DEUTSCHE
BUNDESBANK
EUROSYSTEM

Discussion Paper

Deutsche Bundesbank
No 13/2020

Central bank information shocks and exchange rates

Thorsten Franz

Deutsche Bundesbank, Wilhelm-Epstein-Straße 14, 60431 Frankfurt am Main,
Postfach 10 06 02, 60006 Frankfurt am Main

Tel +49 69 9566-0

Please address all orders in writing to: Deutsche Bundesbank,
Press and Public Relations Division, at the above address or via fax +49 69 9566-3077

Internet http://www.bundesbank.de

ISBN 978–3–95729–684–9 (Printversion)
ISBN 978–3–95729–685–6 (Internetversion)

Non-technical summary

Research Question

Information in the economy is dispersed among agents. Consequently, announcements by central banks at times contain information on the state of the economy that has not previously been available to the public and which has real implications that are distinct from those of pure monetary policy surprises. Until recently, announcement effects have been solely attributed to monetary policy shocks, ignoring the existence of information shocks. In this paper, I raise the question as to how far a more granular view of central bank announcements affects our understanding of the impact of these announcements on exchange rates, with ECB Governing Council meetings as the main object of study.

Contribution

Recent empirical research already emphasizes non-negligible real effects of central bank information shocks and, simultaneously, how controlling for them can resolve some commonly found puzzles in responses to monetary policy shocks. However, an open economy context has so far been ignored, which this paper aims to address. Drawing on high-frequency reactions around ECB Governing Council meetings, I identify the two types of shocks and analyze dynamic responses of nominal effective and bilateral exchange rates of the euro. The results provide novel insights into exchange rate propagation on international financial markets, especially following central bank information surprises.

Results

Contractionary monetary policy shocks lead to a sizable appreciation of the nominal effective euro exchange rate and, with some variation, of the eight bilateral euro exchange rates examined in this paper. The strongest reaction is observable on impact. In contrast, heterogeneity between the responses of the different currency pairs is much more pronounced after a central bank information shock, with the result that the nominal effective exchange rate does not react significantly. Investors' risk sentiment is a possible explanation for these findings. In case of a surprisingly positive macroeconomic outlook by the ECB, investors' risk appetite increases and triggers capital flows into speculative currencies. Consequently, the euro depreciates against these speculative currencies despite rising domestic yields. I also show that currency carry trades might very well be the main reason for these responses.

Nichttechnische Zusammenfassung

Fragestellung

Ankündigungen von Zentralbanken können Informationen über makroökonomische Größen enthalten, welche nicht allen Marktteilnehmern zuvor bekannt waren. Die ökonomischen Effekte dieser Informationsschocks unterscheiden sich grundlegend von denen geldpolitischer Schocks. Lange Zeit war es in der Forschung üblich, Ankündigungseffekte allein auf geldpolitische Schocks zurückzuführen und die Existenz möglicher Informationsschocks nicht zu berücksichtigen. In dem vorliegenden Forschungspapier stelle ich mit dem Augenmerk auf EZB-Ratssitzungen die Frage, inwiefern ein differenzierterer Blick auf Zentralbank-Ankündigungen unser bisheriges Wissen über die Auswirkungen dieser Ankündigungen auf Wechselkurse verändert.

Beitrag

Jüngere empirische Forschungsbeiträge legen nahe, dass Zentralbank-Informationsschocks nicht zu vernachlässigende Effekte haben und deren Berücksichtigung bei der Analyse geldpolitischer Schocks daher wichtig ist. Im Kontext einer offenen Volkswirtschaft wurden diese Informationsschocks jedoch bisher nicht betrachtet. Hier setzt das vorliegende Forschungspapier an. Unter Zuhilfenahme von hochfrequenten Daten identifiziere ich beide Arten von Schocks bei Ankündigungen im Rahmen von EZB-Ratssitzungen. Die folgende Analyse nominaler effektiver und bilateraler Wechselkursänderungen des Euro führt zu neuartigen Erkenntnissen vor allem im Hinblick auf die Auswirkungen von Zentralbank-Informationsschocks.

Ergebnisse

Kontraktive geldpolitische Schocks führen zu einer deutlichen Aufwertung des Euro in nominaler effektiver Rechnung und im Allgemeinen auch bilateral gegenüber acht untersuchten Währungen. Dabei ist der stärkste Effekt gleich zu Beginn zu beobachten. Wechselkursreaktionen nach Zentralbank-Informationsschocks fallen dagegen über die verschiedenen Währungspaare hinweg sehr viel heterogener aus, sodass der nominale effektive Wechselkurs des Euro nicht signifikant reagiert. Eine mögliche Erklärung sind Veränderungen der Investorenstimmung. Im Falle eines überraschend positiven makroökonomischen Ausblicks der EZB steigt die Risikoneigung von Investoren und löst Kapitalflüsse in spekulative Währungen aus. Folglich wertet der Euro trotz steigender einheimischer Renditen gegenüber diesen spekulativen Währungen ab. Zusätzlich zeige ich, dass „Currency Carry Trades“ dafür verantwortlich sein könnten.

Deutsche Bundesbank Discussion Paper No 13/2020

Central Bank Information Shocks and Exchange Rates*

Thorsten Franz†

This Version: February 2020

Abstract

The dynamic effects of ECB announcements, disentangled into pure monetary policy and central bank information shocks, on the euro (EUR) exchange rate are examined using a Bayesian Proxy Vector Autoregressive (VAR) model fed with high-frequency data. Contractionary monetary policy shocks result in a sizable appreciation of the nominal effective and bilateral EUR exchange rates, peaking on impact. By contrast, despite similar effects on interest rate differentials, responses to central bank information shocks exhibit strong heterogeneities across currency pairs. This disparity can be rationalized by an increase in investors' risk appetite, as measured by the VIX, triggering capital flows into speculative currencies when the ECB reveals a surprisingly sanguine economic outlook. In line with this, the EUR depreciates against a high-yielding carry trade investment portfolio, while it appreciates against a low-yielding carry trade funding portfolio.

Keywords: central bank information, monetary policy, exchange rate, Proxy VAR, high-frequency data, carry trades

JEL Classification: E52, E58, F31

*I would like to thank Christoph Fischer, Ulrich Grosch, Marek Jarociński, Sören Karau, Mark Kerssenfischer and participants at the Bundesbank seminar, the 12th FIW-Research Conference on 'International Economics' in Vienna and the DIW workshop on 'Macroeconometrics' in Berlin for their valuable comments and discussions. I also thank Refet Gürkaynak and Mark Kerssenfischer for generously sharing their data with me.

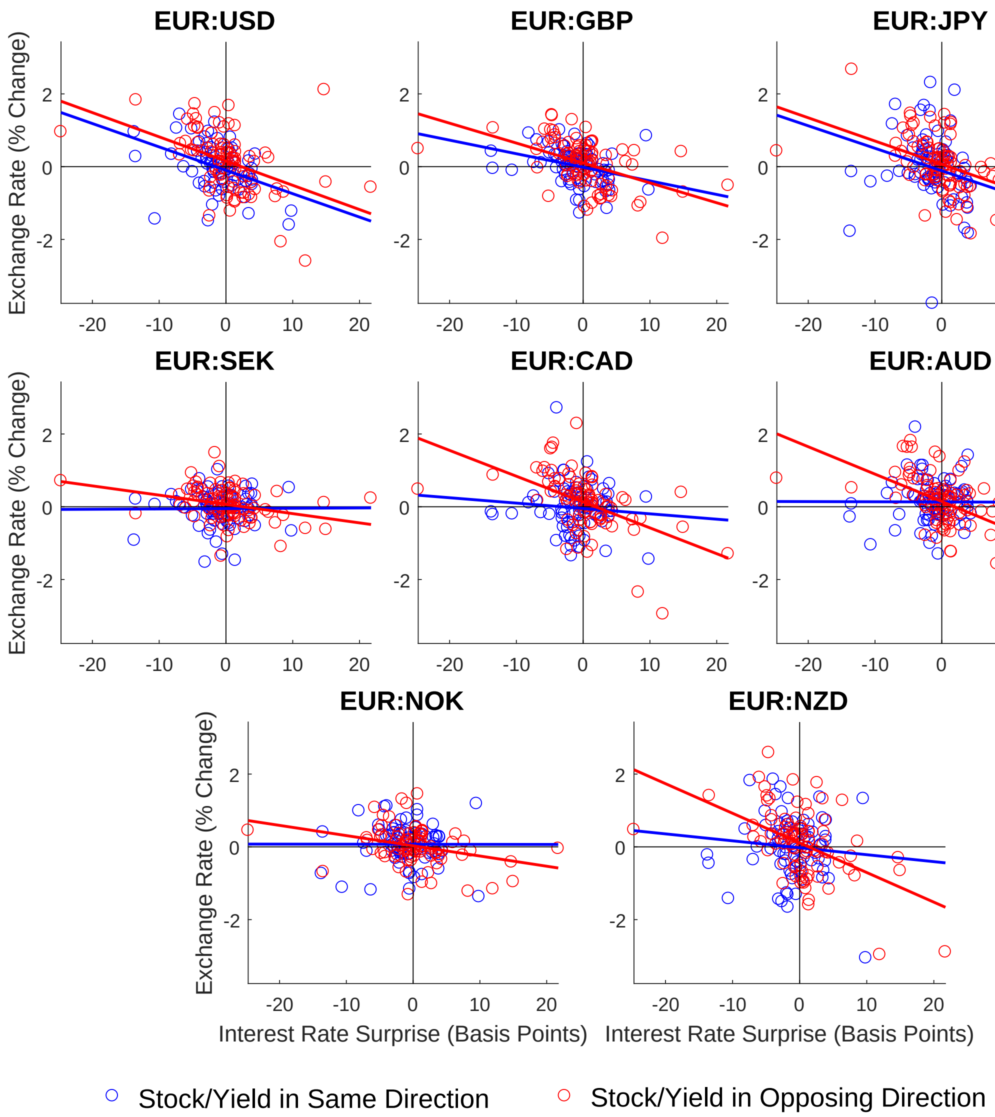
†Contact Address: Deutsche Bundesbank, Wilhelm-Epstein-Strasse 14, 60431 Frankfurt am Main, Email: thorsten.franz@bundesbank.de. The views expressed in this paper are those of the author and do not necessarily reflect the views of the Deutsche Bundesbank or the Eurosystem.

1 Introduction

In recent years, more nuanced and higher quality tick-by-tick financial market data has popularized high-frequency approaches to identifying monetary policy shocks. Not only do these advances allow for a cleaner identification, but they also enable us to isolate central bank information shocks. In distinction to pure monetary policy shocks, these capture surprises in central banks' announcements that reveal private information about economic fundamentals. Despite unresolved empirical questions in international macroeconomics such as the existence of exchange rate overshooting along the lines of Dornbusch (1976) the literature is strangely mute on how these advances in identification affect our understanding of the interplay between monetary policy announcements and exchange rate movements. To this end, Figure 1 plots high-frequency responses of 2-year German government bond yields in futures markets around ECB monetary policy announcements against daily exchange rate changes of the euro (EUR) *vis-à-vis* eight currencies, taking contemporaneous high-frequency movements in the EURO STOXX 50 into account. As long as surprises in stocks and bond yields negatively co-move, as theory predicts for pure monetary policy shocks, the EUR appreciates on average against all eight currencies in case of a yield hike. If, however, stocks and bond yields both increase, akin to a disclosure of surprisingly positive private information on the state of the economy, the picture becomes less clear. Understanding where this disparity originates is vital in appraising the effects of central bank announcements on international financial markets.

Feeding high-frequency surprises of government bond yields and stock prices into a Proxy Vector Autoregressive (VAR) model in the fashion of Mertens and Ravn (2013) and estimated with Bayesian techniques as in Miranda-Agrippino and Ricco (2018), I identify a monetary policy shock and a central bank information shock via sign restrictions similar to Jarociński and Karadi (2019). In line with Dornbusch's (1976) overshooting model, the nominal effective EUR exchange rate appreciates strongest directly on impact following a monetary policy shock. After around two years, however, its response becomes insignificant. These results do not support the delayed overshooting hypothesis established in early empirical work by Eichenbaum and Evans (1995) and later supported, *e.g.*, in Scholl and Uhlig (2008). Subsequent contributions attribute delayed overshooting to the identification method (Kim and Roubini, 2000, Faust and Rogers, 2003, Bjørnland, 2009) or the sample (Kim, Moon and Velasco, 2017) and are in general more sympathetic to Dornbusch's (1976) original findings. One major deviation of the present paper is the focus on EUR exchange rates. Interestingly, the only bilateral exchange rate where the responses exhibit some form of delayed overshooting is the euro-US-dollar pair.

Figure 1 Exchange Rate Reactions on ECB Meeting Days



Note: The dots display the daily exchange rate reactions to interest rate surprises (2-year German government yields) in short windows around ECB Governing Council meetings between March 2002 and September 2018, as described in Section 3.1. Blue dots indicate that the Euro STOXX 50 positively co-moved with yields, while the opposite is true for red dots. A negative value of the exchange rate indicates an appreciation of the EUR.

In contrast, I do not find a significant reaction of the nominal effective EUR exchange rate following a central bank information shock. At least since Romer and Romer (2000) it is conjectured that central banks hold private information on the state of the economy distinct to that held by other market participants. Melosi (2017) shows in a dispersed information model that central bank announcements "signal" information to market participants that might drastically alter the transmission of monetary policy compared to perfect information. Indeed, Nakamura and Steinsson (2018) find that an unexpected increase in real rates following Federal Open Market Committee (FOMC) announcements leads to an upward revision of expected output growth in survey estimates, which they rationalize with a "Fed information effect." Building on this result, Cieslak and Schrimpf (2019) identify, alongside a pure monetary policy shock, a growth and a risk premium shock via positive co-movements in stocks and yields and observe a similar large incidence for ECB announcements. Although part of the literature cleanses monetary policy shocks from these information effects (see, notably, Miranda-Agrippino and Ricco, 2018), they have interesting macroeconomic implications in their own right. Jarociński and Karadi (2019) observe responses that sharply contrast with those of standard monetary policy shocks and are consistent with the central bank's disclosure of private information on current and future demand conditions. Increasing yields are therefore accompanied by an expansion of the real economy. To the best of my knowledge, the present study is the first one to investigate these shocks in an open economy context.

Having established these different reactions of the effective EUR exchange rate to the two identified shocks, in a next step I run the Bayesian Proxy VAR for each of the eight currency pairs with the EUR displayed in Figure 1 individually: the US-dollar (USD), the pound sterling (GBP), the yen (JPY), the Swedish krona (SEK), the Canadian dollar (CAD), the Australian dollar (AUD), the Norwegian krone (NOK), and the New Zealand dollar (NZD). Heterogeneous spillovers of ECB announcements to foreign yields turn out to explain little of the differences. Against some currencies, the EUR even depreciates, despite positive interest rate differentials of German yields compared to the respective foreign yields following the central bank information shock. This points towards ex-post violations of the uncovered interest rate parity (UIP), as nominal exchange rates do not, for the most, exhibit responses that are significantly different from zero two years after the shock. There is now a large body of literature documenting such violations of UIP, building on the seminal article by Fama (1984) (for a recent overview on empirical evidence, see Engel, 2014). Reassuringly, I also show that this profoundly different propagation of central bank information shocks to exchange rates also holds true for FOMC announcements and USD exchange rates.

It appears that a fruitful avenue to rationalize these findings is to take into account "sentiment" of currency investors. I first show that positive ECB central bank information shocks bolster US stock market valuation as well as global risk appetite, approximated by a decrease in the VIX index. For monetary policy shocks, this is much less the case. With an increase in global risk appetite, capital flows into speculative currencies such as the AUD, the NZD or the NOK appear to become more widespread. The opposite seems true for safe haven, hedge, or carry trade funding currencies as classified in Hossfeld and MacDonald (2015). These responses are in line with the disclosure of information by the ECB that not only alters market participants' general growth forecasts but also their risk sentiment. Accordingly, I also present evidence that announcements by the ECB that trigger an increase in market participants' risk appetite, identified via risk premium shocks as in Cieslak and Schrimpf (2019), even lead to a depreciation of the effective EUR exchange rate, despite an associated interest rate hike.[1]

Closely related to investors' "risk-on" sentiment are carry trade flows, where an investment in a high-yielding currency is funded in a low-yielding currency. The carry trade literature identifies the VIX as an important indicator that is negatively correlated with such speculator carry positions (see *e.g.* Brunnermeier, Nagel and Pedersen, 2009). Accordingly, the EUR appreciates strongly against a low-yielding carry trade funding portfolio while it depreciates against a high-yielding carry trade investment portfolio following a positive central bank information shock. Carry trade flows might therefore very well be the main cause of the marked heterogeneities observed in bilateral exchange rate responses.

These results add a new layer to the growing literature that utilizes high-frequency financial market data to study exchange rate responses to monetary policy announcements. Early work in this field established a quick, significant and economically meaningful response of exchange rates to monetary policy surprises within event studies (Zettelmeyer, 2004; Kearns and Manners, 2006; Faust et al., 2007). Focus has since shifted towards more recently implemented unconventional policies. While Glick and Leduc (2018) and Ferrari, Kearns and Schrimpf (2017) find these to have stronger effects on exchange rates, the latter attribute this result to an increasing responsiveness of exchange rates to monetary policy over time. Splitting the monetary policy shock into a so-called target and a path shocks that roughly capture conventional and unconventional policies, respectively, I do not find major differences in exchange rate responses. This implies that the previous findings are independent of the type of monetary policy shock, in line with the results from a Proxy VAR in Rogers, Scotti and Wright (2018) who disentangle monetary policy into asset purchase surprises, forward guidance surprises and conventional monetary policy surprises. Information effects as discussed here, however, have thus far been ignored in this strand of literature.

The remainder of this paper is structured as follows: the next section explores the potential effects of central bank information shocks on exchange rates. Section 3 provides a description of the data, identification and estimation. Results are subsequently presented in Section 4 while Section 5 concludes.

[1] "Risk-on" sentiment in markets triggers a flight to more speculative assets, leading to a lower demand for safe government bonds and, hence, an increase in government bond yields. Possibly the most famous example for such a risk premium shock is ECB president Draghi's "whatever it takes" speech.

2 Central Bank Information Shocks and Exchange Rates

Since the seminal contributions of Kuttner (2001) and Gürkaynak, Sack and Swanson (2005), high-frequency approaches have slowly emerged as the benchmark in identifying monetary policy shocks. The general idea lies in observing changes in financial market variables in short windows around monetary policy announcements. Assuming that (i) the financial markets under investigation are efficient and that (ii) no other relevant information regarding the variables is released during this short window, all observed movements can be assigned to the monetary policy announcement. However, at least since Romer and Romer (2000) it has been known that the information set of central banks does not necessarily align with the one of other market participants, which complicates the structural identification of monetary announcement surprises.

Following the outline in Miranda-Agrippino (2017), consider a futures contract with the policy rate as the underlying asset that pays the prevailing rate at some date $t+h$ in the future. Shortly before a monetary policy announcement scheduled in the interval $[t-\Delta t, t]$, the future contract's price, $p_{t-\Delta t}$, is a function, $f(.)$, of market participants' projection of the future nominal interest rate and a risk premium for holding the contract until maturity

$$p_{t-\Delta t} = f(\hat{i}_{t+h}, \widehat{rp}_{t+h} | \widehat{\Omega}^M_{t-\Delta t}) \tag{1}$$

where $\widehat{\Omega}^M_{t-\Delta t}$ displays the market participants' information set at time $t-\Delta t$. Assume that at t the price of the contract is fully determined by the decision and communication of the central bank, such that $p_{t-\Delta t}$ can be expressed as

$$p_{t-\Delta t} = \zeta(\widehat{\Omega}^M_{t-\Delta t}) + \psi(\widehat{\Omega}^M_{t-\Delta t}) \tag{2}$$

where $\zeta(.)$ is the central bank's reaction function and $\psi(.)$ is a function of the risk premium, both assumed to be known by market participants.

The decision, however, ultimately depends on the central bank's information set at $t-\Delta t$, $\widehat{\Omega}^{CB}_{t-\Delta t}$.[2] Under the assumption that eventually no other relevant information is revealed between $t-\Delta t$ and t, the futures price after the announcement is given

[2] Note that even if market participants have the same access to data as the central bank, information sets can diverge: not only might there be differences in forecasting models used, but the publication lag in macroeconomic data forces both to nowcast even the current state of the economy. The "$\widehat{.}$" indicates this uncertainty.

by

$$p_t = \zeta(\widehat{\Omega}^{CB}_{t-\Delta t}) + \varepsilon_t + \psi(\widehat{\Omega}^{CB}_{t-\Delta t}) \tag{3}$$

where ε_t is a pure monetary policy shock, i.e. a deviation of the central bank from its policy rule, given its information set at the time of the decision. It becomes clear that besides the pure monetary policy shock, the announcement surprise, $p_t - p_{t-\Delta t}$, also captures differences in the information set of central bankers and other market participants (linear separability of ζ and ψ is assumed for ease of purpose):

$$p_t - p_{t-\Delta t} = \varepsilon_t + \zeta(\widehat{\Omega}^{CB}_{t-\Delta t} - \widehat{\Omega}^{M}_{t-\Delta t}) + \psi(\widehat{\Omega}^{CB}_{t-\Delta t} - \widehat{\Omega}^{M}_{t-\Delta t}) \tag{4}$$

Consequently, changes in futures prices in a short window around a monetary policy announcement only amount to a pure monetary policy shock if information sets of central bankers and other market participants align.[3]

Ignoring this information channel can have profound repercussions for the propagation of monetary policy shocks in VARs (see Miranda-Agrippino, 2017, and Miranda-Agrippino and Ricco, 2018). Likewise, for announcements by the ECB, past evidence points towards information revisions by market participants being a distinct contributor to movements in interest rates (see Cieslak and Schrimpf, 2019, or Jarociński and Karadi, 2019). Here, I follow Jarociński and Karadi (2019) in disentangling pure monetary policy shocks and central bank information shocks by imposing sign restrictions from high-frequency movements in stocks and yields around ECB monetary policy announcements in the structural identification.[4] In particular, a pure contractionary monetary policy shock deteriorates the economic

[3]Note that the principal idea of formalizing the connection between high-frequency responses and monetary policy shocks stems from Barakchian and Crowe (2013). However, they assume that market participants predict the monetary stance prior to a central bank announcement correctly with only a noise in beliefs that is not affected by the announcement itself. Thus, a change in the price of the contract around the announcement only captures a monetary policy shock and no update in beliefs about the information set of the central bank. Romer and Romer (2004) actually estimate a version of $\zeta(\widehat{\Omega}^{CB}_{t-\Delta t})$ on the intended funds rate using Greenbook forecasts specifically prepared for FOMC meetings, whereby they interpret the residual as a monetary policy shock. Besides the problem of having to specify the form of the reaction function and the information set of the central bank, as argued by Barakchian and Crowe (2013), this shock series might also misinterpret information surprises as monetary policy surprises. Miranda-Agrippino (2017) and Miranda-Agrippino and Ricco (2018), on the other hand, make use of the Greenbook forecasts by regressing them and their revisions on the announcement surprise, effectively controlling for the central bank information set. The residual is interpreted as a monetary policy shock cleansed of potential information surprises. For the euro area, however, no publication similar to the Greenbook forecasts is publicly available.

[4]In comparison to the estimation outlined in Section 3, Jarociński and Karadi (2019) directly plug in the high-frequency variables into their VAR. One advantage of the proxy variables approach utilized here is that the high-frequency variables only have to capture some of the exogenous variation of the shock of interest and can therefore still deliver reliable results under measurement error (see Stock and Watson, 2018, for a discussion).

outlook and depresses the present value of future dividends via an increase in the discount rate. Both these effects point towards a lower stock market valuation accompanying the increase in nominal interest rates throughout the yield curve. A disclosure of positive information on the economy that exceeds market participants' expectations, however, pushes up stock market valuation in unison with interest rates. As outlined above, such information shocks can also work through the risk premium. Consequently, Cieslak and Schrimpf (2019) further disentangle the information shock into a growth and a risk premium shock via the change in the shape of the yield curve. I only follow up on this distinction briefly in Section 4.3.1, since the identification relies on comparably strict assumptions regarding the yield curve. Integrating these two separated shocks into an open economy context begs the question of whether exchange rate reactions are distinct from each other. First, consider the uncovered interest rate parity (UIP) condition

$$i_t - i_t^* = \mathbb{E}_t s_{t+h} - s_t - \xi_t \tag{5}$$

where i_t is the domestic nominal interest rate, i_t^* is its foreign counterpart, s_t is the log nominal exchange rate (price of foreign currency in terms of domestic currency) and ξ_t displays the deviation from the UIP, which can be interpreted as a foreign exchange risk premium (see *e.g.* Engel, 2014). For now, suppose that $\xi_t = 0$. Assuming a small open economy such that i_t^* is exogenous, an increase in the domestic nominal interest rate requires the expectation of a domestic depreciation between t and $t + h$. Additionally, assuming sticky prices, purchasing power parity (PPP) in the long-run and rational expectations, $\mathbb{E}_t s_{t+h}$ is determined by the price level for $h \to \infty$. As a contractive pure monetary policy shock is generally expected to be accompanied by a lower price level, UIP and long-run PPP together predict a steeper appreciation in the spot exchange rate on impact compared to its long-run counterpart. This overshooting hypothesis was originally developed in the seminal work by Dornbusch (1976) and, even today, empirical studies continue to be carried out into its validity. Depending on the identification and time period under consideration, some authors find overshooting present in the data (*e.g.* Kim and Roubini, 2000, Bjørnland, 2009, or Kim, Moon and Velasco, 2017) while other empirical work favors delayed overshooting (*e.g.* Eichenbaum and Evans, 1995, or Scholl and Uhlig, 2008).

For central bank information shocks, predictions regarding the direction of the exchange rate are not straightforward. According to Jarociński and Karadi (2019), these shocks mostly convey private information on current and future demand conditions in the economy. Consequently, following a shock that reveals positive information, one would expect upward pressure on the domestic price level, leading to depreciation in the long-run as per PPP. Despite the increase in the domestic interest rate, it is therefore not clear in which direction the spot exchange rate will move following a central bank information shock.

The previous theoretical considerations, however, have to be taken with some caution. First of all, the assumption of a small open economy is far-fetched when analyzing the euro area. Foreign variables, such as interest rates in the UIP and prices in the PPP, are possibly not exogenous to ECB announcements. Second, empirical research is, to say the least, inconclusive on whether the UIP actually holds in reality, that is, if $\xi_t = 0$ holds in Equation (5) (see Engel, 2014, for an overview). Third, currencies fulfill distinct roles for investors that depend, among other things, on market "sentiment". In "risk-on" times, investors tend to move capital into high-yielding speculative currencies (*e.g.* the NZD or the AUD), independent of marginal changes in interest rate differentials. This could be thought of as a decrease in the foreign exchange risk premium ($\Delta\xi_t < 0$) of these currencies from the perspective of foreign investors. The opposite is true for hedge currencies (*e.g.* the EUR). During high stress regimes, safe haven currencies (*e.g.* the USD) become attractive and low-yielding currencies (*e.g.* the JPY) might appreciate due to carry trade reversals. Drawing on the classification of the G-10 currencies in Hossfeld and MacDonald (2015), I try to factor in these prevalent functions as far as possible in a linear VAR. Lastly, central bank information shocks are a comparably new concept and have not been subject to much scrutiny. Accordingly, the identification via a Proxy VAR presented in the next section refrains from imposing restrictions on the responses of the variables of interest as is generally necessary in other identification strategies.

3 Data, Identification and Estimation

3.1 High-Frequency Responses and Monthly Data

In order to discriminate between pure monetary policy shocks and central bank information shocks, I resort to changes in high-frequency data around ECB Governing Council meetings. In particular, changes in 2-year German government bond yields and the Euro STOXX 50 index from the Eurex Exchange are taken from Kerssenfischer (2019). On each date of a scheduled ECB Governing Council meeting between March 2002 and September 2018, the difference between quotes 20 minutes after the end of the press conference and 10 minutes before the preceding press statement are calculated, implying a window length of approximately 2 hours and 15 minutes. These changes are considered as surprises solely attributable to ECB announcements and allow for an identification of the two shocks of interest in the Proxy VAR setup outlined in the next subsection. Compared to Overnight Index Swap (OIS) rates often used (*e.g.* Ferrari, Kearns and Schrimpf, 2017, or Jarociński and Karadi, 2019), the present data is based on actual trades, not on reported quotes on OTC markets. For more detail on the two high-frequency series, see Kerssenfischer (2019).

The VAR itself is estimated with monthly data on 2-year German government bond yields, the Euro STOXX 50, and euro area industrial production and consumer prices. To capture the international dimension, effective values of foreign 2-year government bond yields, foreign consumer prices and the respective nominal exchange rate are included. Building on evidence that the reaction of actual credit costs to monetary policy surprises might exceed those of simple yield changes in government bonds (see *e.g.* Gertler and Karadi, 2015), I further add the euro area bank credit spread developed by Gilchrist and Mojon (2018). All variables, except the interest rate yields and the spread, enter in logs. Effective rates are calculated against a total of twelve trading partners, with three year period trade weights chained over time. The countries included are those of the G-10 currencies besides the EUR (United States, Japan, United Kingdom, Switzerland, Sweden, Canada, Australia, Norway, New Zealand), as well as Denmark, the Czech Republic and Poland. These cover approximately 50% of euro area trade.[5] The estimation sample covers monthly data from January 1999 to September 2018, whereby the high-frequency proxies are available starting in March 2002. Additional details on the data sources are given in Table A1.

3.2 Identification via Proxy Variables

Identification of the two shocks follows the idea of Proxy VARs, developed by Stock and Watson (2012) and advanced to multiple shocks by Mertens and Ravn (2013). Consider the structural form of a VAR with p lags

$$\mathbf{A}_0\mathbf{y}_t = \mathbf{k} + \mathbf{A}_1\mathbf{y}_{t-1} + \cdots + \mathbf{A}_p\mathbf{y}_{t-p} + \boldsymbol{\varepsilon}_t, \quad \boldsymbol{\varepsilon}_t \sim N(\mathbf{0}, \mathbf{I}) \tag{6}$$

where $\mathbf{y}_t$ is a $(n \times 1)$ vector of endogenous variables and $\boldsymbol{\varepsilon}_t$ is a $(n \times 1)$ vector of structural shocks. Equation (6) can be rewritten in its estimable reduced-form

$$\mathbf{y}_t = \mathbf{c} + \mathbf{B}_1\mathbf{y}_{t-1} + \cdots + \mathbf{B}_p\mathbf{y}_{t-p} + \boldsymbol{\mathcal{A}}\boldsymbol{\varepsilon}_t, \quad \boldsymbol{\mathcal{A}}\boldsymbol{\varepsilon}_t \sim N(\mathbf{0}, \boldsymbol{\Sigma}) \tag{7}$$

where $\mathbf{c} = \mathbf{A}_0^{-1}\mathbf{k}$, $\mathbf{B}_i = \mathbf{A}_0^{-1}\mathbf{A}_i$ with $i = 1, \ldots, p$ and $\boldsymbol{\mathcal{A}} = \mathbf{A}_0^{-1}$. Consider that interest lies in the identification of just $k < n$ structural shocks. The relationship between the reduced-form shocks, $\mathbf{u}_t$, from the estimated model in (7) and the

[5]With a recent trade weight of around 18.5%, China is the most noteable omission. However, due to data limitations, especially in the early years of the estimation, I refrain from including it.

structural shocks, $\boldsymbol{\varepsilon}_t$, in (6) can be expressed as

$$\mathbf{u}_t = \begin{pmatrix} \mathbf{u}_{1t} \\ \mathbf{u}_{2t} \end{pmatrix} = \begin{pmatrix} \boldsymbol{\alpha}_{11} & \boldsymbol{\alpha}_{12} \\ \boldsymbol{\alpha}_{21} & \boldsymbol{\alpha}_{22} \end{pmatrix} \begin{pmatrix} \boldsymbol{\varepsilon}_{1t} \\ \boldsymbol{\varepsilon}_{2t} \end{pmatrix} = \boldsymbol{\mathcal{A}}\boldsymbol{\varepsilon}_t \tag{8}$$

where the $(n \times k)$ matrix $\boldsymbol{\alpha}_1 = (\boldsymbol{\alpha}'_{11}, \boldsymbol{\alpha}'_{21})'$ recovers the impact responses to the k structural shocks of interest captured in $\boldsymbol{\varepsilon}_{1t}$. The Proxy VAR literature proposes to obtain covariance restrictions on $\boldsymbol{\mathcal{A}}$ from one or multiple proxies, $\mathbf{m}_t$, in order to identify $\boldsymbol{\alpha}_1$. In the study at hand, $\mathbf{m}_t$ is comprised of the high-frequency responses of stocks and yields around ECB announcements as described in the last subsection, added up to a monthly frequency. Furthermore, $k = 2$ with $\boldsymbol{\varepsilon}_{1t}$ capturing the pure monetary policy shocks and the central bank information shock. In general, assuming $\mathbb{E}(\mathbf{m}_t) = \mathbf{0}$, the proxy variables need to fulfill the following conditions

$$\mathbb{E}(\mathbf{m}_t\boldsymbol{\varepsilon}'_{1t}) = \boldsymbol{\Phi} \tag{9}$$

$$\mathbb{E}(\mathbf{m}_t\boldsymbol{\varepsilon}'_{2t}) = \mathbf{0} \tag{10}$$

comparable to those in an instrumental variable approach: the proxies (i) have to be correlated with the structural shocks of interest, $\boldsymbol{\varepsilon}_{1t}$, and (ii) have to be uncorrelated with all other structural shocks, $\boldsymbol{\varepsilon}_{2t}$. From (8)-(10), it follows that $\mathbb{E}(\mathbf{m}_t\boldsymbol{u}'_t) = \boldsymbol{\Phi}\boldsymbol{\alpha}'_1$. Further, partitioning $\mathbb{E}(\mathbf{m}_t\mathbf{u}'_t) = [\mathbb{E}(\mathbf{m}_t\mathbf{u}'_{1t}), \mathbb{E}(\mathbf{m}_t\mathbf{u}'_{2t})]$:

$$\boldsymbol{\alpha}_{21} = \left[\mathbb{E}(\mathbf{m}_t\mathbf{u}'_{1t})^{-1}\mathbb{E}(\mathbf{m}_t\mathbf{u}'_{2t})\right]'\boldsymbol{\alpha}_{11} \tag{11}$$

Estimates of $\mathbb{E}(\mathbf{m}_t\mathbf{u}'_{1t})$ and $\mathbb{E}(\mathbf{m}_t\mathbf{u}'_{2t})$ can be readily obtained from regressing the residuals from the estimated reduced-form VAR in (7) on the proxies, $\mathbf{m}_t$. Here, this amounts to regressing the residuals of the monthly yields and stocks data in the VAR, $\mathbf{u}_{1t}$, on $\mathbf{m}_t$ and doing the same for the residuals of the remaining variables, $\mathbf{u}_{2t}$. When $k = 1$ and, accordingly, $\boldsymbol{\alpha}_{11}$ is scalar, combining the restrictions in (11) with the standard restrictions from $\mathbb{E}(\mathbf{u}_t\mathbf{u}'_t) = \boldsymbol{\mathcal{A}}\boldsymbol{\mathcal{A}}'$, $\boldsymbol{\alpha}_1$ is already identified up to a sign convention (see *e.g.* footnote 4 in Gertler and Karadi, 2015). In the case of $k > 1$ and non-zero values on the off-diagonal of the correlation matrix between the proxies and the proxied variables, however, the structural shocks in $\boldsymbol{\varepsilon}_{1t}$ are still not isolated from each other. Mertens and Ravn (2013) consider the following parameterization of the relationship between $\mathbf{u}_t$ and $\boldsymbol{\varepsilon}_t$ to isolate the causal effects of the k structural shocks

$$\mathbf{u}_{1t} = \boldsymbol{\eta}\mathbf{u}_{2t} + \mathbf{S}_1\boldsymbol{\varepsilon}_{1t} \tag{12}$$

$$\mathbf{u}_{2t} = \boldsymbol{\zeta}\mathbf{u}_{1t} + \mathbf{S}_2\boldsymbol{\varepsilon}_{2t} \tag{13}$$

where $\boldsymbol{\eta}$, $\boldsymbol{\zeta}$, $\mathbf{S}_1$ and $\mathbf{S}_2$ contain the structural coefficients underlying $\boldsymbol{\mathcal{A}}$. Solving this system of equations for $\mathbf{u}_t$ and utilizing (8), $\boldsymbol{\mathcal{A}}$ can be expressed as

$$\boldsymbol{\mathcal{A}} = \begin{pmatrix} \boldsymbol{\alpha}_1 & \boldsymbol{\alpha}_2 \end{pmatrix} = \begin{pmatrix} (\mathbf{I} + \boldsymbol{\eta}(\mathbf{I} - \boldsymbol{\zeta}\boldsymbol{\eta})^{-1})\mathbf{S}_1 & \boldsymbol{\eta}(\mathbf{I} - \boldsymbol{\zeta}\boldsymbol{\eta})^{-1}\mathbf{S}_2 \\ (\mathbf{I} - \boldsymbol{\zeta}\boldsymbol{\eta})^{-1}\boldsymbol{\zeta}\mathbf{S}_1 & (\mathbf{I} - \boldsymbol{\zeta}\boldsymbol{\eta})^{-1}\mathbf{S}_2 \end{pmatrix} \tag{14}$$

With the help of the restriction from (11), $\boldsymbol{\alpha}_1\mathbf{S}_1^{-1}$ as well as $\mathbf{S}_1\mathbf{S}_1'$ can be identified in (14). In a last step, an additional assumption is needed to identify $\mathbf{S}_1$. Since in the application both structural shocks in $\boldsymbol{\varepsilon}_{1t}$ are assumed to directly influence bond yields and stock markets, zero restrictions on $\mathbf{S}_1$ are not justifiable.[6] Instead, sign-restrictions are imposed on $\mathbf{S}_1$ in the following way: the first structural shock, a pure monetary policy shock, increases bond yields but decreases stock market valuation on impact; the second structural shock, a central bank information shock, increases both, bond yield and stock market valuation on impact. The sign restrictions are imposed following the algorithm of Rubio-Ramírez, Waggoner and Zha (2010), while the "correct" draw is chosen via the median target approach developed by Fry and Pagan (2011).

3.3 Bayesian Estimation

Instead of directly estimating the Proxy VAR as described in the last subsection, I make use of Bayesian inference. This choice is motivated by the "curse of dimensionality" problem that frequentist estimation of medium-scale VARs runs into in the case of the euro area, where data is only available as of 1999.[7] In particular, I adopt a natural conjugate Normal-Inverse Wishart prior and inform estimation via "Minnesota"-type prior information pioneered by Litterman (1986). Insofar, I extend the Bayesian VAR approach in Miranda-Agrippino and Ricco (2018) to multiple proxies and shocks. They prefer results from a Bayesian approach where local projections are informed at each impulse response horizon by VAR coefficients from a pre-sample estimation. In the current case, however, utilizing pre-sample data prior to the induction of the euro might misinform the local projections due to a structural break in the data.
The prior information follows a Normal-Inverse Wishart distribution

$$\boldsymbol{\Sigma}|\lambda \sim \mathcal{IW}(\underline{\mathbf{S}}, \underline{\alpha}) \tag{15}$$

$$vec(\mathbf{B})|\boldsymbol{\Sigma}, \lambda \sim \mathcal{N}(vec(\underline{\mathbf{B}}), \boldsymbol{\Sigma} \otimes \underline{\boldsymbol{\Omega}}) \tag{16}$$

[6] Mertens and Ravn (2013) solve $\mathbf{S}_1\mathbf{S}_1'$ for $\mathbf{S}_1$ using a Cholesky decomposition, which is reasonable for their research question.

[7] While it is possible to extend most data series beyond 1999 via weighting country-specific time-series, the introduction of the euro area constitutes a structural break in monetary policy that might render linear models implausible.

where $\underline{\mathbf{S}}$, $\underline{\alpha}$, $\underline{\mathbf{B}}$, $\underline{\mathbf{\Omega}}$ and λ are hyperparameters. While hyperparameters should normally only depend on prior knowledge, I follow common practice and set $\underline{\mathbf{S}}$ equal to a $(n \times n)$ diagonal matrix with variances of residuals from an AR(1) regression for each of the n variables, σ_j^2, on the diagonal. In order to ensure that $\mathbb{E}(vec(\mathbf{B})) = vec(\underline{\mathbf{B}})$ and $\mathbb{V}ar(vec(\mathbf{B})) = \underline{\mathbf{S}} \otimes \underline{\mathbf{\Omega}}$, the prior degrees of freedom, $\underline{\alpha}$, are set equal to $n + 2$. The other two hyperparameters are fixed according to the idea of "Minnesota" priors: setting $\underline{\mathbf{B}}_1 = \mathbf{I}_n$, $\underline{\mathbf{c}} = \mathbf{0}$ and $\underline{\mathbf{B}}_i = \mathbf{0}$ for $i > 1$ in $\underline{\mathbf{B}} = [\underline{\mathbf{c}}, \underline{\mathbf{B}}_1, \ldots, \underline{\mathbf{B}}_p]'$ imposes random walk behaviour on all elements of $\mathbf{y}_t$. Additionally, the variance of the prior coefficients is specified such that it increases with lag size p and depends on the σ_i^2s. This is achieved by setting $\underline{\mathbf{\Omega}}$ equal to (see Miranda-Agrippino and Ricco, 2018):

$$\underline{\mathbf{\Omega}} = \begin{pmatrix} \epsilon & \mathbf{0} \\ \mathbf{0} & \mathbf{J}_p \otimes \lambda^2 diag\left([\sigma_1^2, \ldots, \sigma_n^2]\right)^{-1} \end{pmatrix} \tag{17}$$

where $\mathbf{J}_p = diag([1, 2, \ldots, p])^{-1}$ and ϵ is chosen to be a large number, reflecting a loose prior on the constants. Lastly, the overall tightness of the prior, defined by λ, is set according to the hierarchical modeling approach outlined in Giannone, Lenza and Primiceri (2015).[8]

Combining this prior with the likelihood function, the posterior can be shown to also be of a Normal-Inverse Wishart type

$$\mathbf{\Sigma}|\mathbf{y}, \lambda \sim \mathcal{IW}(\overline{\mathbf{S}}, \overline{\alpha}) \tag{18}$$

$$vec(\mathbf{B})|\mathbf{y}, \mathbf{\Sigma}, \lambda \sim \mathcal{N}(vec(\overline{\mathbf{B}}), \mathbf{\Sigma} \otimes \overline{\mathbf{\Omega}}) \tag{19}$$

where $\overline{\mathbf{S}}$, $\overline{\alpha}$, $\overline{\mathbf{B}}$ and $\overline{\mathbf{\Omega}}$ are standard and can be looked up *e.g.* in Koop and Korobilis (2010).

$\mathbf{\Sigma}$ and $vec(\mathbf{B})$ are then drawn 5,000 times from the posterior and for each draw, the proxy approach outlined in Section 3.2 is utilized to find the respective impulse responses to the two structural shocks of interest. As monthly data is used, the lag order chosen is twelve.

4 Empirical Results

In this section, I first present impulse responses of the baseline Proxy VAR where the effective exchange rate of the EUR is considered and foreign variables are comprised of the trade-weighted average of the twelve countries discussed above. Subsequently,

[8] The method chooses a λ of 0.0657 in the baseline VAR. This is in the same ballpark as the λ selected by the large VAR in Giannone, Lenza and Primiceri (2015) for their simplified model (see Figure 1 in their paper). Thus, there is quite some Bayesian shrinkage involved in the estimation. Nevertheless, my baseline results qualitatively hold in a frequentist approach (see Figure A1 in the appendix), showing that they are not mainly driven by the prior.

I try to capture heterogeneities between countries and currencies by including each country individually in the Proxy VAR and, building on these results, go on to report additional findings.

4.1 Effective Exchange Rate

Figure 2 displays impulse responses retrieved from the proxy identification outlined in Section 3.2 for a central bank information shock and a pure monetary policy shock. Restrictions via the proxies are imposed on the bottom two variables, the 2-year German government bond yield and the Euro STOXX 50. For the sake of comparison, a naive monetary policy shock is plotted in the outermost right column. Identification is achieved here by solely proxying the monthly yields with the high-frequency reactions of bond yields around monetary policy announcements. The different shocks are normalized such that, on impact, 2-year German government bond yields increase by 100 basis points.

The naive approach that ignores potential effects of information shocks produces some responses not in line with theory. First, the well-known price puzzle emerges as the domestic CPI increases on impact following a contractionary monetary policy shock (see Ramey, 2016, for a recent discussion on the price puzzle). Second, in contrast to the findings in Gertler and Karadi (2015), credit costs decrease upon the impact of the shock. They argue that in response to a contractionary monetary policy shock, credit constraints in the economy tighten and thus amplify the effect on private borrowing. Third, stock markets, whose response is not restricted in the naive approach, do not react on impact. According to theory, higher interest rates coupled with a depressed economic outlook due to the policy tightening decrease the expected present value of future cash flows and, therefore, stock market valuation.

Similar to the findings in Jarociński and Karadi (2019), disentangling information shocks from monetary policy shocks reconciles empirical impulse responses to pure monetary policy shocks with theory: the price puzzle is gone, credit costs increase, although not directly on impact, and, imposed by the identification, stock market valuation dwindles (second column of Figure 2). The other domestic variables also respond in line with theory, and real effects of monetary policy seem to be sizable, as seen by the stark response of industrial production.

More strikingly for exchange rate analysis, though, are the economically and statistically significant reactions of foreign effective yields and, to a lesser extent, of foreign consumer prices. Their responses highlight the importance of treating foreign variables as endogenous when assessing exchange rate responses to shocks originating in large open economies. Foreign 2-year government bond yields increase on impact by about 40 basis point, in line with Kearns, Schrimpf and Xia (2018)'s findings of significant ECB monetary policy spillovers for 2-year yields, especially to advanced economies.[9] This, *ceteris paribus*, dampens the effect of the pure monetary policy shocks on the effective exchange rate via the UIP. Still, the impact response of the effective exchange rate against the twelve countries in the sample is a sizable appreciation of around 7%. With the interest rate responses dying out after some time, the effective exchange rate depreciates again. In the long-run, domestic and foreign price levels should determine the exchange rate according to the PPP. Interestingly, the response of foreign consumer prices is comparable to the one of domestic prices and, as a consequence thereof, the exchange rate response becomes insignificant after around two years.[10] In part, this finding can be rationalized by global commonality in inflation (Ciccarelli and Mojon, 2010) and the leading role of monetary policy in center economies for the global financial cycle (Rey, 2015). Thus, refraining from these non-existent long-run effects on the effective exchange rate, the findings are in line with Dornbusch's (1976) overshooting hypothesis in the sense that the peak exchange rate response appears on impact of the shock.

The proposed identification also allows a novel investigation of exchange rate responses to central bank information shocks, as opposed to pure monetary policy shocks. First of all, in accordance with Jarociński and Karadi (2019), information shocks that increase domestic interest rates exhibit expansionary effects on the economy. Not only do they push up the domestic price level, but also industrial production with a delay of a few months, amplified by lower credit costs. Thus, central bank information shocks are relevant in that they depict a shock distinguishable from a traditional monetary policy shock. Moreover, the increase in domestic yield does not translate into a statistically significant appreciation as is the case after a pure monetary policy shock. In the appendix, I also show that these marked differences in exchange rate responses towards the two distinct shocks still hold true in a frequentist setup (Figure A1) and with OIS high-frequency data from Altavilla et al. (2019) (Figure A2).

While the increase in foreign yields seems to be a bit more pronounced in the first couple of months compared to the pure monetary policy shock, this alone most certainly cannot explain the huge difference in exchange rate reactions between the two shocks. Price levels, again, react domestically as well as in the foreign countries ex-

[9]Note that some amount of spillover effects are to be expected by design, as not all included currencies were free floating against the EUR over the whole sample: the Danish krone participated in the ERMII over the whole sample, the Czech national bank stabilized the koruna against the EUR for some time and the Swiss national bank defended the franc against appreciation *vis-à-vis* the EUR over a non-negligible period within the sample.

[10]The similar responses of domestic and foreign CPI imply comparable responses of the real exchange rate and the nominal exchange rate presented here. Thus, results can be directly contrasted to those in *e.g.* Eichenbaum and Evans (1995) or Kim, Moon and Velasco (2017), who utilize the real exchange rate.

amined here, but this time, more so domestically. The somewhat stronger increase in domestic prices also supports a weaker exchange rate reaction by virtue of PPP. A deeper assessment of these differences in exchange rate reactions is carried out in the next subsection, where bilateral exchange rates are taken into account.

4.2 Bilateral Exchange Rates

4.2.1 Currency Characteristics

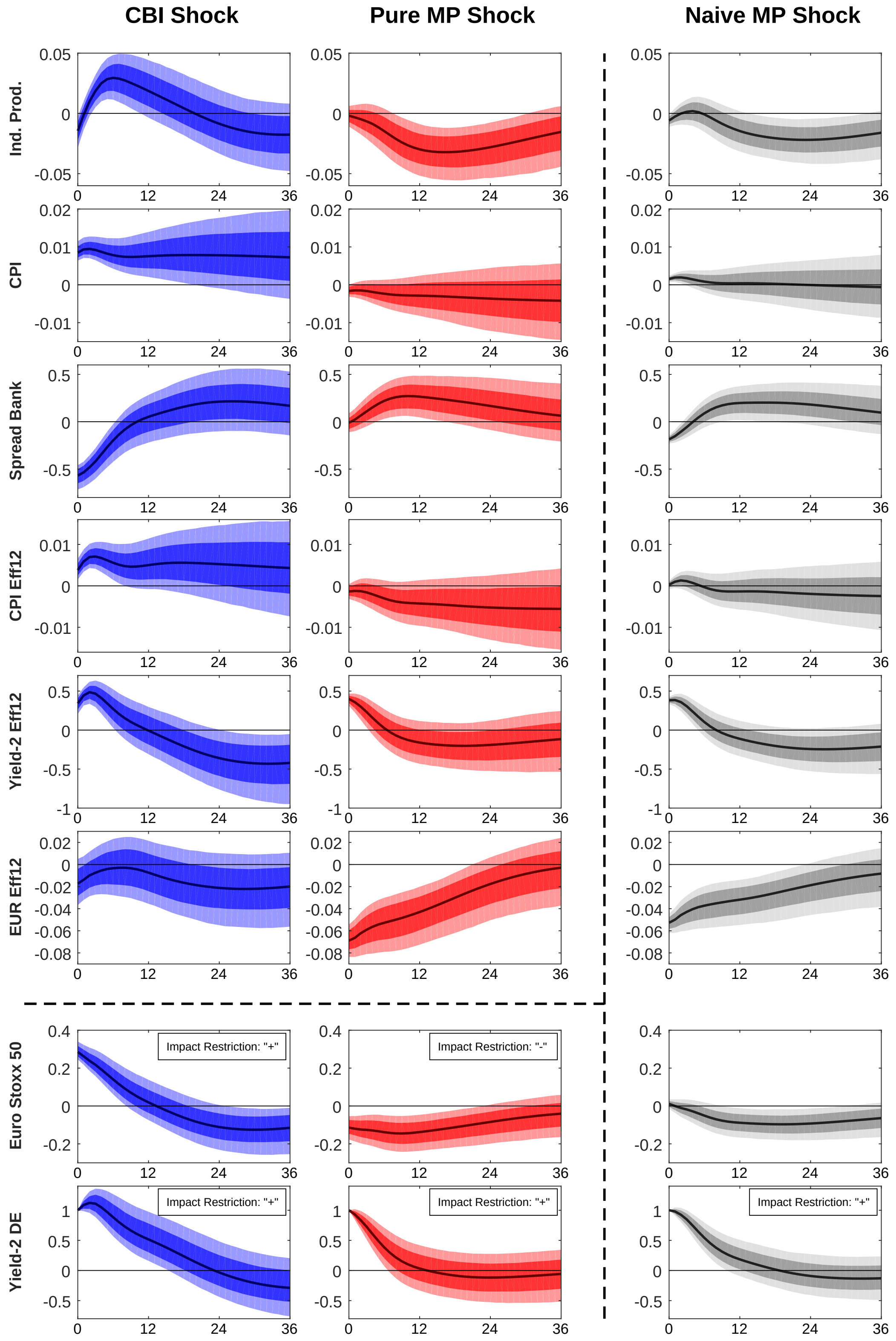
Bilateral exchange rates might shine a brighter light on the different transmission of pure monetary policy shocks and central bank information shocks that could be concealed by the aggregate perspective of effective exchange rates. To this end, Table 1 depicts the 13 currencies (including the EUR) according to different characteristics that assist in explaining heterogeneities in exchange rate responses. In order to give economic meaning to the responses, only currencies classified as "free floating" are considered in the subsequent analysis. This excludes the Swiss franc, which was inhibited from appreciating above 1.20 franc per EUR between September 2011 and January 2015, the Czech koruna, which was stabilized within a narrow band against the EUR between November 2013 and April 2017, and the Danish krone, which participated in the ERMII over the whole sample. I additionally exclude the Polish zloty due to its status as a transition economy, at least over part of the sample. This leaves us with eight currency pairs *vis-à-vis* the EUR.[11]

Table 1 also reports G-10 currency classifications according to their prevalent characteristics on financial markets that go beyond fundamental exchange rate determinants such as UIP and long-run PPP as found in Hossfeld and MacDonald (2015) in column (3). After controlling for such fundamental determinants, a speculative currency is positively related to stock market valuation, while the opposite is true for a hedge currency. A safe haven currency, in contrast to a hedge currency, only exhibits a negative relation to stock markets in times of high financial stress. Lastly, a currency is classified as carry funding when it produces low yields compared to its peers but appreciates in times of high financial stress due to carry trade reversals, or *vice versa*.

Column (5) of Table 1 allocates the G-10 currencies to different clusters as found by Aloosh and Bekaert (2019). Allowing for two factors, currencies either belong to a dollar bloc or a euro bloc, whereby the affiliation to the latter seems to be highly related to the euro area trade dependency reported in the previous column of the table. An additional commodity bloc emerges when the possibility of a third factor is taken into account, which consists of three previous dollar bloc currencies.

[11] For the sake of completeness, bilateral exchange rate responses for the four currencies left out are reported in the appendix in Figure A3.

Figure 2 Baseline Impulse Responses



Note: The figure displays the impulse responses to a central bank information (CBI) shock, a pure monetary policy (Pure MP) shock and a naive monetary policy (Naive MP) shock that increase 2-year German government bond yields (Yield-2 DE) by 100 basis points on impact. The shaded areas show the 68% and 90% credibility bands. A negative response of the effective euro exchange rate indicates an appreciation of the EUR.

Interestingly, the GBP switches from being a euro bloc currency to being a dollar bloc currency, accentuating its ambiguity already seen in the currency classification.

4.2.2 Exchange Rate Responses and Interest Rate Differentials

Figure 3 clearly shows that the insignificant reaction of the nominal effective exchange rate to a central bank information shock cannot be attributed to a general irrelevance of this shock for exchange rates, but rather to the strong heterogeneity in reactions among different currency pairs. Furthermore, I present evidence in this subchapter that a different extent of spillovers to foreign yields can to some degree explain the variation in the magnitudes of exchange rate reactions between currency blocs but cannot be seen as the cause of disparities between the two shocks (see Figure 4).

But first things first: Figure 3 plots the impulse responses of the exchange rates of the eight currencies examined here against the EUR for a pure euro area monetary policy shock and a central bank information shock. The strong heterogeneity observable in these responses, especially following a central bank information shock, points towards different roles these currencies play with respect to the EUR, but also on a global scale. In line with the significant and sizable appreciation of the effective EUR in Figure 2 following a contractionary monetary policy shock, the EUR also appreciates bilaterally on impact against all currencies and statistically significantly so for all but the SEK. The immediate effect varies between a considerable appreciation of 13.8% against the CAD and a mere 1.4% against the SEK. Generally, the effect peters out quite fast and is statistically insignificant at the 10% level for all currency pairs besides the EUR-USD exchange rate after two years. This is in contrast to past findings of quite persistent nominal exchange rate responses to monetary policy shocks (see *e.g.* Faust and Rogers, 2003, or Scholl and Uhlig, 2008). For the central bank information shock, even the direction of the response is not predictable without further knowledge about the respective currency pair, as we observe appreciations of the EUR of up to 15.5% (against the JPY) contrasted by depreciations of up to 4.6% (against the NZD).

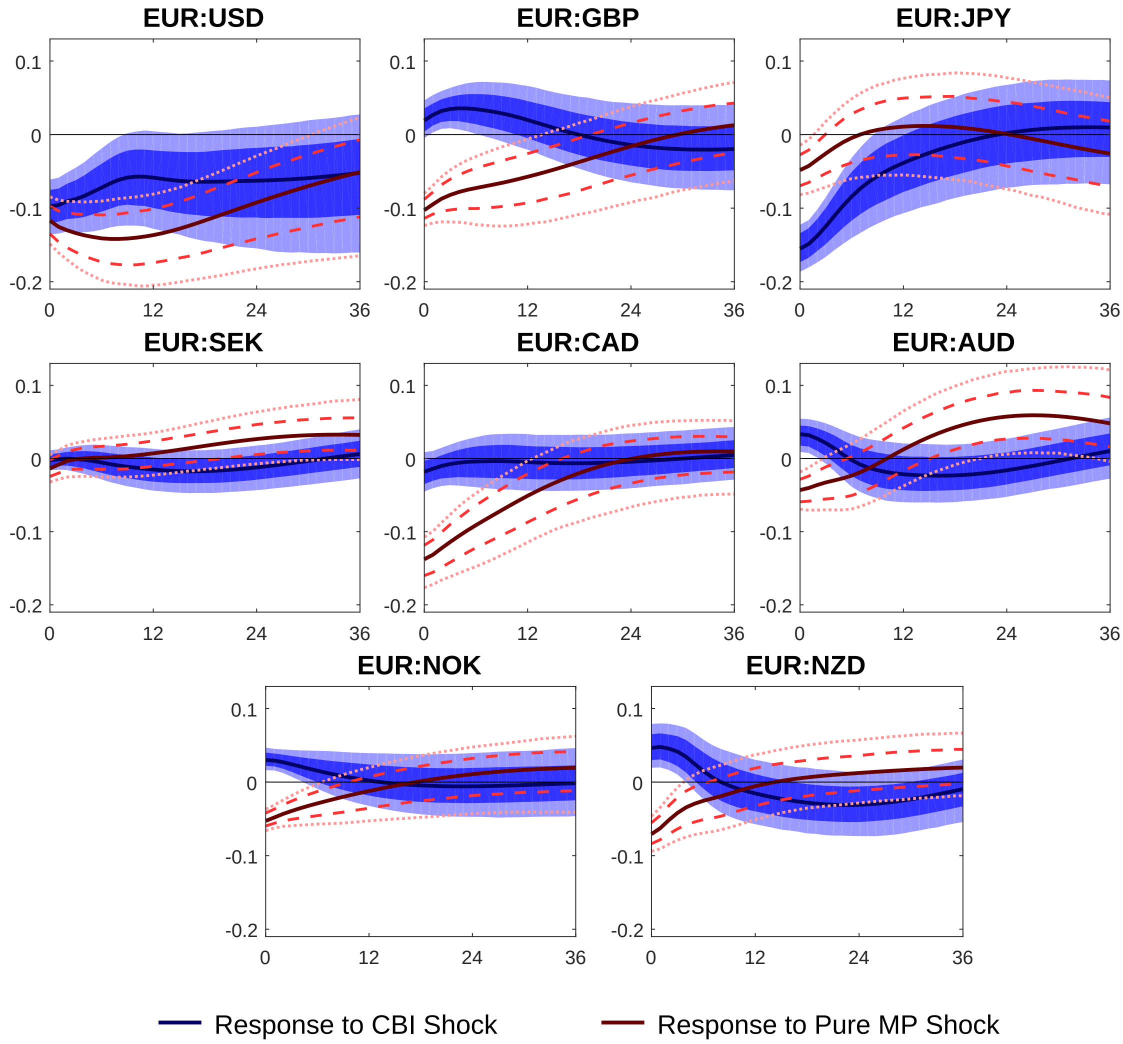
Arguing from a UIP perspective, different spillovers of ECB announcements on foreign yields might help to explain the observed heterogeneity in exchange rate responses among countries and shocks. Financial spillovers generally depend on a myriad of conditions, such as financial integration with the country of origin, financial openness, trade linkages or the exchange rate arrangement to name a few. More broadly, monetary policy in center economies might also propagate across borders via the global financial cycle as outlined in Rey (2015). Indeed, past empirical research finds sizable financial spillovers from ECB monetary policy decisions, at least to other European countries (see *e.g.* Falagiarda, McQuade and Tirpák, 2015, or

Table 1 Currency Characteristics

Country	Currency	(1) Euro Area Weight[1]	(2) Free Floating[2]	(3) Classification[3]	(4) Euro Area Trade Dependency[4]	(5) Currency Cluster[5]
Euro Area	EUR	-	yes	Hedge	-	Euro
United States	USD	26.7	yes	Carry Funding/Safe Haven	16.6	Dollar
United Kingdom	GBP	20.4	yes	Unclear	42.7	Euro (Dollar)
Poland	PLZ	10.8	yes[6]	-	52.6	-
Switzerland	CHF	10.5	no	Hedge/Safe Haven	45.1	Euro
Czech Republic	CZK	8.1	no	-	51.8	-
Japan	JPY	8.0	yes	Carry Funding	12.7	Dollar
Sweden	SEK	6.6	yes	Speculative	43.7	Euro
Denmark	DKK	3.3	no	-	40.7	-
Canada	CAD	2.4	yes	Speculative	9.4	Dollar (Commodity)
Norway	NOK	1.7	yes[7]	Speculative	33.4	Euro
Australia	AUD	1.3	yes	Speculative	15.8	Dollar (Commodity)
New Zealand	NZD	0.2	yes[8]	Speculative	15.7	Dollar (Commodity)

[1] Latest trade weight (2013-2015) in euro area trade weight matrix against the group of twelve countries observed here.
[2] According to the Currency Classifications in International Monetary Fund (2019) and its preceding publications. A currency is considered free floating if it has been classified so (or as "floating") in IMF publications since March 2002, the start of high-frequency series used in the shock identification.
[3] According to Hossfeld and MacDonald (2015).
[4] Latest trade weight (2013-2015) of the euro area in a specific country's trade weight matrix against 56 countries.
[5] According to Aloosh and Bekaert (2019). Allowing for two clusters, they find a dollar and a euro bloc. Allowing for a third cluster, they additionally identify a commodity bloc. The bloc affiliation with three clusters is given in paranthesis if it deviates from the one with only two clusters.
[6] The Polish Zloty was pegged to a basket consisting of EUR and USD in the beginning of 1999 and, after a gradual adjustment via a crawling peg, was allowed to freely float, effective April 12, 2000.
[7] Prior to its adoption of an inflation target, effective March 29, 2001, the stability of the NOK against the EUR was one policy objective of the Bank of Norway and the NOK was classified as a "managed float with no preannounced path for the exchange rate."
[8] As of the end of 2012, the Reserve Bank of New Zealand may intervene "if the exchange rate is exceptionally high or low, if that rate is not justified by economic fundamentals, and if there is a material prospect that the intervention will influence the exchange rate." Consequently, from 2013 onwards, the NZD is classified as "floating" instead of "free floating."

Figure 3 Exchange Rate Responses



Note: The figure displays exchange rate responses and their respective 68% and 90% credibility bands to a central bank information (CBI) shock and a pure monetary policy (Pure MP) shock that increase 2-year German government bond yields by 100 basis points on impact. A negative response indicates an appreciation of the EUR.

ter Ellen, Jansen and Midthjell, 2020), which are stronger for countries with a high financial integration (Potjagailo, 2017). This financial integration with the euro area can be roughly proxied by the currency bloc classification in Aloosh and Bekaert (2019) (see Table 1). Accordingly, Figure 4 plots the impulse responses of 2-year government bond interest rate differentials categorized by currency bloc affiliation. A first glance already reveals highly diverse spillovers between currency blocs, but less so between different shocks.

Not surprisingly, the euro bloc countries, consisting of Sweden and Norway, exhibit the highest spillovers: interest rate differential responses are never statistically different from zero for both shocks. These findings resemble the strong and persistent spillover of path factor surprises[12] to Norwegian and Swedish medium-term yields found in ter Ellen, Jansen and Midthjell (2020). Consequently, attenuated exchange rate responses of the NOK and, especially, the SEK are in line with UIP considerations.

In contrast, and also compatible with a comparably low trade dependency on the euro area, interest rate differentials for the dollar bloc currencies all respond significantly for at least the first few months after impact of each of the two shocks. While for the most part, the increases in interest rate differentials translate into a strong appreciation of the euro *vis-à-vis* the dollar bloc currencies, this is not necessarily the case. The appreciation against the JPY following a monetary policy shock is rather small and after a central bank information shock the EUR even depreciates against the GBP.

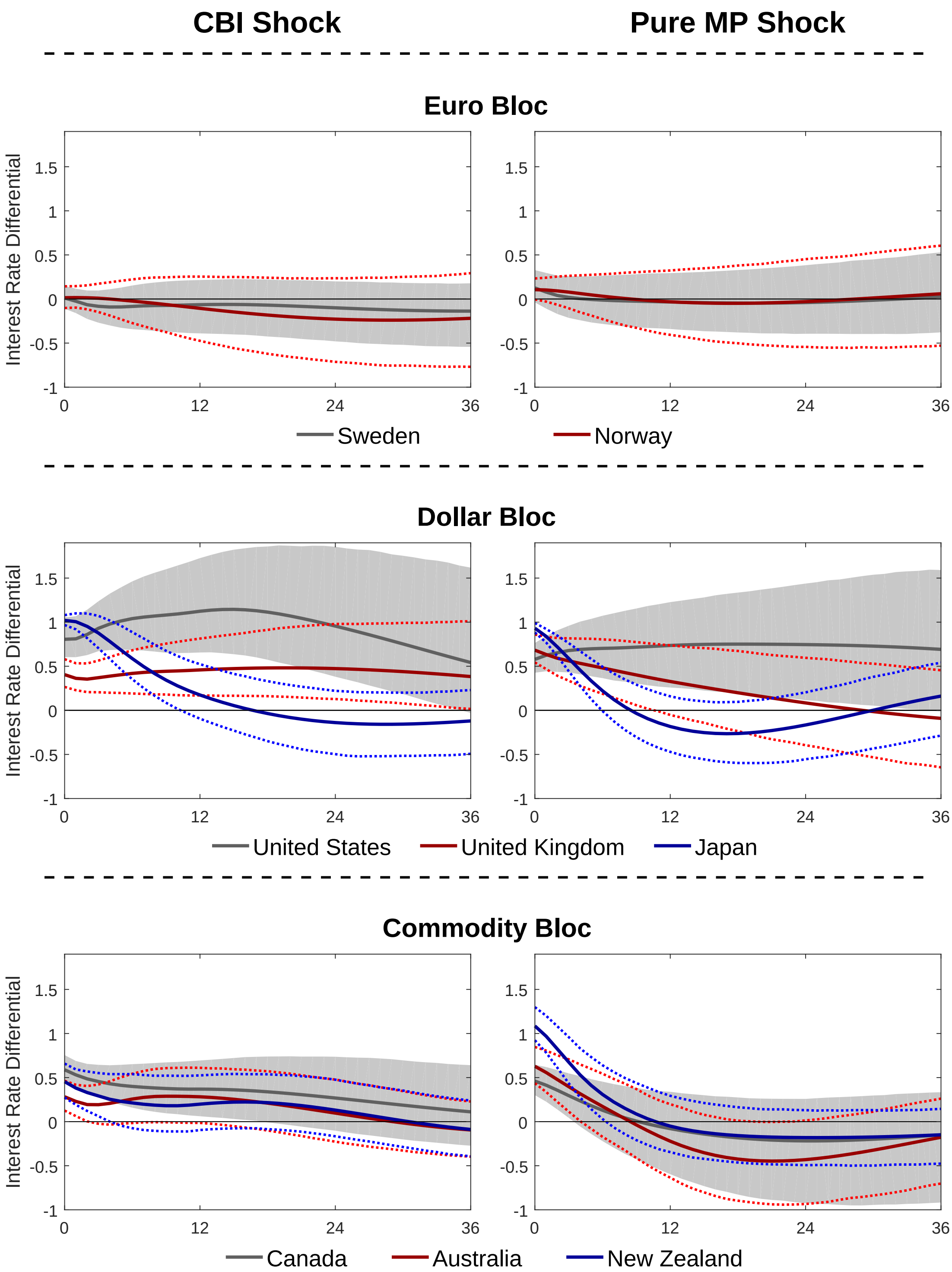
Although interest rate differentials respond positively and significantly, at least on impact, commodity bloc currencies mostly do not exhibit strong depreciations against the EUR. Compared to the dollar bloc, however, responses of the differential are surprisingly similar among the three currencies. Thus, monetary spillovers and the associated smaller interest rate differentials might partially explain attenuated responses of exchange rates of the EUR, such as against the SEK and the NOK, but most certainly cannot rationalize heterogeneities between the two shocks.

4.2.3 Beyond the UIP: Risk Sentiment and the Role of Carry Trades

Under the assumption that exchange rate expectations are anchored by PPP in the long run, the previous analysis implies a failure of the UIP in the case of central bank information shocks. One important component captured by deviations from

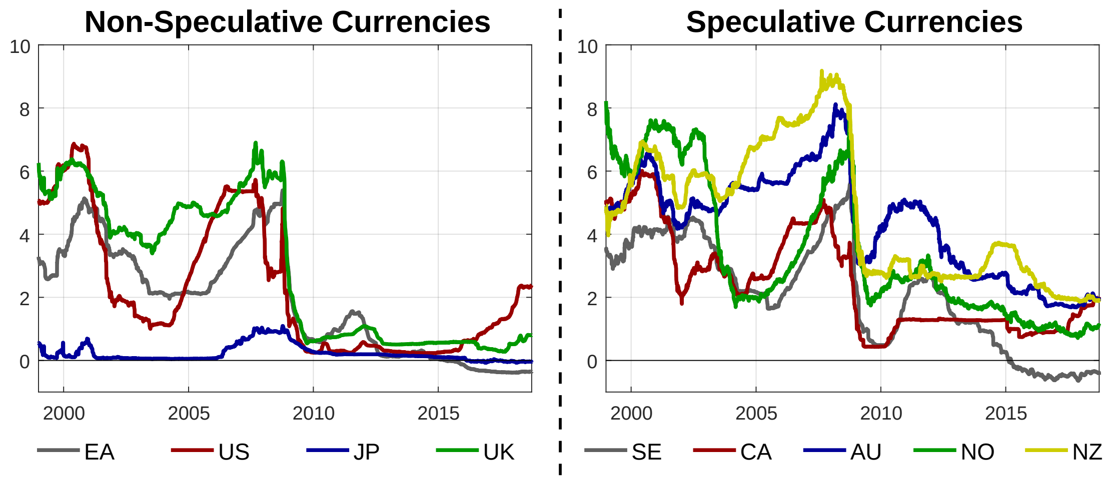
[12] The path factor, in contrast to the target factor, is the change in medium-term yields orthogonal to changes in short-term rates. It is generally interpreted as capturing forward guidance and, in more recent samples, possibly also central bank asset purchases. Section 4.3.1 investigates the differentiation between target and path shocks more thoroughly.

Figure 4 Interest Rate Differential Responses



Note: The figure displays the impulse responses of the 2-year government bond interest rate differentials between German yields and the respective foreign yields and their 90% credibility bands following a central bank information (CBI) shock and a pure monetary policy (Pure MP) shock that increase 2-year German government bond yields by 100 basis points on impact.

Figure 5 3-Month Interbank Rates



Note: The figure depicts 3-month interbank rates for currencies classified as non-speculative (left panel) and speculative (right panel) retrieved from Thomson Reuters Datastream.

the UIP in Equation (5), ξ_t, is the time-varying foreign exchange risk premium.[13] The current subchapter, accordingly, establishes an important role for investors' risk sentiment in the responses of exchange rates following central bank information shocks that can rationalize previous results.

A defining feature in the currency classification in Table 1 is that the value of speculative currencies is positively related to investors' risk appetite, while the opposite is true for hedge, safe haven and carry funding currencies. With this in mind, it is striking that the EUR does not appreciate significantly following a positive central bank information shock against any of the speculative, typically high-yielding, currencies in Figure 3. One subset of these speculative currencies are those of the commodity bloc. As argued by Ready, Roussanov and Ward (2017), high-yielding currencies naturally emerge in commodity countries due to their stronger insulation from global productivity shocks and, as a consequence thereof, a weaker motive for precautionary savings. Figure 5 confirms this, especially for New Zealand and Australia.[14]

A readily available proxy for investors' risk appetite in financial markets is the CBOE Volatility (VIX) index, which measures the implied volatility of options on the S&P500. Figure 6 displays the responses of both the S&P500[15] and the VIX,

[13]Another important component related to failures of the UIP is the convenience yield (see, among others, Jiang, Krishnamurthy and Lustig, 2018, or Valchev, 2019, for current research in this area). It displays the non-pecuniary benefit investors draw from holding a safe and liquid asset, such that they are willing to pay a premium. However, although government bonds in other currencies may posses a convenience yield, it is generally related to the USD as the global reserve currency.

[14]Note that following Hossfeld and MacDonald (2015), the figure depicts 3-month interbank rates instead of 2-year government bond yields. Carry trades, as an important form of speculation in high-yielding currencies, are generally concentrated on the short end of the yield curve.

[15]A broader choice for global stock market performance would be the MSCI World. However,

when additionally included in the baseline Proxy VAR. Following a monetary policy shock, US stocks decrease, but not significantly. A central bank information shock, however, pushes up stock prices in the US by about half as much compared to euro area stocks in Figure 2. This is accompanied by a decrease in implied stock market volatility. According to Rey (2015), the VIX approximates the global financial cycle quite well and it is strongly associated with capital flows (see *e.g.* Forbes and Warnock, 2012). International consequences thereof seem to be more pronounced when ECB announcements reveal information beyond monetary policy decisions. In the case of that information being positive, the lower VIX boosts investors' risk appetite. High-yielding currencies become a popular investment target in these "risk-on" times. Thus, notwithstanding the positive response of the interest rate differential in Figure 4, the AUD and the NZD, but also the NOK appreciate against the EUR. Importantly, the carry funding, safe haven and hedge currencies in the sample behave quite differently.

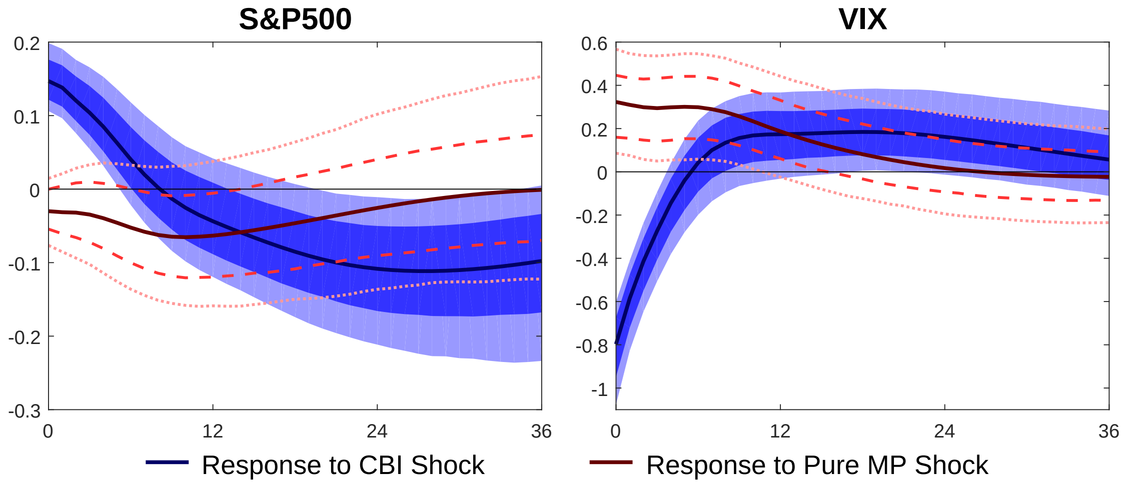
The EUR itself, classified as a hedge currency, potentially reinforces these effects as it is assumed to depreciate in times of "risk-on" sentiment in financial markets and *vice versa*. The same is true for safe haven currencies such as the USD, although only to the extent that global financial markets additionally have to be in a high stress regime. Judging from the reaction of the VIX, that might very well happen when the ECB announces a gloomy outlook on future economic activity. Thus, it is not surprising that the EUR appreciates strongly against the USD, regardless ofwhether the increase in the interest rate differential in Figure 4 comes from an information or a monetary policy shock.

An important form of speculative trading in foreign exchange markets is the currency carry trade. Due to violations in the UIP, going short in a low-yielding currency while simultaneously going long in a high-yielding currency provided speculators with positive abnormal returns on average in the past (see *e.g.* Menkhoff et al., 2012). As Brunnermeier, Nagel and Pedersen (2009) show, these returns come at a higher crash risk. This negative (positive) skewness of investment (funding) currency returns introduces asymmetries that are difficult to track in a VAR setting.[16] Still, a linear VAR gives us an indication of the qualitative effects of the two shocks to currencies on both ends of the carry trade. To this end, I follow Brunnermeier, Nagel and Pedersen (2009) and construct a carry trade funding portfolio of low-yielding currencies and a carry trade investment portfolio of high-yielding currencies from

as the euro area makes up a non-negligible part of the MSCI World, the index would mechanically react to ECB announcements that move exchange rates. With a weight of around 40%-60% in the MSCI World over the sample, US equity should be a good proxy for global stock market valuation. Nevertheless, including the MSCI World delivers similar results.

[16]The VAR in the present approach is already large compared to the sample size as it is. Non-linearities in such a setting are almost impossible to capture.

Figure 6 Stocks and Volatility



Note: The figure displays the impulse responses of the S&P500 and the VIX and their respective 68% and 90% credibility bands to a central bank information (CBI) shock and a pure monetary policy (Pure MP) shock that increase 2-year German government bond yields by 100 basis points on impact.

the eight currencies. In the beginning of each month, both portfolios are newly assembled, such that the carry trade funding portfolio encompasses the k currencies with the lowest yield, while the k highest yielding currencies are introduced into the carry investment portfolio. Within both portfolios, currencies are equally weighted. Then, from monthly exchange rate changes, an artificial index of the EUR exchange rate against these two portfolios is calculated. I set $k = 2, 3$.[17]

First of all, for $k = 3$, the JPY is always part of the funding portfolio and the USD makes it 57% of the time, in line with their classifications in Table 1. On the other end, the NZD (93%), the AUD (85%) and the NOK (67%) are the main investment currencies. The SEK and the CAD, also labeled as speculative, however, tend to be, if at all, part of the funding portfolio. This could actually explain the weaker exchange rate responses following a central bank information shock compared to the other speculative currencies. Lastly, in line with the ambiguous classification in Table 1, the GBP is part of each portfolio with equal frequency.

Figure 7 displays the responses of theses two portfolios to the shocks under investigation when included in the baseline Proxy VAR instead of the effective exchange rate. These responses articulate a clear message: namely, carry trades make an important contribution to the different propagation of the two shocks on the bilateral EUR exchange rates, as seen in Figure 3. The responses of the EUR exchange rate against both portfolios to the monetary policy shock are mostly indistinguishable. If at all, the appreciation of the euro is somewhat stronger against the carry trade invest-

[17] Brunnermeier, Nagel and Pedersen (2009) also set $k = 1$. In the present case, this translates into funding almost exclusively in JPY and investing in the AUD or the NZD. Thus, for $k = 1$, responses look quite similar to those of these currencies as presented in Figure 3.

ment portfolio, in line with a slight increase in risk-aversion. For the central bank information shock, this is different: the appreciation of the EUR against the funding portfolio is marked, while it even depreciates against the investment portfolio. These responses can be rationalized by capital flows from low-yielding currencies to high-yielding currencies. As previously established, risk appetite increases following a positive information shock. While the relationship is more pronounced in times of high financial stress (see *e.g.* Clarida, Davis and Pedersen, 2009), the VIX is in general negatively correlated with speculator carry positions (see *e.g.* Brunnermeier, Nagel and Pedersen, 2009). Thus, *ceteris paribus*, the decrease in the VIX sets in motion a flow from low-yielding funding currencies to high-yielding investment currencies, which is accompanied by a depreciation of the former and an appreciation of the latter.

Taking into account these carry trade flows, it is not surprising anymore that the EUR appreciates so strongly against the carry trade funding currencies USD and, above all, the JPY, following a central bank information shock. Also, depreciations against the speculative currencies, especially the AUD, the NZD and the NOK, are completely in line with an increasing risk appetite and subsequent carry trade flows.

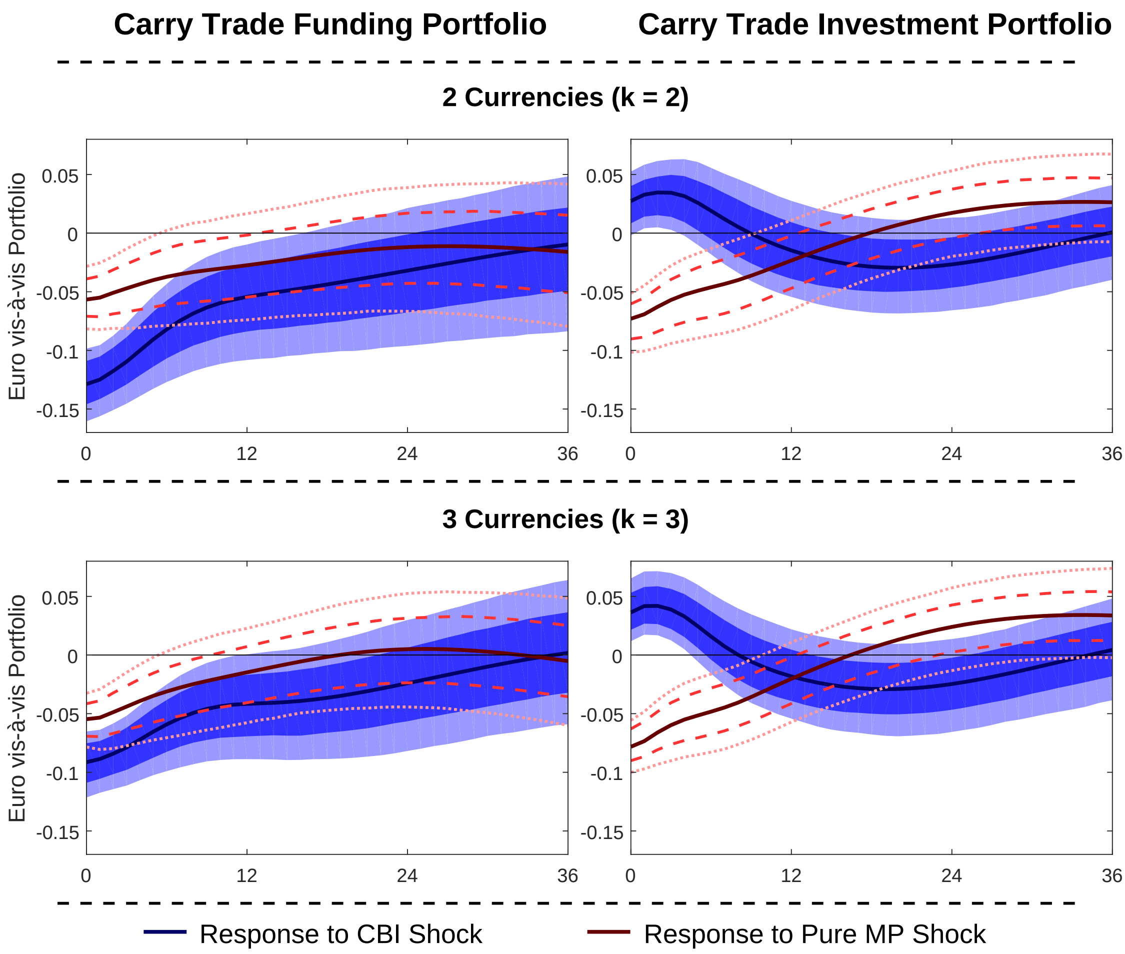
4.3 Additional Findings

4.3.1 Further Decomposing ECB Announcements

The previous analysis pools together surprises concerning policy rates, forward guidance and asset purchases in the monetary policy shock. Some studies, such as Gürkaynak, Sack and Swanson (2005), however, differentiate between so-called target shocks that concern surprises in the current policy rate and path shocks that capture surprises in the future path of monetary policy, mainly via communication on future policy rate changes (forward guidance), but to some extent also via announcements on central bank asset purchases. To discriminate between these shocks, I draw on Altavilla et al. (2019), who provide high-frequency reactions of a broad array of financial data around ECB Governing Council meetings.[18] A target surprise is then assumed to have its peak impact on the short end of the yield curve, represented by the 3-month OIS rate. A path surprise, on the other hand, is assumed to operate via somewhat longer maturities and should capture unconventional monetary policy surprises. In the Proxy VAR, the differentiation between the two shocks is implemented by imposing sign restrictions on the yield spread between 2-year German government bonds and 3-month OIS, as depicted in the upper part

[18]The high-frequency reactions in Altavilla et al. (2019) are measured as the change between the average quote 20 to 10 minutes before the press release and the average quote about 10 to 20 minutes after the press conference (assuming the press conference takes one hour).

Figure 7 Exchange Rate Reactions of Carry Trade Portfolios



Note: The figure displays the impulse responses of the EUR exchange and rate *vis-à-vis* the carry trade funding portfolios (left panels) and the carry trade investment portfolios (right panels) and the respective 68% and 90% credibility bands to a central bank information (CBI) shock and a pure monetary policy (Pure MP) shock that increase 2-year German government bond yields by 100 basis points on impact. A negative response indicates an appreciation of the EUR.

of Table 2.[19] Thus, the spread is added as a monthly variable to the baseline Proxy VAR, as well as a high-frequency variable to the vector of proxies, m_t.

Panel a) of Figure 8 displays the impulse responses of the effective EUR exchange rate to the three sign-identified shocks. Differences between the target and the path shock are comparably small.[20] On impact, a contractionary target surprise induces a stronger EUR appreciation, while for the path surprise the peak response is delayed by a few months. This is similar to the Proxy VAR findings in Rogers, Scotti and Wright (2018). In contrast, a higher exchange rate sensitivity to unconven-

[19]The 2-year German bond yield is taken instead of 2-year OIS rates as the trading volume on OIS contracts above 1 year is comparably low. High-frequency data in Altavilla et al. (2019) for the two rates utilized are available from 1999 onwards.

[20]Note that the target shock is normalized such that the 3-month OIS increases on impact by 100 basis points, while the path shock is normalized such that the 2-year German government bond yield increases by 100 basis points on impact.

tional monetary policy as often found in event studies (see *e.g.* Ferrari, Kearns and Schrimpf, 2017, or Glick and Leduc, 2018) cannot be confirmed.

Similarly, there have also been approaches to further disentangle the central bank information shock. Most notably, Cieslak and Schrimpf (2019) argue that central banks communicate novel information on the level of real activity to investors (growth shocks), but, at times, also provide information regarding the uncertainty of future economic conditions that mainly work through changes in risk premia (risk premium shocks). A prime example for the latter is the "whatever it takes" speech by ECB President Draghi on July 26, 2012. Along with a decrease in uncertainty on future economic conditions, premia on risky assets fall, creating "risk-on" sentiment among investors. Subsequently, stock prices surge and a lower demand for riskless asset pushes up yields of safe government bonds.[21] Compared to information on the level of economic activity, Hansen, McMahon and Tong (2019) argue that the impact of uncertainty accumulates over time. Consequently, the effect of these risk premium shocks should be felt more thoroughly at longer maturities. Thus, in line with Cieslak and Schrimpf (2019), a risk premium shock is disentangled from a growth shock via a sign restriction on the yield spread between 10-year and 2-year German government bonds, as depicted in the lower part of Table 2.

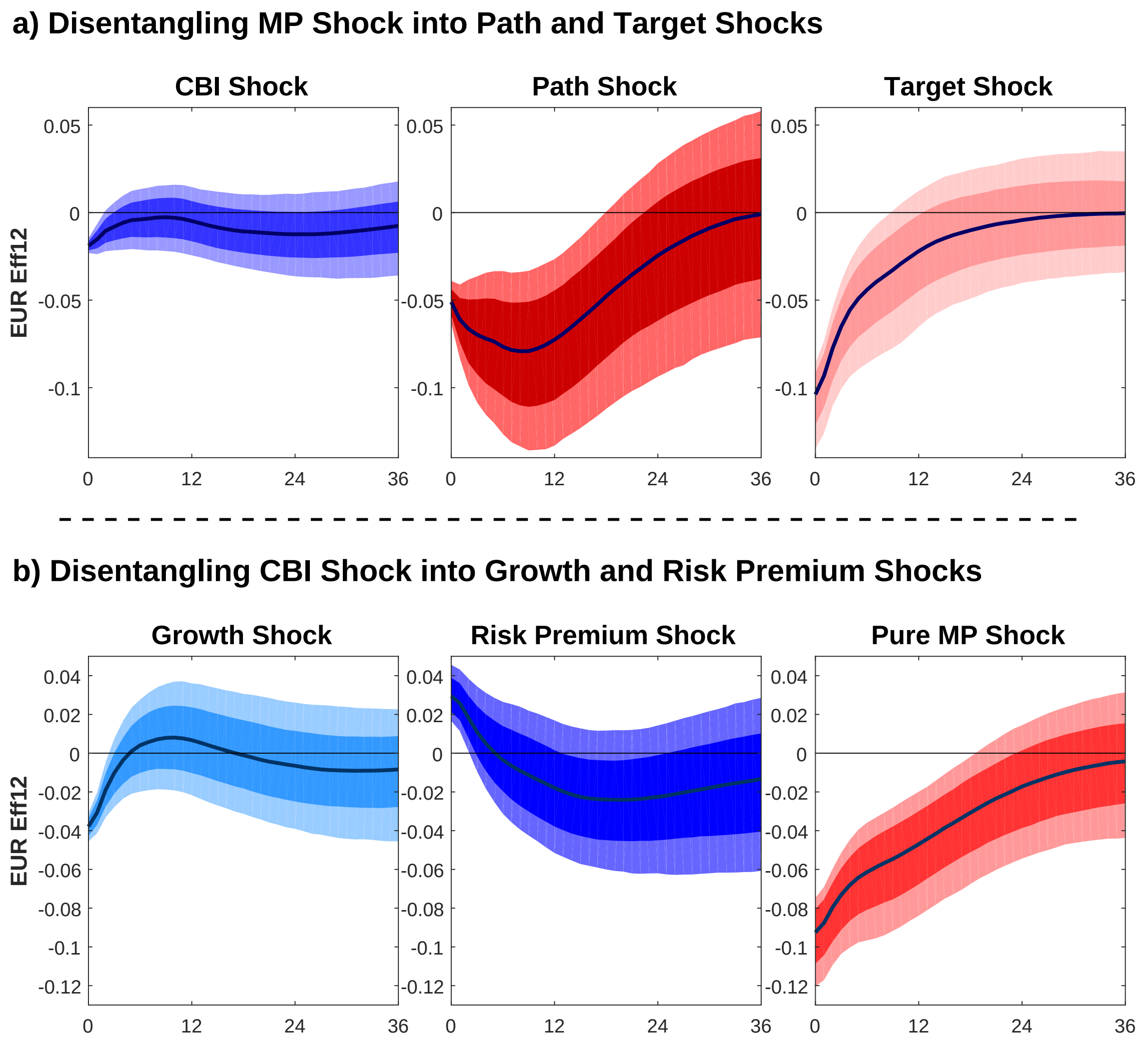
The respective impulse responses of the effective EUR exchange rate are displayed in panel b) of Figure 8. Compared to the monetary policy shock, the response of the EUR exchange rate is attenuated to both, the growth shock and the risk premium shock. Interestingly, however, we observe a slight appreciation following the growth shock, while the exchange rate exhibits a small depreciation ensuing the risk premium shock. This is in line with the notion of "risk-on" sentiment, described above, that brings along the capital flows into speculative currencies. Thus, despite the positive response in the interest rate differential *vis-à-vis* the foreign countries in the sample, the EUR depreciates due to its role as a hedge currency that experiences capital outflows in times of surging investors' risk appetite. While these findings underpin the hypothesis that investor "sentiment" plays a key role in the heterogeneous exchange rate reactions to central bank information shocks, the differentiation between growth and risk premium shocks rests upon assumptions on the yield curve response that are not beyond dispute.

4.3.2 FOMC Announcements

While not the focus of the present study, it is worthwhile having a look at the response of USD exchange rates to announcements by the FOMC. To that end, I

[21] As outlined in Cieslak and Schrimpf (2019), 10-year German yields increased by 8 basis points and DAX futures gained more than 2.3%. The speech, however, is excluded here as Draghi did not voice these famous words on a press conference following a scheduled Governing Council meeting.

Figure 8 Exchange Rate Responses Target, Path, Growth and Risk Premium Shocks



Note: The figure displays the impulse responses of the effective EUR exchange rate to a) a Proxy VAR that identifies a CBI, a path and a target shock and b) a Proxy VAR that identifies a growth, a risk premium and a MP shock via the sign restrictions given in Table 2 and the respective 68% and 90% credibility bands. The shocks are standardized such that on impact, the 3-month OIS rate increases by 100 basis points (target shock) or the 2-year German government bond yield increases by 100 basis points (all other shocks). A negative response indicates an appreciation of the EUR.

Table 2 Sign Restrictions of Additional Shocks

a) Target vs Path Surprises			
	CBI Shock	Path Shock	Target Shock
Euro Stoxx	+	−	−
2-year Yield	+	+	+
2Y-3M Yield Spread		+	−

b) Risk Premium vs Growth Surprises			
	Growth Shock	Risk Premium Shock	MP Shock
Euro Stoxx	+	+	−
2-year Yield	+	+	+
10Y-2Y Yield Spread	−	+	

resort to an updated version of the high-frequency data from Gürkaynak, Sack and Swanson (2005). As proxies, the reaction of the S&P500 and 3-month Fed funds futures are utilized. Thus, compared to the ECB analysis, the proxies only capture target surprises and forward guidance surprises regarding the near future.[22] Since the FOMC did not explicitly announce its decisions before 1994, this is where the estimation sample starts. This has the advantage that the financial crises in Sweden and Norway in the early 1990s do not drive the responses in the respective bilateral and the effective USD exchange rate.

Figure 9 plots the impulse responses of the USD exchange rate against eight currencies and in effective terms following a central bank information shock as well as a monetary policy shock. Similar to the EUR, the USD clearly reacts differently depending on which shock initiates the domestic interest rate hike. A monetary policy shock leads, on impact, to an appreciation of the USD against all but one currency (GBP). The responses, however, are mostly small and die out quite fast. Following a central bank information shock, on the other hand, the USD mostly depreciates. This is particularly the case against speculative currencies such as the AUD or the NZD. Moreover, the USD appreciates slightly against the only other currency classified by Hossfeld and MacDonald (2015) as carry funding, namely the JPY. Thus, similar forces seem to be at work here as was the case for the EUR. The effect is even more pronounced in the sense that the USD as a carry funding currency is a prime target of capital outflows in "risk-on" times. All in all, this short glimpse at the other side of the Atlantic reinforces the hypothesis that investor "sentiment" plays a key role in the observed exchange rate reactions to central bank information

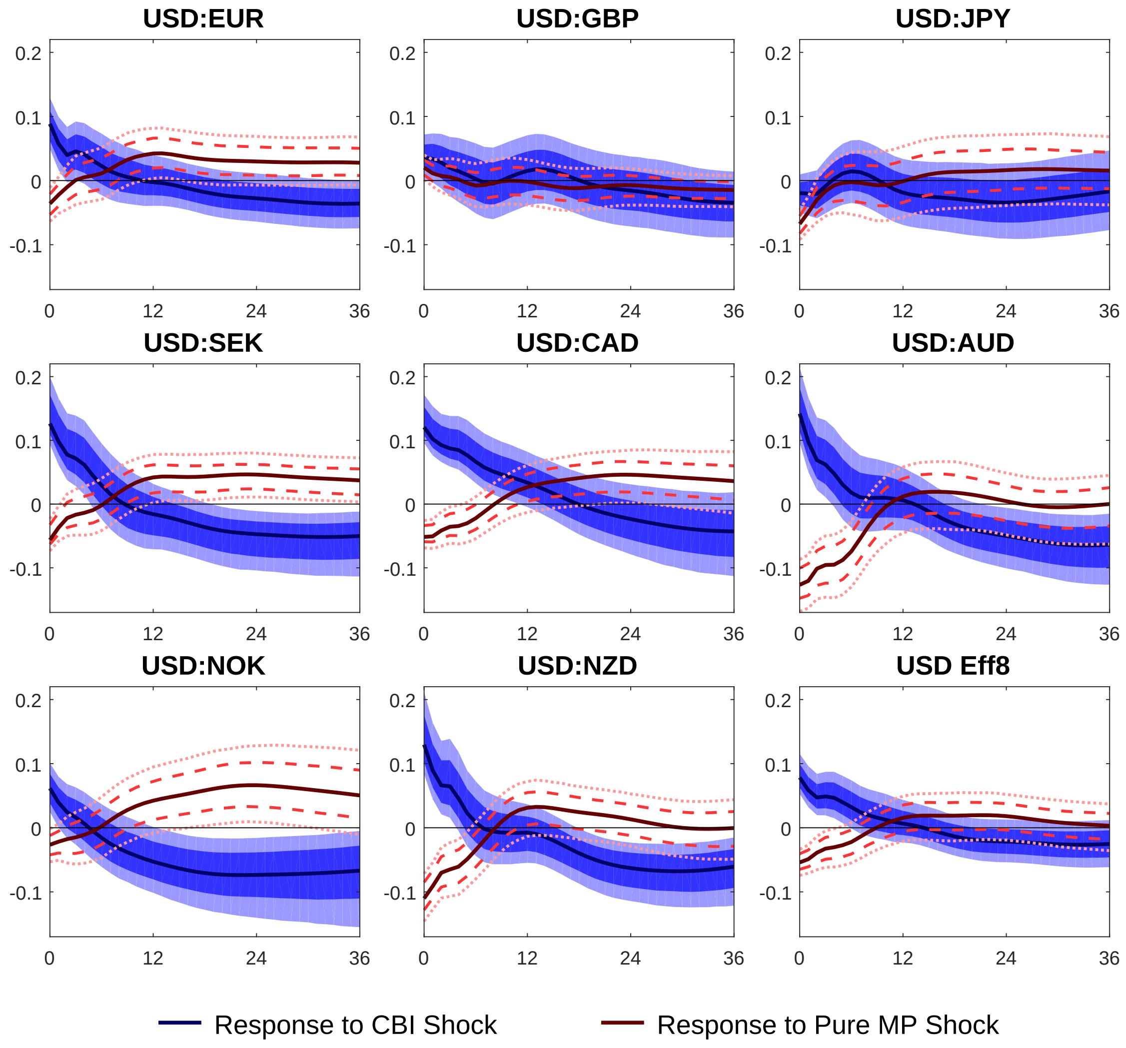
[22]Longer term high-frequency yields are available in the dataset but do not exhibit a strong correlation with daily and monthly 2-year US government bond yields. Therefore, I resort to 3-month Fed funds futures in order to circumvent a weak instrument problem. Jarociński and Karadi (2019) use the same high-frequency series, but a direct comparison to the responses following ECB announcements in Figure 2 and Figure 3 should, therefore, be taken with a pinch of salt.

shocks.

5 Conclusion

In this paper, I estimate the dynamic effects of ECB announcements, disentangled into pure monetary policy surprises and central bank information surprises, on the EUR exchange rate in effective terms and, separately, *vis-à-vis* eight developed countries' currencies. To that end, I feed a Bayesian Proxy VAR with high-frequency data on yields and stocks around monetary policy announcements. Contractionary monetary policy shocks turn out to result in a sizable and statistically significant appreciation of the nominal effective EUR exchange rate and nearly all bilateral exchange rates with its peak response on impact. In the case of the central bank information shock, however, responses of bilateral EUR exchange rates exhibit a strong heterogeneity, leading to a statistically insignificant reaction of the nominal effective EUR exchange rate. The most convincing avenue to rationalize this finding takes into account investor "sentiment". ECB announcements that surprise market participants with a sanguine economic outlook push up investors' risk appetite as measured by the VIX, bringing in its wake capital flows into speculative currencies such as the AUD, the NZD, or the NOK. Thus, despite the increasing interest rate differential in favor of EUR investments, the EUR actually depreciates against these speculative currencies. The opposite is true against carry funding and safe haven currencies such as the USD and the JPY. More broadly, the EUR appreciates against a low-yielding carry trade funding portfolio following a central bank information shock, while it depreciates against a high-yielding carry trade investment portfolio. In comparison, following a pure monetary policy shock, the EUR appreciates against both portfolios in line with the increasing interest rate differential.
The deployed identification allows for a more thorough measurement of monetary policy shocks and thereby adds to the literature that puts Dornbusch's (1976) overshooting hypothesis to the test. More importantly, investigating the dynamic effects of central bank information orthogonal to pure monetary policy shocks on exchange rates is novel. Understanding how central bank announcements propagate onto foreign exchange markets is pivotal in formulating monetary policy, even more so when its effect on import prices is taken into account. As outlined in Forbes, Hjortsoe and Nenova (2018), the exchange rate pass-through decisively depends on the underlying shock. Investigating whether import prices respond differently to exchange rate reactions triggered by central bank information shocks compared to pure monetary policy shocks could provide a fruitful path for future research.

Figure 9 Exchange Rate Responses to Fed Announcements



Note: The figure displays the exchange rate responses and the respective 68% and 90% credibility bands to a US central bank information (CBI) shock and a pure monetary policy (Pure MP) shock that increase 3-month US interbank yields by 100 basis points on impact. A negative response indicates an appreciation of the USD.

References

Aloosh, Arash, and Geert Bekaert. 2019. "Currency Factors." *NBER Working Paper*, No. 25449.

Altavilla, Carlo, Luca Brugnolini, Refet S. Gürkaynak, Roberto Motto, and Giuseppe Ragusa. 2019. "Measuring Euro Area Monetary Policy." *Journal of Monetary Economics*, 108: 162–179.

Barakchian, S. Mahdi, and Christopher Crowe. 2013. "Monetary Policy Matters: Evidence from New Shocks Data." *Journal of Monetary Economics*, 60: 950–966.

Bjørnland, Hilde C. 2009. "Monetary Policy and Exchange Rate Overshooting: Dornbusch was Right After All." *Journal of International Economics*, 79: 64–77.

Brunnermeier, Markus K., Stefan Nagel, and Lasse H. Pedersen. 2009. "Carry Trades and Currency Crashes." *NBER Macroeconomics Annual 2008*, 23(1): 313–348.

Ciccarelli, Matteo, and Benoît Mojon. 2010. "Global Inflation." *The Review of Economics and Statistics*, 92(3): 524–535.

Cieslak, Anna, and Andreas Schrimpf. 2019. "Non-Monetary News in Central Bank Communication." *Journal of International Economics*, 118: 293–315.

Clarida, Richard, Josh Davis, and Niels Pedersen. 2009. "Currency Carry Trade Regimes: Beyond the Fama Regression." *Journal of International Money and Finance*, 28: 1375–1389.

Dornbusch, Rüdiger. 1976. "Expectations and Exchange Rate Dynamics." *Journal of Political Economy*, 84(6): 1161–1176.

Eichenbaum, Martin, and Charles L. Evans. 1995. "Some Empirical Evidence on the Effects of Shocks to Monetary Policy on Exchange Rates." *The Quarterly Journal of Economics*, 110: 975–1009.

Engel, Charles. 2014. "Exchange Rates and Interest Parity." *Handbook of International Economics*, 4: 453–522.

Falagiarda, Matteo, Peter McQuade, and Marcel Tirpák. 2015. "Spillovers from the ECB's non-standard Monetary Policies on non-euro area EU countries: Evidence from an Event-Study Analysis." *ECB Working Paper*, No. 1869.

Fama, Eugene F. 1984. "Forward and Spot Exchange Rates." *Journal of Monetary Economics*, 14: 319–338.

Faust, Jon, and John H. Rogers. 2003. "Monetary Policy's Role in Exchange Rate Behavior." *Journal of Monetary Economics*, 50: 1403–1424.

Faust, Jon, John H. Rogers, Shing-Yi B. Wang, and Jonathan H. Wright. 2007. "The High-Frequency Response of Exchange Rates and Interest Rates to Macroeconomic Announcements." *Journal of Monetary Economics*, 54: 1051–1068.

Ferrari, Massimo, Jonathan Kearns, and Andreas Schrimpf. 2017. "Monetary Policy's Rising FX Impact in the Era of Ultra-Low Rates." *CEPR Discussion Paper*, No. DP11918.

Forbes, Kristin J., and Francis E. Warnock. 2012. "Capital Flow Waves: Surges, Stops, Flight, and Retrenchment." *Journal of International Economics*, 88: 235–251.

Forbes, Kristin J., Ida Hjortsoe, and Tsvetelina Nenova. 2018. "The Shocks Matter: Improving our Estimates of Exchange Rate Pass-Through." *Journal of*

International Economics, 114: 255–275.

Fry, Renée, and Adrian Pagan. 2011. "Sign Restrictions in Structural Vector Autoregressions: A Critical Review." *Journal of Economic Literature*, 49(4): 938–960.

Gertler, Mark, and Peter Karadi. 2015. "Monetary Policy Surprises, Credit Costs, and Economic Activity." *American Economic Journal: Macroeconomics*, 7(1): 44–76.

Giannone, Domenico, Michele Lenza, and Giorgio E. Primiceri. 2015. "Prior Selection for Vector Autoregressions." *The Review of Economics and Statistics*, 97(2): 436–451.

Gilchrist, Simon, and Benoît Mojon. 2018. "Credit Risk in the Euro Area." *The Economic Journal*, 128: 118–158.

Glick, Reuven, and Sylvain Leduc. 2018. "Unconventional Monetary Policy and the Dollar: Conventional Signs, Unconventional Magnitudes." *International Journal of Central Banking*, 14(5): 103–152.

Gürkaynak, Refet S., Brian Sack, and Eric T. Swanson. 2005. "Do Actions Speak Louder Than Words? The Response of Asset Prices to Monetary Policy Actions and Statements." *International Journal of Central Banking*, 1(1): 55–93.

Hansen, Stephen, Michael McMahon, and Matthew Tong. 2019. "The Long-Run Information Effect of Central Bank Communication." *Journal of Monetary Economics*, 108: 185–202.

Hossfeld, Oliver, and Ronald MacDonald. 2015. "Carry Funding and Safe Haven Currencies: A Threshold Regression Approach." *Journal of International Money and Finance*, 59: 185–202.

International Monetary Fund. 2019. "Annual Report on Exchange Rate Arrangements and Exchange Restrictions 2018."

Jarociński, Marek, and Peter Karadi. 2019. "Deconstructing Monetary Policy Surprises: The Role of Information Shocks." *American Economic Journal: Macroeconomics*, forthcoming.

Jiang, Zhengyang, Arvind Krishnamurthy, and Hanno Lustig. 2018. "Foreign Safe Asset Demand and the Dollar Exchange Rate." *NBER Working Paper*, No. 24439.

Kearns, Jonathan, and Phil Manners. 2006. "The Impact of Monetary Policy on the Exchange Rate: A Study using Intraday Data." *International Journal of Central Banking*, 2(4): 157–183.

Kearns, Jonathan, Andreas Schrimpf, and Fan Dora Xia. 2018. "Explaining Monetary Spillovers: The Matrix Reloaded." *BIS Working Papers*, No. 757.

Kerssenfischer, Mark. 2019. "Information Effects of Euro Area Monetary Policy: New Evidence from High-Frequency Futures Data." *Deutsche Bundesbank Discussion Paper*, No. 07/2019.

Kim, Seong-Hoon, Seongman Moon, and Carlos Velasco. 2017. "Delayed Overshooting: Is it an '80s Puzzle." *Journal of Political Economy*, 125(5): 1570–1598.

Kim, Soyoung, and Nouriel Roubini. 2000. "Exchange Rate Anomalies in the Industrial Countries: A Solution with a Structural VAR Approach." *Journal of Monetary Economics*, 45: 561–586.

Koop, Gary, and Dimitris Korobilis. 2010. "Bayesian Multivariate Time Series Methods for Empirical Macroeconomics." *Foundations and Trends in Economet-*

rics, 3(4): 267–358.

Kuttner, Kenneth N. 2001. "Monetary Policy Surprises and Interest Rates: Evidence from the Fed Funds Futures Market." *Journal of Monetary Economics*, 47: 523–544.

Litterman, Robert B. 1986. "Forecasting with Bayesian Vector Autoregression: Five Years of Experience." *Journal of Business & Economic Statistics*, 4(1): 25–38.

Melosi, Leonardo. 2017. "Signalling Effects of Monetary Policy." *Review of Economic Studies*, 84: 853–884.

Menkhoff, Lukas, Lucio Sarno, Maik Schmeling, and Andreas Schrimpf. 2012. "Carry Trades and Global Foreign Exchange Volatility." *The Journal of Finance*, 67(2): 681–718.

Mertens, Karel, and Morten O. Ravn. 2013. "The Dynamic Effects of Personal and Corporate Income Tax Changes in the United States." *American Economic Review*, 103(4): 1212–1247.

Miranda-Agrippino, Silvia. 2017. "Unsurprising Shocks: Information, Premia, and the Monetary Transmission." *mimeo.*

Miranda-Agrippino, Silvia, and Giovanni Ricco. 2018. "The Transmission of Monetary Policy Shocks." *CEPR Discussion Paper*, No. DP13396.

Nakamura, Emi, and Jón Steinsson. 2018. "High-Frequency Identification of Monetary Non-Neutrality: The Information Effect." *The Quarterly Journal of Economics*, 133(3): 1283–1330.

Potjagailo, Galina. 2017. "Spillover Effects from Euro Area Monetary Policy across Europe: A Factor-Augmented VAR Approach." *Journal of International Money and Finance*, 72: 127–147.

Ramey, Valerie A. 2016. "Macroeconomic Shocks and their Propagation." In *Handbook of Macroeconomics.* Vol. 2, ed. John B. Taylor and Harald Uhlig, Chapter 2, 71–162. Elsevier.

Ready, Robert, Nokolai Roussanov, and Colin Ward. 2017. "Commodity Trade and the Carry Trade: A Tale of Two Countries." *The Journal of Finance*, 72(6): 2629–2684.

Rey, Hélène. 2015. "Dilemma not Trilemma: The Global Financial Cycle and Monetary Policy Independence." *NBER Working Paper*, No. 21162.

Rogers, John H., Chiara Scotti, and Jonathan H. Wright. 2018. "Unconventional Monetary Policy and International Risk Premia." *Journal of Money, Credit and Banking*, 50(8): 1827–1850.

Romer, Christina D., and David H. Romer. 2000. "Federal Reserve Information and the Behavior of Interest Rates." *American Economic Review*, 90(3): 429–457.

Romer, Christina D., and David H. Romer. 2004. "A New Measure of Monetary Shocks: Derivation and Implications." *American Economic Review*, 94(4): 1055–1084.

Rubio-Ramírez, Juan, Daniel F. Waggoner, and Tao Zha. 2010. "Structural Vector Autoregressions: Theory of Identification and Algorithms for Inference." *The Review of Economic Studies*, 77: 665–696.

Scholl, Almuth, and Harald Uhlig. 2008. "New Evidence on the Puzzles: Results from Agnostic Identification on Monetary Policy and Exchange Rates." *Journal of International Economics*, 76: 1–13.

Stock, James H., and Mark W. Watson. 2012. "Disentangling the Channels of the 2007-2009 Recession." *NBER Working Paper*, No. 18094.

Stock, James H., and Mark W. Watson. 2018. "Identification and Estimation of Dynamic Casual Effects in Macroeconomics using External Instruments." *The Economic Journal*, 128: 917–948.

ter Ellen, Saskia, Edvard Jansen, and Nina Larsson Midthjell. 2020. "ECB Spillovers and Domestic Monetary Policy Effectiveness in Small Open Economies." *European Economic Review*, 121.

Valchev, Rosen. 2019. "Bond Convenience Yields and Exchange Rate Dynamics." *American Economic Journal: Macroeconomics*, forthcoming.

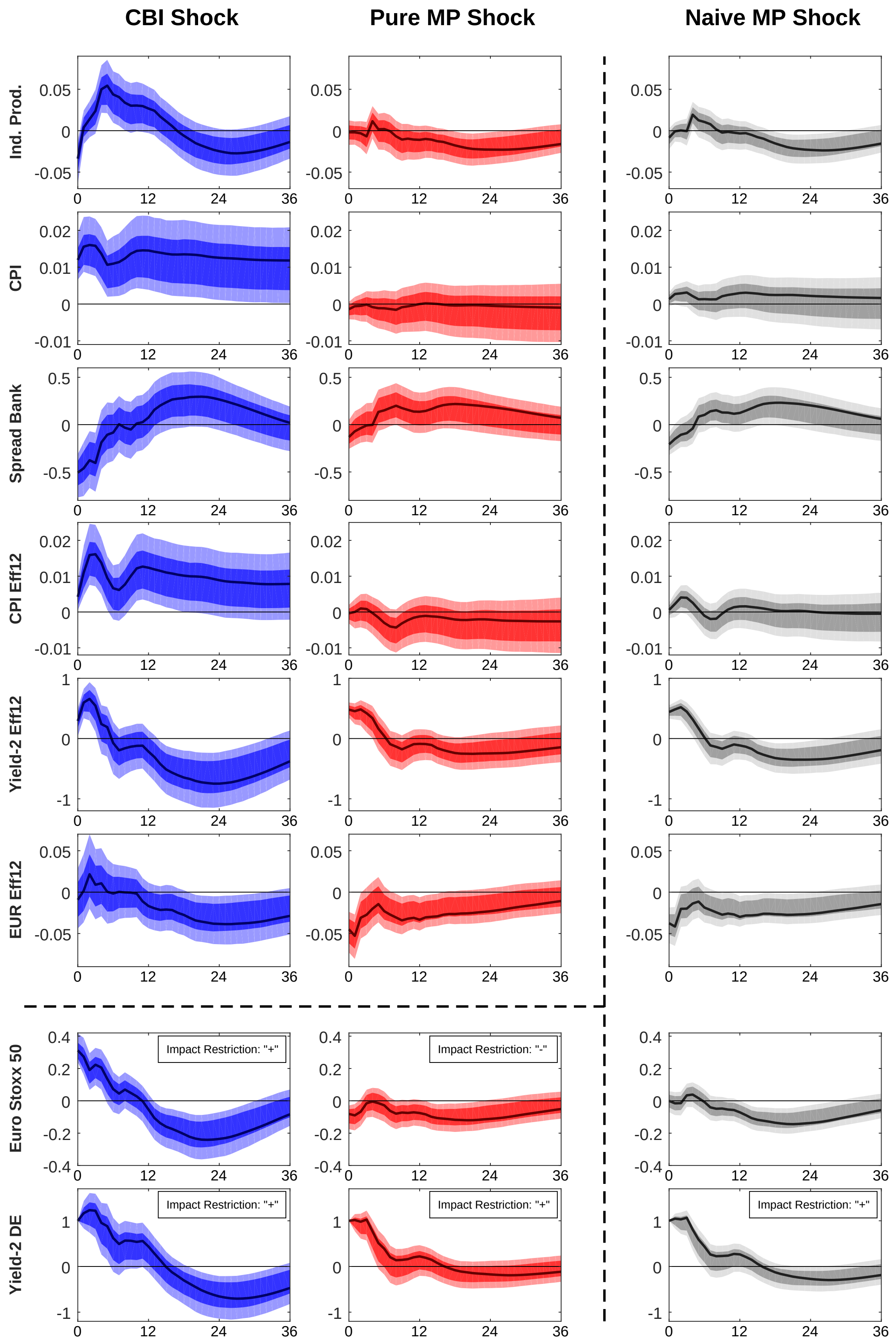
Zettelmeyer, Jeromin. 2004. "The Impact of Monetary Policy on the Exchange Rate: Evidence from Three Small Open Economies." *Journal of Monetary Economics*, 51: 635–652.

Appendix

Table A1 Monthly Data and their Sources

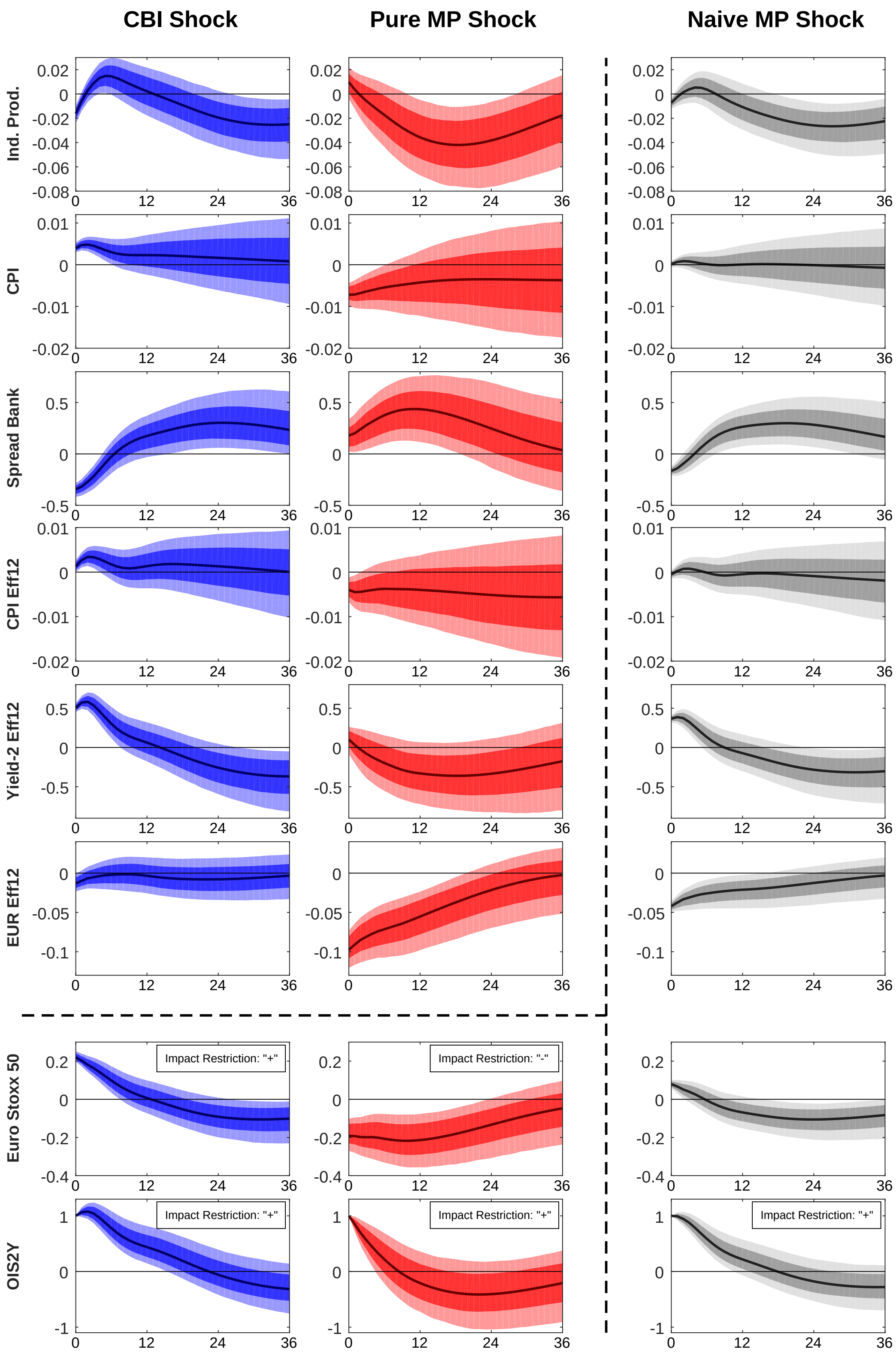
Variable	Description	Source
Industrial Production Euro Area	Fixed composition (19 countries), index, working day and seasonally adjusted	ECB
Consumer Price Index Euro Area	Fixed composition (19 countries), harmonized index, working day and seasonally adjusted	ECB
Consumer Price Index Other Countries	Index, seasonally adjusted, AU and NZ interpolated from quarterly data	OECD
2-year Government Bond Yields	Thomson Reuters Benchmark Bid Yields, 5-year yields for NO and NZ	Thomson Reuters, Haver
3-Month Interbank Rates		Thomson Reuters
Euro Stoxx 50	Closing value	Yahoo! Finance
Exchange Rates	WM/Reuters Closing Spot Rate	Thomson Reuters
Bank Spread	Euro area bank credit spread with respect to German Bunds	Gilchrist and Mojon (2018)
S&P500	Closing value	Yahoo! Finance
VIX	CBOE Implied Volatility of S&P500, closing value	Yahoo! Finance
Euro Area Trade Weights	Fixed composition (19 countries) against respective trading partner	ECB

Figure A1 Frequentist Proxy VAR Impulse Responses



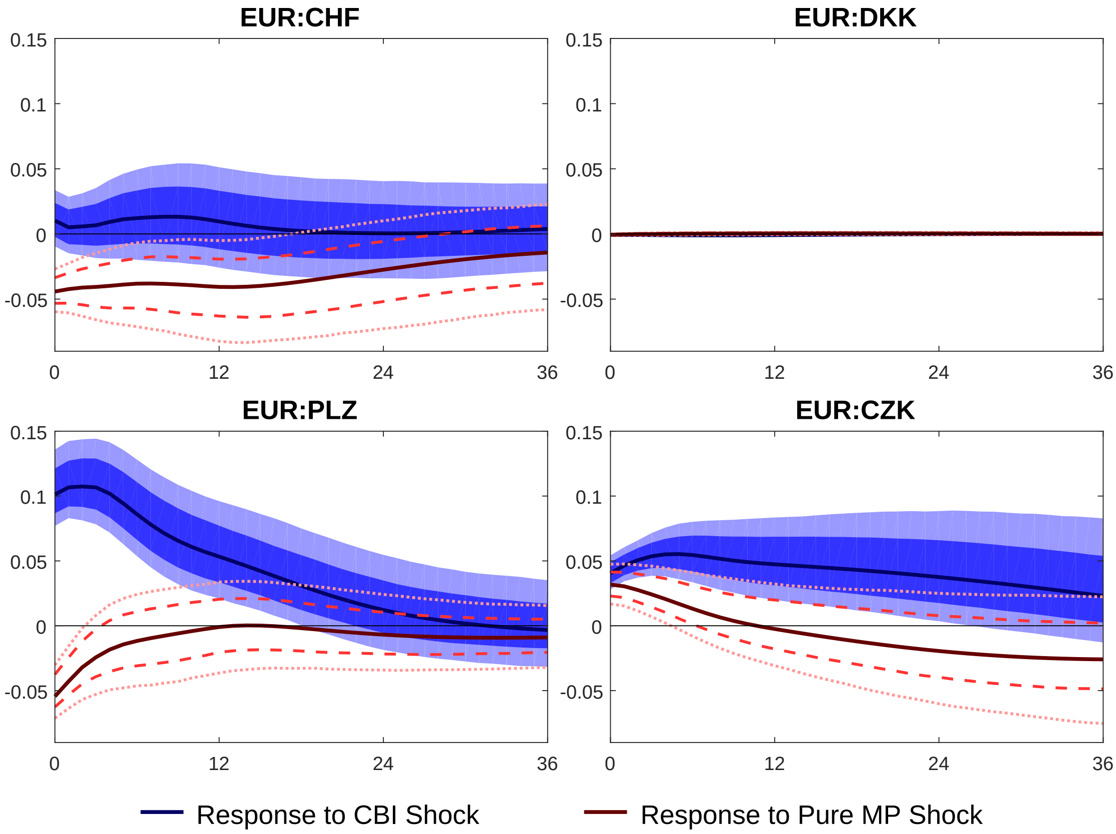
Note: See Figure 2. Estimation of the Proxy VAR follows Mertens and Ravn (2013). The number of lags is restricted to 6. 68% and 90% confidence intervals are estimated utilizing a wild bootstrap.

Figure A2 High-Frequency Identification with Altavilla et al. (2019) Data



Note: See Figure 2. The 2-year German bond yields are replaced by the 2-year OIS rate and its respective high-frequency variable from Altavilla et al. (2019). The sample starts in January 2000 and ends in September 2018.

Figure A3 Responses of Other Bilateral Exchange Rates



Note: See Figure 3.