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International Spillovers of (Un)Conventional Monetary Policy: The Effect of the ECB and US Fed on Non-Euro EU Countries

Jan Hájek and Roman Horváth *

Abstract

We estimate a global vector autoregression model to examine the effects of euro area and US monetary policy stances, together with the effect of euro area consumer prices, on economic activity and prices in non-euro EU countries using monthly data from 2001-2016. Along with some standard macroeconomic variables, our model contains measures of the shadow monetary policy rate to address the zero lower bound and the implementation of unconventional monetary policy by the European Central Bank and US Federal Reserve. We find that these monetary shocks have the expected qualitative effects but their magnitude differs across countries, with Southeastern EU economies being less affected than their peers in Central Europe. Euro area monetary shocks have greater effects than those that emanate from the US. We also find certain evidence that the effects of unconventional monetary policy measures are weaker than those of conventional measures. The spillovers of euro area price shocks to non-euro EU countries are limited, suggesting that the law of one price materializes slowly.

Abstrakt

Odhadujeme model globální vektorového autoregrese, který zkoumá dopady měnové politiky eurozóny a amerického Fedu společně s dopadem spotřebitelských cen v eurozóně na hospodářskou aktivitu a ceny v zemích mimo eurozónu. Používáme měsíční údaje z let 2001-2016. Spolu s některými standardními makroekonomickými proměnnými obsahuje náš model odhady míry stínové měnové politiky kvůli nulové dolní mezi na úrokové sazby a kvůli provádění nekonvenční měnové politiky ze strany Evropské centrální banky a Federálního rezervního systému USA. Zjistili jsme, že tyto měnové šoky mají očekávané kvalitativní efekty, ale jejich dopady se v jednotlivých zemích liší, přičemž ekonomiky jihovýchodní EU jsou ovlivněny méně než země střední Evropě. Nalézáme, že měnové šoky v eurozóně mají větší efekty než ty, které pocházejí z USA. Naše výsledky rovněž naznačují, že efekty nekonvenčních opatření měnové politiky jsou slabší než efekty konvenčních opatření. Efekt cenových šoků zemí eurozóny do zemí mimo eurozónu je omezený, což naznačuje, že zákon jedné ceny se projevuje pomalu.

JEL Codes: E52, E58.
Keywords: Global VAR, international spillovers, monetary policy, shadow rate.

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Nontechnical Summary

European economies, regardless whether they are members of the monetary union or not, are strongly integrated by trade and financial links. As a consequence, economic shocks in one European country may easily translate to other European countries. Therefore, examining how these shocks propagate internationally is vital for understanding the prospects of domestic economies.

In this paper, we focus on several policy relevant shocks emanating from the euro area and investigate how these shocks affect the non-euro EU countries such as the Czech Republic, Denmark, Hungary, Poland and the United Kingdom. More specifically, we examine how the changes in the euro area monetary policy and the euro area prices affect real activity and prices in these non-euro EU countries. In addition, we also examine how the changes in the US Fed monetary policy affect our economies of interest to provide a comparison of how two major central banks (ECB and US Fed) influence non-euro EU countries.

Given that both the ECB as well as the US Fed adopted large-scale unconventional monetary policy measures during the financial crisis, one must use a measure of monetary policy stance that considers this feature. For this reason, we use the so-called shadow policy rate (estimates) instead of the monetary policy rate. Shadow policy rates are designed to account for unconventional measures, are not constrained by the zero lower bound and have been argued to successfully approximate the overall monetary policy stance

Together with these monetary shocks, we also look at how the changes in prices in the euro area affect the non-euro EU countries. Many non-euro EU countries are small open economies, and therefore, their domestic prices are likely to have a strong international dimension. The relevant policy question arises: To what extent are the central bankers in neighboring small open economies such as the Czech Republic constrained by the prolonged low to zero inflation environment in the euro area?

To examine these policy relevant shocks, we employ the so-called global vector autoregression model, which is well-suited to consistently and systematically investigate the international propagation of economic and financial shocks in a large group of countries with actual data.

Our results suggest that a higher ECB shadow policy rate has a negative effect on the economic activity and to some extent also prices in all non-euro EU countries. However, we find somewhat weaker effects of unconventional monetary policy measures as opposed to the conventional measures. Therefore, in terms of policy implications, our results suggest that monetary policy spillovers to the Central Europe emanating from the ECB can become stronger in the future once the ECB reduces the intensity or abandons its unconventional policy measures. Regarding the scenario with changes in the Fed shadow policy rate, the results point to similar quantitative direction as for the euro area monetary shocks but they are slightly less pronounced.

Next, we find that unexpected changes in the euro area consumer prices do not have significant bearing on inflationary/deflationary risks in the analyzed countries. If there are some significant effects, they are relatively small. Regardless the type of shock we examine, the Southeastern European economies are affected less than its peers from Central Europe, which is in line with their lower degree of trade and financial integration with the euro area.

1. Introduction

The European Central Bank (ECB) has undertaken large-scale unconventional monetary policy measures to restore macroeconomic and financial stability in the euro area. Whereas these measures have been primarily intended to affect the euro area economies, given the high degree of financial and trade integration in the European Union (EU), these measures are likely to have non-negligible spillovers to non-euro EU members. Although analyses of international spillovers of monetary policy have typically focused on the US (e.g., Bauer and Neely, 2014; Chen et al., 2016; Fratzscher et al., 2017; Neely, 2015), the evidence for international spillovers of ECB monetary policy is growing (Babecka Kucharcukova et al., 2016; Hajek and Horvath, 2016; Horvath and Voslarova, 2017; Potjagailo, 2017).

Cuaresma et al. (2016) find that international monetary policy spillovers typically become more pronounced over time. Taylor (2016) emphasizes that strong monetary policy spillovers across countries may result in an accommodative monetary policy stance worldwide, thereby contributing to financial imbalances with potentially harmful real effects. For this reason, Taylor (2016) argues that sound policy rules are vital to promote stable international monetary arrangements.

Nevertheless, we still think that we can contribute to this body of literature. Including more recent data and a wider set of non-euro EU countries allows us to examine international spillovers of monetary policy in an ultra-low- or even negative-interest rate environment in a more complete manner. We explicitly account for the fact that the ECB has implemented a number of unconventional measures, such as the Securities Markets Programme, Outright Monetary Transactions and the Expanded Asset Purchase Programme; for this reason, we use shadow policy interest rates (Wu and Xia, 2016; Chen et al., 2017; Krippner, 2013). Shadow rates are designed to account for unconventional measures, are not constrained by the zero lower bound and have been argued to successfully approximate the overall monetary policy stance (Wu and Xia, 2016).[1]

To provide perspective regarding the importance of euro area monetary shocks, we also examine the effect of US Fed monetary shocks (again using the aforementioned shadow policy interest rates) on non-euro EU countries. Note that many other vector autoregression studies that examine European countries do not control for the US economy. We explicitly model the EU-US interactions using a global vector autoregression model (GVAR).

Moreover, we examine not only monetary policy shocks but also international spillovers of inflation shocks. Despite the large scale of the unconventional ECB monetary policy measures that have been implemented, inflation in the euro area has remained near zero (during our sample period). An important policy question arises: to what extent are the central bankers in neighboring small open economies, such as the Czech Republic, constrained by the zero-inflation environment in the euro area? In this light, we examine the international propagation of (or the lack thereof) inflationary shocks in the euro area on inflation in non-euro area countries.

Our results suggest that increasing the ECB shadow policy rate decreases economic activity and, to some extent, also decreases prices in all countries studied. Comparing our results to those of Hajek and Horvath (2016), it seems that the international spillovers of unconventional ECB monetary policy measures are weaker than those of conventional measures, given that the present article

[1] Damjanović and Masten (2016) and Chen et al. (2017) recently adopted a shadow policy rate as an approximation of monetary policy under a zero lower bound and applied it to examine its effects on the real economy and prices. Some other studies, such as Belke and Klose (2013), propose examining the real interest rate instead of the nominal interest rate to address the issues related to the zero lower bound and associated structural break in interest rates.

uses the shadow policy rate (and therefore addresses both conventional and unconventional policy measures), whereas Hajek and Horvath (2016) solely focus on conventional monetary policy and find somewhat stronger international monetary spillovers.

We also find that euro area monetary shocks are more important for non-euro EU countries than monetary shocks that emanate from the US. In addition, our results demonstrate that unexpected changes in euro area consumer prices do not have a significant effect on inflationary/deflationary risks in non-euro area countries. In general, Southeastern European economies are less affected by ECB and US monetary shocks than their peers from Central Europe.

The paper is organized as follows. Section 2 discusses the related literature regarding international spillovers of monetary policy. Section 3 introduces the GVAR model. Section 4 presents the data. We provide the results in section 5 and conclude in section 6. Some additional statistical tests are presented in the Appendix.

2. Related Literature

We provide a brief review of the literature examining international macroeconomic spillovers using various types of VAR models. We specifically focus on monetary policy spillovers involving non-euro EU countries.[2] We refer the reader to Svensson and van Wijnbergen (1989) and Dedola et al. (2013) for the theoretical underpinnings of international monetary spillovers (for conventional and unconventional monetary policy spillovers, respectively).

Bluwstein and Canova (2016) introduce a Bayesian mixed-frequency structural vector autoregressive model and examine international spillovers of the ECB's unconventional monetary policy on several non-euro area EU countries in the period of 2008-2014. The magnitude of international spillovers into output and inflation increases with the size of the financial market and the share of domestic banks, and the spillovers are stronger in terms of output responses than in terms of inflation. Interestingly, the exchange rate regime does not matter. Bluwstein and Canova (2016) use a sum of long-term refinancing operation programs, the Securities Markets Programme, and covered bond purchase programs I and II as the measure of the ECB's unconventional monetary policy.

Babecka Kucharcukova et al. (2016) construct monetary conditions index for the ECB policy; the index is comprised of both conventional and unconventional monetary policies. Using this monetary conditions index, they examine the effects on inflation and output of several countries outside the euro area (three Central European countries and three non-euro area countries). The results suggest heterogeneity in terms of the importance of international spillovers of ECB policy. Whereas conventional policy has important spillover effects on all countries (especially for output), the international spillovers stemming from unconventional policy are typically weak, and their magnitudes vary across countries.

[2] A number of GVAR studies examine the international transmission of credit and demand shocks. See, for example, Eickmeier and Ng (2015) and Fadejeva et al. (2017). In addition, some other contributions focus on the global effects of US monetary policy; see Feldkircher and Huber (2016) and Feldkircher et al. (2017). There are also studies that apply GVAR models to the euro area.Georgiadis (2015) examines the effect of euro area monetary policy on individual euro area countries and investigates whether and why individual countries react heterogeneously to euro area monetary shocks. Belke and Osowski (2016) uses a GVAR model to study fiscal spillovers in the euro area.

Horvath and Voslarova (2017) use a panel VAR model to examine spillovers of the ECB's unconventional monetary policy on economic activity and prices in the Czech Republic, Hungary and Poland. They use the shadow rates from Wu and Xia (2016) and Krippner (2013) and the Eurosystem's central bank assets as the measure of the ECB's unconventional monetary policy. Economic activity reacts more strongly than prices to the ECB's unconventional policy. Using vector decompositions, they find that the ECB's unconventional policy explains greater than 10% of economic activity fluctuations but only approximately 2% of price fluctuations. The evidence that the responses of output are stronger than those of prices are consistent with the convex shape of aggregate supply; therefore, monetary shocks result in output fluctuations rather than in price fluctuations during recessions.

There are also other papers that examine international spillovers of the ECB's monetary policy. However, these papers consider conventional monetary policy only. Horvath and Rusnak (2009) investigate the effect of the ECB's (conventional) monetary policy on Slovak output and prices before Slovakia adopted the euro (in the period of 1999-2007), whereas the evidence from the period of the global financial crisis (for example, that presented by Horvath and Voslarova (2017)) suggests that spillovers are stronger for output than for prices; Horvath and Rusnak (2009), using pre-crisis data from a high-economic-growth environment, find the opposite result. The ECB's monetary policy explains 25% of prices fluctuations in Slovakia, whereas it explains only 5% of output fluctuations. According to Horvath and Rusnak (2009), Slovak monetary policy explains only 2% of domestic price fluctuations. Therefore, the ECB's monetary policy was already more powerful than domestic monetary policy in terms of affecting prices prior to Slovakia's entry into the euro area.

Hajek and Horvath (2016) use a GVAR model to examine international spillovers of the ECB's conventional monetary policy on output and prices in Central and Southeast Europe. They find that whereas the responses of non-euro area Central European countries to the ECB's monetary shocks are almost as strong as the responses of euro area countries, the responses of non-euro area Southeast European countries are more muted. In contrast with the present article, Hajek and Horvath (2016) do not examine the effects of unconventional monetary policy, nor do they consider the effects of the US Fed's monetary policy. Similarly, an important contribution by Feldkircher (2015) does not examine unconventional monetary policy. Another stream of literature examines the effects of the ECB's unconventional monetary policy on the euro area's output and prices but not on international spillovers (Gambacorta et al., 2014; Peersman, 2011).

3. Global Vector Autogregression

The spillover literature often suffers from the use of reduced-form frameworks without sufficient theoretical underpinnings. The reason for this shortcoming is that large models for examining interactions in a complex high-dimensional system such as the global economy are often incomplete and do not represent a closed system, which is essential for simulation analysis Granger and Jeon (2007). Consequently, we use the GVAR model developed by Pesaran et al. (2004), which extends reduced-form frameworks (e.g., standard VAR models) to explicitly analyze the nature of the international transmission of shocks. This coherent method allows for both long-term theory-consistent and short-term data-consistent relationships. In addition, the GVAR framework includes higher-round effects to examine the propagation of shocks in a more complete manner Backe et al. (2013). Canova and Ciccarelli (2013) emphasize that GVAR intuitively captures important features of a comprehensive economic system while maintaining a simple structure allowing for easy estimation. A survey of GVAR models, including their applications, is provided by Pesaran et al. (2004).

In general, a GVAR model consists of two steps. The first step is to estimate the vector error correction models (VECMs) for each individual country separately. The second step is to generate a global representation by taking the individual-country estimates and connect them through some bilateral (time-varying) trade or financial links. Our model description in this section draws heavily on Feldkircher (2015) and Hajek and Horvath (2016).

3.1 First Stage: The Country Models

Following Feldkircher (2015), the system of equations for each country $i \varepsilon \{1,\dots,N\}$ is as follows:

$$\Delta y_t = c_{y0} + c_{y1}t + \Pi_y z_{t-1} + \sum_{k=1}^{p-1} \Gamma_{yy,i}\Delta y_{t-k} + \sum_{k=1}^{q-1} \Gamma_{yx,i}\Delta x_{t-k} + \sum_{k=1}^{lex-1} \Psi_i \Delta d_{t-k} + \Lambda_x \Delta x_t + \Lambda_d \Delta d_t + e_{yt} \tag{3.1}$$

$$\Delta x_t = c_{x0} + c_x t + \sum_{k=1}^{p-1} \Gamma_{xy,i}\Delta y_{t-k} + \sum_{k=1}^{q-1} \Gamma_{xx,i}\Delta x_{t-k} + e_{xt} \tag{3.2}$$

where $z_t = (y_t, x_t)$, $u_t = (e_{yt}, e_{xt}) \sim N(0, \sum_u)$, and Δ represents the first-difference operator.

The variables presented above are divided into three main groups: domestic, foreign and global variables. The $m \times 1$ vector y_t consists of domestic variables, which include the measures of output, prices, exchange and (shadow) interest rates. (Chen et al., 2017) also use shadow policy rates within the GVAR framework. x_t is a $n \times 1$ vector of the corresponding foreign variables. For each country, we construct a set of foreign variables as a cross-country weighted average of their domestic counterparts (Feldkircher, 2015):

$$x_t^i := \sum_{j \neq i}^{N} \omega_{ij} y_t^j.$$

the weights $\omega_{ij} \, \varepsilon \, W$ represent bilateral financial or trade integration between countries (di Mauro et al., 2007; Pesaran et al., 2004, 2007). In this paper, we use (time-invariant) trade flows because our model primarily contains macroeconomic variables. The corresponding $N \times N$ weight matrix W is row-standardized and has zero entries on its diagonal: $\omega_{ij} \geq 0$, $\omega_{ii} = 0$, $\sum_{j=1}^{N} \omega_{ij} = 1$ (Feldkircher, 2015).

To control for the global environment, we include oil prices and treat them as a strictly exogenous component d_t in the model. In contrast to di Mauro et al. (2007), Pesaran et al. (2004) and Pesaran et al. (2007) and consistent with Feldkircher (2015) and Hajek and Horvath (2016), we exclude strictly exogenous variables from the cointegrating relationship.[3] Weakly and strictly exogenous

[3] That is, similar to Lütkepohl (1993), we exclude strictly exogenous covariates as control variables from Π, which enhances the stability of the global model.

variables enter the conditional model presented in equation (3.1) contemporaneously. We include lagged domestic variables and add a trend and an intercept term, which we further restrict to lie in the cointegration space (di Mauro et al., 2007).

Following Feldkircher (2015), the system of equations for country i can be written more compactly as follows:

$$\Delta z_t = c_0 + c_1 t + \Pi z_{t-1} + \Lambda_x x_t + \Lambda_d \Delta d_t + \sum_{k=1}^{p-1} \Gamma_i \Delta z_{t-k} + \sum_{k=1}^{lex-1} \Psi_i \Delta d_{t-k} + u_t \tag{3.3}$$

3.2 Second Stage: Forming a Global Representation

Once the N single-country models presented in equation (3.3) are estimated, they are transformed into their VAR representations and aggregated into a single global representation.

Therefore, following Feldkircher (2015), we rewrite the model presented in equations (3.1) and (3.2) in its VAR form:

$$\left(I - B_0^i\right) \begin{pmatrix} y_t^i \\ x_t^i \end{pmatrix} = \tilde{c}_0^i + \tilde{c}_1^i t + \sum_{k=1}^{r_i} \left(A_k^i, B_k^i\right) \begin{pmatrix} y_{t-k}^i \\ x_{t-k}^i \end{pmatrix} + \sum_{k=0}^{lex_i} \tilde{\Upsilon}_k^i d_{t-k}^i + \tilde{u}_t^i, \tag{3.4}$$

where $r_i := max(q_i, p_i)$ and the matrices A_k^i and B_k^i are equal to zero for lags k.

Furthermore, equation (3.4) can be written as

$$\tilde{G}^i z^i = \tilde{c}_0^i + \tilde{c}_1^i t + \sum_{k=1}^{r_i} \overline{H}_k^i z_{t-k}^i + \sum_{k=0}^{lex_i} \tilde{\Upsilon}_k^i d_{t-k}^i + \tilde{u}_t^i$$

where $\overline{H}_k^i$ represents the aggregated matrices of the coefficients linked to domestic and foreign variables. These coefficient matrices denote estimates from the former stage, as described in the sub-section 3.1. Feldkircher (2015) invokes an $m \times \sum_{k=1}^{N} m_i$ global link matrix Ξ^i that specifies how individual shocks are transmitted through the system:

$$\tilde{G}^i \Xi^i y_t = \tilde{c}_0^i + \tilde{c}_1^i t + \sum_{k=1}^{r_i} \overline{H}_k^i \Xi^i y_{t-k} + \sum_{k=0}^{lex_i} \tilde{\Upsilon}_k^i d_{t-k}^i + \tilde{u}_t^i, \; or$$

$$G^i y_t = \tilde{c}_0^i + \tilde{c}_1^i t + \sum_{k=1}^{r_i} \tilde{H}_k^i y_{t-k} + \sum_{k=0}^{lex_i} \tilde{\Upsilon}_k^i d_{t-k}^i + \tilde{u}_t^i$$

where Ξ^i assigns domestic to foreign variables. In this context, we build links between all countries; these links correspond to the links created when constructing the foreign variables. As already noted, we construct the weights W_t using trade flows over the chosen period.

Aggregating the single country models results in the following:

$$Gy_t = \tilde{c}_0^i + \tilde{c}_1^i t + \sum_{k=1}^{r} \tilde{H}_k y_{t-k} + \sum_{k=0}^{lex} \tilde{\Upsilon}_k d_{t-k} + \tilde{u}_t, \tag{3.5}$$

where

$$r := \max_{i=1,\dots,N} r_i, \, lex := \max_{i=1,\dots,N} lex_i$$

For lags k, the matrices H_k and Υ_k are both set to zero. Feldkircher (2015) shows that the aggregated square matrix G is non-singular; thus, equation (3.5) can be multiplied by G^{-1} from the left-hand side to yield the ultimate GVAR model:

$$y_t = c_t + c_1 t + \sum_{k=1}^{r} H_k y_{t-k} + \sum_{k=0}^{lex} \Upsilon_k d_{t-k} + u_t. \tag{3.6}$$

Consequently, a final representation of our economy in equation (3.6) allows us to connect all individual countries by bilateral trade flows and to link domestic variables to the global representation.

4. Data and Model Setup

We use monthly data from January 2001 to January 2016. We do not use data prior to the year 2000 because prior to the year 2000, many Central and Eastern European countries, which are now EU members, had been undertaking large scale structural reforms to transform to market-oriented economies.[4] Our data set covers the 28 current members of the European Union and the world's biggest economy - the US - to account for the global economic environment and the role that the US economy plays in EU economic developments. As opposed to Hajek and Horvath (2016), the euro area is considered as a single entity only for the monetary policy variable to reflect the inability of euro area member states to conduct monetary policy solely according to national preferences. Otherwise, the euro area countries are treated individually as 19 countries.

We use the IMF-IFS data for real activity (proxied by industrial production), consumer prices, the real exchange rate, and short-term and long-term interest rates; we include them as domestic variables. We present descriptive statistics with the data definitions in Table 1. We use the shadow

[4] Also, the yields in the early 2000s were already much lower than in the 1990s (or earlier), as Belke et al. (2017) document.

policy rates from Wu and Xia (2016) for short-term interest rates in the euro area and the US. This is particularly important since the shadow rates mirror the use of both conventional and unconventional monetary policy tools. To our knowledge, this is a clear distinction from the previous GVAR literature. In addition, we choose foreign real activity, consumer prices, and short-term and long-term interest rates as weakly exogenous variables. Since this paper does not attempt to model oil prices, we include oil prices as strictly exogenous variables for the two largest producers and consumers - the US and the euro area. The exchange rate is used as an additional weekly exogenous variable for the US only. For the estimation of trade weights, we use IMF-DoTS bilateral data regarding the exports and imports of goods and services covering the whole time span.

Table 1: Descriptive Statistics

Variable	Description	Min	Max	Mean	Sdev
y	industrial production index, 2010=100, SA, logs	4.02	5.07	4.61	0.15
p	consumer prices, 2010=100, SA, logs	3.64	4.75	4.58	0.13
rer	exchange rate vis-a-vis USD, deflated by price level	-5.25	1.57	-4.28	1.19
stir	3M market rates / Wu and Xia (2016) rates	-0.04	0.49	0.02	0.04
ltir	government bond yields, per annum	0.00	0.29	0.04	0.02
poil	1M average price of BRENT oil, SA, logs	2.94	4.84	4.16	0.53

We perform an Augmented Dickey-Fuller test on the levels and first differences of all variables. Most of the time series are integrated of order one, as the test results presented in Tables A1 and A2 in the Appendix document. However, we abstain from first-differencing the data (i.e., using only stationary series in the case of I(1) variables) such that we also capture long-term information in our model. Including non-stationary series does not pose restrictions on our econometric framework as long as the GVAR model passes the overall stability test. The results presented in Table A3 in the Appendix indicate that the GVAR model is stable overall.

We also test whether we treat the deterministic components of individual VECMs appropriately. The results of the nested likelihood test appear satisfactory and are available in Table A4 of the Appendix. Consequently, we treat the intercept term as unrestricted and the trend term as restricted for all countries. In addition, we provide the results from performing the F-test for exogeneity in Table A5 and the F-test for serial correlation in Table A6. We present the aggregation weights in Table A7.

We use a fixed-weight matrix based on trade flows covering the period of 2001-2015. If fixed-weight matrices based on shorter time spans or time-varying matrices are used, the stability of our model decreases substantially. We apply the lags suggested by the Schwartz-Bayesian Information Criteria because they tend to be more accurate for small samples (Ivanov and Kilian, 2005).

We present three different shock scenarios. They include shocks (unexpected increases) in (i) the ECB shadow policy rate and (ii) the Fed shadow policy rate. For the ease of exposition, we hereafter refer to these shocks as monetary shocks. To mirror recent development in inflation in the euro area (i.e., when deflationary risks are imminent), we also focus on a shock (unexpected decrease) in (iii) euro area prices. We choose these three shock scenarios because they are policy-relevant and have rarely been explored in the previous literature.

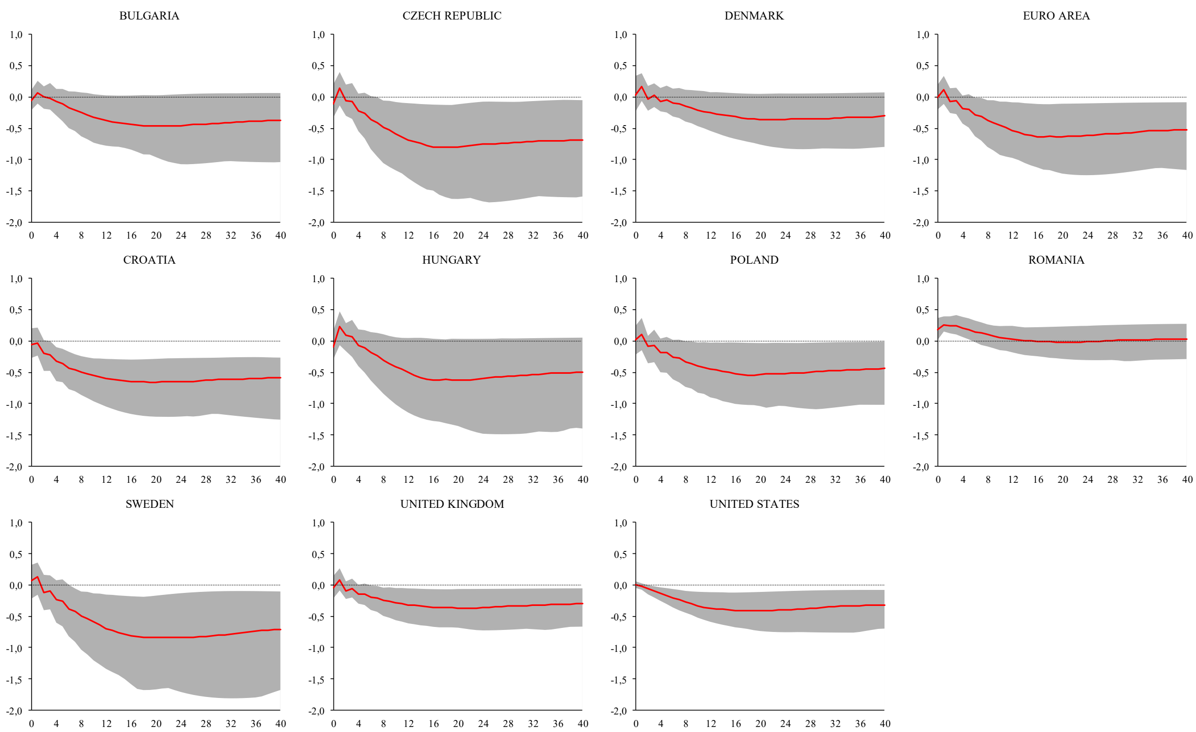
We utilize the generalized impulse response functions (GIRFs) presented by (Pesaran and Shin, 1998) because they are insensitive to the ordering of the variables. Even though the remaining correlation in residuals is generally weak, we prefer not to give the impulse responses a structural representation. Note that (unconventional) monetary policy shocks are approximated by shocks to the shadow policy rate, which differs from the standard approach, such as Choleski decomposition or sign restrictions.

5. Results

5.1 Shock to the ECB Shadow Policy Rate

In the first shock scenario, we examine the domestic and cross-country effects of an unexpected 100-bp increase in the ECB shadow policy rate. We present the results for real activity in Figure 1. To give some perspective about the importance of international spillovers, we also present the results for the response of the euro area real activity. In terms of the domestic effects, we conclude that the unexpected increase in the shadow policy rate leads to a 0.6% decrease in real activity on the monetary policy horizon. This result is similar to results obtained when "conventional" interest rates are used, as presented in Feldkircher (2015) and Hajek and Horvath (2016). Feldkircher et al. (2017) also find that tighter monetary conditions in the euro area result in lower economic activity in Central Europe. They distinguish two channels via which monetary conditions propagate into real activity: 1) the interest rate and asset prices channel and 2) the exchange rate channel; they find that the first channel dominates.

Figure 1: Response of Industrial Production to a 100-bp Increase in the ECB Shadow Policy Rate



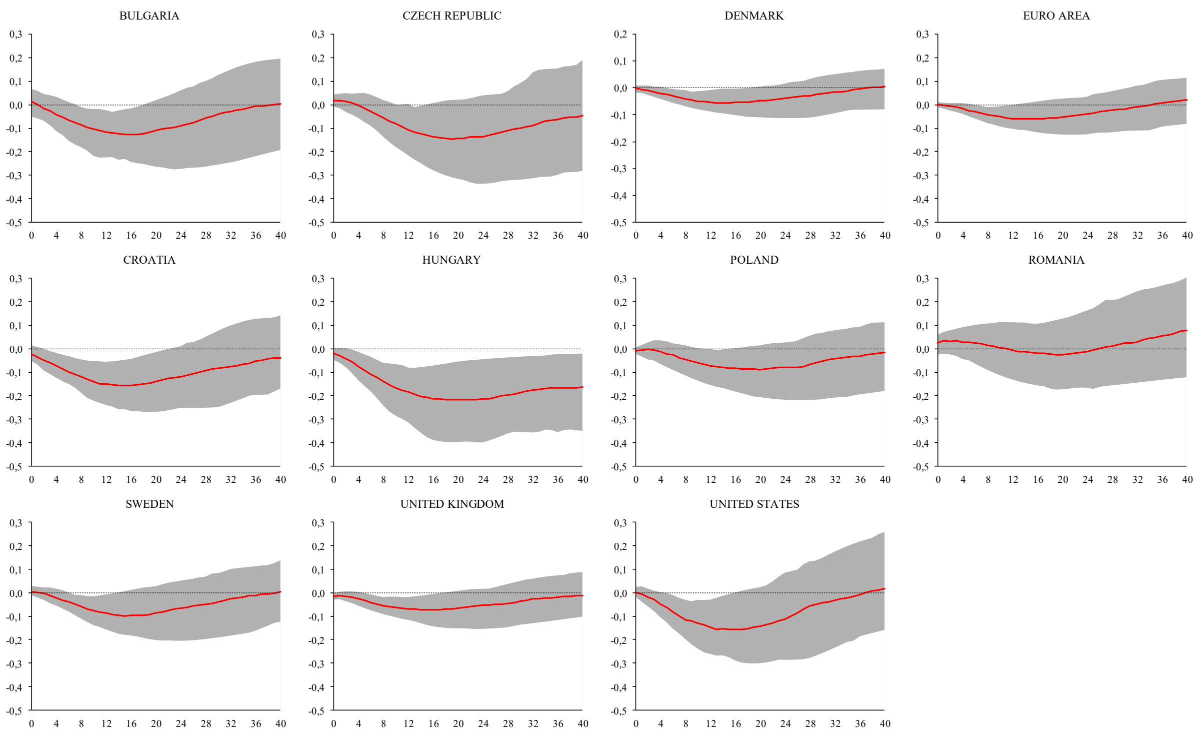
Note: Generalized impulse responses with 95% bootstrapped confidence intervals.

For the other advanced European economies, the lowest effect is observed for the UK (-0.4% both), whereas Swedish industrial production reacts more pronouncedly (-0.8%). The responses of the Central European economies (CEEs) are largely similar. The Polish real activity reacts somewhat less (-0.6%) than that of the Czech Republic (-0.8%). These differences among these so-called Visegrad countries are likely to be a consequence of the greater trade openness of the Czech economy, and they are also consistent with the previous literature.

In the context of the Southeastern European economies (SEEs), the reactions in Romania and Bulgaria on the monetary policy horizon are statistically insignificant, and the effect in Croatia is approximately -0.7%. These results are slightly different than those obtained when conventional interest rates are used. Overall, the SEEs tend to react less pronouncedly than the CEEs. This difference is consistent with our expectations since the trade links between the euro area and the CEEs are stronger than those between the euro area and the SEEs.

In addition to the effects on real activity, we also focus on the effects of consumer prices in all economies and present the impulse responses in Figure 2. Monetary tightening in the form of an unexpected 100-bp increase in the ECB shadow policy rate leads to a decrease in domestic consumer prices of approximately 0.1% on the monetary policy horizon. This is a substantially weaker effect than that observed when conventional interest rates are considered (see, for instance, Hajek and Horvath (2016)).

Figure 2: Response of Consumer Prices to a 100-bp Increase in the ECB Shadow Policy Rate



Note: Generalized impulse responses with 95% bootstrapped confidence intervals

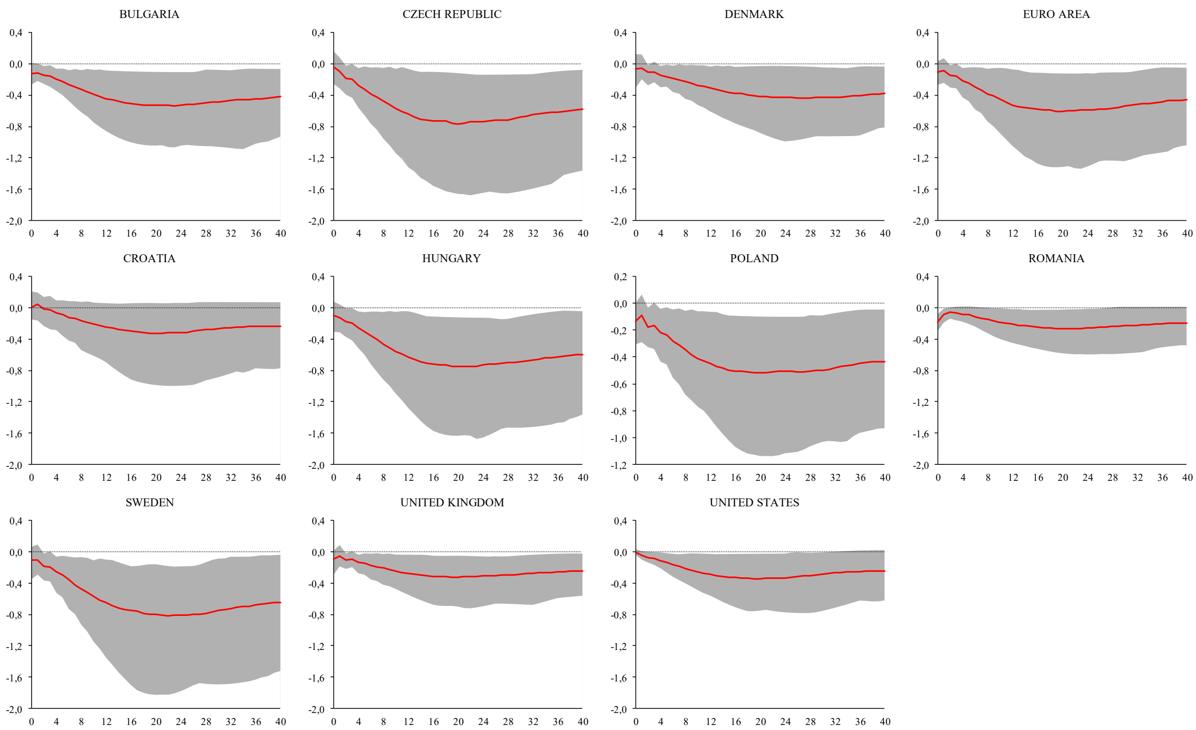
The responses in other European economies are also much weaker when shadow rates are used instead of conventional interest rates. More specifically, in the advanced European economies, the spillover effect is approximately -0.1%. In context of the CEEs, the response is more pronounced than in the case of the euro area countries, with the highest values observed for Hungary (-0.2%). Similarly, as for real activity, the effects of ECB monetary tightening on the SEEs are somewhat weaker than the effects on the CEEs. The highest response is observed in Croatia (-0.2%).

Comparing our results to those of Hajek and Horvath (2016), who focus only on international spillovers of conventional monetary policy, our results suggest somewhat weaker effects of unconventional monetary policy measures compared with conventional measures. However, this difference largely applies only to consumer prices, not real activity measures. This conclusion is consistent with the observed development in the European economies since the ECB launched its quantitative easing program. Whereas real activity started to increase, inflation still remained at very low levels (during our sample period).

5.2 Shock to the Fed Shadow Policy Rate

In the second shock scenario, we consider the domestic and cross-country effects of an unexpected 100-bp increase in the Fed shadow policy rate. Figure 3 presents the impulse responses of the real activity variables of all studied economies. Regarding the domestic environment, US industrial production shrinks by 0.4% on the monetary policy horizon as a result of the shock.

Figure 3: Response of Industrial Production to a 100-bp Increase in the Fed Shadow Policy Rate

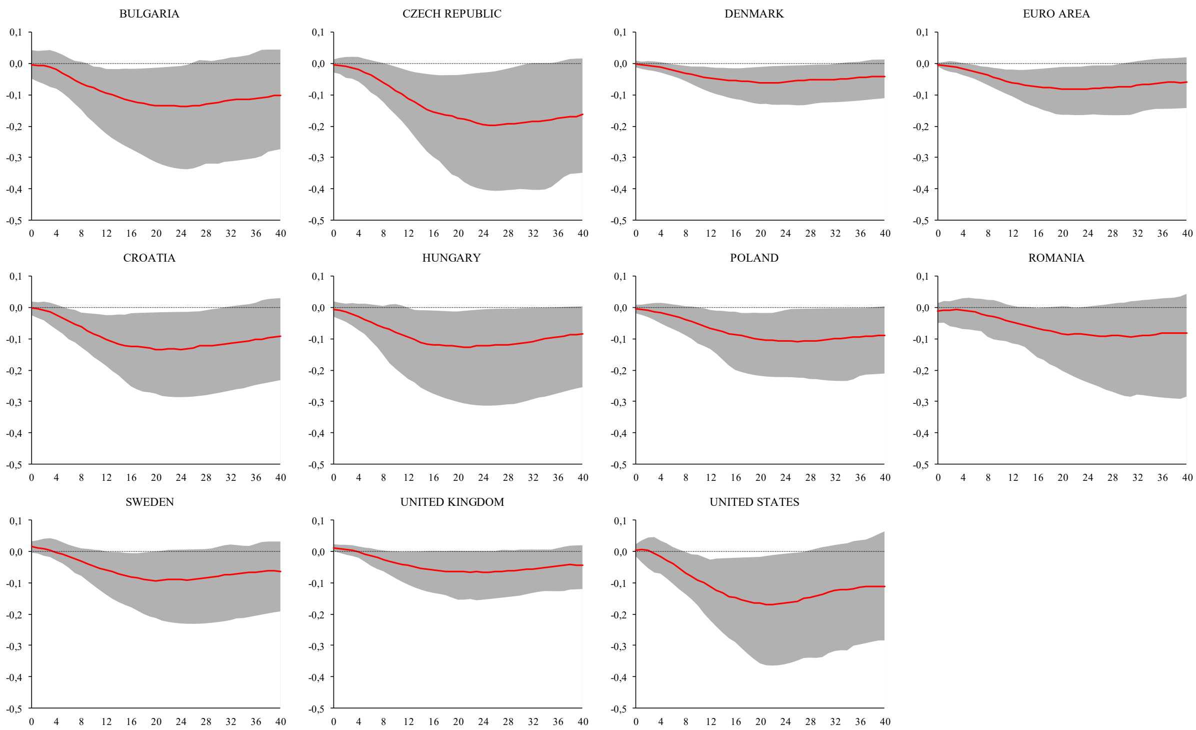


Note: Generalized impulse responses with 95% bootstrapped confidence intervals.

Regarding cross-country effects, there is generally greater uncertainty than in the first shock scenario. This difference reflects two key aspects of our system. First, the US economy is linked mostly to the euro area economy; thus, the euro area may well absorb a portion of the US shocks before they hit non-euro area EU countries (especially the CEEs and SEEs). Second, the US economy is the biggest unit in our system; thus, any shock that affects this economy causes higher volatility than a shock to any other unit within our system. Chen et al. (2017) compare the importance of spillovers from ECB and US Fed monetary policy for 24 different countries around the world, including the Czech Republic, Poland, Romania, Sweden and the UK, and find that US Fed shocks are more powerful than ECB shocks for all countries analyzed except for the Czech Republic. This finding of the prominence of US Fed shocks on non-euro area countries in the EU is not fully supported by our results.

In terms of the domestic environment, an unexpected 100-bp increase in the Fed shadow policy rate translates into a 0.4% decrease in real activity. Regarding the euro area, the respective spillover effect amounts to a 0.6% decrease in real activity. The results for other advanced European economies are largely similar. The strongest response is observed in Sweden (-0.8%), whereas the effect is somewhat less pronounced in Denmark (-0.4%) and the UK (-0.3%). In context of the CEEs, the Fed's monetary policy tightening has the strongest effect in the Czech Republic and Hungary (-0.7% for both), whereas industrial production in Poland decreases by 0.5%. Similarly, as in the first shock scenario, the SEEs react more weakly than their counterparts from the Central Europe. Industrial production in Bulgaria decreases by 0.5%.

Figure 4: Response of Consumer Prices to a 100-bp Increase in the Fed Shadow Policy Rate



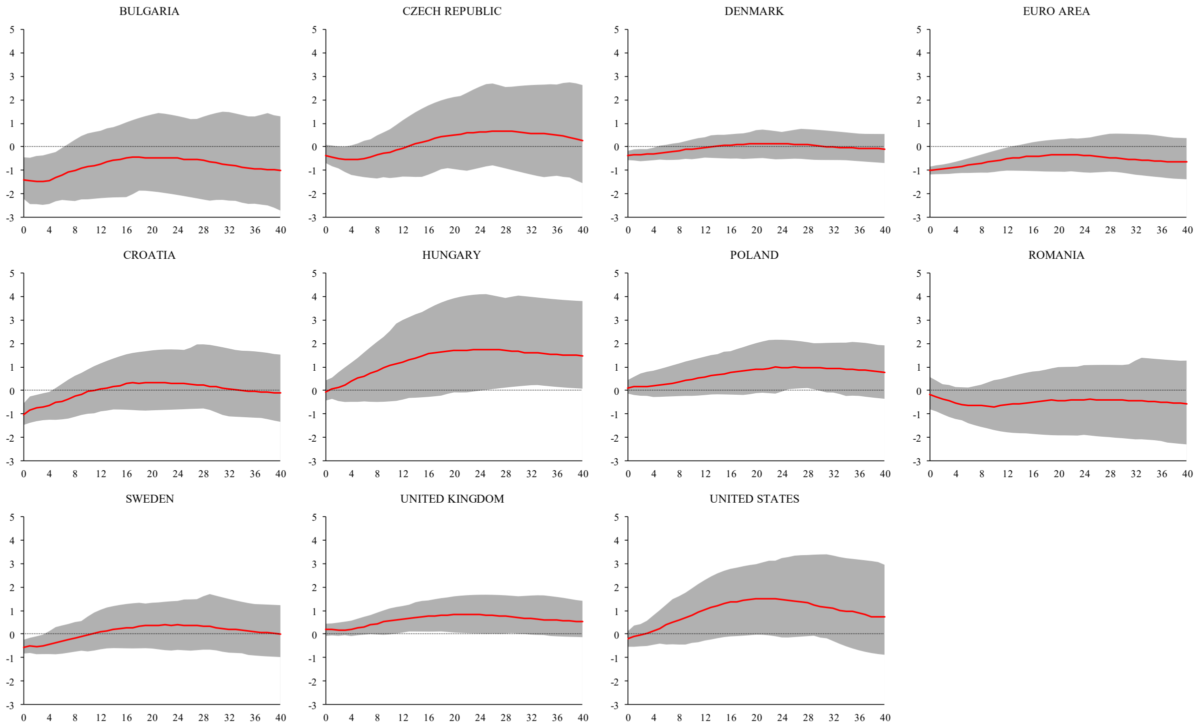
Note: Generalized impulse responses with 95% bootstrapped confidence intervals.

Next, we investigate the impacts on consumer prices. Figure 4 provides a summary of the responses of all analyzed economies. Monetary tightening in the form of an unexpected 100-bp increase in the Fed shadow policy rate has a very small effect on euro area consumer prices (-0.1%), and similar values are observed for Denmark. This is not surprising because the exchange rate of the Danish Krone is pegged to the euro. The highest response is observed in the Czech Republic and the domestic environment (-0.2%). The price puzzle does not occur in this shock scenario either.

5.3 Shock to Euro Area Prices

In response to imminent deflationary risks, in the third scenario, we focus on an unexpected 1% decrease in the euro area consumer prices; the resulting impulse responses are presented in Figure 5. In terms of the domestic environment, the simulated shock leads to a decrease in the euro area consumer prices of 0.5% 12 months after the shock and then becomes insignificant.

Figure 5: Response of Consumer Prices to a 1% Decrease in the Euro Area Consumer Prices



Note: Generalized impulse responses with 95% bootstrapped confidence intervals.

Shifting focus to the cross-country effects, consumer prices decrease the most in Bulgaria (a -1.4% immediate effect) and Croatia (a -1.0% immediate effect), whereas the responses in other countries, such as Sweden or Denmark, are somewhat weaker (-0.6% and -0.4% immediate effects, respectively); 6 months after the shock, the responses of consumer prices in these economies become even weaker, and within 12 months after the shock, they lose significance.

In light of these results, it seems that an unexpected decrease in euro area consumer prices of 1.0% does not translate quickly into lower prices in other countries. The effects are somewhat heterogeneous and somewhat uncertain. From the perspective of monetary policymakers, these results might serve as important evidence justifying inaction in the case of an unexpected change in euro area consumer prices. Our results also imply that the law of one price is slower than the horizons on which we focus using the GVAR model.

The response in the UK becomes statistically significant on the monetary policy horizon, and the estimated effects are positive. We do not find any economic explanation for this result and regard it as puzzling.

5.4 Robustness Checks

Unlike conventional monetary policy rates, shadow policy rates approximate the monetary policy stance once the economy hits the zero lower bound and unconventional monetary policy is in place. However, shadow rate estimates are somewhat uncertain. Therefore, it is vital to employ more shadow policy rate estimates and examine the robustness of our findings. As a result, in addition to the Wu and Xia (2016) shadow policy rate measures, we use the shadow rates provided by Krippner (2013) and Lombardi and Zhu (2014).

The measure provided by Krippner (2013) is available for several countries and is based on an option-pricing model. Lombardi and Zhu (2014) also present a shadow rate measure. Their framework is based on estimating the unobservable policy rate using data regarding additional financial variables and central bank operations. Unfortunately, the Lombardi and Zhu (2014) measure of the shadow policy rate is available only for the US economy.

We estimate two alternative versions of our original GVAR model using the alternative measures of shadow policy rates sequentially and then perform the same shock scenarios.[5]

The results are compared to our benchmark results based on the Wu and Xia (2016) shadow rate measure. Summaries of these comparisons are presented in the Appendix in Tables A8–A10. We also present Figures A1 to A5 in the Appendix to provide the reader with a broader picture of the resulting effects across different versions of the model.

The general tendencies of the responses under all shadow policy alternatives is similar, but there are some differences in the sizes of the effects. Nevertheless, the results of all of the presented models do not exhibit the price puzzle and are generally consistent with one another. Overall, the responses are strongest when the Wu and Xia (2016) shadow policy rates are used. The greatest amount of uncertainty is observed in the model based on the Lombardi and Zhu (2014) shadow policy rate, which yields the fewest statistically significant results.

In most cases, the results of the model based on the Lombardi and Zhu (2014) measure lie somewhere between the results when the Krippner (2013) or (Wu and Xia, 2016) measures are used. Given that the three shadow rate measures differ considerably, this comparison provides evidence for the robustness of our results.

6. Concluding Remarks

In this paper, we examine international spillovers of monetary policy using a global VAR model (Pesaran et al., 2004). In particular, we investigate how monetary shocks that emanate from the euro area and the US affect economic activity and prices in non-euro EU countries. Given that both the US Fed and the ECB have implemented a number of unconventional monetary policy measures and have been affected by the zero lower bound, we use shadow rates, which are designed to address these two issues (Wu and Xia, 2016). Therefore, the shadow rates serve as the proxy for the overall monetary policy stance. More specifically, we examine three policy-relevant shock scenarios that involve the following: (i) the ECB shadow policy rate, (ii) the US Fed shadow policy rate and (iii) euro area consumer prices.

[5] When using the Lombardi and Zhu (2014) shadow policy rate, we consider only the scenario in which there is a shock to the Fed shadow policy rate.

We find that increasing the ECB shadow policy rate decreases economic activity and, to some extent, also decreases prices in all non-euro EU countries. However, our results suggest somewhat weaker effects of unconventional monetary policy measures compared with conventional measures. Therefore, in terms of policy implications, our results suggest that monetary policy spillovers to Central Europe emanating from the ECB can become stronger in the future once the ECB reduces the intensity of or abandons its unconventional policy measures. Regarding the scenario involving changes to the Fed shadow policy rate, the results yield similar quantitative effects as found for euro area monetary shocks, but they are slightly less pronounced.

Our results further demonstrate that unexpected changes in euro area consumer prices do not have a significant effect on the inflationary/deflationary risks of the analyzed countries. If there are some significant effects, they are small and fade away quite quickly.

For all of the types of shock that we examine, the Southeastern European economies are affected less than their peers from Central Europe, which is consistent with their lower degree of trade and financial integration with the euro area.

In terms of future research, it may be vital to employ different econometric models, such as Mixed-Cross-Section GVAR, Bayesian GVAR or time-varying-parameter GVAR, and eventually to examine other policy scenarios, such as jointly examining the effects and interactions of monetary and macroprudential policies, explicitly examining changes in the uncertainty of financial markets or comparing the importance of domestic vs. euro area monetary policy for domestic prices and the real economy. The time-varying parameter GVAR model could be helpful to assess potential non-linearities and the time evolution of the importance of shocks.

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Appendix A:

Table A1: ADF Test on Variables in Levels

Variable	BG	CZ	DK	EA	HR	HU	PL	RO	SE	UK	US
y	-1.90	-1.86	-1.91	-2.14	-1.75	-1.92	-1.64	-2.85	-2.13	-1.88	-2.09
p	-2.06	-2.81	-2.10	-1.92	-2.48	-2.28	-2.03	-4.14	-2.33	-2.26	-3.98
rer	-0.56	-0.95	-1.32	-1.65	-0.91	-1.48	-1.52	-0.80	-1.67	-2.20	-
stir	-2.03	-1.92	-1.46	-0.44	-2.58	-1.11	-4.62	-4.54	-1.54	-1.26	-1.70
ltir	-1.10	-0.85	-0.83	-0.60	-	-1.00	-2.63	-	-0.95	-0.93	-1.72
y*	-2.13	-2.08	-2.13	-1.90	-2.12	-2.08	-2.08	-2.07	-1.98	-2.15	-2.06
p*	-2.06	-1.93	-2.39	-2.58	-1.98	-1.95	-2.00	-1.87	-2.36	-2.54	-1.97
rer*	-2.12	-1.87	-2.03	-1.62	-1.78	-2.08	-1.98	-2.00	-1.84	-1.73	-1.60
stir*	-1.79	-0.84	-0.67	-2.05	-0.56	-1.31	-0.66	-0.50	-0.91	-0.76	-0.73
ltir*	-0.65	-0.68	-0.74	-1.12	-0.60	-0.70	-0.59	-0.55	-0.76	-0.82	-0.59
poil	-	-	-	0.25	-	-	-	-	-	-	0.25

Note: The regressions for all variables except interest rates and inflation, in addition to their foreign counterparts, contain a constant and a trend term. The ADF tests for interest rates and inflation are based on a constant in the ADF regression only. The 5% critical value of the ADF statistic including a trend and intercept is -3.47; the value without a trend is -2.91.

Table A2: ADF Test on Variables in First Differences

Variable	BG	CZ	DK	EA	HR	HU	PL	RO	SE	UK	US
Dy	-7.37	-8.89	-21.1	-7.56	-10.27	-8.42	-8.31	-13.10	-8.34	-27.72	-5.09
Dp	-7.69	-6.77	-8.36	-7.03	-10.27	-7.57	-7.67	-6.33	-5.06	-7.25	-8.92
Drer	-8.30	-8.29	-8.51	-8.79	-8.72	-8.17	-8.34	-8.34	-8.24	-7.72	-
Dstir	-6.74	-7.23	-4.64	-7.09	-15.80	-8.68	-5.06	-7.10	-5.91	-10.63	-4.72
Dltir	-6.87	-9.80	-9.16	-9.17	-	-11.14	-6.43	-	-8.33	-8.61	-9.89
Dy*	-7.20	-7.47	-7.27	-5.05	-7.30	-7.36	-7.41	-7.25	-7.59	-6.77	-7.94
Dp*	-7.17	-7.10	-7.20	-8.21	-6.99	-7.02	-6.72	-6.79	-7.44	-7.55	-6.97
Drer*	-8.74	-8.84	-9.22	-7.97	-8.85	-8.79	-8.96	-8.89	-8.98	-8.84	-9.03
Dstir*	-6.99	-6.79	-6.56	-3.87	-6.98	-7.02	-6.80	-6.94	-6.51	-7.08	-6.91
Dltir*	-9.25	-9.16	-9.22	-9.47	-9.32	-9.14	-9.37	-9.29	-9.37	-9.52	-9.20
Dpoil	-	-	-	-8.32	-	-	-	-	-	-	-8.32

Note: The regressions for all variables contain a constant term in the ADF regression only. The 5% critical value of the ADF statistic is -2.91.

Table A3: The Moduli of All Transformed Eigenvalues of the Coefficient Matrices.

M1	M2	M3	M4	M5	M6	M7	M8	M9	M10
0.975	0.955	0.955	0.922	0.860	0.860	0.799	0.782	0.626	0.591

Note: Numbers less than 1 indicate that the model is stable (Lütkepohl, 2005).

Table A4: Nested Likelihood Ratio Test on Specification of Deterministic Terms

	BG*	CZ	DK	EA	HR	HU*	PL	RO	SE	UK	US
Stat	10.08	49.52	26.56	-51.25	-32.24	14.01	51.39	66.48	23.58	32.55	-52.72

Note: The null hypothesis is as follows: unrestricted intercept, no trend. The alternative hypothesis is the following: unrestricted intercept, restricted trend. The critical value is 6.00 for all countries except for EA, HR and US. For the remaining countries, the critical value is 3.80. * The Schwartz-Bayesian statistic was used instead of the log-likelihood statistic because the latter was statistically insignificant.

Table A5: F-test for Exogeneity

	DoF	ys	ps	rers	stirs	ltirs	poil
BG	F(3.168)	0.92	3.73	-	3.18	0.80	-
CZ	F(3.168)	2.27	1.45	-	2.24	0.05	-
DK	F(3.168)	2.52	1.81	-	0.11	0.33	-
EA	F(3.168)	1.71	3.88	-	0.08	0.45	0.01
HR	F(3.169)	2.21	1.21	-	1.20	-	-
HU	F(3.168)	7.35	0.90	-	0.26	0.10	-
PL	F(3.163)	3.11	0.19	-	0.08	0.65	-
RO	F(3.168)	2.79	0.35	-	4.46	0.75	-
SE	F(3.168)	2.50	1.45	-	0.73	0.50	-
UK	F(3.168)	2.76	4.73	-	4.65	0.20	-
US	F(3.163)	0.11	8.95	1.22	6.64	-	4.58

Note: The 5% critical value of the F-test is 3.05 for all countries except for EA, HR and US. For the remaining countries, the critical value is 3.80.

Table A6: F-test for Serial Correlation

	DoF	y	p	rer	stir	ltir
BG	F(3,168)	3.05	1.49	7.98	4.57	4.68
CZ	F(3,168)	0.50	0.85	2.95	2.30	1.52
DK	F(3,168)	4.20	2.41	6.91	0.65	0.73
EA	F(3,168)	0.50	3.07	3.72	2.46	4.60
HR	F(3,169)	11.74	1.33	4.08	15.78	-
HU	F(3,168)	2.42	0.92	2.86	2.17	9.57
PL	F(3,163)	3.29	1.54	0.03	5.77	0.26
RO	F(3,168)	5.45	1.03	4.91	6.92	-
SE	F(3,168)	5.05	2.54	6.10	4.75	3.60
UK	F(3,168)	10.51	3.78	6.13	2.17	5.80
US	F(3,163)	3.67	0.78	-	0.77	0.56

Note: The 5% critical value of the F-test is 2.66.

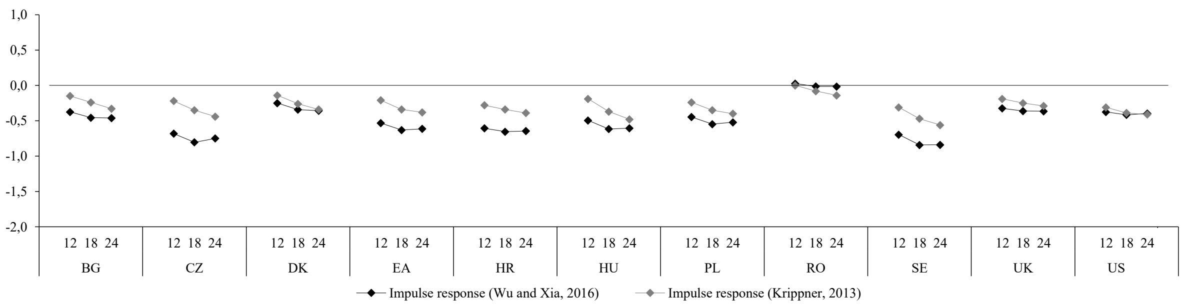
Table A7: Data for Constructing Aggregation Weights

Country	GDP	Country	GDP	Country	GDP
AT	316299	IT	1778233	CZ	246512
BG	384804	LT	57002	DK	200036
CY	23161	LU	40918	HR	76042
DE	2849479	LV	36141	HU	188428
EE	27155	MT	10021	PL	708112
ES	1344672	NL	637993	RO	292717
FI	183041	PT	239315	SE	342913
FR	2057959	SK	117948	UK	2019613
EL	270121	SI	49833	US	13379334
IR	166768	BG	96410		

Source: Feenstra et al. (2015).

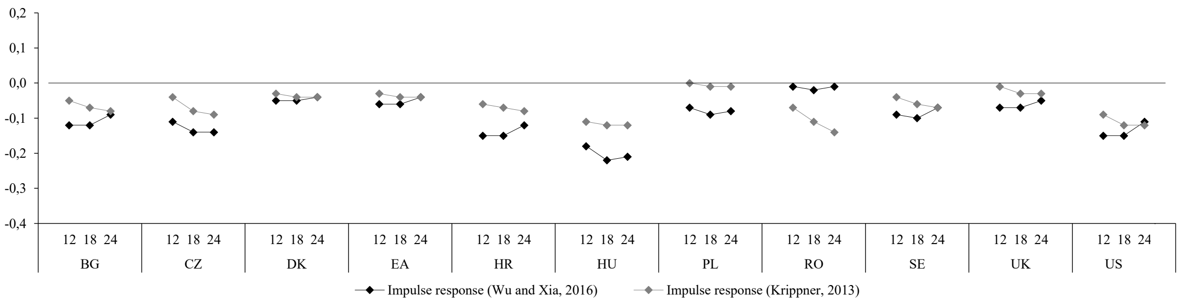
Note: GDP at PPP (current international USD), millions, average over 2000-2011.

Figure A1: Responses of Industrial Production to a 100-bp Increase in the ECB Shadow Policy Rate Across Models With Different Shadow Policy Rates



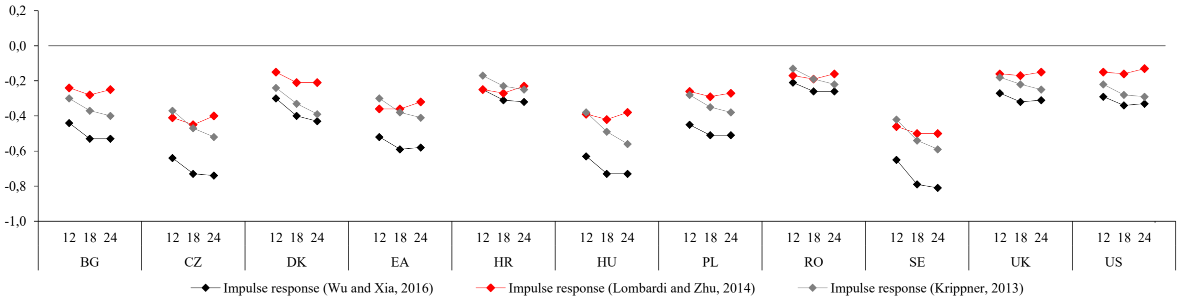
Note: Generalized impulse responses on three horizons: 12, 18 and 24 months.

Figure A2: Responses of Consumer Prices to a 100-bp Increase in the ECB Shadow Policy Rate Across Models With Different Shadow Policy Rates



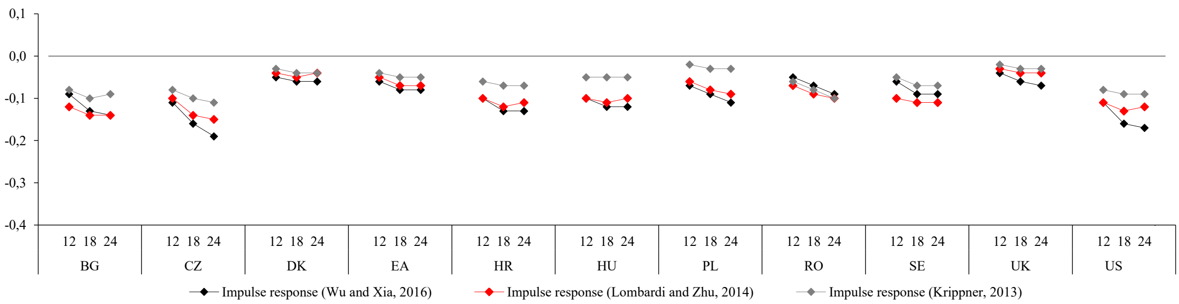
Note: Generalized impulse responses on three horizons: 12, 18 and 24 months.

Figure A3: Responses of Industrial Production to a 100-bp Increase in the Fed Shadow Policy Rate Across Models With Different Shadow Policy Rates



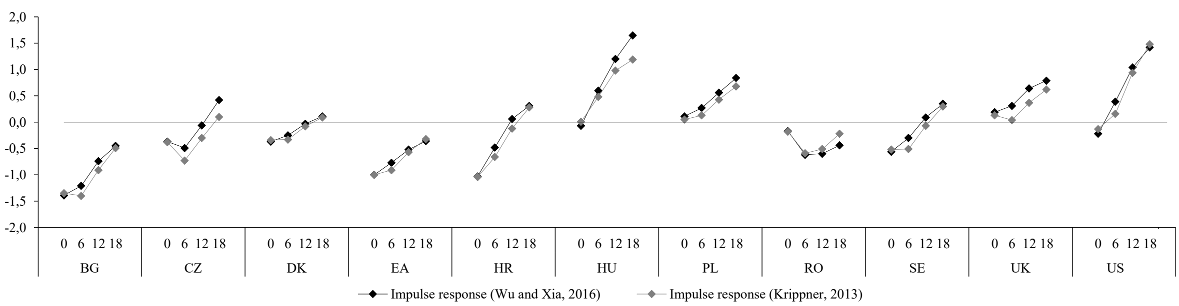
Note: Generalized impulse responses on three horizons: 12, 18 and 24 months.

Figure A4: Responses of Consumer Prices to a 100-bp Increase in the Fed Shadow Policy Rate Across Models With Different Shadow Policy Rates



Note: Generalized impulse responses on three horizons: 12, 18 and 24 months.

Figure A5: Responses of Consumer Prices to a 1% Increase in the Euro Area Consumer Prices Across Models With Different Shadow Policy Rates



Note: Generalized impulse responses on four horizons: 0, 6, 12 and 18 months.

Table A8: Summary of Impulse Responses Under Different Scenarios Using the Wu and Xia (2016) Shadow Policy Rate

	BG	CZ	DK	EA	HR	HU	PL	RO	SE	UK	US
100bp increase in the ECB shadow policy rate (effect on activity)											
12M	-0.38	-0.68*	-0.25	-0.53*	-0.61*	-0.5	-0.45*	0.03	-0.7*	-0.32*	-0.38*
18M	0.46	-0.8*	-0.34	-0.63*	-0.65*	-0.62	-0.55*	-0.01	-0.84*	-0.36*	-0.41*
24M	0.46	-0.75*	-0.36	-0.61*	-0.65*	-0.6	-0.52*	-0.02	-0.84*	-0.36*	-0.4*
100bp increase in the ECB shadow policy rate (effect on prices)											
12M	-0.12*	-0.11	-0.05*	-0.06*	-0.15*	-0.18*	-0.07*	-0.01	-0.09*	-0.07*	-0.15*
18M	-0.12	-0.14	-0.05*	-0.06	-0.15*	-0.22*	-0.09	-0.02	-0.1	-0.07	-0.15
24M	-0.09	-0.14	-0.04*	-0.04	-0.12	-0.21*	-0.08	-0.01	-0.07	-0.05	-0.11
100bp increase in the Fed shadow policy rate (effect on activity)											
12M	-0.44*	-0.64*	-0.3*	-0.52*	-0.25	-0.63*	-0.45*	-0.21	-0.65*	-0.27*	-0.29*
18M	-0.53*	-0.73*	-0.4*	-0.59*	-0.31	-0.73*	-0.51*	-0.26	-0.79*	-0.32*	-0.34*
24M	-0.53*	-0.74*	-0.43*	-0.59*	-0.32	-0.73*	-0.51*	-0.26	-0.81*	-0.31*	-0.33*
100bp increase in the Fed shadow policy rate (effect on prices)											
12M	-0.09*	-0.11*	-0.05*	-0.06*	-0.1*	-0.1*	-0.07*	-0.05	-0.06*	-0.04*	-0.11*
18M	-0.13*	-0.16*	-0.06*	-0.08*	-0.13*	-0.12*	-0.09*	-0.07	-0.09*	-0.06	-0.16*
24M	-0.14*	-0.19*	-0.06*	-0.08*	-0.13*	-0.12*	-0.11*	-0.09	-0.09	-0.07	-0.17*
1% decrease in the euro area consumer prices (effect on prices)											
0M	-1.39*	-0.37	-0.37*	-1*	-1.03*	-0.07	0.11	-0.17	-0.56*	0.19	-0.22
6M	-1.21*	-0.49	-0.25	-0.77*	-0.48	0.6	0.27	-0.62	-0.3	0.31	0.39
12M	-0.74	-0.06	-0.03	-0.52*	0.06	1.2	0.56	-0.6	0.09	0.64*	1.4
18M	-0.45	0.42	0.11	-0.36	0.31	1.65	0.84	-0.44	0.35	0.79*	1.42

Note: * denotes 5% statistical significance, M represents months.

Table A9: Summary of Impulse Responses Under Different Scenarios Using the Krippner (2013) Shadow Policy Rate

	BG	CZ	DK	EA	HR	HU	PL	RO	SE	UK	US
100bp increase in the ECB shadow policy rate (effect on activity)											
12M	-0.15	-0.22*	-0.14	-0.21*	-0.28*	-0.19	-0.24*	0	-0.31*	-0.19*	-0.31*
18M	-0.24	-0.35*	-0.26	-0.34*	-0.34*	-0.37	-0.35*	-0.08	-0.47*	-0.25	-0.39*
24M	-0.33	-0.44*	-0.34	-0.38*	-0.39*	-0.48	-0.4*	-0.14	-0.56*	-0.29	-0.41*
100bp increase in the ECB shadow policy rate (effect on prices)											
12M	-0.05	-0.04	-0.03*	-0.03	-0.06	-0.11*	0	-0.07	-0.04	-0.01	-0.09*
18M	-0.07	-0.08	-0.04*	-0.04	-0.07	-0.12*	-0.01	-0.11	-0.06	-0.03	-0.12*
24M	-0.08	-0.09	-0.04*	-0.04	-0.08	-0.12*	-0.01	-0.14	-0.07	-0.03	-0.12*
100bp increase in the Fed shadow policy rate (effect on activity)											
12M	-0.3*	-0.37*	-0.24*	-0.3*	-0.17	-0.38*	-0.28	-0.13*	-0.42*	-0.18*	-0.22*
18M	-0.37*	-0.47*	-0.33*	-0.38*	-0.23*	-0.49*	-0.35	-0.19*	-0.54*	-0.22*	-0.28*
24M	-0.4*	-0.52*	-0.39*	-0.41*	-0.25*	-0.56*	-0.38	-0.22*	-0.59*	-0.25*	-0.29*
100bp increase in the Fed shadow policy rate (effect on prices)											
12M	-0.08*	-0.08*	-0.03*	-0.04*	-0.06*	-0.05*	-0.02	-0.06*	-0.05	-0.02	-0.08*
18M	-0.1*	-0.1*	-0.04*	-0.05*	-0.07*	-0.05*	-0.03	-0.08*	-0.07	-0.03	-0.09*
24M	-0.09*	-0.11*	-0.04*	-0.05*	-0.07*	-0.05*	-0.03	-0.1*	-0.07	-0.03	-0.09*
1% decrease in the euro area consumer prices (effect on prices)											
0M	-1.35*	-0.38	-0.34*	-1*	-1.04*	0.01	0.05	-0.18	-0.52*	0.13	-0.13
6M	-1.4*	-0.73	-0.33*	-0.91*	-0.66*	0.48	0.13	-0.59	-0.51*	0.04	0.16
12M	-0.91	-0.3	-0.08	-0.57*	-0.12	0.98	0.43	-0.51	-0.07	0.37	0.94
18M	-0.49	0.1	0.09	-0.32	0.28	1.19*	0.68	-0.22	0.3	0.62*	1.48

Note: * denotes 5% statistical significance, M represents months.

Table A10: Summary of Impulse Responses Under Different Scenarios Using the Lombardi and Zhu (2014) Shadow Policy Rate

	BG	CZ	DK	EA	HR	HU	PL	RO	SE	UK	US
100bp increase in the Fed shadow policy rate (effect on activity)											
12M	-0.24	-0.41*	-0.15	-0.36*	-0.25	-0.39	-0.26	-0.17	-0.46	-0.16	-0.15
18M	-0.28	-0.45	-0.21	-0.36	-0.27	-0.42	-0.29	-0.19	-0.5	-0.17	-0.16
24M	-0.25	-0.4	-0.21	-0.32	-0.23	-0.38	-0.27	-0.16	-0.5	-0.15	-0.13
100bp increase in the Fed shadow policy rate (effect on prices)											
12M	-0.12*	-0.1*	-0.04*	-0.05*	-0.1*	-0.1*	-0.06*	-0.07*	-0.1*	-0.03	-0.11*
18M	-0.14*	-0.14*	-0.05	-0.07	-0.12*	-0.11*	-0.08*	-0.09*	-0.11*	-0.04	-0.13*
24M	-0.14*	-0.15	-0.04	-0.07	-0.11	-0.1*	-0.09	-0.1	-0.11*	-0.04	-0.12

Note: * denotes 5% statistical significance, and M represents months. The shadow policy rate from Lombardi and Zhu (2014) is estimated only for the US. For the EA shadow policy rate variable, the Wu and Xia (2016) version is used.

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