International spillovers of the Fed and ECB monetary policy surprises*

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Abstract

This paper uses a structural vector autoregression identified with the high frequency approach to study the international spillovers of the Fed and ECB monetary policy surprises. It distinguishes between the news about monetary policy (monetary policy shocks) and news about the economy in these surprises. The paper finds that the Fed monetary policy shocks have a very strong effect on the euro area, mainly through financial channels rather than through trade. By contrast, the ECB monetary policy shocks have no detectable effect on the US. The news about the state of the economy affect the risk appetite of global investors, with significant implications for the capital flows and financial conditions.

JEL Classification: E52, F31, F42

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1 Introduction

How does the Fed's monetary policy affect the euro area? How does the ECB's monetary policy affect the US? These questions matter for interpreting economic developments and for policy, e.g. for understanding the scope for international coordination of monetary policies. This paper studies

*The opinions in this paper are those of the author and do not necessarily reflect the views of the European Central Bank.

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these questions using a state-of-the-art approach for identifying monetary policy shocks: the high frequency identification. In this approach, initiated by Kuttner (2001), financial market responses to central bank policy announcements serve to isolate the unexpected component of monetary policy. A growing literature follows this approach to identify monetary policy shocks and track their effect on asset prices (Kuttner, 2001; Gürkaynak et al., 2005; Gürkaynak et al., 2005; Bernanke and Kuttner, 2005) and the macroeconomy (Barakchian and Crowe, 2013; Gertler and Karadi, 2015; Nakamura and Steinsson, 2013; Paul, 2017). Recently, Jarociński and Karadi (2018) refine the standard high frequency identification and distinguish between *two* shocks in the announcements: monetary policy shocks and central bank information shocks, which capture the information effects studied among others in Nakamura and Steinsson (2013) and Melosi (2017). The present paper finds that distinguishing between monetary policy shocks and central bank information shocks is useful for understanding international spillovers.

Identification is crucial, and this paper uses two alternative identification schemes. The goal is to address the main obstacle for econometric estimation of the effects of monetary policy, namely that this policy mostly involves endogenous responses to the economic developments. The VAR literature isolates the exogenous part of monetary policy, monetary policy shocks, by imposing certain assumptions about what variables central banks respond to. High frequency identification arguably achieves more precision than the standard VAR approaches, as market participants are likely to understand the reaction function of the central bank quite well. When the central bank announces its policy, markets have already priced in the systematic response to the economic developments, so interest rate derivatives will only move to the extent a monetary policy shock is present. The market's view of the reaction function of the central bank can be quite sophisticated, nonlinear, and include all real-time information, so it is much refined compared with the reaction function in a typical VAR. In this paper, the first identification approach is the standard high frequency identification along the lines above, and the shocks obtained with this approach are called 'interest rate surprises'.

The second identification approach, following Jarociński and Karadi (2018), is motivated by the observation that central bank policy announcements contain two distinct pieces of information. First, they contain news about current and future monetary policy. Second, they explain the central bank's assessment of the economic outlook. The surprises in this assessment, or central bank information shocks, affect the financial markets and the economy independently and distinctly from the monetary policy shocks. The interest rate surprise from the first approach will not be a pure monetary policy shock, because the central bank responds to its own assessment, and that response is endogenous policy and not part of the monetary policy shock. The presence of the central bank information shocks is manifested in the empirical observation, documented in Jarociński and Karadi (2018), that the co-movement of interest rate and stock price responses to central bank announcements is sometimes negative and sometimes positive, while the theory predicts that it should always be negative if the announcements conveyed only monetary policy shocks.

This paper estimates the impulse responses of euro area variables to Fed's monetary policy and information shocks, and of the US variables to ECB's monetary policy and information shocks. Four main findings emerge. First, Fed's monetary policy shocks spill over very strongly to the euro area, in the sense that the euro area variables respond to this shock similarly to the US variables. Second, the international transmission is mainly by financial channels: interest rate spreads of all sorts respond strongly to Fed's shocks, while trade in goods and services play little role in the transmission. Third, ECB's monetary policy shocks have no discernible effect on the US variables. Fourth, Fed's and ECB's information shocks are 'risk-on' shocks, such that good news depreciate the US dollar and reduce spreads in the US and the euro area (and vice versa for bad news).

The decomposition into monetary policy shocks and central bank information shocks explains two puzzles of the standard high frequency approach: 1) lack of response of the dollar/euro exchange rate to the Fed's interest rate surprises and 2) positive response of the US economy to positive ECB interest rate surprises.

The dollar/euro exchange rate does not respond significantly to the Fed's interest rate surprises, because, in light of the decomposition, these interest rate surprises are a mix of monetary policy and information shocks that move the exchange rate in the opposite directions. The dollar appreciates upon positive interest rate surprises driven by monetary policy shocks, and depreciates upon positive interest rate surprises driven by positive Fed information shocks. The finding that the US dollar depreciates on good news (and appreciates on bad news) is a reflection of its 'safe haven' status, at least in much of the sample studied here, which is 1999-2017.

The positive response of the US economy to positive ECB's interest rate surprises is a result of the weak spillovers of the ECB's monetary policy and strong spillovers of the ECB information shocks. A positive ECB's interest rate surprise affects the US only if it reflects the ECB's response to positive news, and hence the spillover is positive.

This paper's findings echo with many results in the literature. A large literature studies spillovers of the Fed's monetary policy using various identifications. For example, Kim (2001), Mackowiak (2007) and Georgiadis (2016) use a standard VAR identification, Dedola et al. (2017) use sign restrictions, and Miranda-Agrippino and Rey (2018) use the VAR methods as well as the narrative identification. Gerko and Rey (2017) is the closest to us and studies the spillovers of the Fed's monetary policy surprises on the UK using the high frequency identification. Unlike the last paper, this paper focuses on the euro area instead of the UK and uses a refinement of the high frequency identification that helps to rationalize some of the results. All the aforementioned papers find strong spillovers of the US monetary policies on other economies. The global role of the Fed's policy as the driver of the world financial cycle is recognized since Rey (2013).

All the aforementioned papers except Dedola et al. (2017) find that the transmission of the Fed's shocks is mostly through financial channels and less through the trade channel, a finding confirmed in this paper. Gilchrist et al. (2018) study the high frequency effects of the Fed's policies on international bond markets.

Several papers find that the monetary policy shocks of non-US central banks generate disproportionately smaller spillovers than the Fed. The finding that the ECB's monetary policy fails to affect the US variables echoes an analogous finding in Gerko and Rey (2017) that the Bank of England's policy fails to affect the US variables. Also Mackowiak (2006) finds that the monetary policy shocks of the Bank of Japan fail to strongly affect other Asian economies. On the other hand, in light of this paper, information shocks spill over very strongly. News in both Fed's and ECB's economic assessments appear to have global impact.

The findings on the Fed's and ECB's information shocks are new. The responses of the US dollar reflect its 'safe haven' status. Habib and Stracca (2015), among others, also confirm the 'safe haven' status of the US in the recent samples using econometric methods.

2 The econometric approach

I estimate a VAR with monetary policy surprises and monthly macroeconomic variables, and identify shocks in this VAR. The econometric approach follows Jarociński and Karadi (2018), so it is described only briefly here and the reader is referred to that earlier paper for further details.

Data on monetary policy surprises. A crucial piece of data in this approach are financial market *surprises* triggered by monetary policy announcements. A surprise is defined as the change in a financial asset price in a narrow window around a monetary policy announcement. Following the literature (Gürkaynak et al., 2005, and others), the surprises in this paper are computed as the change in the window starting 10 minutes prior to the announcement and ending 20 minutes after the announcement. The Fed announces its monetary policy via press releases, usually issued at 14:00 EDT on the day of the FOMC meeting. The data on the Fed monetary policy surprises comes from the dataset of Gürkaynak et al. (2005) (updated). The ECB announces its monetary policy decisions via press releases usually issued at 11:45 CET on Governing Council meeting days, and usually followed by a press conference. In these cases the window covers also the press conference. The data on the ECB monetary policy surprises comes from the dataset of Jarociński and Karadi (2018). I use two kinds of surprises: interest rate surprises and stock price surprises.

For the Fed, the interest rate surprises are captured by the 'policy indicator' constructed as in Nakamura and Steinsson (2013) (who build on Gürkaynak et al., 2005). Namely, this is the first principal component of the surprises in the current month and 3-month fed funds futures and 2-, 3-, and 4- quarters ahead 3-month eurodollar futures. I use this broad measure of the interest rate surprises in order to capture both the immediate changes in monetary policy, as well as near term forward guidance and possibly other nonstandard policies. This is appealing because for a large part of the sample the Fed funds rate is at the zero lower bound which constrains the immediate changes in monetary policy. The stock price surprises are the changes in the S&P500 index.

For the ECB, the interest rate surprises are the changes in the 3-month Eonia swaps and the stock price surprises are the changes in the Euro-Stoxx 50 index. The 3-month swap also includes some near term forward guidance.

Monthly variables. The baseline vector of monthly variables consists of five variables: the one-year government bond yield, a stock index, a corporate bond spread, real GDP and GDP deflator. Except for the stock index, these are the variables used in a similar context in the baseline VAR of Gertler and Karadi (2015). The stock index is added as a natural counterpart of the stock price surprises. After studying this baseline VAR I add to it further variables one by one.

The VAR. I estimate a VAR with central bank announcement surprises and standard macroeconomic and financial variables. Let y_t be a vector of N_y macroeconomic and financial variables observed in month t. Let m_t be a vector of surprises in N_m financial instruments observed in month t (here $N_m = 2$). m_t is the sum of the intra-day surprises occurring in month t on the days with monetary policy announcements. The model is a VAR with m_t and y_t and a restriction that m_t does not depend on the lags of either m_t or y_t and has zero mean,

$$\begin{pmatrix} m_t \\ y_t \end{pmatrix} = \sum_{p=1}^{P} \begin{pmatrix} 0 & 0 \\ B_{YM}^p & B_{YY}^p \end{pmatrix} \begin{pmatrix} m_{t-p} \\ y_{t-p} \end{pmatrix} + \begin{pmatrix} 0 \\ c_Y \end{pmatrix} + \begin{pmatrix} u_t^m \\ u_t^y \end{pmatrix}, \quad \begin{pmatrix} u_t^m \\ u_t^y \end{pmatrix} \sim \mathcal{N}(0, \Sigma), \tag{1}$$

where $\mathcal{N}$ denotes the normal distribution. As long as the financial market surprises are unpredictable, the above zero restrictions are plausible. The estimation is Bayesian. The priors on the coefficients of the above model follow Litterman (1979) and the ensuing Bayesian VAR literature. I use standard hyperparameter values.

Identification I: Standard high-frequency identification (HFI).

Table 1: Identifying restrictions: standard high-frequency identification

	shock	
variable	Interest rate surprise	other
Interest rate surprise (m_t^1)	+	0
All other variables	•	•

Note: Restrictions on the contemporaneous responses of variables to shocks. +, 0 and • denote the positive sign normalization, zero restrictions, and unrestricted responses.

This identification scheme assumes that the interest rate surprise, i.e. the high-frequency response of the fed funds-based financial instruments to the announcement, is only affected by one shock, which we call here 'an interest rate surprise' and is not affected by any other shock. This is because m_t is measured in a narrow window around monetary policy announcements and it is unlikely that any other shocks systematically occur within this narrow window. Table 1 summarizes these identifying restrictions. Similar approaches have been used in the literature. Some papers go one step further and associate the interest rate surprise with the monetary policy shock (e.g. Barakchian and Crowe, 2013). Instead, in this paper I continue calling it 'an interest rate surprise' to avoid confusion with the monetary policy shock identified later. Other papers go one step further and assume that the interest rate surprise is correlated with the monetary policy shock but does not reflect it perfectly, and use an instrumental variables approach instead of the simple scheme in Table 1 (e.g. Gertler and Karadi, 2015). This affects the scale, but not the shape of the impulse responses (see Paul, 2017).

Identification II: Jarociński and Karadi (2018). This identification scheme distinguishes *two* shocks contained in vector m_t: a monetary policy shock and a central bank information shock. This is motivated by the fact that central bank announcements contain two distinct kinds of news: news about monetary policy and news about the central bank's assessment of the economy. Two identifying restrictions are used. The first identifying restriction is that m_t is affected only by these two shocks, the monetary policy shock and the central bank information shock. Again, this is plausible because of the narrow window in which the surprises are measured. The second identifying restriction is a sign restriction. According to standard models a contractionary monetary policy shock depresses stock prices. A contractionary monetary policy shock lowers future dividends, and increases the discount rate, so the present discounted value of future dividends falls. Hence, a negative co-movement between interest rate surprises and stock price surprises is interpreted as a manifestation of a monetary policy shock. A positive co-movement is then interpreted as a manifestation of a central bank information shock, i.e. the impact of the news in the central bank's assessment of the economy. Table 2 summarizes these identifying restrictions.

An important point on both identification schemes is that the resulting monetary policy shocks are broadly defined: they capture both current monetary policy, forward guidance and non-standard monetary policies, such as asset purchases, to the extent they change interest rate expectations for the next year. This is because the interest rate surprises used for identification capture not just near-term policy interest rates but also their expectations in some near future.

Table 2: Identifying restrictions: sign restrictions

variable	shock: Monetary policy (negative co-movement)	CB information (positive co-movement)	other
Interest rate surprise (m_t^1)	+	+	0
Stock price surprise (m_t^2)	−	+	0
All other variables	•	•	•

Note: Restrictions on the contemporaneous responses of variables to shocks. +, −, 0 and • denote the respective sign restrictions, zero restrictions, and unrestricted responses.

3 Statistical properties of the surprises and shocks

This section shows that there is no correlation between the Fed's and ECB's surprises or identified shocks.

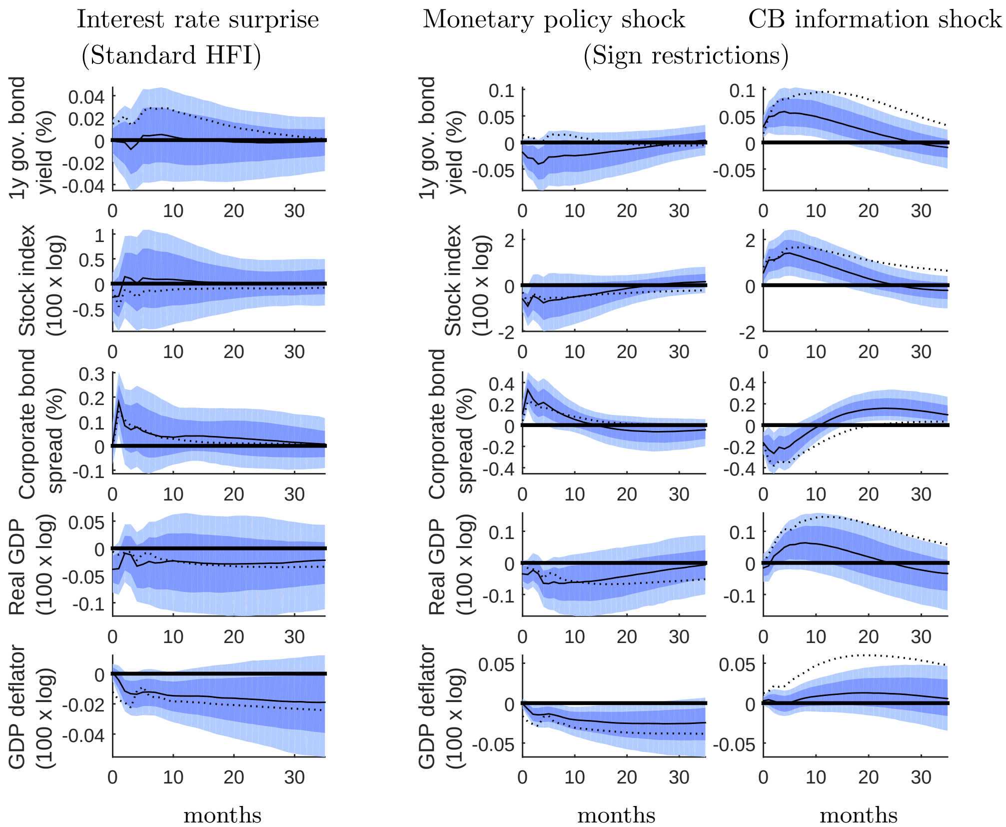
4 Spillovers of the Fed's shocks to the euro area

4.1 The baseline VAR

I start by estimating the baseline VAR for the US and the baseline VAR for the euro area, each time including the US monetary policy surprises. The US VAR includes the one-year treasury bond yield, the S&P500 stock index, the BofAML Option-Adjusted Spread (OAS) between an index of all bonds below investment grade (BB and lower) and a spot Treasury curve, real GDP and GDP deflator interpolated to monthly frequency. The Euro area VAR includes the analogous variables: one-year German government debt yield, the Euro Stoxx 50 stock index, the analogous BofAML OAS for the European bonds, and interpolated real GDP and GDP deflator. The estimation samples in both cases start in January 1999, when the euro area came into being. The US sample ends December 2017 and the euro area sample ends in March 2017. In each of these two VARs I compute the responses to the Fed's monetary policy surprises (using Identification I), and then their decomposition into monetary policy and central bank information shocks (using Identification II).

Figure 1 reports the impulse responses in the baseline VAR. The US responses are qualitatively

Figure 1: Euro area impulse responses to Fed's shocks, baseline VAR.



Note: Euro area responses: median (line), percentiles 16-84 (darker band), percentiles 5-95 (lighter band). US responses: median (dotted line). The estimation sample is January 1999 to December 2017 (US) or to March 2017 (Euro area).

similar as in Jarociński and Karadi (2018), though they differ somewhat because of the different estimation sample and small changes in the variable definitions.[1] Therefore, the figure focuses on the euro area impulse responses with their uncertainty bands and US impulse responses are only shown as point estimates, with dotted lines. The main lesson from this figure is that Fed's monetary policy generates strong financial and real spillovers to the euro area.

As we can see in the first column, a one standard deviation positive interest rate surprise of the

[1] Jarociński and Karadi (2018) start their sample in 1979, instead of 1999. Furthermore, the excess bond premium used in Jarociński and Karadi (2018) is replaced here with the OAS. Both these changes in the present paper are meant to ensure comparability of the US and euro area results.

Fed is followed by an increase in the Treasury bond yield, a decline in the US stock prices and an increase in the corporate bond spread of about 20 basis points. The increase in the corporate bond spread spills over almost one-to-one to the euro area, the European stock market declines for one month, only the German government bond yields do not react. Euro area output and prices decline similarly as in the US.

The next two columns decompose the Fed interest rate surprises into monetary policy shocks and central bank information shocks. We can see that a contractionary US monetary policy shock also has contractionary effects on the euro area. Increasing bond spreads suggest that financial frictions are important both for the internal propagation of monetary policy shocks and for their spillovers to the euro area. Stock prices decline similarly in both economies, by less than 1%. Both real GDP and GDP deflator fall in the euro area about as much as in the US. 1-year government bond yields move little in both economies. Jarociński and Karadi (2018) find a strong increase in the US 1-year government bond yields when they estimate the same VAR on a longer sample (starting in 1979), but the restricted sample used here (starting in 1999) is more affected by the zero lower bound and the average response in the 1-year rate is not significant. The German 1-year government bond yield actually declines after a Fed's monetary policy tightening. One interpretation of this finding is that German government bonds are a safe haven for the European investors and hence their yields fall after adverse global shocks, such as the Fed's contractionary monetary policy shock.

Let us turn to the spillovers from a Fed's central bank information shock. A positive shock raises the German 1-year government bond yields by about 5 basis points in the first year. European stock prices increase by about 1 percent. Corporate bond spreads decline by about 20 basis points. Real GDP increases by about 5 basis points within a year. Only the European GDP deflator responds insignificantly. The appendix shows that the picture is similar when we measure real activity and prices by means of the indexes of industrial production and of consumer prices. Overall, Fed's monetary policy and information shocks affect the euro area economy in a similar direction and to a comparable extent as the US economy.

To shed further light on these spillovers, Figure 2 reports the impulse responses of more variables added one-by-one to the baseline VAR.

4.2 The exchange rate

The first row of Figure 2 reports the response of the exchange rate in terms of the euros per one US dollar (so that an increase is a dollar appreciation). The lessons are similar when I add the exchange rate to the euro area VAR (solid line response with the bands) and to the US VAR (dotted line). The result is a puzzle: the effect of a positive Fed's interest rate surprise on the exchange rate of the dollar to the euro is insignificant. The decomposition of the surprises into monetary policy and central bank information shocks suggests that this insignificant response is a mix of two effects. A Fed's monetary policy tightening appreciates the dollar versus the euro. By contrast, a positive Fed's central bank information shock depreciates the dollar with versus the euro.

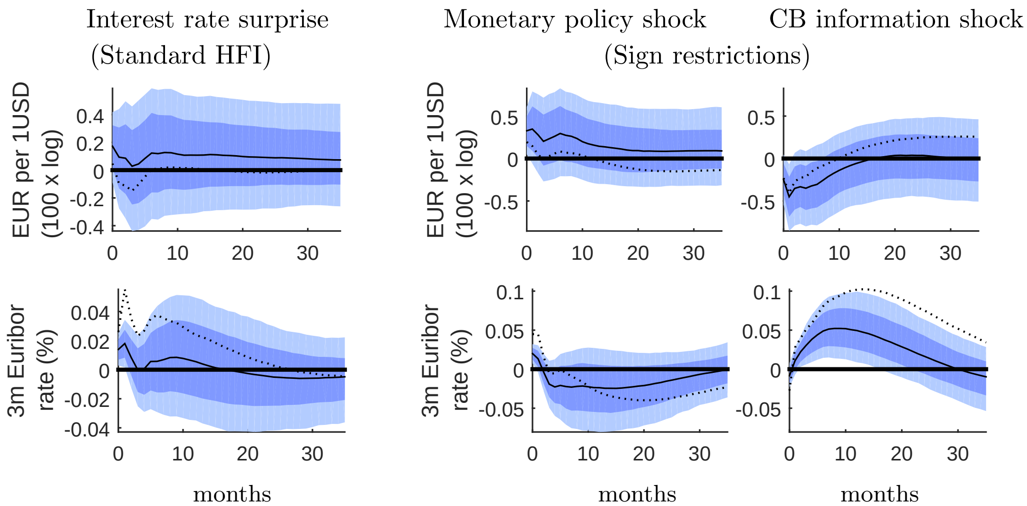
Dollar's depreciation after a positive central bank information shock is an interesting new finding. At first sight it may be surprising that the dollar depreciates following positive news in the Fed's economic assessment. However, this finding can be rationalized in light of the dollar's role of the safe haven. Good news about the US economy are good news about the world economy, as witnessed by the strong real and financial spillovers documented above. For investors, this is a 'risk-on' shock after which they want to increase their non-US exposures. Reversing the argument, bad news about the US economy are bad news about the world economy and an inflow of capital to the safe haven. A prominent example of such an effect is the appreciation of the dollar in the second half of 2008 accompanying the stream of bad news about the US economy. However, the 'safe-haven' effect is not limited to this period.[2] However, a safe haven status is not permanent and in a maximum US sample it is no longer significant (see the Appendix).

The second row of Figure 2 reports the responses of interbank interest rates. The solid line is the 3-months Euribor and the dotted line is the 3-months Libor. The impulse responses are similar for other maturities of Libor and Euribor. A positive interest rate surprise opens a small positive gap of about 2 basis points between the Libor and the Euribor, resulting in a transitory and small excess returns in the US dollar if we take the exchange rate response to be zero.

A contractionary monetary policy shock also opens a transitory gap of about 3 basis points between the Libor and the Euribor. The dollar appreciates on impact and subsequently depreciates, which anihilates the excess returns in US dollars, as in the Dornbush' overshooting model. Taking

[2]E.g. the impulse responses are similar when we zero-out the surprises in the second half of 2008.

Figure 2: Impulse responses to Fed's shocks, additional variables.



Note: Euro area responses: median (line), percentiles 16-84 (darker band), percentiles 5-95 (lighter band). US responses: median (dotted line). The estimation sample is January 1999 to December 2017 (US) or to March 2017 (Euro area).

into account the estimation uncertainty we would probably not reject the null that the uncovered interest rate parity (UIP) holds conditionally on the monetary policy shock.

The situation is very different after a central bank information shock: the dollar depreciates on impact and subsequently appreciates. The interest rates do not differ on impact, but eventually the Libor increases more than the Euribor. As a result, the US dollar generates excess returns after this shock. This compensates investors who are otherwise, after this shock, hungry for risky and non-US exposures.

4.3 Further evidence on financial spillovers

Figure 3 shows that Fed's interest rate surprises lead to tighter financial conditions in Europe by increasing a number of interest rate spreads. Furthermore, after decomposing the interest rate surprises into economic shocks we see that Fed's contractionary monetary policy shocks increase European spreads (by more than interest rate surprises do), while positive Fed's information shocks reduce them.

The Fed's shocks affect the European credit spreads constructed by Gilchrist and Mojon (2018). The NFC credit spread (first row) is the difference between NFC corporate bond yields and German bund yields of the same maturities. The bank credit spread (second row) is the difference between bank bond yields and German bund yields of the same maturities. Comparing the figures we can see that NFC credit spreads are more responsive Fed shocks than bank credit spreads. Gilchrist and Mojon (2018) also disaggregate spreads across countries, and one can find that Spanish bank spreads are more responsive to Fed shocks than German bank spreads (see the Appendix).

The Fed's shocks also have a strong effect on the spread between the Italian and German government bond yields. Throughout the sample studied here the Italian public debt is universally considered to be more risky and the spread is positive. The spread for the 10-year bond maturity (third row) responds to Fed shocks similarly as the other spreads.

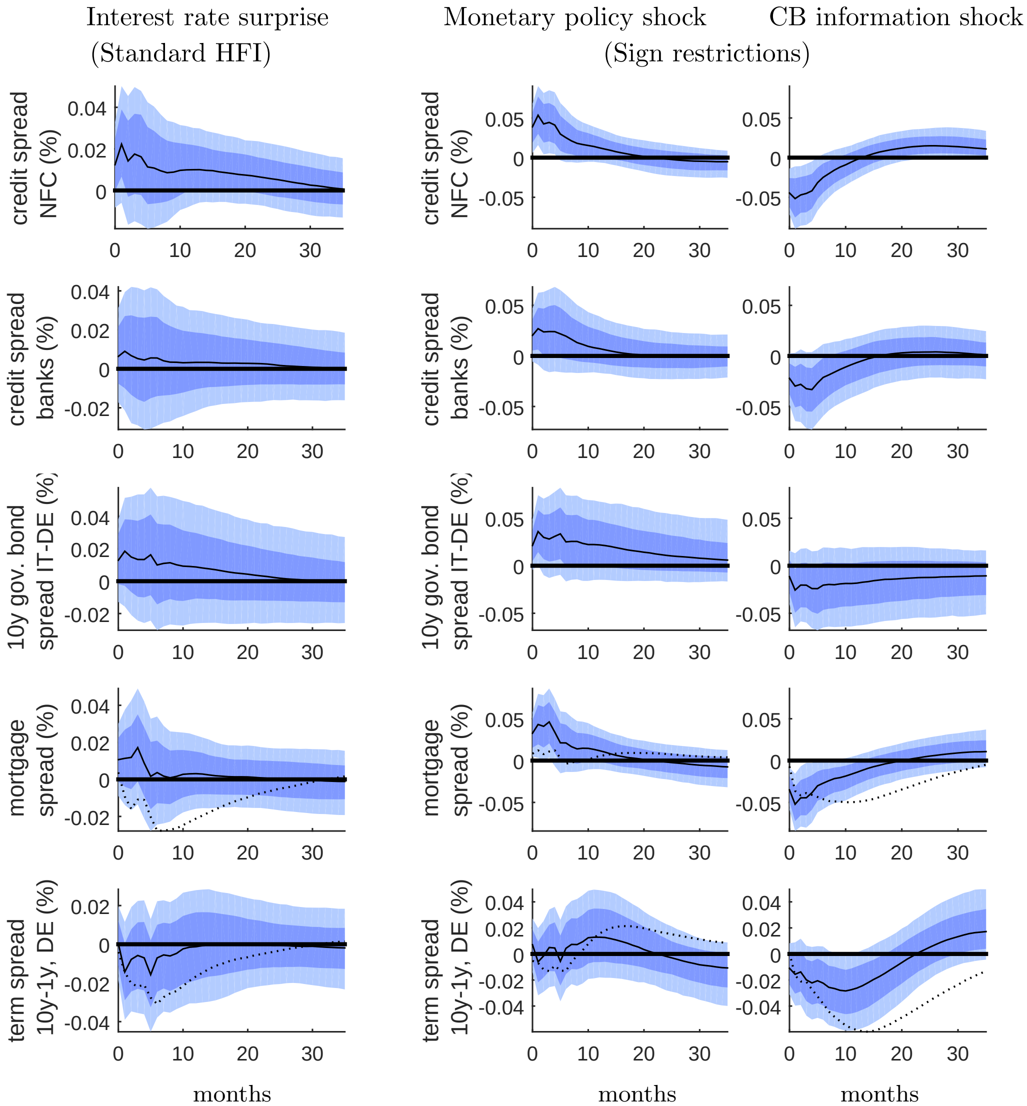
From the household's point of view, it is even more important that the Fed's shocks affect the European mortgage spreads. The mortgage spread (fourth row) is computed as the difference between the the average rate on loans for the house purchase in the euro area and one-year German bond yield. For comparison, the dotted line shows the response of the US 30-years fixed rate mortgage rate (FRED, after Freddie Mac) minus one-year Treasury bond yield. The euro area mortgage spread appear to be more responsive to the Fed's shocks than the US morgtage spread. However, the US – euro euro area comparison is only rough, as the mortgage rates are different due to data limitations.

The final row shows that the Fed's shocks affect the term spreads. The figures report the responses of the difference between the 10-year yield and the 1-year German government bond yield. Term spread does not increase significantly after interest rate surprises or monetary policy shocks, but it does fall after positive Fed information shocks.

4.4 Responses of portfolio capital flows

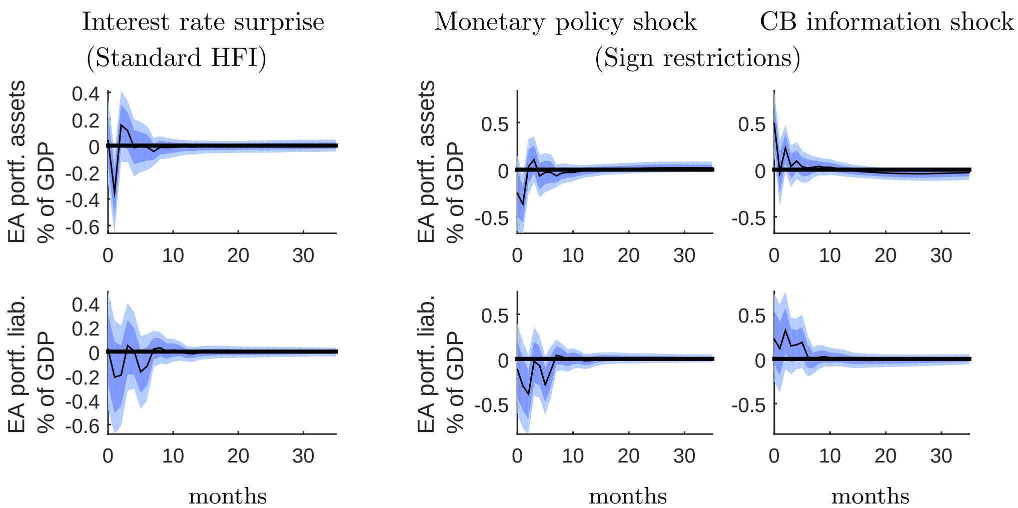
Figure 4 shows that portfolio investors reduce their foreign exposures after bad shocks and increase them after good shocks coming from the Fed. The variables reported in this figure are the portfolio capital flows recorded in the balance of payments (cumulate these impulse responses to see the impact on the stocks). The balance of payments records the foreign debt and equity acquired by

Figure 3: Euro area impulse responses to Fed's shocks, spreads.



Note: Euro area responses: median (line), percentiles 16-84 (darker band), percentiles 5-95 (lighter band). US responses: median (dotted line). The estimation sample is January 1999 to December 2017 (US) or to March 2017 (Euro area).

Figure 4: Euro area impulse responses to Fed's shocks, portfolio capital.



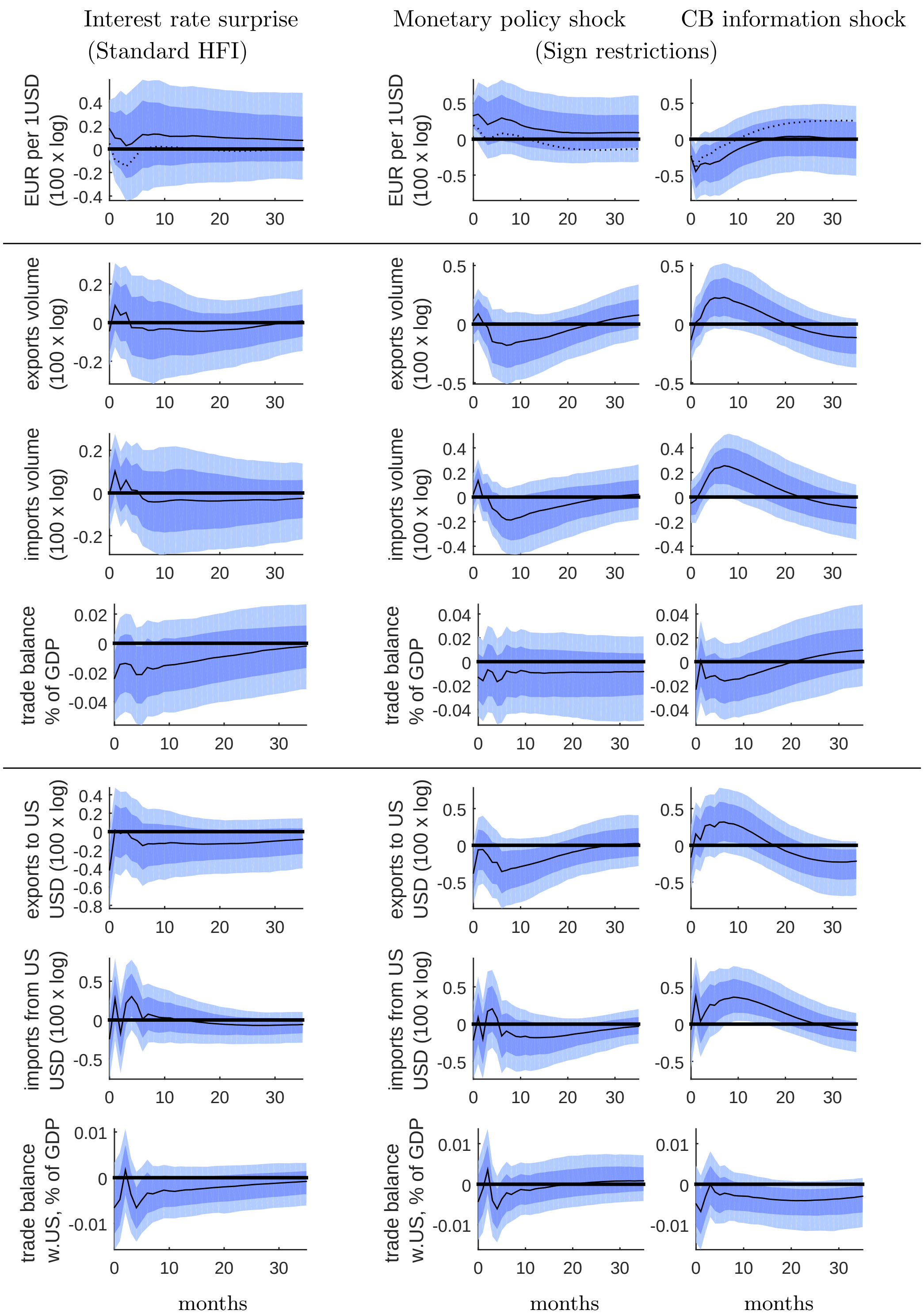
Note: Euro area responses: median (line), percentiles 16-84 (darker band), percentiles 5-95 (lighter band). US responses: median (dotted line). The estimation sample is January 1999 to December 2017 (US) or to March 2017 (Euro area).

the euro area investors as assets, and the euro area debt and equity acquired by foreign investors as liabilities. Both portfolio assets and liabilities fall after an interest rate surprise, although this fall is not very significant. After decomposing the interest rate surprises we see that foreign exposures fall more significantly after Fed's monetary policy shocks and increase after Fed's positive information shocks.

4.5 Responses of trade flows

The effects of the Fed's shocks on the euro area trade flows are not very strong. Fed's interest rate surprises do not have significant effects on euro area exports and import volumes. The trade balance deteriorates. Fed's contractionary monetary policy shock decreases both exports and imports. The fact that the volume of exports decreases in spite of the weaker euro is consistent with viewing this shock as a contractionary global shock. Fed's positive information shock increases both exports and imports. The fact that the volume of imports increases in spite of a stronger euro is consistent with viewing this shock as an expansionary global shock that stimulates also the euro area demand.

Figure 5: Impulse responses to Fed's shocks, euro area trade and the exchange rate.

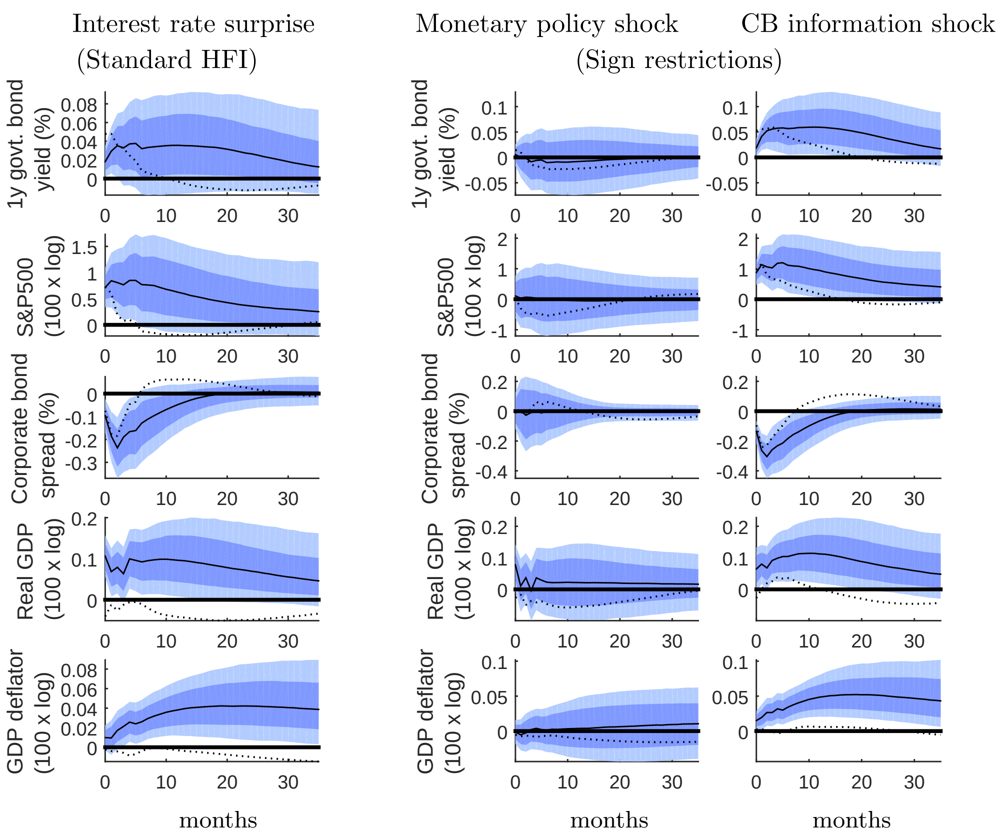


Note: Euro area responses: median (line), percentiles 16-84 (darker band), percentiles 5-95 (lighter band). The estimation sample is January 1999 to March 2017.

Euro area's trade balance deteriorates after both shocks. The trade of the euro area with the US responds similarly as the trade of the euro area with the rest of the world.

4.6 Spillovers of ECB's shocks to the US

Figure 6: US impulse responses to ECB's shocks, baseline VAR.



Note: US responses: median (line), percentiles 16-84 (darker band), percentiles 5-95 (lighter band). Euro area responses: median (dotted line). The estimation sample is January 1999 to December 2017 (US) or to March 2017 (Euro area).

In this subsection I estimate the baseline VAR for the US and for the euro area, each time including the ECB's monetary policy surprises. Figure 6 reports the results. To focus on the spillovers to the US, the figure reports the US responses with solid lines and with uncertainty bands, and the euro area responses with dotted lines.[3]

The standard high-frequency identification produces a striking puzzle: a positive ECB's interest rate surprise has an expansionary effect on the US. This is shown in the first column of Figure

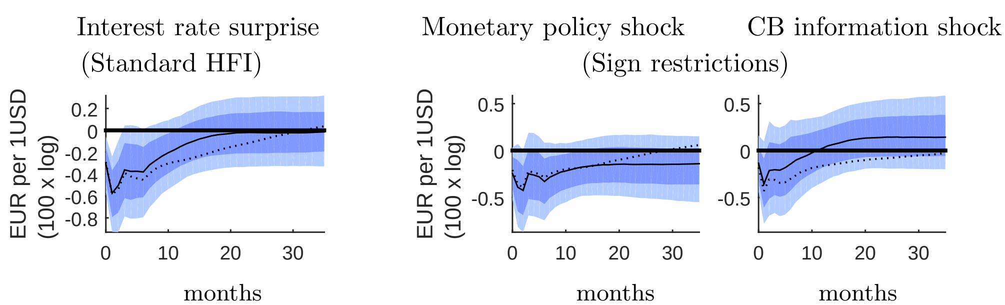
[3] Jarociński and Karadi (2018) discuss the euro area responses with more detail.

6. We can see that although the 1-year US government bond yield increases (by up to 4 basis points in the first months after the shock), the stock market booms, the corporate bond spread falls, and both real GDP and GDP deflator increase (by 10 and 4 basis points respectively). These effects are puzzling. The depreciation of the dollar versus the euro by 1 percent (see Figure 7) helps stimulate the US economy but it seems unlikely that the depreciation of half a percent has such strong expansionary effects on the US economy.

The decomposition of the monetary policy surprises into monetary policy shocks and central bank information shocks rationalizes these results. In light of this decomposition (reported in the second and third columns of Figure 6) the responses just discussed are a mix of the insignificant spillover of the euro area monetary policy shock on the US economy, and the significant spillover of the positive central bank information shock on the US economy. This explains why the average response of the US economy is expansionary.

More in detail, the ECB's monetary policy shock have basically no effect on the US economy. By contrast, the spillovers of the ECB's central bank information shocks are very strong. US 1-year government bond yields increases roughly one-for-one with German 1-year government bond yield. The US S&P500 stock index increases roughly one-for-one with the European Euro Stoxx 50. The US corporate bond spread falls roughly one-for-one with the European corporate bond spread. If anything, the US responses are more persistent, although it is not clear how singificant this difference is. The effect of the ECB central bank information shock on the US real GDP and

Figure 7: Impulse responses to ECB's shocks, the exchange rate.



Note: Euro area responses: median (line), percentiles 16-84 (darker band), percentiles 5-95 (lighter band). The estimation sample is January 1999 to March 2017.

GDP deflator appears even stronger than the domestic effect, although, again, it is not clear how significant this difference is.

The strong responses of the US economy can be at most partly explained by the exchange rate responses, shown in Figure 7: the euro appreciates by about 25 basis points against the dollar after this shock. The exchange rate response amplifies the spillover to the US economy and dampens the effect on the euro area economy but these effects are likely to be small.

5 Conclusions

I have studied the impact of the Fed on the euro area and of the ECB on the US using VARs with high frequency identification. To rationalize the results, it turns out to be useful to decompose the spillovers of the Fed and ECB interest rate surprises into two distinct components: the effect of monetary policy shocks and the effect of central bank information shocks. This yields several new results. First, positive news about the economy, i.e. positive central bank information shocks, are followed by a relaxation of financial conditions and an economic expansion in both the US and the euro area. The dollar depreciates upon good news and appreciates upon bad news, consistently with its safe haven status in this sample period. Second, the spillovers of the US monetary policy shocks to the euro area are strong and the spillovers of the euro area monetary policy shocks to the US are weak. Third, these results explain the puzzling result of the standard high-frequency identification that contractionary ECB interest rate surprises have an expansionary effect on the US. This expansionary effect is a result of the absence of spillovers of the ECB monetary policy shock and the positive effect of the ECB's central bank information shock.

Appendix

Appendix A Data

Data sources: FRED (St. Louis Fed database); SDW - Statistical Data Warehouse of the ECB; Haver Analytics.

Table A.1: Data definitions and sources

Variable	US data	Euro area data
1y gov. bond yield	1-Year Treasury Constant Maturity Rate, monthly average (FRED)	Germany: Estimated 1-Year Government Debt Yield, end-of-period (Haver)
Stock index	S&P500 stock index, monthly average (FRED)	Dow Jones Euro Stoxx 50 Price Index, monthly average (SDW)
Corporate bond spread	ICE BofAML Option-Adjusted Spread (OAS) between a computed OAS index of all bonds below investment grade (rated BB and lower) and a spot Treasury curve, monthly average. (FRED)	Option-Adjusted Spread (OAS) of the ICE BofAML Euro High Yield Index of Euro denominated below investment grade corporate debt publicly issued in the euro domestic or eurobond markets, monthly average. (FRED)
Real GDP	Interpolated by Macroeconomic Advisors (Haver)	Own interpolation following Stock and Watson (2010).
GDP deflator	The ratio of nominal to real GDP, source as above.	The ratio of nominal to real GDP, source as above.

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