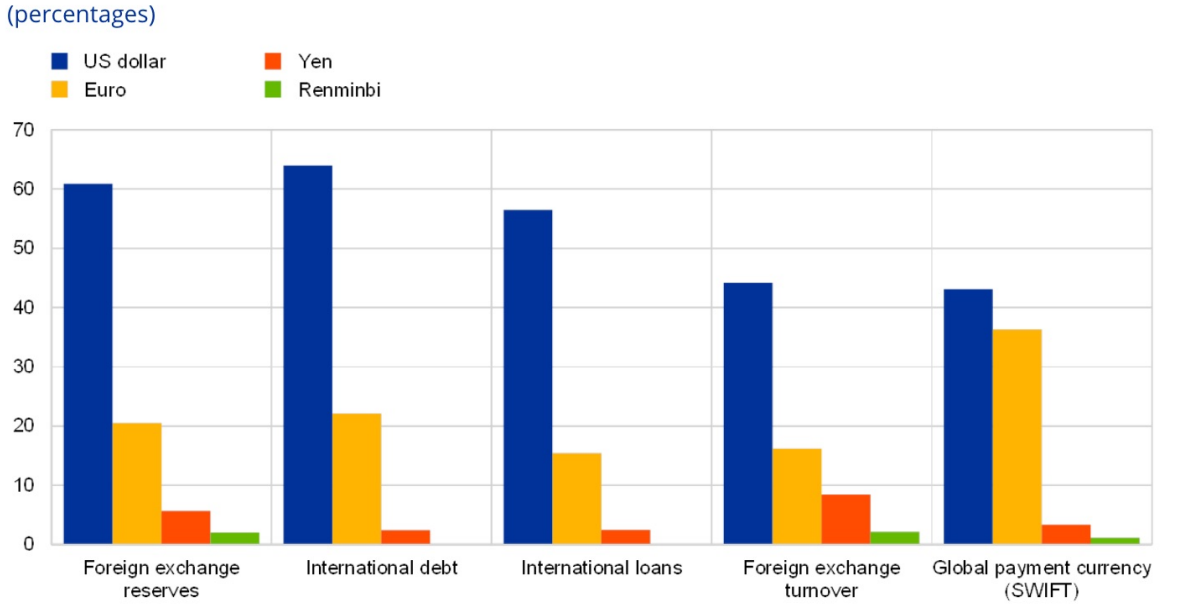


(b) ECB QE Shocks.



(c) *Notes:* Median IRFs to monetary policy shocks with 68% and 90% posterior credible sets. BVAR(6). 2000:01-2018:12.

FIGURE A.7: INTERNATIONAL USE OF MAJOR CURRENCIES



Sources: BIS, IMF, SWIFT and ECB calculations.Note: The latest data are for the fourth quarter of 2019.

Source: ECB (2020).