# Spreading the word or reducing the term spread? Assessing spillovers from euro area monetary policy

Feldkircher, Martin; Gruber, Thomas; Huber, Florian

*DOI:*
10.57938/b3fa9747-e621-4762-8429-592adb6d5ef9

*Published: 01/05/2017*

*Document Version:*
Publisher's PDF, also known as Version of record

Department of Economics
Working Paper No. 248

# Spreading the word or reducing the term spread? Assessing spillovers from euro area monetary policy

Martin Feldkircher
Thomas Gruber
Florian Huber

May 2017

# Spreading the word or reducing the term spread? Assessing spillovers from euro area monetary policy

Martin Feldkircher*[1], Thomas Gruber[1], and Florian Huber[2]

[1]Oesterreichische Nationalbank (OeNB)
[2]Vienna University of Economics and Business

April 24, 2017

**Abstract**

As a consequence of asset purchases by the European Central Bank (ECB), longer-term yields in the euro area decline, and spreads between euro area long-term yields narrow. To assess spillovers of these recent financial developments, we use a Bayesian variant of the global vector autoregressive (BGVAR) model with stochastic volatility and propose a novel mixture of zero impact and sign restrictions that we impose on the cross-section of the data. Both shocks generate positive and significant spillovers to industrial production in Central, Eastern and Southeastern Europe (CESEE) and other non-euro area EU member states. These effects are transmitted via the financial channel (mainly through interest rates and equity prices) and outweigh costs of appreciation pressure on local currencies vis-á-vis the euro (trade channel). While these results represent general trends, we also find evidence for both cross-country heterogeneity of effects within the euro area and region-specific spillovers thereof.

**Keywords:** Euro area monetary policy, quantitative easing, spillovers
**JEL Codes:** C30, E52, F41, E32.

*Corresponding author: Martin Feldkircher, Oesterreichische Nationalbank (OeNB), Phone: +43-1-404 20-5251. E-mail: martin.feldkircher@oenb.at. Any views expressed in this paper represent those of the authors only and not necessarily of the Oesterreichische Nationalbank or the Eurosystem. We would like to thank Alessandro Galesi, Axel Jochem, Milan Nedeljković, participants of the 14th emerging markets workshop, Banco de Espana, Madrid, and participants of the Jean Monnet workshop on Financial globalization and its spillovers, Cologne and Maastricht for helpful comments.

## 1 Introduction

Following the global financial crisis in 2007 and the failure of Lehman in 2008, major central banks have considerably lowered their policy rates to stimulate economic growth and consumer price inflation. Since the room for conventional monetary policy quickly eroded and against the background of deflationary pressures and weak economic growth, major central banks switched from traditional interest rate targeting to other forms of monetary policy. One of these non-conventional monetary policies works through an extension of the central banks' balance sheet by purchasing longer-term securities from the private sector , so-called *Quantitative Easing* (QE, see e.g., Fawley and Neely, 2013, for a detailed overview).

The main domestic transmission channels are the "portfolio re-balancing" channel and the "asset price channel" (see Joyce et al., 2012, for an excellent summary). In a nutshell, investors who sell bonds to the central bank, are likely to purchase other long-dated assets (e.g., corporate bonds) to restore the original duration of their overall portfolio. Given zero short-term rates, this leads to a decline in the term spread and ideally to a broad easing of financial conditions in a variety of market segments. Second, the reduction of bond yields should trigger a rise in asset prices, which in turn increases consumer wealth and overall aggregate demand ("asset price channel"). Since the extent of financial deepening within the euro area differs, it seems likely that the within-euro area transmission of these policy measures differ as well (see Georgiadis, 2015, for the case of conventional monetary policy). This implies that to analyze spillovers from euro area monetary policy, it is essential to use a coherent multi-country framework, that accounts for both heterogeneity of effects within the euro area and spillovers thereof.

Gambacorta et al. (2014) and Burriel and Galesi (2016) follow these lines of arguments and focus on within euro area spillovers. Gambacorta et al. (2014) estimate a structural panel VAR for eight advanced euro area countries to asses the effects of an exogenous increase in central banks' assets. The shocks of interest are pinned down by relying on a mixture of zero and sign restrictions. The findings in Gambacorta et al. (2014) suggest that an exogenous increase in central bank assets leads to a rise in economic activity and – to a lesser degree - positive effects on prices. Moreover, these effects are rather homogeneous among euro area countries. Burriel and Galesi (2016) use a wider set of euro area countries, a global vector autoregressive framework that takes cross-country spillovers into account, and a similar identification strategy. They find that an exogenous increase in ECBs total assets leads to a significant rise in aggregate output and inflation, a depreciation of the effective exchange rate and an increase in real equity prices and private credit. They also find a significant degree of within-euro area heterogeneity contrasting results of Gambacorta et al. (2014) and conclude that positive spillovers to countries with less fragile banks are largest.

In this paper we assess spillovers from financial market developments induced by recent euro area monetary policy to non-euro area EU member states. Which economies are more strongly affected from euro area monetary policy, and which are more insulated? On the one hand, the increase in euro area demand is likely to boost economic activity in those countries that share strong trade links with euro area member states. On the other hand, loose monetary policy in the euro area is expected to put appreciation pressure on euro area's trading partners' currencies, which might mitigate stimulus to economic growth.

Hitherto, there is a small but growing literature examining international effects of euro area unconventional monetary policy. Bluwstein and Canova (2015) use two-country Bayesian mixed frequency structural vector autoregressions to asses spillovers to non-euro area EU member states. Overall, they find positive but heterogeneous spillovers on output. In line with Burriel and Galesi (2016) the financial channel seems important in transmitting spillovers. Moder (2017) employs two-country vector-autoregressions to asses spillovers to Southeastern Europe drawing on a similar identification scheme as in Boeckx et al. (2017) and Burriel and Galesi (2016). She finds positive output and price effects that are amplified by second-round effects through international trade links. Horváth and Voslářová (2016) use a panel vector autoregressive framework to examine the reaction of macroeconomic variables in CESEE economies to both a shock to the shadow rate as a measure of unconventional policy (Wu and Xia, 2016) and an exogenous increase in central banks' assets. Corroborating results of Gambacorta et al. (2014) on within-euro area spillovers, they find strong effects on output, while spillovers to prices are rather weak. Last, Ciarlone and Colabella (2016) and Falagiarda et al. (2015) take a different route and conduct event study analyses to investigate announcement effects of the ECB's non-standard measures on financial variables in neighboring countries of the euro area, mainly from CESEE.[1] Ciarlone and Colabella (2016) find that the ECB's asset purchases trigger an appreciation of local currencies against the euro, drive up equity prices and – to a lesser extent – decrease long term yields in the region. These reactions can be attributed to a surge in portfolio and banking flows to the region as international investors search for higher yields.

We contribute to that young literature by investigating spillovers first, from a reduction in euro area term spreads and secondly, from a narrowing of euro area long-term yields. Both financial market developments could be induced by recent euro area monetary policy, namely large scale asset purchases by the ECB. That these cause a compression of the yield curve in an environment of low interest rates, has been demonstrated by Baumeister and Benati (2013) for the USA and by Altavilla et al. (2015), Ambler and Rumler (2016) for the euro area. The second shock we assess is a reduction in the risk spread - which we define as long-term yields over German long-term yields. This could capture other forms of unconventional monetary policy such as forward guidance as a form to successfully committing to a loose monetary policy and thereby convincing and reducing uncertainty in the markets. To complement our analysis, we examine a reduction in a newly proposed metric that reflects overall monetary policy stance, the effective monetary stimulus (EMS) measure of Halberstadt and Krippner (2016).

[1]See Georgiadis and Grab (2015) for a study on the impact of the ECBs announcement of the extended asset purchase program on global financial markets.

As an econometric rationale, we use a multi-country framework that is able to fully take into account both, within euro area heterogeneity of monetary policy effects and resulting spillovers from these effects. More specifically, we use a variant of the Bayesian global vector autoregressive (BGVAR) framework put forth in Crespo Cuaresma et al. (2016), and Feldkircher and Huber (2016). The proposed framework features shrinkage priors on the parameters of the model as well as time-varying error variances and is thus a very flexible approach to handle volatile and higher frequency time series. The BGVAR with local shrinkage priors reduces estimation uncertainty that can lead to imprecise inference.[2] To identify the shocks, we propose a mixture of zero impact and sign restrictions that is novel to the GVAR literature.

Our main results may be summarized as follows. First, we find that a reduction in the term or risk spread leads to an increase in euro area output, equity prices and a depreciation of the euro (Burriel and Galesi, 2016). In terms of magnitudes, both shocks yield quite similar results - estimates for the risk spread shock, however, are often accompanied with wider credible sets. We also find evidence for cross-country heterogeneity within the euro area, generalizing the results of Georgiadis (2015). Differences in within-euro area transmission of the shocks lead to different spillovers thereof. More specifically, we find that responses in CESEE economies tend to be more similar to those of euro area core than periphery economies. Second, and looking at international effects, we find that both shocks trigger a) an increase in industrial production, b) a rise in equity prices, which is mitigated by c) an appreciation of local exchange rates vis-á-vis the euro. Evidence for spillovers to international prices is weak. These results represent general trends in the data. In addition we find region-specific responses, such as a pronounced increase in private credit in CESEE economies, which reflects the regions' strong financial links to the euro area. More generally, countries with a low GDP per capita ratio, a sound banking sector or few regulations on setting up a new firm benefit more from the expansionary euro area shocks. Our results remain qualitatively robust to a series of alternative specifications including a shock to effective monetary stimulus, a new monetary policy metric derived from yield curve data, variations in the set of sign restrictions, permutations of the ordering of the variables in the system and more generally different treatments of shock identification in the GVAR framework.

The paper is structured as follows. The next section introduces the econometric framework, while Section 3 summarizes the data and model specification. Section 4 lays out the strategy to identify term and risk spread shocks. Section 5 discusses the results and section 6 and concludes the paper.

## 2 Econometric framework

In this section we turn to the description of the econometric framework. We employ an extension of the traditional GVAR approach put forward by Pesaran et al. (2004)

[2] Chen et al. (2016) notes that confidence / credible intervals in GVAR analysis are typically wide. Moreover, Huber (2016) and Dovern et al. (2016) show that GVARs with shrinkage priors and stochastic volatility perform extraordinarily well in terms of forecasting.

that adopts flexible stochastic volatility specifications. In general, time variation can be accounted for by either letting coefficients in the model drift, or by allowing residual variances to change over time. Several studies (Sims and Zha, 2006; Primiceri, 2005) find rather limited evidence in favor of time-variation in the autoregressive parameters but recognize the importance to control for heteroscedasticity. Hence, and in light of the present dataset, which is monthly and covers a rather limited time span, we use a stochastic volatility specification within the GVAR framework in order to capture dynamic properties commonly observed in macroeconomic and financial time series.

The first subsection describes the global vector autoregressive model with stochastic volatility in fairly general terms. In the second subsection we briefly discuss the prior setup adopted and the Markov chain Monte Carlo (MCMC) algorithm.

### 2.1 The global vector autoregressive model with stochastic volatility

The GVAR model, originally proposed by Pesaran et al. (2004) builds on a sequence of $N+1$ country-specific VAR models that feature a set of $k_i^*$ weakly exogenous predictors constructed by taking weighted averages of other countries' $k_j$ endogenous variables $x_{jt}$,

$$\boldsymbol{x}_{it}^* = \sum_{j=0}^{N} w_{ij}\boldsymbol{x}_{jt}, \quad \text{for} \quad i \in \{0, \dots, N\}, \tag{2.1}$$

with $w_{ij}$ denoting a set of weights between countries $i$ and $j$, normalized to sum up to unity.[3] In the GVAR literature, these weights are typically assumed to be based on bilateral trade relationships or other measures of economic connectivity. The $x_{it}^*$ variables are included to approximate the presence of observed or unobserved global factors and serve as a means to control for economic dependencies across countries.

We assume that the dynamics of the $k_i$ endogenous variables in country $i$ are described by the following VARX($p$,$q$) model,

$$\boldsymbol{x}_{it} = \sum_{j=1}^{p} \boldsymbol{A}_{ij}\boldsymbol{x}_{it-j} + \sum_{s=0}^{q} \boldsymbol{B}_{is} x_{it-s}^* + \boldsymbol{\varepsilon}_{it}, \tag{2.2}$$

with $\boldsymbol{A}_{ij}$ $(j = 1, \dots, p)$ being $k_i \times k_i$-dimensional coefficient matrices, $\boldsymbol{B}_{is}$, $(s = 0, \dots, q)$ are coefficient matrices of dimension $k_i \times k_i^*$ associated with the weakly-exogenous variables and $\boldsymbol{\varepsilon}_{it}$ is a normally distributed vector error term with a time-varying variance-covariance matrix $\boldsymbol{\Sigma}_{it}$. Following Cogley and Sargent (2005) we can decompose $\boldsymbol{\Sigma}_{it}$ as follows

$$\boldsymbol{\Sigma}_{it} = \boldsymbol{U}_i \boldsymbol{H}_{it} \boldsymbol{U}_i', \tag{2.3}$$

where $\boldsymbol{U}_i$ is a $k_i \times k_i$-dimensional lower triangular matrix with unit diagonal and off-diagonal elements denoted by $u_{ij,n}$ $(j = 2, \dots, k_i; n = 1, \dots, j-1)$ and $\boldsymbol{H}_{it}$ is a diagonal

[3] Note that we assume for simplicity that all countries feature the same number of endogenous variables in $\boldsymbol{x}_{jt}$, an assumption that will be relaxed in the next section.

matrix with $\boldsymbol{H}_{it} = \text{diag}(e^{h_{i1,t}}, \dots, e^{h_{ik_i,t}})$. Hereby we assume that the log-volatilities $h_{ij,t}$ follow an AR(1) process,

$$h_{ij,t} = \mu_{ij} + \rho_{ij}(h_{ij,t-1} - \mu_{ij}) + \kappa_{ij,t}, \tag{2.4}$$

where $\kappa_{ij,t}$ denotes a white noise error with variance $\varsigma_{ij}^2$.

It is straightforward to show that the sequence of $N+1$ can be combined to yield a global VAR model,

$$\boldsymbol{G}\boldsymbol{x}_t = \sum_{n=1}^{p^*} \boldsymbol{F}_n \boldsymbol{x}_{t-n} + \boldsymbol{\eta}_t. \tag{2.5}$$

Hereby, we let $\boldsymbol{x}_t = (\boldsymbol{x}'_{0t}, \dots, \boldsymbol{x}'_{Nt})'$ denote a $k = \sum_{j=0}^{N} k_j$-dimensional vector that collects all endogenous variables in the system, $\boldsymbol{G}$ is a $k \times k$ matrix of contemporaneous coefficients that are a function of the $\boldsymbol{B}_{i0}$ matrices and the weights in $w_{ij}$ and $p^* = \max(p, q)$. Moreover, $\boldsymbol{F}_n$ are $k \times k$ matrices of autoregressive coefficients that are driven by the weights and the estimates of $\boldsymbol{A}_{ij}$ for all countries and $\boldsymbol{\eta}_t$ is a $k$-dimensional vector white noise process with a block-diagonal matrix $\boldsymbol{\Sigma}_t = \text{bdiag}(\boldsymbol{\Sigma}_{0t}, \dots, \boldsymbol{\Sigma}_{Nt})$. Multiplying with $\boldsymbol{G}^{-1}$ from the left yields the reduced-form GVAR model that closely resembles a standard VAR model with parametric restrictions imposed through the weights $w_{ij}$,

$$\boldsymbol{x}_t = \sum_{n=1}^{p^*} \boldsymbol{\psi}_n \boldsymbol{x}_{t-n} + \boldsymbol{v}_t. \tag{2.6}$$

The reduced-form VAR coefficients are given by $\boldsymbol{\psi}_n = \boldsymbol{G}^{-1}\boldsymbol{F}_n$ and $\boldsymbol{v}_t$ is a $k$-dimensional vector of white noise errors with variance given by $\boldsymbol{\Omega}_t = \boldsymbol{G}^{-1}\boldsymbol{\Sigma}_t(\boldsymbol{G}^{-1})'$.

### 2.2 Bayesian estimation and inference

While the GVAR modeling approach imposes parsimony by restricting the coefficients related to other countries' endogenous variables to be driven by economic weights (see Eq. (2.1)), the remaining number of parameters in Eq. (2.2) is still typically higher than the number of available observations. This calls for Bayesian shrinkage priors that effectively deal with this problem by shrinking the parameter space towards some stylized prior model.

Before proceeding to the actual prior implementation it is convenient to rewrite Eq. (2.2) into a standard regression model,

$$\boldsymbol{x}_{it} = \boldsymbol{C}_i \boldsymbol{z}_{it} + \boldsymbol{\varepsilon}_{it}, \tag{2.7}$$

with $\boldsymbol{z}_{it} = (\boldsymbol{x}'_{it-1}, \dots, \boldsymbol{x}'_{it-p}, \boldsymbol{x}^{*'}_{it}, \dots, \boldsymbol{x}^{*'}_{it-q})'$ being a $K_i = k_i p + k_i^* q$-dimensional vector and $\boldsymbol{C}_i = (\boldsymbol{A}_{i1}, \dots, \boldsymbol{A}_{ip}, \boldsymbol{B}_{i0}, \dots, \boldsymbol{B}_{iq})$ is a $k_i \times K_i$ matrix of stacked coefficients.

We follow Feldkircher and Huber (2016) and Crespo Cuaresma et al. (2016) and specify a stochastic search variable selection (SSVS) prior in the spirit of George and McCulloch (1993) and George et al. (2008) on each element of $\boldsymbol{c}_i = \text{vec}(\boldsymbol{C}_i)$,

$$c_{ij}|\delta_{ij} \sim \mathcal{N}(0, \tau_{ij,0}^2)\delta_{ij} + \sim \mathcal{N}(0, \tau_{ij,1}^2)(1 - \delta_{ij}). \tag{2.8}$$

Hereby we assume that the prior on $c_{ij}$ depends on a Bernoulli distributed random variable $\delta_{ij}$ that selects the prior scaling parameter $\tau^2_{ij,0} \gg \tau^2_{ij,1}$. Thus, if $\delta_{ij}$ equals unity, we choose the first Gaussian distribution with mean equal to zero and a rather large variance $\tau^2_{ij,0}$. This case imposes little prior information on $c_{ij}$, implying that the posterior is strongly driven by the likelihood information. By contrast, if $\delta_{ij}$ equals zero, the Gaussian prior adopted features a tiny prior variance, strongly pushing the corresponding posterior distribution of $c_{ij}$ towards zero.[4] On each $\delta_{ij}$, we impose a Bernoulli prior with

$$\delta_{ij} \sim Bernoulli(p_{ij}). \tag{2.9}$$

We set $p_{ij} = Prob(\delta_{ij} = 1) = 1/2$ for all $i, j$. This implies that a priori, all variables are equally likely to enter Eq. (2.2).

Similarly to the prior on the regression coefficients we impose a SSVS prior on the off-diagonal elements of $U_i$,

$$u_{ij,n}|\kappa_{ij,n} \sim \mathcal{N}(0, \varphi^2_{ij,n0})\kappa_{ij,n} + \mathcal{N}(0, \varphi^2_{ij,n1})(1 - \kappa_{ij,n}), \tag{2.10}$$

where $\kappa^2_{i,jn}$ is again a Bernoulli distributed random quantity that selects the mixture Gaussian component and $\varphi^2_{ij,n0}, \varphi^2_{ij,n1}$ are prior scalings such that $\varphi^2_{ij,n0} \gg \varphi^2_{ij,n1}$.

Since prior information on inclusion/exclusion of a given covariance parameter is rather scarce, we again adopt a Bernoulli prior with prior inclusion probability set to $q_{ij,n} = Prob(\kappa_{ij,n} = 1) = 1/2$,

$$\kappa_{ij,n} \sim Bernoulli(q_{ij,n}). \tag{2.11}$$

We follow Kastner and Frühwirth-Schnatter (2014) and impose a normally distributed prior on $\mu_{ij} \sim \mathcal{N}(0, v_\mu)$, a Beta distributed prior on $\frac{\rho_{ij}+1}{2} \sim \mathcal{B}(a_0, b_0)$ and a Gamma prior on $\varsigma^2_{ij} \sim \mathcal{G}(1/2, 1/2B_\varsigma)$. This prior setup has several convenient properties that are discussed in length in Kastner and Frühwirth-Schnatter (2014).

Posterior simulation is carried out by sampling from the $N + 1$ country-specific posterior distributions in parallel. The MCMC algorithm is standard in the literature for VAR models. Specifically, we sample $C_i$ on an equation-by-equation basis (for details, see Carriero et al., 2015) from an multivariate normal distribution. The free elements of $U_i$ can be simulated by noting that the system can be rewritten as a set of $k_i$ univariate regression models with standard normally distributed errors (see Cogley and Sargent, 2005). The log-volatilities and the parameters of the state equation Eq. (2.4) are simulated by means of the algorithm stipulated in Kastner and Frühwirth-Schnatter (2014) and implemented in the R package stochvol (Kastner, 2016). Finally, we sample the indicator variables $\delta_{ij}$ and $\kappa_{ij,n}$ from their Bernoulli distributed conditional posterior distributions. [5]

Last, we specify the remaining hyperparameters for the prior. More specifically, following George et al. (2008) we set $\tau^2_{ij,0} = 3\hat{\sigma}^2_{ij}$ and $\tau^2_{ij,1} = 0.1\hat{\sigma}^2_{ij}$, where $\hat{\sigma}^2_{ij}$ are the OLS

[4]For both Gaussian components in Eq. (2.8), the prior mean of the first own lag of a given variable/equation is specified to equal unity to mimic features of the Minnesota prior.

[5]For further information on the specific posterior moments, see Feldkircher and Huber (2016).

variances associated with $c_{ij}$. For the covariance parameters, we simply specify $\varphi^2_{ij,n0} = 3$ and $\varphi^2_{ij,n1} = 0.1$ for all $i, j, n$. For $\mu_j$ we set $v_\mu = 10^2$, leading to a rather uninformative prior on the level of the log-volatility. Finally, for the persistence parameter we set $a_0 = 25$ and $b_0 = 5$, placing significant mass on high persistence regions and $B_\varsigma = 1$. We execute the MCMC algorithm for each country simultaneously and use 20,000 iterations with the first 20,000 being discarded as burn-in.[6]

## 3 Data and country coverage

We use monthly data spanning the period from 2000:M10 to 2016:M06. We focus on the spillover effects of a reduction in euro are term spreads or narrowing of euro area long-term yields to non-euro area EU member states. To allow for a broad range of potential transmission channels, we try to include a sufficiently large number of variables. More specifically, we collect data on industrial production ($y_t$, index 2015=100), consumer prices ($p_t$, index 2010=100), short- and long-term interest rates ($i_{st}$ and $i_{lt}$, 3-months and 10-year, respectively), stock prices ($eq$, index 2010=100), private credit ($pc_t$, index 2010=100), house prices ($hp_t$, index 2010=100), the nominal exchange rate vis-á-vis the euro ($er_t$) and oil prices ($poil_t$, Brent, in US dollar). All variables are in levels and with the exception of interest rates in logarithmic transform. Data on industrial production, consumer prices and house prices are de-seasonalized.

These data are collected for a broad set of countries. More specifically, the euro area countries covered consist of the EA-18 bar the Baltics, Cyprus and Malta due to their relative small role in the asset purchase program. It will prove convenient to distinguish between euro area **core** (Austria, Belgium, Germany, Finland, France, Netherlands and Slovakia)[7] and **periphery** (Ireland, Italy, Portugal, Spain, Greece) countries. Non-euro area EU countries consist mainly of economies from Central, Eastern and Southeastern Europe (**CESEE**), namely Bulgaria, Croatia, the Czech Republic, Hungary, Poland, Romania and Slovenia). We further add to this group two countries that are not members of the European Union, but share close economic ties with both euro area and CESEE economies, namely Russia and Turkey. Other non-euro EA member states include advanced economies (**other non-EA**, Denmark, Great Britain and Sweden). For completeness we also include data on the USA, China, Canada and Japan to control for global factors. That leaves us with a sample of good coverage of the euro area, non-euro area EU-member states and the G-8 industrialized advanced economies.

In each country model, the set of *domestic* variables is complemented by its *foreign* counterparts denoted by asterisks. These are the main channels in the GVAR framework

[6]Due to storage limits we use a thinning interval to select 2,000 out of the 20,000 posterior draws. From these, we sort out unstable posterior draws which are characterized by large eigenvalues of the companion form of the global model which leads to approximately 1,000 posterior draws upon which the impulse response analysis in section 5 is based.

[7]Slovakia and Slovenia, both adopted the euro over the sample period covered in this study. We assign Slovakia to the "core" group, and Slovenia to the periphery, since for the latter data on long-term yields are not available, which prevents calculating spread shocks. Regional results are unaffected by the inclusion of both countries.

through which spillovers and feedback is passed on between countries. To construct these foreign variables, we use cross-country bilateral trade flows, averaged over the period from 2000 to 2014, from the World Input Output Database (WIOD).[8] Recently, other weights based on e.g., financial flows have been proposed in the literature (see, e.g., Eickmeier and Ng, 2015). However, Feldkircher and Huber (2016) present a sensitivity analysis with respect to the choice of weights in Bayesian GVAR specifications and show that trade weights yield a reasonable fit. Basically, we include for all domestic variables their foreign counterparts. There are two exceptions, though. First, and to control for exchange rate movements in a broader sense, we include trade weighted exchange rates in euro area countries where no domestic exchange rate (vis-á-vis the euro) exists. The second exception relates to how we model monetary policy in the euro area. Following Georgiadis (2015) we introduce an "ECB" country model where monetary policy is governed by a simple Taylor rule. More specifically, the 3-month Euribor is regressed on purchasing power parity (PPP) weighted averages of output and consumer prices of euro area countries. Euro area short-term interest rates enter then into all (also non-euro area) country models as a weakly exogenous variable. In this sense, the treatment of domestic interest rates is not symmetric among euro area countries on the one hand and the rest of the countries included in the analysis on the other hand. Last, we include oil prices as a global control variable. Following the bulk of the literature, oil prices are assumed to be endogenously determined within the US country model (see e.g., Pesaran et al., 2004).

## 4 Identification

In what follows we look at spillovers from financial developments in the euro area induced by recent monetary policy steps. First we follow the framework of Baumeister and Benati (2013) and assume that large scale purchases of longer-term securities result into a compression of the yield curve in the euro area. This approach has been recently adopted by European Central Bank (2017) and Bobeica and Jarociński (2017) to uncover the effects of unconventional monetary policy on inflation, and by Chen et al. (2016) to look at international effects of US unconventional monetary policy. That central banks use unconventional measures to reduce interest rate spreads such as the term spread has been argued in Blinder (2012) and empirically validated for the euro area by Ambler and Rumler (2016), Altavilla et al. (2016). Fig. 1, top panel shows the dynamics of 10-year government bond yields for the euro area, Germany, euro area core and periphery countries.

[INSERT Fig. 1 HERE]

The figure shows how long-term yields increased significantly in the aftermath of the global financial crisis and the euro area debt crisis, especially so for periphery countries.

[8] Data are retrieved from `http://www.wiod.org/home` and described in more detail in Timmer et al. (2015).

In July 2012, when Mario Draghi, President of the European Central Bank delivered his famous "whatever it takes speech" at the Global Investment Conference in London[9], however, yields started to decline strongly. Yields also decreased in January 2015 when the ECB announced to start its expanded asset purchase program in March the same year, albeit by a considerably smaller amount probably caused by the then prevailing persistent downward trend in yields.

We complement the term spread analysis by assessing the effect of a reduction in the risk spread, which we define as the spread of long-term rates in Germany (perceived as risk free) over domestic long-term rates. This should give an indication of how important "calming" the markets is compared to the actual purchase of longer-term securities. Fig. 1, bottom panel, illustrates that also a significant decrease in risk spreads was observable in July 2012.

Both shocks are empirically implemented by imposing a mixture of zero and sign restrictions on the impulse response functions. A similar identification approach has been proposed in Mumtaz and Surico (2009) in an international context and originally stipulated by Bernanke et al. (2005) within a factor augmented VAR model applied to US data. Specifically, while the GVAR literature avoids imposing $k(k-1)/2$ identifying restrictions by using Eq. (2.5), our identification approach is based on using the structural form of the global model,

$$\boldsymbol{\Lambda}\boldsymbol{x}_t = \sum_{n=1}^{p^*} \tilde{\boldsymbol{\psi}}_n \boldsymbol{x}_{t-n} + \boldsymbol{u}_t, \tag{4.1}$$

where $\boldsymbol{\Lambda}$ is a $k \times k$ matrix of coefficients that determines the contemporaneous relationships between the elements in $\boldsymbol{x}_t$ and $\tilde{\boldsymbol{\psi}}_n = \boldsymbol{\Lambda}\boldsymbol{\psi}_n$ is a structural coefficient matrix associated with the $n$th lag of $\boldsymbol{x}_t$ and $\boldsymbol{u}_t$ is a vector of structural shocks with variance given by $\boldsymbol{H}_t$. In what follows we assume that $\boldsymbol{\Lambda} = \boldsymbol{G}\boldsymbol{U}^{-1}$ with $\boldsymbol{U}^{-1} = \text{bdiag}(\boldsymbol{U}_0^{-1}, \dots, \boldsymbol{U}_N^{-1})$.

We identify the model by introducing a $k \times k$-dimensional permutation matrix $\boldsymbol{P}$ that reorders the equations/rows in Eq. (4.1) such that

$$\boldsymbol{\Lambda}^+ \boldsymbol{x}_t^+ = \sum_{n=1}^{p^*} \tilde{\boldsymbol{\psi}}_n^+ \boldsymbol{x}_{t-n}^+ + \boldsymbol{u}_t^+, \tag{4.2}$$

with $\boldsymbol{\Lambda}^+ = \boldsymbol{P}\boldsymbol{\Lambda}, \boldsymbol{x}_t^+ = \boldsymbol{P}\boldsymbol{x}_t, \tilde{\boldsymbol{\psi}}_n^+ = \boldsymbol{P}\tilde{\boldsymbol{\psi}}_n, \boldsymbol{u}_t^+ = \boldsymbol{P}\boldsymbol{u}_t$ and $Var(\boldsymbol{u}_n^+) = \boldsymbol{H}_t^+ = \boldsymbol{P}\boldsymbol{H}_t$.

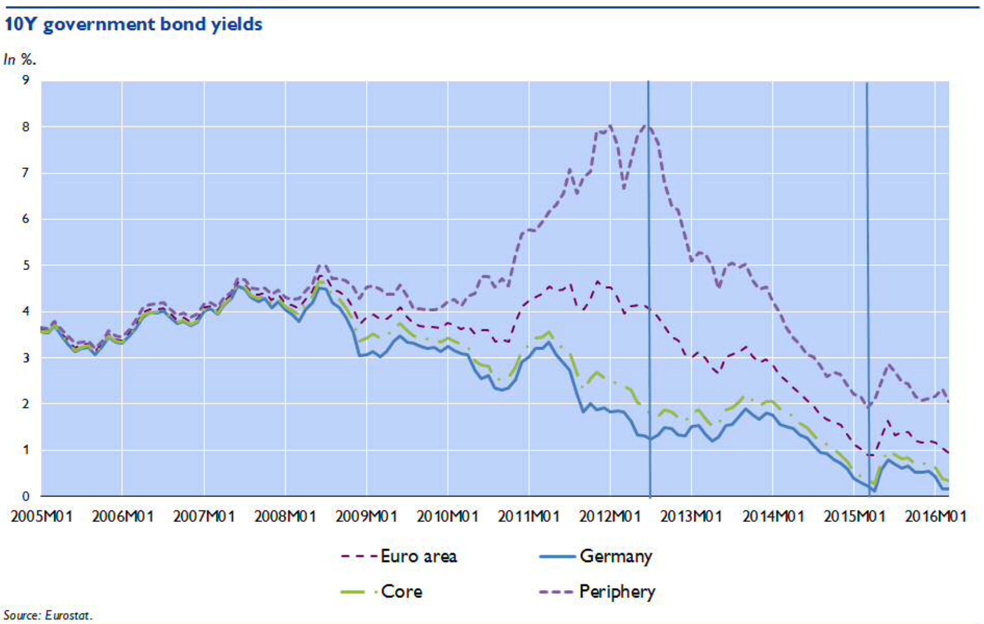
The permutation matrix is specified such that all quantities that are typically assumed to react sluggishly to euro area financial developments (i.e., real output, inflation and total credit *and* do not belong to the euro area are ordered first in Eq. (4.2). We let $\boldsymbol{x}_t^{\text{RA}}$ be a $r_{\text{RA}}$-dimensional vector that stacks these variables. The next equation is the ECB's policy rule, denoted by $i_{st}^{\text{EA}}$, followed by a block of variables that consists of euro area macroeconomic quantities[10] collected in an $r_{\text{EA}}$-dimensional vector $\boldsymbol{x}_t^{\text{EA}}$. Finally,

[9]See Acharya et al. (2015) for an empirical assessment of the macroeconomic effects of the "Whatever it takes" speech.

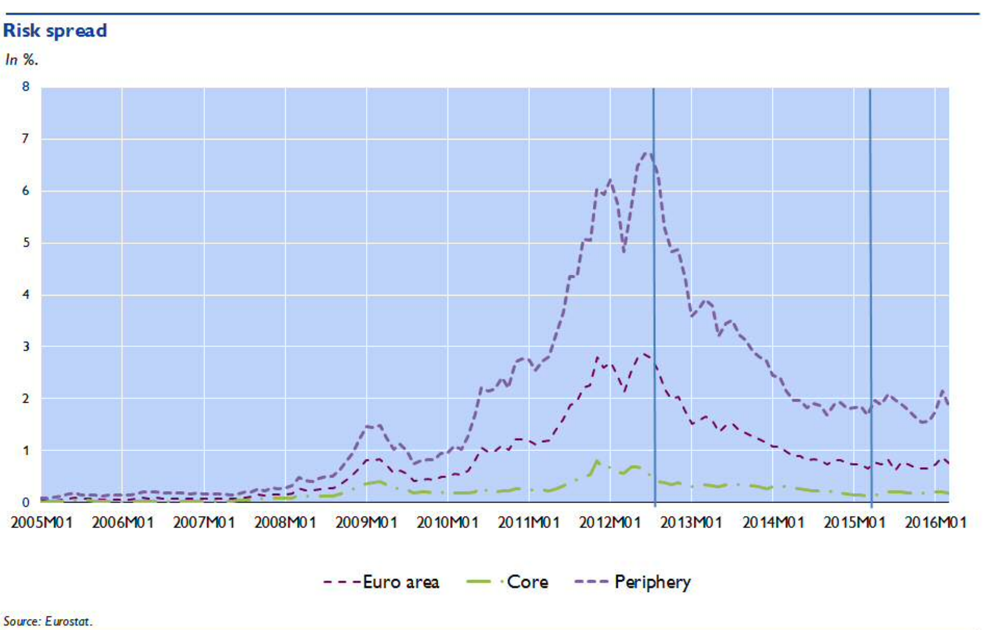
[10]This includes real activity quantities as well as financial market quantities.

**Fig. 1:** Evolution of 10-year government bond yields and the risk spread

**(a)** 10-year government bond yields




**(b)** Risk spread




*Notes*: The top panel of the plot shows the evolution of 10-year government bond yields, whereas the bottom panel shows movements in the risk spread. The risk spread is defined as the spread of 10-year government bond over German 10-year government bond yields. Core and periphery refer to euro area core and periphery countries as defined in the main text. Purchasing power parities used to calculate regional aggregates. The first vertical bar refers to the "whatever it takes speech" (July 2012), and the second vertical bar to the launch of the extended asset purchase program (March 2015).

we assume that financial market quantities outside the euro area are fast moving and react instantaneously to the shocks (exchange rate, equity prices, house prices and the oil price). Variables belonging tho this final block are collected in an $r_{\text{FI}}$-dimensional vector denoted as $\boldsymbol{x}_t^{\text{FI}}$.

Conditional on this ordering of variables we can rewrite Eq. (4.2) as

$$\boldsymbol{\Lambda}^{+}\begin{pmatrix}\boldsymbol{x}_t^{\text{RA}}\\ i_{st}^{\text{EA}}\\ \boldsymbol{x}_t^{\text{EA}}\\ \boldsymbol{x}_t^{\text{FI}}\end{pmatrix}=\sum_{n=1}^{p^*}\tilde{\boldsymbol{\psi}}_n^{+}\begin{pmatrix}\boldsymbol{x}_{t-n}^{\text{RA}}\\ i_{st-n}^{EA}\\ \boldsymbol{x}_{t-n}^{\text{EA}}\\ \boldsymbol{x}_{t-n}^{\text{FI}}\end{pmatrix}+\boldsymbol{u}_t^{+}. \tag{4.3}$$

Within the EA block $\boldsymbol{x}_t^{\text{EA}}$ we introduce a set of sign restrictions outlined in Table 1. These restrictions are imposed by introducing a $k \times k$-dimensional block-diagonal rotation matrix $\boldsymbol{R} = \text{bdiag}(\boldsymbol{I}_{r_{RA}+1}, \hat{\boldsymbol{R}}, \boldsymbol{I}_{r_{FI}})$ with $\boldsymbol{R}\boldsymbol{R}' = \boldsymbol{I}_k$ and $\hat{\boldsymbol{R}}$ denoting an orthonormal rotation matrix. This rotation matrix implies that we introduce sign restrictions only on the responses of euro area countries whereas all remaining quantities follow a timing restriction that captures the notion that international real activity reacts with an one month lag to unconventional monetary policy shocks in the euro area and international financial quantities are allowed to react on impact. The rotation matrices are obtained following the algorithm proposed in Arias et al. (2015). In principle, the fact that we rely on the Cholesky decomposition of $\boldsymbol{\Omega}_t$ indicates that the corresponding IRFs are not invariant with respect to different orderings of the elements in $\boldsymbol{x}_t^{\text{RA}}$ and $\boldsymbol{x}_{t-n}^{\text{FI}}$. Based on 30 random permutations of the elements in $\boldsymbol{x}_t^{\text{RA}}$ and $\boldsymbol{x}_t^{\text{FI}}$ we show that the ordering has empirically little influence on the results. This is demonstrated in Figs. B.1 and B.2 in the appendix.

The proposed implementation of zero and sign restrictions differs from the treatment of sign restriction in the GVAR framework outlined in Eickmeier and Ng (2015) and applied among others in Fadejeva et al. (2017) and Feldkircher and Huber (2016). They propose a local identification of the shock, which implies orthogonal structural shocks in the countries where the shock is applied and weakly correlated shocks elsewhere. In this case, any influence of the ordering is ruled out by construction. To see whether our identification approach yields marked differences relative to an identification strategy that is consistent with Eickmeier and Ng (2015), we carry out a further robustness analysis in subsection B.2.

Estimated volatility plays a role since we define a multiple shock and thus a simple standardization of the size of the shock can not be used. For instance, in the case of a single shock a simple normalization would be to restrict the shock variable to increase by a certain amount. In the case of a simultaneous shock this is not straightforward since individual impact responses are time-varying and when viewed as an aggregate shock it could well be the case that the relative magnitude of the shocks changes. Thus, we report results based on the mean (over the sample period) estimated volatility. Median impulse response functions are nearly identical when taking the last data point of volatility, but credible sets are slightly wider.[11]

[11] Detailed results are available from the authors upon request.

The sign restrictions we use are outlined in Table 1 below:

[INSERT Table 1 HERE]

**Table 1:** Sign restrictions.

| Shock | $sp_t$ | $y_t$ | $p_t$ | $i_{st}^{EA}/i_{lt}^{DE}$ | $eq_t$ | $pc_t$ | $hp_t$ |
|---|---|---|---|---|---|---|---|
| Term spread | ↓, all EA | ↑, ⌀ EA | ↑, ⌀ EA | 0, ECB | ↑, ⌀ EA | ↑, ⌀ EA | ↑ ,⌀ EA |
| Risk spread | ↓, all EA | ↑, ⌀ EA | ↑, ⌀ EA | 0, DE | ↑, ⌀ EA | ↑, ⌀ EA | ↑, ⌀ EA |

Notes: The restrictions are imposed as $\geq$ / $\leq$ and for 3 periods after impact. ⌀ indicates that at least half of the countries have to fulfill the sign restrictions in the restricted country group. EA refers to the euro area (core and periphery countries), ECB to the ECB country model and DE to Germany.

To model spillovers from a shock to the term spread we construct for all countries the difference between long- and short-term interest rates ($sp_t$). For the second experiment, we construct for all *euro area* countries the spread of long-term interest rates over German long-term rates ($sp_t$). By construction, this risk spread is not included in the German country model and also excluded from other non-euro area countries. This implies, that the variable coverage depends on the country block to which a country belongs. For completeness, we have summarized variable coverage for both shocks in Table A.1 in the appendix.

The term spread shock is pinned down by assuming a simultaneous decrease of euro area term spreads. The shock is calibrated to yield a simple average decrease of 100bp in the euro area. The cross-country composition of the shock is displayed in Table A.2 in the appendix. The compression of the yield curve – as a consequence of quantitative easing – should increase economic activity ($y_t$) and prices ($p_t$), while short-term interest rates in the euro area stay at zero. These restrictions basically follow Baumeister and Benati (2013). On top of that, we impose restrictions on financial variables: since the decrease in the term-spread should be driven by a reduction in longer-term yields (given short-term interest rates at the zero lower bound), equity ($eq_t$) and house prices ($hp_t$) should pick up. Also, stimulus to economic activity should drive up demand for private credit ($pc_t$). The positive effect on credit could be re-enforced by an explicit credit easing / bank lending channel. As asset purchases by the central bank are financed by issuing reserves, which currently pay zero or negative interest rates, banks have a strong incentive to lend out additional liquidity. See Wieladek and Pascual (2016) for recent empirical evidence. Note that we have only imposed the restriction on the variable we shock, the term spread, to hold for all euro area economies simultaneously. For the other restrictions, we require only the majority of euro area countries to fulfill the restrictions. By this we allow effects to vary across euro area countries (Burriel and Galesi, 2016; Georgiadis, 2015) and impose as little structure a priori as possible.

Sign restrictions are complemented by zero impact restrictions. As outlined above, we assume that spillovers to real output, prices and private credit set in with at least one month delay. In the same fashion we implement zero impact restriction on short-term interest rates in the euro area (term spread shock) and German long-term yields (risk spread shock). All other international variables (namely, interest rates, exchange rates, asset prices and the oil price) are assumed to be fast moving and allowed to be affected within the same month.

The risk spread shock, implemented by an average decrease of euro area risk spreads by 100bp, follows a similar logic as before: calming the markets should increase economic activity and prices for the majority of euro area countries, boosting demand for private credit. In analogy to the term spread shock, long-term interest rates in Germany stay at zero on impact. This restrictions ensures that we identify a spread shock, which is characterized by overall yield decreases as opposed to a shock that is defined by risk spreads decreases driven by an increase in German long-term yields. The reduction in the risk spread should drive up equity and house prices. Further zero impact restrictions are again imposed on real activity, prices and private credit in non-euro area countries.

Our mixture approach of zero and sign restrictions fully exploits the cross-section of the data which helps pinning down the shock of interest.[12] An alternative to identify the shocks would be by using a recursive ordering. For example, Walentin (2014) examines the effect of QE on macroeconomic quantities through its impact on mortgage spreads in the USA, UK and Sweden. However, we aim to distinguish a reduction in the term spread that is driven by a decrease of longer term yields given short-rates standing at zero, from a reduction caused by a contractionary monetary policy shock.[13] We accomplish this by requesting output (and prices) to pick up, which would not be straightforward to implement using a recursive ordering.

## 5 Empirical results

In this section we examine the domestic and international effects of a simultaneous compression of euro area single countries' term spreads as well as a simultaneous narrowing of longer-term yields in the euro area. Results are depicted in Figs. 2 to 5. In each figure we display the posterior median (in solid blue) along with 68% (dark blue) and 50% (light blue) credible intervals. The use of less stringent credible intervals, such as the 50% set, is not uncommon in highly parametrized models, such as the GVAR model.[14]

[12] Cross-country sign restrictions have been proposed by Chudik and Fidora (2011) and successfully applied in Cashin et al. (2014) to identify international effects from an oil price shock.

[13] As pointed out in Benati and Goodhart (2008), an unexpected monetary tightening that lowers inflation, and therefore inflation expectations, causes longer term rates to increase less than short-rates, causing a flattening of the yield curve.

[14] In the context of spillover analysis, see e.g., Chudik and Fratzscher (2012), Almansour et al. (2015) or Eller et al. (2017).

### 5.1 Effects of a compression of the yield curve

Results for the term spread shock are depicted in Figs. 2 and 3.

[INSERT Fig. 2 HERE]

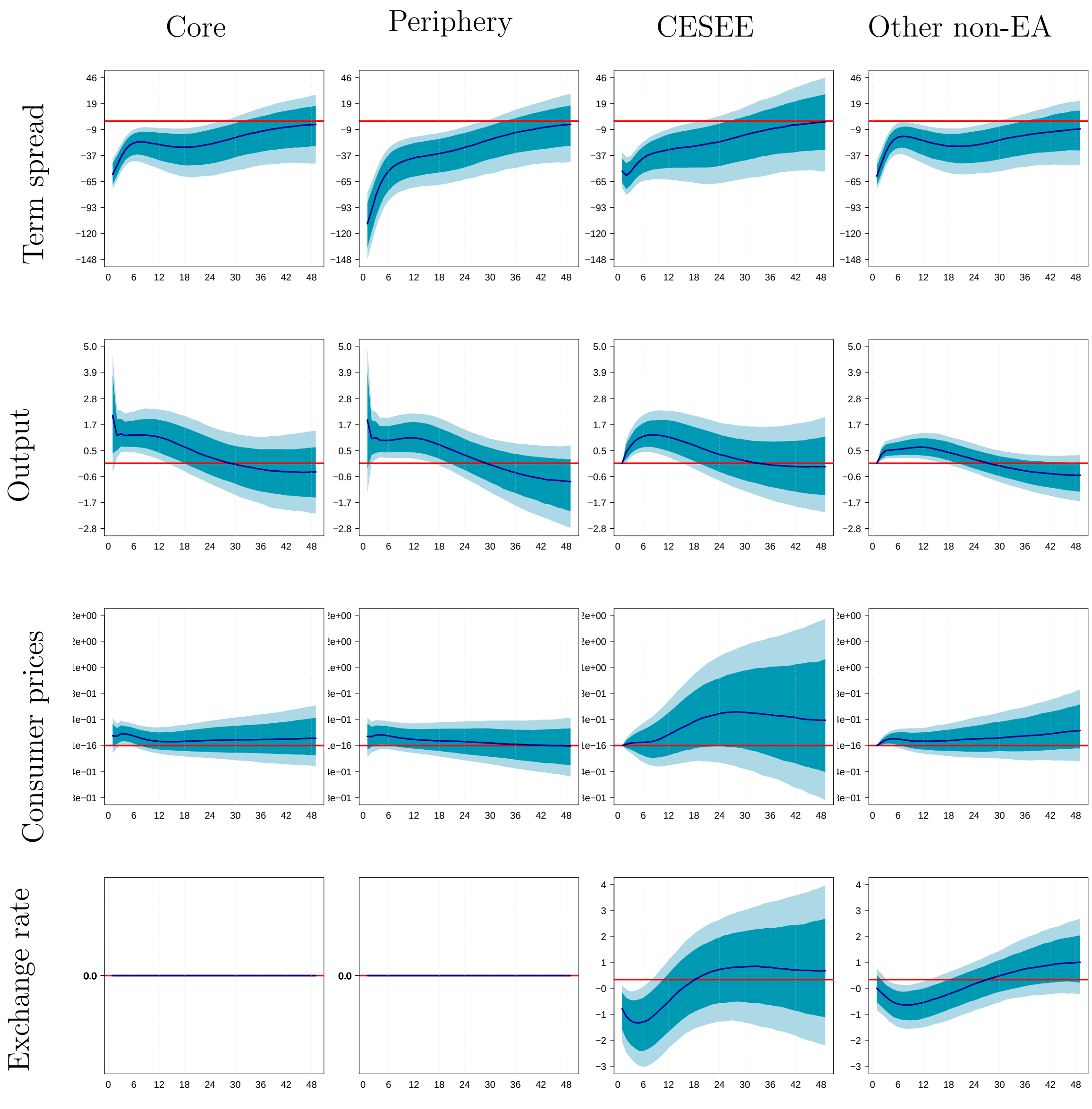
The response of the term spread in the euro area is gradual and negative up to 26 months. Immediate effects are more pronounced for euro area periphery relative to core economies, reflecting the shock composition, which is more tilted towards the latter (see Table A.2). In both CESEE and other non-euro area EU member states, the immediate decline in term spreads is of about the same size as in euro area core countries and thus rather sizable. The reduction in the term spread, brought about by a decline in long-term yields, drives up industrial production in the euro area. Despite the larger immediate reduction in periphery countries' term spreads relative to those in core countries, short-run output effects are slightly larger in the latter. Estimated impact effects of 1.7% (periphery) and 2% (core) are comparable to effects reported in Baumeister and Benati (2013), who analyze term spread shocks for the USA, and effects are in general rather persistent. A heterogeneous transmission of the shock within the euro area – as evidenced for a conventional monetary policy shock in Georgiadis (2015) – might trigger distinct spillovers abroad. More specifically and in terms of output, CESEE economies seem to follow euro area core countries, showing more pronounced positive spillovers to industrial production than other non-euro area EU member states.

Next, as economic activity picks up, consumer prices start to grow in all regions but to a varying degree. In more advanced economies, namely euro area core and other non-euro area EU member states, prices increase significantly in the short-run. Estimates are more uncertain for periphery and CESEE countries. A stronger effect on prices in selected euro area core compared to periphery countries was recently demonstrated in Wieladek and Pascual (2016). Note also that, relative to output responses, the reaction of consumer prices are less persistent. This might be driven by the link between asset prices and inflation, which has been recently analyzed by de Haan and Willem van den End (2016). They find that the transmission of financial developments to inflation can be quite long and that overall effects of quantitative easing on inflation can be uncertain, both in timing and direction. Monetary easing in the euro area strengthens CESEE economies' currencies vis-á-vis the euro. More specifically, domestic exchange rates in CESEE tend to appreciate significantly up to 8 months. Other non-euro area EU member states do not respond immediately with an appreciation of their currency, however, after 6 to 18 months their exchange rates strengthen significantly as well.

[INSERT Fig. 3 HERE]

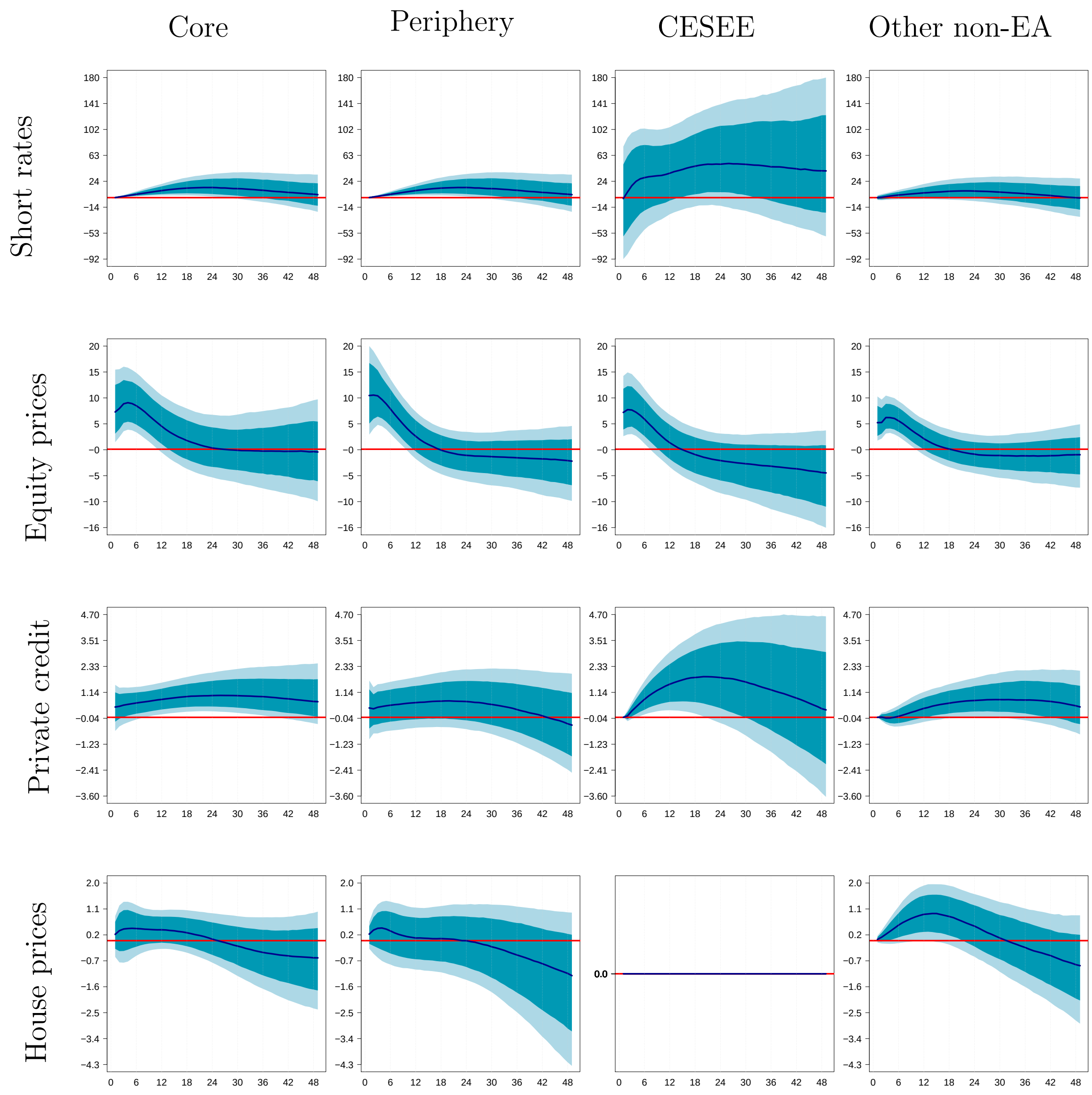
Looking at the dynamic responses of short-term interest rates yields multiple insights on the reactions of international central banks with respect to euro area monetary policy. While the impact response of short-term interest rates in the euro area is by construction zero to mimic the zero lower bound environment, the longer-run behavior is determined

**Fig. 2:** Term spread shock - regional results I




*Notes*: The figure shows impulse responses to a simultaneous 100bp reduction in the euro area term spread. Dark blue shaded area denotes 68%, light blue 50% credible sets and the blue solid line the posterior median. Exchange rate refers to nominal exchange rates vis-á-vis the euro (decrease implying a depreciation of the euro). Regional figures are aggregated using purchasing power parities.

**Fig. 3:** Term spread shock - regional results II




*Notes*: The figure shows impulse responses to a simultaneous 100bp reduction in the euro area term spread. Dark blue shaded area denotes 68%, light blue 50% credible sets and the blue solid line the posterior median. Regional figures are aggregated using purchasing power parities.

by the assumed Taylor rule. As output and prices in the euro area pick up, short-term rates increase moderately. Short-rates also increase in CESEE and other non-euro area EU member states, but not significantly so. Since single countries in these regions pursue very different forms of monetary policy, this result (on the regional aggregate) is not surprising.

We now turn to spillovers to other financial variables, namely real equity prices, private credit and house prices. Tobin (1969) highlights the importance of equity prices as the link between real and financial sectors of the economy. We expect equity prices to rise due to Keynesian effects that should boost consumption and growth (Nickel and Vansteenkiste, 2013). In fact and in parallel with the reduction of the term spread, equity prices pick up in the euro area and rather persistently so. International responses show a similar pattern with persistent increases in equity prices up to 9 months. Responses of private credit tend to be more diverse across regions: while the rise in economic activity drives up demand for private credit in euro area core countries, there is no significant effect in periphery countries. For CESEE economies, we find pronounced spillovers that even outpace those of euro area core countries – a result that is in line with Fadejeva et al. (2017) who analyze spillovers to credit in response to a range of macroeconomic shocks. The strong responses of credit might reflect the particularly high degree of financial integration between the regions. Non-euro area EU member states show smaller positive responses that are significant in the medium-term.

Finally, we look at the impact of the term spread shock on international house prices. As yields decrease, investors might re-allocate capital into the housing sector driving up real estate prices. In the short-run, this holds true throughout the regions but effects are only precisely estimated for other non-euro area EU member states. For CESEE economies, no data on house prices are available.

Summing up, we find that a reduction in euro area term spreads positively and persistently affects industrial output in the euro area and abroad. This finding is in line with Horváth and Voslářová (2016) for CESEE, and Gambacorta et al. (2014) for euro area core countries. Spillovers transmit via both, the trade and the financial channel as we see a depreciation of the euro on the one hand and a decline in term spreads triggering a rise in equity prices on the other hand. The latter might indicate that wealth effects play an important additional role in providing stimulus to output growth. Reactions of other financial variables are region-specific. For CESEE economies, there is a strong and pronounced increase in private credit, probably driven by a surge in cross-border banking flows to the region (Ciarlone and Colabella, 2016). More generally, CESEE economies seem to be more affected by responses in euro area core countries than by developments in euro area periphery states. This holds true in terms of output, equity price and private credit responses.

### 5.2 How far does "whatever it takes" take you?

In this section we contrast the results of the term spread shock with effects of a reduction in the risk spread. We define the risk spread as the difference between a euro area member states' long-term interest rate and long-term interest rates in Germany. A credible commitment to provide stimulus for an extended period of time might reduce cross-country long-term interest rate spreads. In the spirit of the term spread shock framework, we impose a zero impact restriction on German long-term yields to identify a "pure" risk spread shock, as opposed to a situation where risk spreads decrease because German yields increase. The results are shown in Figs. 4 and 5.

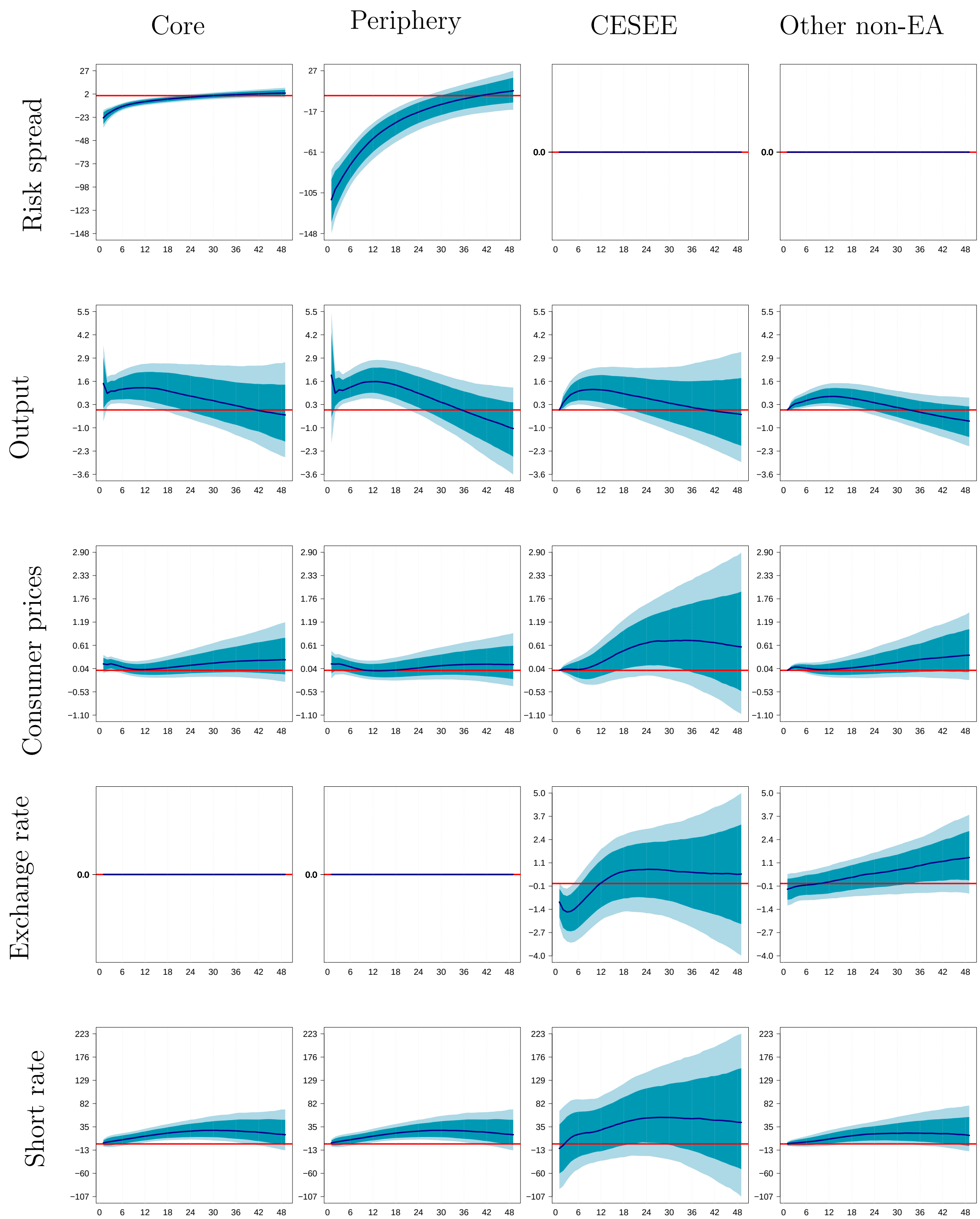
[INSERT Fig. 4 HERE]

[INSERT Fig. 5 HERE]

The reduction in the euro area risk spread is, as a direct consequence of the related variances, stronger in euro area periphery than core economies. For both regions, however, we find evidence for an increase in output which is of similar size. This might imply that in order to boost growth in periphery countries the initial stimulus must be sizable and probably larger relative to core countries. Output increases also in CESEE and other non-euro area EU member states and rather persistently so. Consumer prices pick up throughout the regions but not in a statistically significant manner. This is in contrast to results on the term spread shock. Next, we find an appreciation of CESEE currencies against the euro, while responses are accompanied by wide credible sets in case of other-non euro area EU member states. As with the term spread shock, the Taylor rule indicates a rise in interest rates in response to re-newed economic activity and price growth in the euro area. Also, spillovers to short-term rates in other non-euro area EU member states are positive. Interestingly, the pass-through to long-term rates works differently in CESEE and other-non euro area EU member states: While long-term yields decrease in CESEE - probably through a surge in capital inflows – long-term yields increase in other non-euro area EU member states. Next, and in line with the term spread shock, equity prices increase throughout the regions and private credit increases. However, responses of private credit are surrounded by wide credible sets. House prices increase in all regions where data are available, but only significantly so in other non-euro area EU member states.

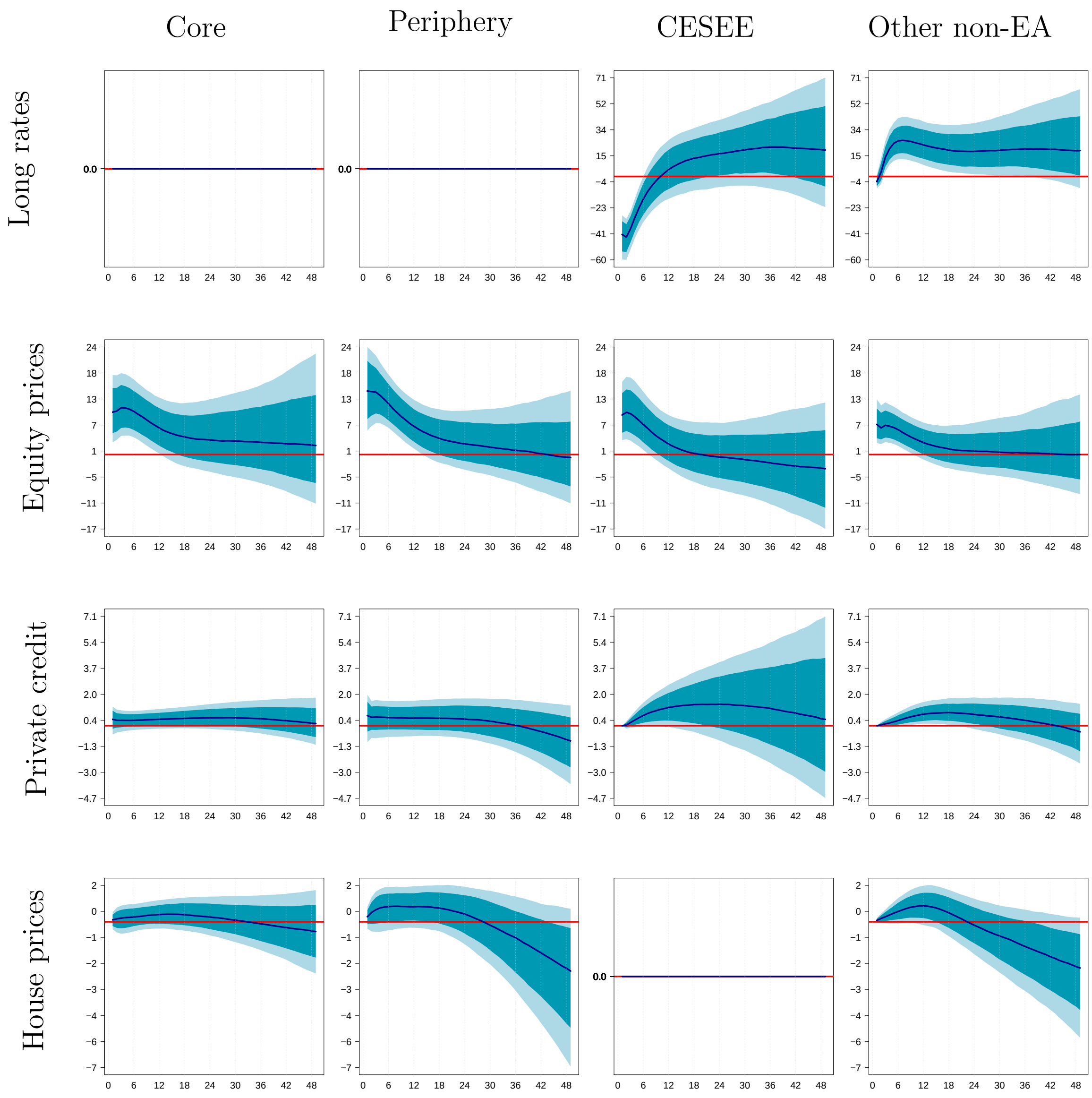
Summing up, a narrowing of long-term yields in the euro area leads in many instances to qualitatively similar results compared to a reduction in the term spread. Output and consumer prices pick up, equity prices increase and local currencies tend to appreciate against the euro. Interestingly, international long-term interest rates respond differently in CESEE and other non-euro area EU member states: while they decrease in the former, they increase in the latter. The decrease in long-term interest rates in CESEE implies that international portfolio re-balancing takes place triggering a strong inflow of financial flows to the CESEE region corroborating results of Ciarlone and Colabella (2016). Compared to the term spread shock, credible sets appear to be generally larger. In particular, while we found evidence for positive effects on consumer prices in the euro area and private credit in CESEE, as well as an appreciation of exchange rates in other non-euro area EU member states in response to a term spread

**Fig. 4:** Risk spread shock - regional results I




*Notes*: The figure shows impulse responses to a simultaneous 100bp reduction in the euro area risk spread. Dark blue shaded area denotes 68%, light blue 50% credible sets and the blue solid line the posterior median. Exchange rate refers to nominal exchange rates vis-á-vis the euro (decrease implying a depreciation of the euro). Regional figures are aggregated using purchasing power parities.

**Fig. 5:** Risk spread shock - regional results II




*Notes*: The figure shows impulse responses to a simultaneous 100bp reduction in the euro area risk spread. Dark blue shaded area denotes 68%, light blue 50% credible sets and the blue solid line the posterior median. Regional figures are aggregated using purchasing power parities.

shock, the data are inconclusive in response to a risk spread shock. Given these shortcomings, a narrowing of long-term yields in the euro area might still serve as a valuable alternative to a more direct approach of monetary policy, which aims at reducing term spreads.

### 5.3 Do effects vary across countries?

In Fig. 3 we assess in more detail the cross-country variation of spillovers. In other words, which CESEE and other non-euro area EU-member states are more strongly affected, which ones are more insulated from the shock. To that end we show peak / trough effects of the spillovers based on the posterior median with accompanying 50% credible sets. We focus on peak / trough effects in response to the term spread shock. Results of the risk spread shock are very similar and provided in Appendix A (see Fig. A.1).

[INSERT Fig. 6 HERE]

There are some salient features emerging from the data: In terms of output, Hungary followed by other CESEE economies benefit most strongly from the economic expansion in the euro area, whereas consumer prices pick up most markedly in Russia and Turkey. Currencies that strengthen most against the euro comprise the Polish zloty and the Turkish lira, both currencies which also showed large swings historically. By contrast, in Denmark and Croatia, both countries that pursue a form of fixed exchange rate regime against the euro, effects are rather small. In response to the term spread shock, short-term rates tend to increase but to a varying degree. Rate increases are most pronounced in Turkey, Romania and Russia. Next, we find negative and sizable peak effects of term spreads for CESEE economies implicitly corroborating findings of Falagiarda et al. (2015) and Ciarlone and Colabella (2016). Peak effects of equity prices are most pronounced for Turkey and Denmark. Spillovers to private credit are sizable in Turkey and Russia on the one hand, and the Czech Republic and Poland on the other hand. While in Turkey and Russia, domestic growth was historically fueled by a surge in lending resulting in a strong credit to output link, the increase in the Czech Republic and Poland might be more related to the close financial ties these two economies share with euro area core countries. Peak effects of house prices are most pronounced in Denmark. Note though that since credible sets of the estimated peak / trough effects frequently overlap across countries, cross-country differences should be interpreted with care.

To explore the differences in peak / trough responses in a more systematic way, we follow Burriel and Galesi (2016), who relate median peak responses of an unconventional monetary policy shock to GDP per capita, the unemployment rate, the soundness of the banking system as measured by capital to assets, and the ease of doing business index of the World bank. Using simple correlation analysis shows that spillovers to output, equity prices and the exchange rate are stronger in poorer economies as measured by real GDP per capita (correlations of about 0.3 to 0.5). Spillovers to output are also stronger in countries with either less regulatory requirements to start the operation of a firm or with a sound banking system as measured by banks' capital to asset ratio. The latter finding is in line with Boeckx et al. (2017) and Burriel and Galesi (2016).

Summing up, we find that countries that have historically witnessed boom-bust periods on the one hand or those who are strongly integrated with the euro area on the other hand, show most pronounced responses when euro area spreads ease. A simple correlation exercise suggests that spillovers to output, equity prices and the exchange rate are higher for comparably poorer countries. Also, spillovers to countries with a friendly regulatory environment for entrepreneurs or to those with a sound banking system are more pronounced – the latter since banks are less constrained by a reduction in long-term interest rates.

### 5.4 Effects of an increase in effective monetary stimulus

In this section we compare our results to spillovers from a conventional monetary policy shock. To this end we employ a new monetary policy metric that is derived from yield curve data and equally well represents the overall monetary policy stance during "normal" and zero-lower bound periods.

A lot of research has been recently devoted to so-called shadow short rates (SSRs) as a proxy for the overall monetary policy stance (see, e.g., for the United States Wu and Xia, 2016; Francis et al., 2014). SSRs are estimated quantities often derived from an implicit term structure model, fully taking into account the shape of the yield curve. The advantage of SSRs is that they are not constrained by the zero lower bound as opposed to nominal short term rates and thus can always be used to assess the monetary policy stance. Albeit appealing, the use of SSRs as a monetary policy metric has been frequently debated. For example, Francis et al. (2014) raises several short-comings, namely that SSRs are unobserved quantities (during zero lower bound periods) and not directly influenced by macroeconomic quantities. The latter fact is in stark contrast to short-term nominal rates, the standard monetary policy metric.

To overcome these difficulties, Halberstadt and Krippner (2016) propose a new metric, the effective monetary stimulus (EMS). We use the model-free version of the EMS, which amounts to the difference of observed long-term forward rates and natural long-term interest rates, scaled by the maturity of the forward rates (in our case 30 years). Note the EMS' components are directly observable and the future path of interest rates is directly shaped by macroeconomic quantities. Also Halberstadt and Krippner (2016) show that the EMS provides plausible judgment during non-zero lower bound periods. The EMS is calculated for all countries whose short-term interest rates hit the zero lower-bound in our sample, namely the euro area, the USA and Great Britain. For data reasons we could not calculate the EMS for Japan. The EMS is displayed in Fig. 7 below.

[INSERT Fig. 7 HERE]

Overall, the EMS follows a similar pattern for all three countries - in the immediate aftermath of the global financial crisis, the EMS indicates a sharp increase in monetary easing in the USA, a period where the first large scale asset purchase program was launched.

In what follows we examine an easing of the EMS in the euro area by 100bp. For that purpose, we substitute the EMS for the short-term interest rate in the ECB Taylor rule model and for the USA and Great Britain in the respective country models. Since the EMS lives on another scale as short-term interest rates, we treat them as exogenous for the remaining country models (as opposed to merging them with other countries' foreign interest rates). The shock is directly applied to the residual in the Taylor rule with no further identification assumptions in place.

[INSERT Fig. 8 HERE]

In Fig. 8 we see that short-term rates increase significantly in other-non euro area EU member states, while responses for the CESEE region, by contrast, are accompanied by large credible sets. An easing of the EMS triggers an increase in euro area core countries' output. This effect, however, sets in with a delay of about 6 months. Interestingly, there is a significant negative response of industrial output in euro area periphery countries, which fades out when output picks up in core countries. Note that for both, the term and risk spread shock, and as a direct consequence of the related variances, the initial response of both spreads is larger in euro area periphery compared to euro area core countries. This is in contrast to a shock to the EMS (or the policy rate) which is assumed to be the same for all euro area countries. Taken at face value, this finding might imply that in order to boost growth in periphery countries the initial stimulus must be sizable and probably larger relative to core countries. CESEE economies show an increase in industrial output, which is significant over the medium term. The fact that we find positive spillovers to output in CESEE and other non-euro area EU member states without any restrictions imposed is a strong finding that emerges solely from the data. Next, we look at consumer prices. Here, responses throughout the regions are accompanied by wide credible sets. Monetary easing in the euro area pushes pressure on trading partners' currencies. Consistent with results of the term and risk spread shocks, international currencies strengthen against the euro.

[INSERT Fig. 9 HERE]

In line with our previous results, the financial channel plays an important role in spreading the shock internationally. Long-term rates decrease throughout all regions. While the effect is significant up to 6 months in the euro area, spillovers are even more persistent (up to 12 months). Easing of the euro area's monetary policy stance triggers a pick up in equity prices throughout all regions and drives up credit in euro area core and periphery countries. While private credit increases markedly in CESEE economies over the medium-term, credible sets are wide. Last, we find a diverging pattern of house prices in the euro area, and a significant negative impact in other non-euro area EU member states.

Summing up we find that spillovers from an easing of euro area monetary policy yield in most instances qualitatively similar results to international effects of term spread and risk spread shocks. Namely, both the financial and the exchange rate channel play an important role in spreading the shock internationally. That said, overall estimation uncertainty seems larger when the EMS eases compared to a reduction in the term spread. Also, the EMS shock seems to trigger a divergence of house prices within the euro area, a finding that was not reconciled with the term and risk spread shocks.

## 6 Closing remarks

Since the global financial crisis, the ECB has implemented several non-standard measures.[15] The latest of these measures constitute buying large amounts of securities issued by euro area governments, agencies and EU institutions, asset-backed securities and covered bonds driving down longer-term yields. Not only the actual purchase of these securities can alter interest rates. Also the successful commitment of the ECB to follow a certain policy path can influence financial markets. In this paper we examine the effects of a 100bp reduction in the euro area term spread and compare them to a reduction in the risk spread, which is defined as the spread of euro area member states' long-term government bond yield over German long term yields. To that end, we propose an identification strategy that is novel to the GVAR literature combining sign with zero impact restrictions. The model is estimated with stochastic volatility and using Bayesian shrinkage priors. To complement our analysis, we further examine a boost to effective monetary stimulus, a monetary policy metric derived from yield curve data that has been recently proposed in Halberstadt and Krippner (2016).

Looking at *within-euro area effects* of the term and risk spread first, our results are well in line with the recent literature on quantitative easing. A reduction in the term or risk spread, tends to yield an increase in output and prices (Gambacorta et al., 2014), a depreciation of the euro and an increase in equity prices (Burriel and Galesi, 2016). We also find a evidence for heterogeneity of within-euro area effects generalizing results of Georgiadis (2015) for a conventional euro area monetary policy shock. For example, the effect on prices tend to be more precisely estimated and larger in euro area core compared to periphery countries (Wieladek and Pascual, 2016) and more generally the impulse to stimulate economic growth in euro area periphery countries has to be rather sizable. That our model is capable of reproducing established findings of the literature adds confidence to our econometric framework and the overall identification strategy.

Our main results on the *international effects* of a reduction in euro area term spreads or a narrowing of euro area long-term yields are as follows: First, both shocks drive up

[15] See, e.g., the studies by Giannone et al. (2012) and Lenza et al. (2010) that examine the early non-standard measures of the ECB that targeted liquidity provisioning and stability of the banking system. These studies find in general, that the ECB measures were quite effective.

industrial production in CESEE and other non-euro area EU member states corroborating findings of Bluwstein and Canova (2015) and Horváth and Voslářová (2016). Spillovers to international consumer prices are rather weak (Gambacorta et al., 2014; Horváth and Voslářová, 2016).

Second, both shocks *transmit* through the trade and the financial channel. The trade channel is defined by movements of international currencies against the euro. In fact, we find strong evidence that local currencies appreciate vis-á-vis the euro, which contrasts findings of Bluwstein and Canova (2015). This is especially true for CESEE economies emphasizing the important role that exports play in the regions' growth model. The difference to findings of Bluwstein and Canova (2015) might arise since we use a multi-country model that is able to take cross-country second-round effects into account, which can be sizable in the context of monetary policy shocks (Burriel and Galesi, 2016). We define the financial channel in a broad way covering interest rates on the one hand and a range of financial variables on the other hand. For example, international term spreads are driven down as investors re-allocate capital as a consequence of smaller yields in the euro area. Also, in response to the risk spread shock, long term yields fall in CESEE revealing evidence for international portfolio re-balancing towards that region. We find especially strong evidence for equity prices. They increase throughout all regions implying that wealth effects are crucial in providing stimulus to the economy (see also Nickel and Vansteenkiste, 2013; Eller et al., 2017, for the case of a fiscal shock). As a consequence of strong financial ties between CESEE and the euro area, we find sizable spillovers to private credit. This result corroborates findings of Ciarlone and Colabella (2016) who demonstrate an increase in cross-border banking flows and portfolio flows to CESEE in response to asset purchase announcements of the ECB. A strong general responsiveness of credit in CESEE has also been demonstrated in Fadejeva et al. (2017). Taken at face value, this implies that policies to absorb foreign shocks have to account for both the trade and the financial channel.

Last, we also observe a considerable degree of *cross-country heterogeneity* in international effects. To a certain degree this heterogeneity might be driven by how the shocks transmit within the euro area. More specifically, we find that responses of CESEE economies often tend to mirror those in euro area core countries in terms of size and shape. Looking at differences in peak / trough responses reveals most pronounced spillovers to countries that have historically witnessed boom-bust periods on the one hand or those who are strongly integrated with the euro area on the other hand. A simple correlation analysis indicates that spillovers to output, equity prices and exchange rates are higher for poorer countries. Spillovers from the term spread shock are also larger to countries with either a sound banking system (Boeckx et al., 2017; Burriel and Galesi, 2016) or and in countries where starting a new business is simple.

Our main results remain qualitatively unchanged when we resort to a new metric of monetary policy, the effective monetary policy stimulus of Halberstadt and Krippner (2016), impose a smaller set of sign restrictions, permute the ordering of the variables in the system or use the treatment of sign restrictions in the GVAR setting proposed in Eickmeier and Ng (2015). This ensures that the identified channels are operational under a range of different assumptions.

## References


**Acharya, Viral V., Tim Eisert, Christian Eufinger, and Christian W. Hirsch**, "Whatever it Takes: The Real Effects of Unconventional Monetary Policy," Mimeo 2015.

**Almansour, Aseel, Aslam Aqib, John Bluedorn, and Rupa Duttagupta**, "How Vulnerable Are Emerging Markets to External Shocks?," *Journal of Policy Modeling*, 2015, *37* (3), 460–483.

**Altavilla, Carlo, Domenico Giannone, and Michele Lenza**, "The Financial and Macroeconomic Effects of OMT Announcements," *Internationl Journal of Central Banking*, September 2016, *12* (3), 29–57.

—, **Giacomo Carboni, and Roberto Motto**, "Asset purchase programmes and financial markets: lessons from the euro area," Working Paper Series 1864, European Central Bank November 2015.

**Ambler, Steve and Fabio Rumler**, "The Effectiveness of Unconventional Monetary Policy in the Euro Area: An Event and Econometric Study," Working Paper Series, The Rimini Centre for Economic Analysis 2016.

**Arias, J., D. Caldara, and J. Rubio-Ramirez**, "The systematic component of monetary policy in svars: an agnostic identification procedure.," Technical Report 1131, FRB International Finance Discussion Paper 2015.

**Baumeister, Christiane and Luca Benati**, "Unconventional Monetary Policy and the Great Recession: Estimating the Macroeconomic Effects of a Spread Compression at the Zero Lower Bound," *International Journal of Central Banking*, June 2013, *9* (2), 165–212.

**Benati, Luca and Charles Goodhart**, "Investigating time-variation in the marginal predictive power of the yield spread," *Journal of Economic Dynamics and Control*, April 2008, *32* (4), 1236–1272.

**Bernanke, Ben S., Jean Boivin, and Piotr Eliasz**, "Measuring The Effects Of Monetary Policy: A Factor-Augmented Vector Autoregressive (FAVAR) Approach," *Quarterly Journal of Economics*, 2005, pp. 387–422.

**Blinder, A. S.**, "Revisiting Monetary Policy in a Low-Inflation and Low-Utilization Environment," *Journal of Money, Credit and Banking*, 2012, *44* (s1), 141–146.

**Bluwstein, Kristina and Fabio Canova**, "Beggar-thy-neighbor? The international effects of ECB unconventional monetary policy measures," CEPR Discussion Papers 10856, C.E.P.R. Discussion Papers October 2015.

**Bobeica, Elena and Marek Jarociński**, "Missing disinflation and missing inflation: the puzzles that aren't," Working Paper Series 2000, European Central Bank January 2017.

**Boeckx, Jef, Maarten Dossche, and Gert Peersman**, "Effectiveness and Transmission of the ECB's Balance Sheet Policies," *International Journal of Central*

*Banking*, 2017, *13* (1), 297–333.

**Burriel, Pablo and Alessandro Galesi**, "Uncovering the heterogeneous effects of ecb unconventional monetary policies across euro area countries," Working Papers 1631, Banco de España December 2016.

**Carriero, Andrea, Todd E Clark, Massimiliano Marcellino et al.**, "Large Vector Autoregressions with Asymmetric Priors," *Queen Mary, University of London Working Paper Series, 759*, 2015.

**Cashin, Paul, Kamiar Mohaddes, Maziar Raissi, and Mehdi Raissi**, "The differential effects of oil demand and supply shocks on the global economy," *Energy Economics*, 2014, *44* (C), 113–134.

**Chen, Qianying, Andrew Filardo, Dong He, and Feng Zhu**, "Financial crisis, US unconventional monetary policy and international spillovers," *Journal of International Money and Finance*, 2016, *67* (C), 62–81.

**Chudik, Alexander and Marcel Fratzscher**, "Liquidity, risk and the global transmission of the 200708 financial crisis and the 201011 sovereign debt crisis title," Globalization and Monetary Policy Institute Working Paper 107, Federal Reserve Bank of Dallas 2012.

__ **and Michael Fidora**, "Using the global dimension to identify shocks with sign restrictions," Working Paper Series No. 1318, European Central Bank 2011.

**Ciarlone, Alessio and Andrea Colabella**, "Spillovers of the ECB's non-standard monetary policy into CESEE economies," *Ensayos sobre política económica*, November 2016, *34* (81), 175–190.

**Cogley, Timothy and Thomas J Sargent**, "Drifts and volatilities: monetary policies and outcomes in the post WWII US," *Review of Economic dynamics*, 2005, *8* (2), 262–302.

**Crespo Cuaresma, Jesús, Martin Feldkircher, and Florian Huber**, "Forecasting with Global Vector Autoregressive Models: a Bayesian Approach," *Journal of Applied Econometrics*, 2016, *Vol. 31* (7), 1371–1391.

**de Haan, Leo and Jan Willem van den End**, "The signalling content of asset prices for inflation: Implications for Quantitative Easing," DNB Working Paper 516, DeNederlandsche Bank 2016.

**Dovern, Jonas, Martin Feldkircher, and Florian Huber**, "Does joint modelling of the world economy pay off? Evaluating global forecasts from a Bayesian GVAR," *Journal of Economic Dynamics and Control*, 2016, *70*, 86 – 100.

**Eickmeier, Sandra and Tim Ng**, "How do US credit supply shocks propagate internationally? A GVAR approach," *European Economic Review*, 2015, *74*, 128 – 145.

**Eller, Markus, Martin Feldkircher, and Florian Huber**, "How would a fiscal shock in Germany affect other European countries? Evidence from a Bayesian global VAR model with sign restrictions," *Focus on European Economic Integration*, 2017, *Q1*, 1–30.

**European Central Bank**, "Low inflation in the euro area: causes and consequences," Technical Report 181, Occasional Paper Series January 2017.

**Fadejeva, Ludmila, Martin Feldkircher, and Thomas Reininger**, "International Spillovers from Euro Area and US Credit and Demand Shocks: A focus on Emerging Europe," *Journal of International Money and Finance*, 2017, *70*, 1–25.

**Falagiarda, Matteo, Peter McQuade, and Marcel Tirpák**, "Spillovers from the ECB's non-standard monetary policies on non-euro area EU countries: evidence from an event-study analysis," Working paper 1869, ECB 2015.

**Fawley, Brett W. and Christopher J. Neely**, "Four stories of quantitative easing," *Review*, 2013, (Jan), 51–88.

**Feldkircher, Martin and Florian Huber**, "The international transmission of US shocks – Evidence from Bayesian global vector autoregressions," *European Economic Review*, 2016, *81* (C), 167–188.

**Francis, N., L. E. Jackson, and M. T. Owyang**, "How has empirical monetary policy analysis changed after the financial crisis?," Working Papers 2014-19, Federal Reserve Bank of St. Louis. 2014.

**Gambacorta, Leonardo, Boris Hofmann, and Gert Peersman**, "The Effectiveness of Unconventional Monetary Policy at the Zero Lower Bound: A Cross-Country Analysis," *Journal of Money, Credit and Banking*, 2014, *46* (4), 615–642.

**George, E. I. and R. McCulloch**, "Variable selection via Gibbs sampling," *Journal of the American Statistical Association*, 1993, *88*, 881–889.

**George, Edward I, Dongchu Sun, and Shawn Ni**, "Bayesian stochastic search for VAR model restrictions," *Journal of Econometrics*, 2008, *142* (1), 553–580.

**Georgiadis, Georgios**, "Examining asymmetries in the transmission of monetary policy in the euro area: Evidence from a mixed cross-section global VAR model," *European Economic Review*, 2015, *75* (C), 195–215.

— **and Johannes Grab**, "Global financial market impact of the announcement of the ECB's extended asset purchase programme," Globalization and Monetary Policy Institute Working Paper 232, Federal Reserve Bank of Dallas March 2015.

**Giannone, Domenico, Michele Lenza, Huw Pill, and Lucrezia Reichlin**, "The ECB and the Interbank Market," *The Economic Journal*, 2012, *122* (564), F467–F486.

**Halberstadt, Arne and L. Krippner**, "The Effect of Conventional and Unconventional Euro Area Monetary Policy on Macroeconomic Variables," Discussion Paper 49/2016, Deutsche Bundesbank 2016.

**Horváth, Roman and Klára Voslářová**, "International spillovers of ECB's unconventional monetary policy: the effect on Central Europe," *Applied Economics*, 2016, *0*, 1–13.

**Huber, Florian**, "Density forecasting using Bayesian global vector autoregressions with stochastic volatility," *International Journal of Forecasting*, 2016, *32* (3), 818–837.

**Joyce, Michael, David Miles, Andrew Scott, and Dimitri Vayanos**, "Quantitative Easing and Unconventional Monetary Policy – an Introduction," *The Economic Journal*, 2012, *122* (564), F271–F288.

**Kastner, Gregor**, "Dealing with Stochastic Volatility in Time Series Using the R

Package stochvol," *Journal of Statistical Software*, 2016, *69* (1), 1–30.

— **and Sylvia Frühwirth-Schnatter**, "Ancillarity-sufficiency interweaving strategy (ASIS) for boosting MCMC estimation of stochastic volatility models," *Computational Statistics & Data Analysis*, 2014, *76*, 408–423.

**Lenza, Michele, Huw Pill, and Lucrezia Reichlin**, "Monetary policy in exceptional times," *Economic Policy*, 04 2010, *25*, 295–339.

**Moder, Isabella**, "Spillovers from the ECB's non-standard monetary policy measures on Southeastern Europe," Technical Report, Eurpean Central Bank 2017.

**Mumtaz, H. and P. Surico**, "The Transmission of International Shocks: A Factor-Augmented VAR Approach," *Journal of Money, Credit and Banking*, 2009, *41*, 71–100.

**Nickel, C. and I. Vansteenkiste**, *The GVAR Handbook: Structure and Applications of a Macro Model of the Global Economy for Policy Analysis*, Oxford University Press,

**Pesaran, M. Hashem, Til Schuermann, and S. M. Weiner**, "Modeling Regional Interdependencies Using a Global Error-Correcting Macroeconometric Model," *Journal of Business and Economic Statistics, American Statistical Association*, 2004, *22*, 129–162.

**Primiceri, Giorgio E**, "Time varying structural vector autoregressions and monetary policy," *The Review of Economic Studies*, 2005, *72* (3), 821–852.

**Sims, Christopher A and Tao Zha**, "Were there regime switches in US monetary policy?," *The American Economic Review*, 2006, *96* (1), 54–81.

**Timmer, M. P., E. Dietzenbacher, B. Los, R. Stehrer, and G. J. de Vries**, "An Illustrated User Guide to the World InputOutput Database: the Case of Global Automotive Production," *Review of International Economics*, 2015, *23*, 575–605.

**Tobin, J.**, "A general equilibrium approach to monetary theory," *Journal of Money, Credit and Banking*, 1969, *1*, 15–29.

**Walentin, Karl**, "Business cycle implications of mortgage spreads," *Journal of Monetary Economics*, 2014, *67*, 62 – 77.

**Wieladek, Tomasz and Antonio I. Garcia Pascual**, "The European Central Bank's QE: A New Hope," CESifo Working Paper Series 5946, CESifo Group Munich 2016.

**Wu, Jing Cynthia and Fan Dora Xia**, "Measuring the Macroeconomic Impact of Monetary Policy at the Zero Lower Bound," *Journal of Money, Credit and Banking*, 2016, *48* (2-3), 253–291.

## Appendix A Additional results

## Appendix B Robustness analysis

### B.1 Identification using different orderings

In this section we examine how strongly the results are shaped by ordering the variables in the fast moving block ($\boldsymbol{x}_t^{\text{FI}}$) and the slow moving block ($\boldsymbol{x}_t^{\text{RA}}$) differently. For that purpose we compute for each, the term and the risk spread shock, 30 random permutations and retrieve the median responses. These are shown in Fig. B.1 for the term and Fig. B.2 for the risk spread shock. The fat black solid line refers to our baseline results given in section 5.

[INSERT Fig. B.1 HERE]

[INSERT Fig. B.2 HERE]

Both figures show that permutations of the variables does not alter our results. In effect, results are remarkably similar across permutations.

### B.2 Global versus local identification

In section 4 we have proposed treating the GVAR as a simple large vector autoregression and achieved identification using a combination of zero and sign restrictions. The traditional approach outlined in Eickmeier and Ng (2015) and applied among others in Fadejeva et al. (2017) and Feldkircher and Huber (2016) identifies the shock locally, which implies orthogonal structural shocks in the countries where the shock is applied and weakly correlated shocks elsewhere. In this section we compare our results to those achieved under traditional "local" GVAR identification. Since the traditional approach turns out to be very time-consuming we have opted for a weaker set of identification restrictions outlined in Table B.1.

[INSERT Table B.1 HERE]

Having weaker identification restrictions imposed, yields as a by-product a valuable cross-check whether the identified spillover channels are operative even under a minimum set of restrictions. Note that we have relaxed the restriction for the risk spread to hold only for the majority of the countries (as opposed to all euro area countries) – which speeds up finding appropriate rotation matrices considerably.

The results are depicted in Fig. B.3 for the term spread shock and Fig. B.4 for the risk spread shock. We show in blue the results from Section 5 and in orange the responses based on restrictions outlined in Table B.1 coupled with the Eickmeier and Ng (2015) approach for identification. Posterior medians and 68% credible intervals shown.

**Table A.1:** Summary of model specification

Term spread shock

| Country | $y$ | $p$ | $i_s$ | $i_{EA}$ | $i_l$ | $sp$ | $er$ | $eq$ | $hp$ | $pc$ | $poil$ | $y^*$ | $p^*$ | ${i_s}^*$ | ${i_{EA}}^{**}$ | ${i_l}^*$ | $sp^*$ | $er^*$ | $eq^*$ | $hp^*$ | $pc^*$ | $poil^{**}$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| EA (excl., DE) | √ | √ | – | – | – | √ | – | √ | √ | √ | – | √ | √ | √ | √ | – | √ | √ | √ | √ | √ | √ |
| DE | √ | √ | – | – | – | √ | – | √ | √ | √ | – | √ | √ | √ | √ | – | √ | √ | √ | √ | √ | √ |
| ECB | – | – | – | √ | – | – | – | – | – | – | – | √ | √ | – | – | – | – | – | – | – | – | √ |
| Non-EA (excl., US) | √ | √ | √ | – | – | √ | √ | √ | √ | √ | – | √ | √ | √ | √ | – | √ | – | √ | √ | √ | √ |
| US | √ | √ | √ | – | – | √ | √ | √ | √ | √ | √ | √ | √ | √ | √ | – | √ | – | √ | √ | √ | – |

Risk spread shock

| Country | $y$ | $p$ | $i_s$ | $i_{EA}$ | $i_l$ | $sp$ | $er$ | $eq$ | $hp$ | $pc$ | $poil$ | $y^*$ | $p^*$ | ${i_s}^*$ | ${i_{EA}}^{**}$ | ${i_l}^*$ | $sp^*$ | $er^*$ | $eq^*$ | $hp^*$ | $pc^*$ | $poil^{**}$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| EA (excl., DE) | √ | √ | – | – | – | √ | – | √ | √ | √ | – | √ | √ | √ | √ | √ | √ | √ | √ | √ | √ | √ |
| DE | √ | √ | – | – | √ | – | – | √ | √ | √ | – | √ | √ | √ | √ | √ | √ | √ | √ | √ | √ | √ |
| ECB | – | – | – | √ | – | – | – | – | – | – | – | √ | √ | – | – | – | – | – | – | – | – | √ |
| Non-EA (excl., US) | √ | √ | √ | – | √ | – | √ | √ | √ | √ | – | √ | √ | √ | √ | √ | √ | – | √ | √ | √ | √ |
| US | √ | √ | √ | – | √ | – | √ | √ | √ | √ | √ | √ | √ | √ | √ | √ | √ | – | √ | √ | √ | – |

**Notes:** Domestic variables marked by no asterisk, weakly exogenous by one and exogenous by two asterisks. In the upper panel, "sp" denotes the term spread, while in the lower panel the risk spread. For the ECB country model, $y^*$ and $p^*$ refer to euro area country aggregates based on purchasing power parities. Note that not all variables are available for all countries covered in the analysis. This relates typically to financial variables, for which coverage of CESEE countries is limited.

**Table A.2:** Impact effects

| Term spread | AT | BE | DE | ES | FI | FR | IE | IT | NL | PT | GR | SK |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Large Ident. | -38.7 | -55.3 | -50.9 | -85.2 | -57.9 | -66.2 | -129.9 | -86.7 | -67.1 | -153.4 | -325.3 | -52.6 |
| Local Ident. | -62.3 | -62.8 | -57.7 | -80.0 | -55.4 | -63.1 | -66.2 | -71.5 | -59.2 | -131.8 | -397.8 | -49.9 |

| Risk spread | AT | BE | DE | ES | FI | FR | IE | IT | NL | PT | GR | SK |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Large Ident. | -13.0 | -23.0 | – | -65.3 | -16.4 | -26.3 | -146.8 | -82.5 | -18.3 | -185.6 | -434.3 | -59.6 |
| Local Ident. | -18.2 | -35.6 | – | -70.5 | -13.9 | -21.3 | -115.2 | -70.5 | -13.0 | -164.2 | -450.0 | -56.0 |

**Notes:** The table shows the impact responses of the term and risk spread. "Large Ident." denotes the identifiation strategy treating the GVAR as simple large vector autoregression, while "Local Ident." stands for local identification of the shock (Eickmeier and Ng, 2015).

**Table B.1:** Sign restrictions.

| Shock | $sp$ | $y$ | $p$ | $i_{s,EA}/i_{l,DE}$ | $eq$ | $pc$ | $hp$ |
|---|---|---|---|---|---|---|---|
| Term spread | ↓, all EA | ↑, ∅ EA | ↑, ∅ EA | – | – | – | |
| Risk spread | ↓, ∅ EA | ↑, ∅ EA | ↑, ∅ EA | – | – | – | |

Notes: The restrictions are imposed as ≥ / ≤ and for 3 periods after impact. ∅ indicates that at least half of the countries have to fulfill the sign restrictions in the restricted country group. EA refers to the euro area (core and periphery countries), ECB to the ECB country model and DE to Germany.

[INSERT Fig. B.3 HERE]

The responses show that a reduction in the term spread still increases output and prices in the euro area and spreads via the financial and the exchange rate channel to CESEE and other non-euro area EU member states. In this sense, our main results remain qualitatively unchanged when using a smaller set of restrictions coupled with the traditional GVAR sign restrictions approach. The results though show a tendency of larger credible sets when treating the GVAR as large vector autoregression compared to the identification strategy of Eickmeier and Ng (2015).

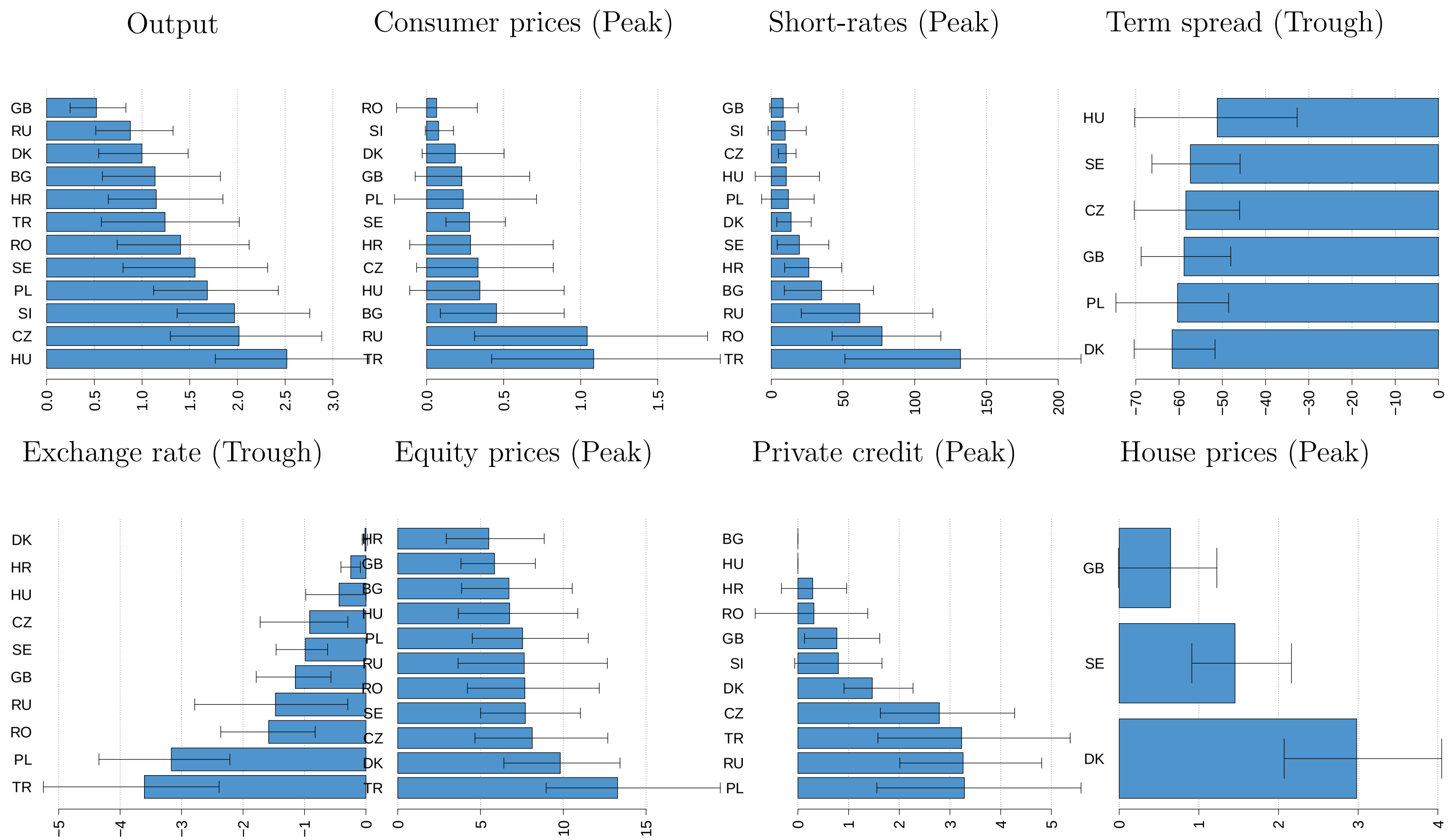
Two things are worth noting: First, the increase in identification uncertainty does not alter results. For example, while credible sets of short-rate equity price and private credit responses in core economies are larger using the approach outlined in Section 4, both identification strategies yield significant responses over the same impulse response horizon. Second, identification differs not only since fewer restrictions have been imposed, but also since the zero impact restriction on euro area short-term interest rates, which is naturally imposed by ordering the variable appropriately in the large vector autoregression, is not implemented in the traditional GVAR sign restriction approach of Eickmeier and Ng (2015). Ultimately, the shock composition varies, as outlined in Table A.2.

[INSERT Fig. B.4 HERE]

Results for the risk spread shock corroborate findings of Section 5. Output tends to increase, driven by a rise in equity prices while exchange rates of CESEE economies appreciate significantly against the euro. Estimates for non-euro area EU member states appear to be surrounded with uncertainty.

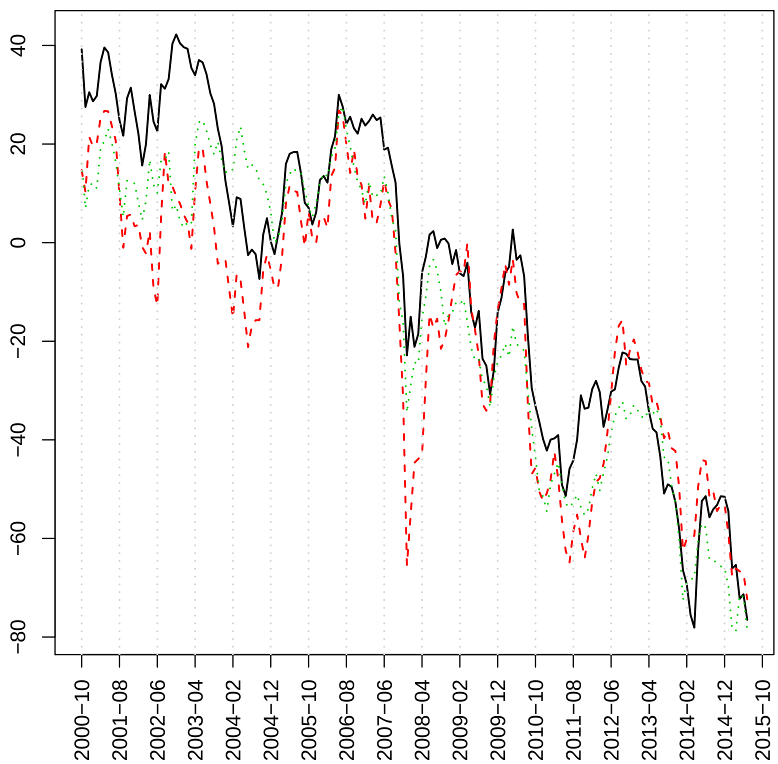
Summing up, we see that the main results are qualitatively unchanged if we vary the technical implementation of the sign restrictions approach as well as reduce the set of restrictions. Credible sets tend to be smaller under the traditional GVAR sign restrictions approach. Since the impact on the results is negligible, treating the GVAR as a simple large vector autoregression compared to local shock identification has the advantage that it is computationally much faster and straightforward to implement. Also, imposing zero impact restrictions seems not restrictive in the context of spillover analysis.

**Fig. 6:** Peak / trough effects of spillovers (term spread shock)



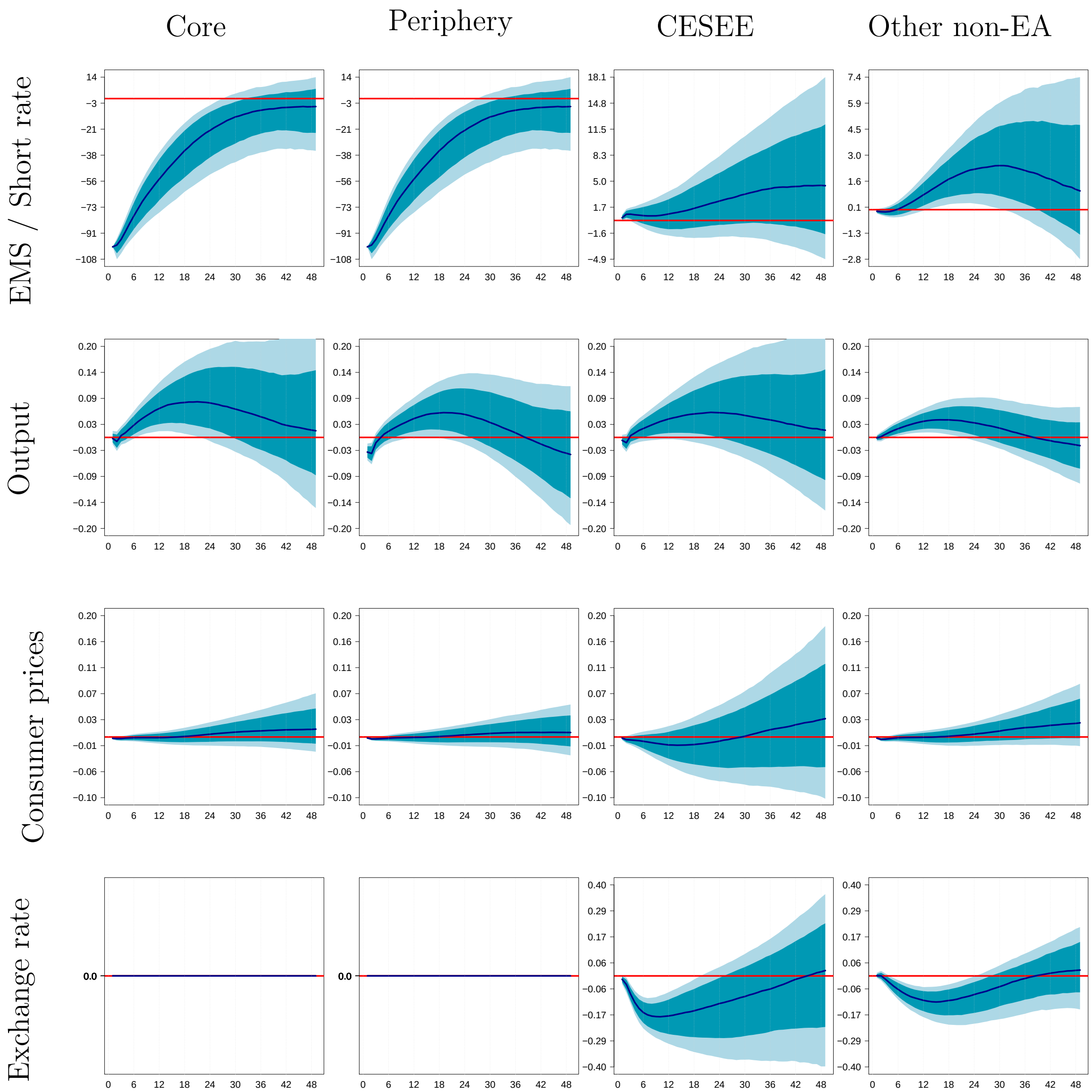

The bar plots show peak / trough effects with the whiskers denoting 50% credible intervals. A decrease of the exchange rate response implies an appreciation of the local currency against the euro.

**Fig. 7:** Effective monetary stimulus (EMS)



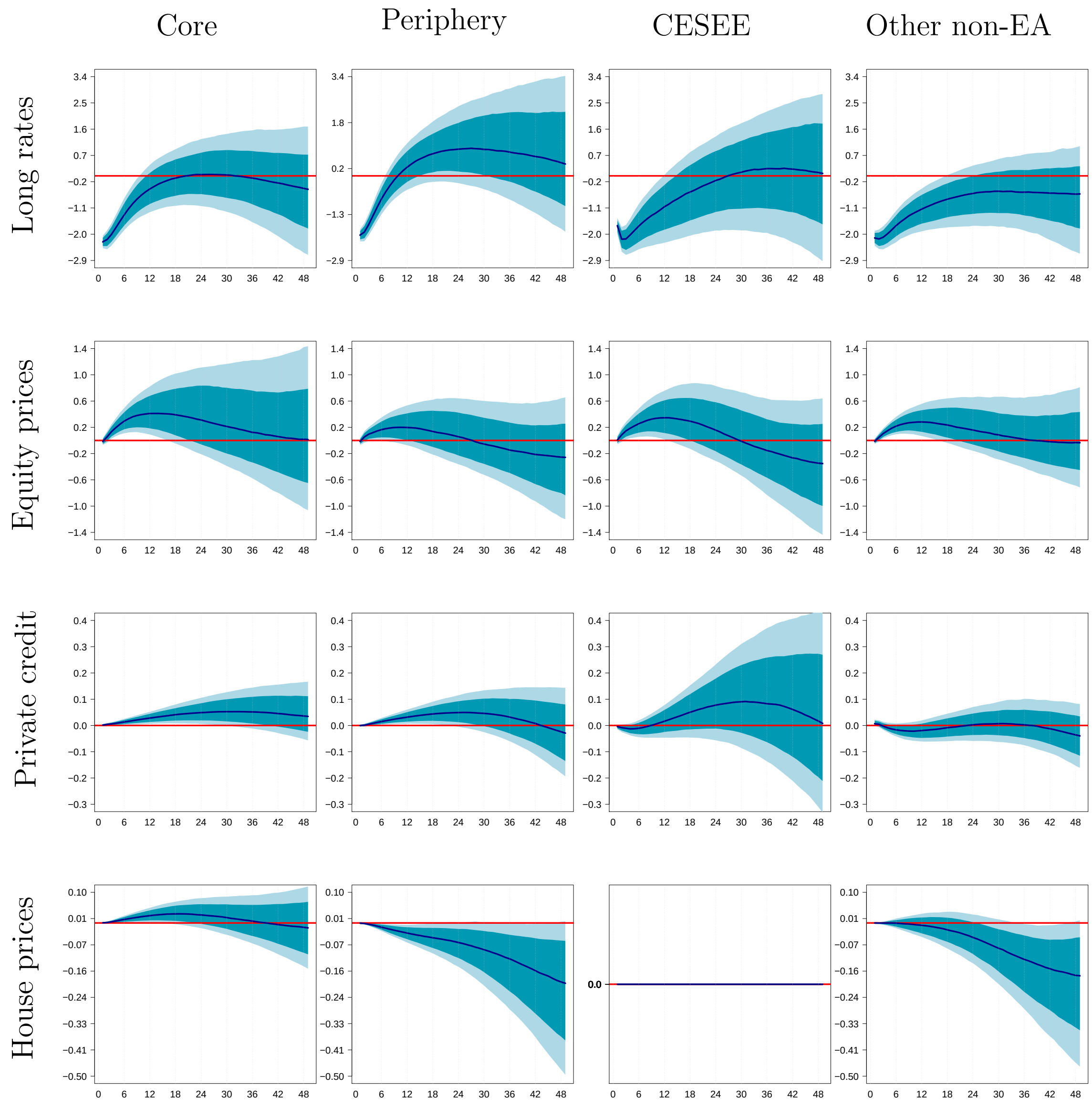

*Notes*: The effective monetary stimulus measure is derived as the difference between 30 years forward rates the nominal natural interest rate, scaled by 30 and refers to the model-free variant proposed in Halberstadt and Krippner (2016). Black solid line refers to the EMS for the euro area, red-dashed line to the EMS for the USA and green-dotted line for Great Britain.

**Fig. 8:** EMS shock - regional results I



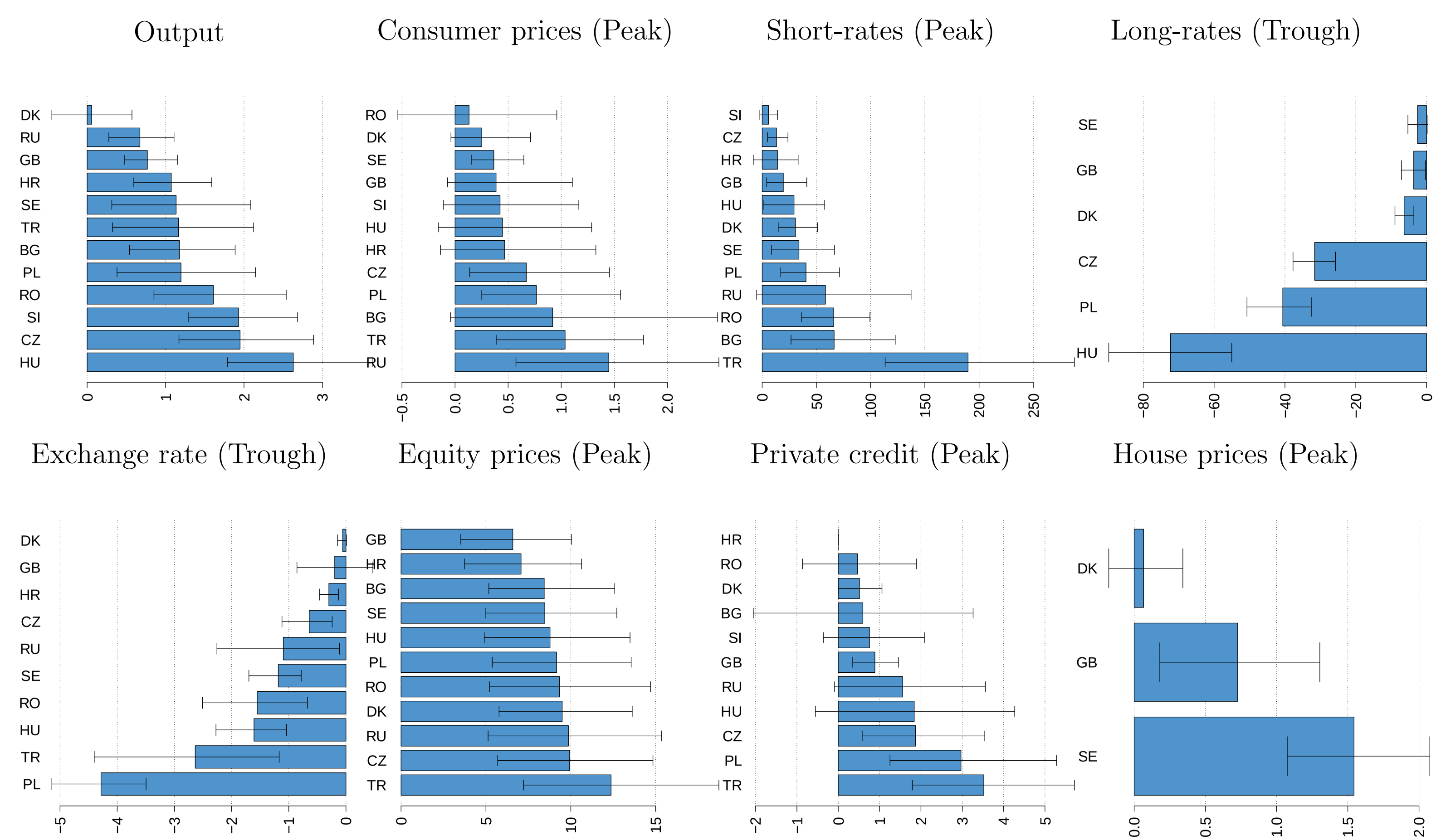

*Notes*: The figure shows impulse responses to a simultaneous 100bp reduction in the effective monetary stimulus measure for the euro area. Dark blue shaded area denotes 68%, light blue 50% credible sets and the blue solid line the posterior median. Exchange rate refers to nominal exchange rates vis-á-vis the euro (decrease implying a depreciation of the euro). Regional figures are aggregate using purchasing power parities.

**Fig. 9:** EMS shock - regional results II



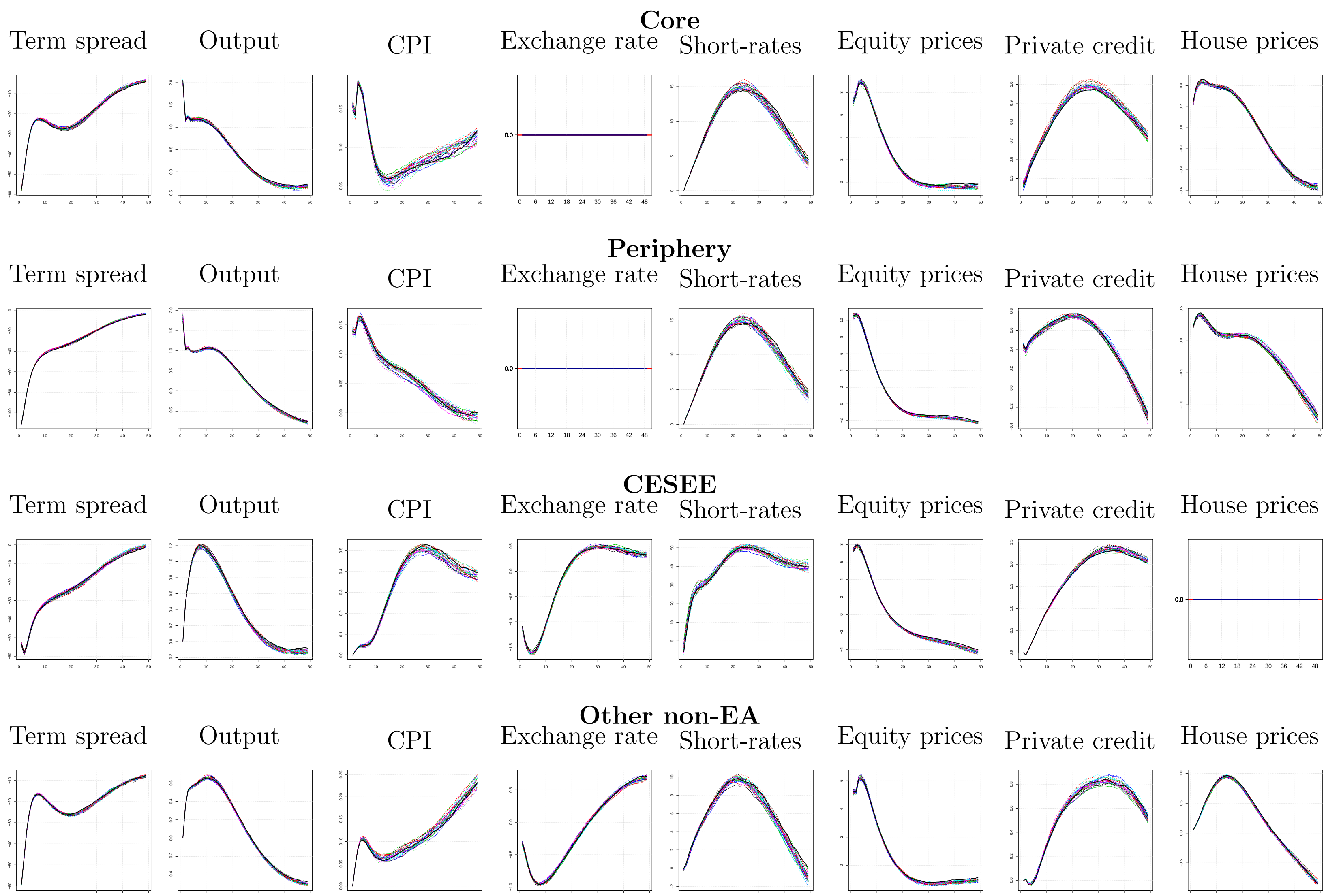

*Notes*: The figure shows impulse responses to a simultaneous 100bp reduction in the effective monetary stimulus measure in the euro area. Dark blue shaded area denotes 68%, light blue 50% credible sets and the blue solid line the posterior median. Regional figures are aggregate using purchasing power parities.

**Fig. A.1:** Peak / trough effects of spillovers (risk spread shock)



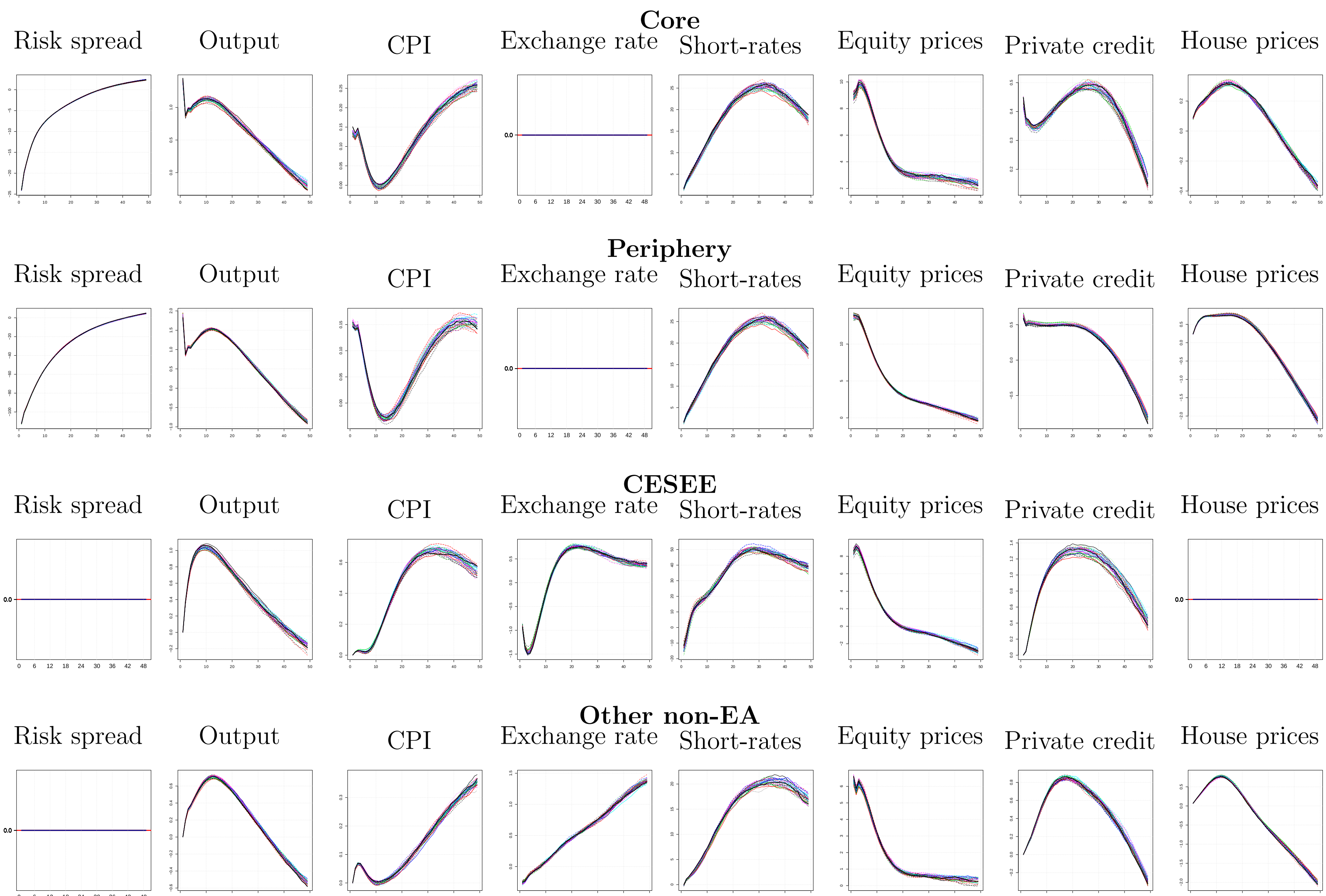

The bar plots show peak / trough effects with the whiskers denoting 50% credible intervals. A decrease of the exchange rate response implies an appreciation of the local currency against the euro.

**Fig. B.1:** Order permutations - Term spread shock



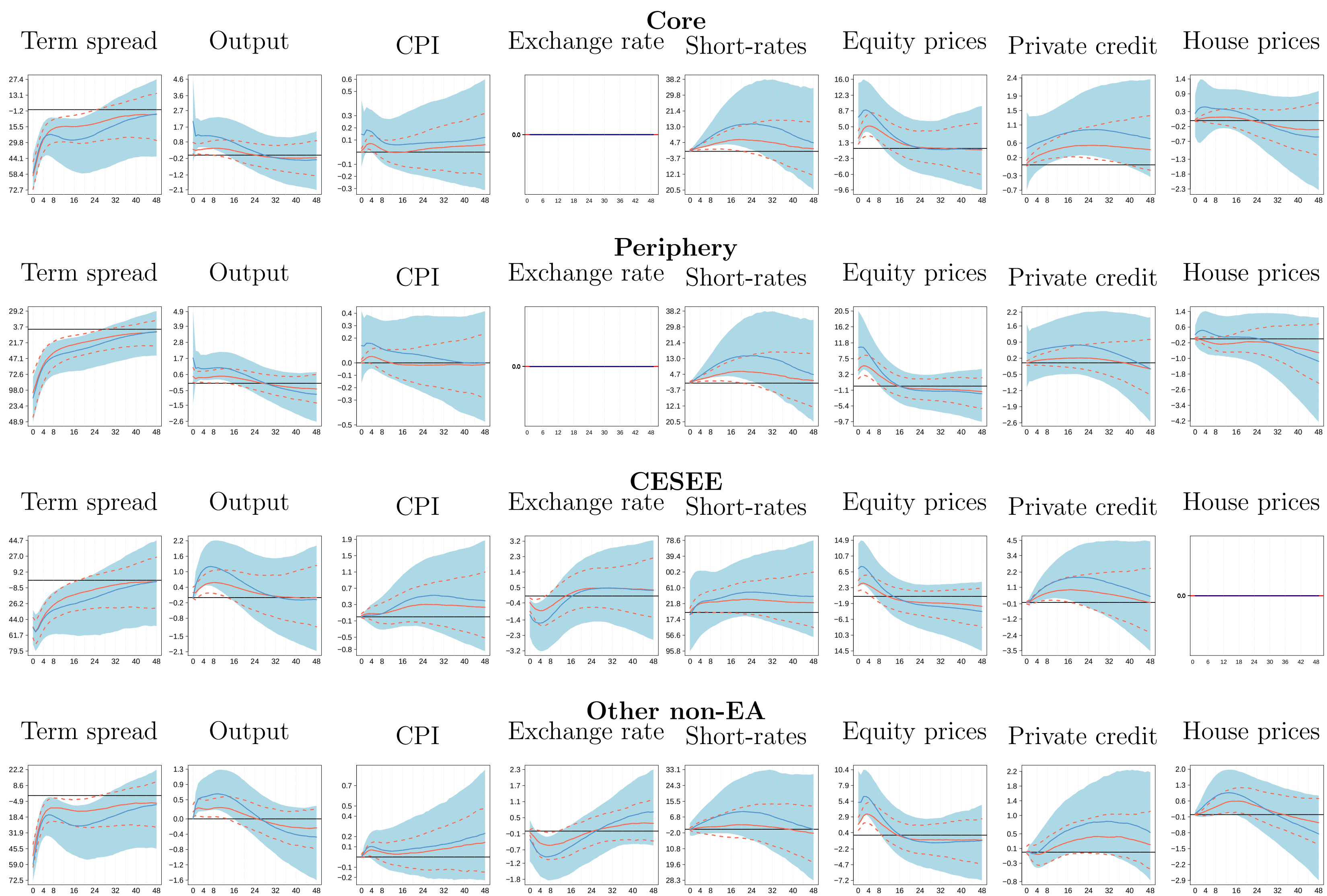

Notes: The plot shows median impulse responses based on 30 random permutation of the variable orderings in the fast ($\boldsymbol{x}_t^{\text{FI}}$) and slow moving ($\boldsymbol{x}_t^{\text{RA}}$) variable blocks. For comparison, in black solid median response of the baseline model from section 5. Results on long-term yields available upon request.

**Fig. B.2:** Order permutations - Risk spread shock



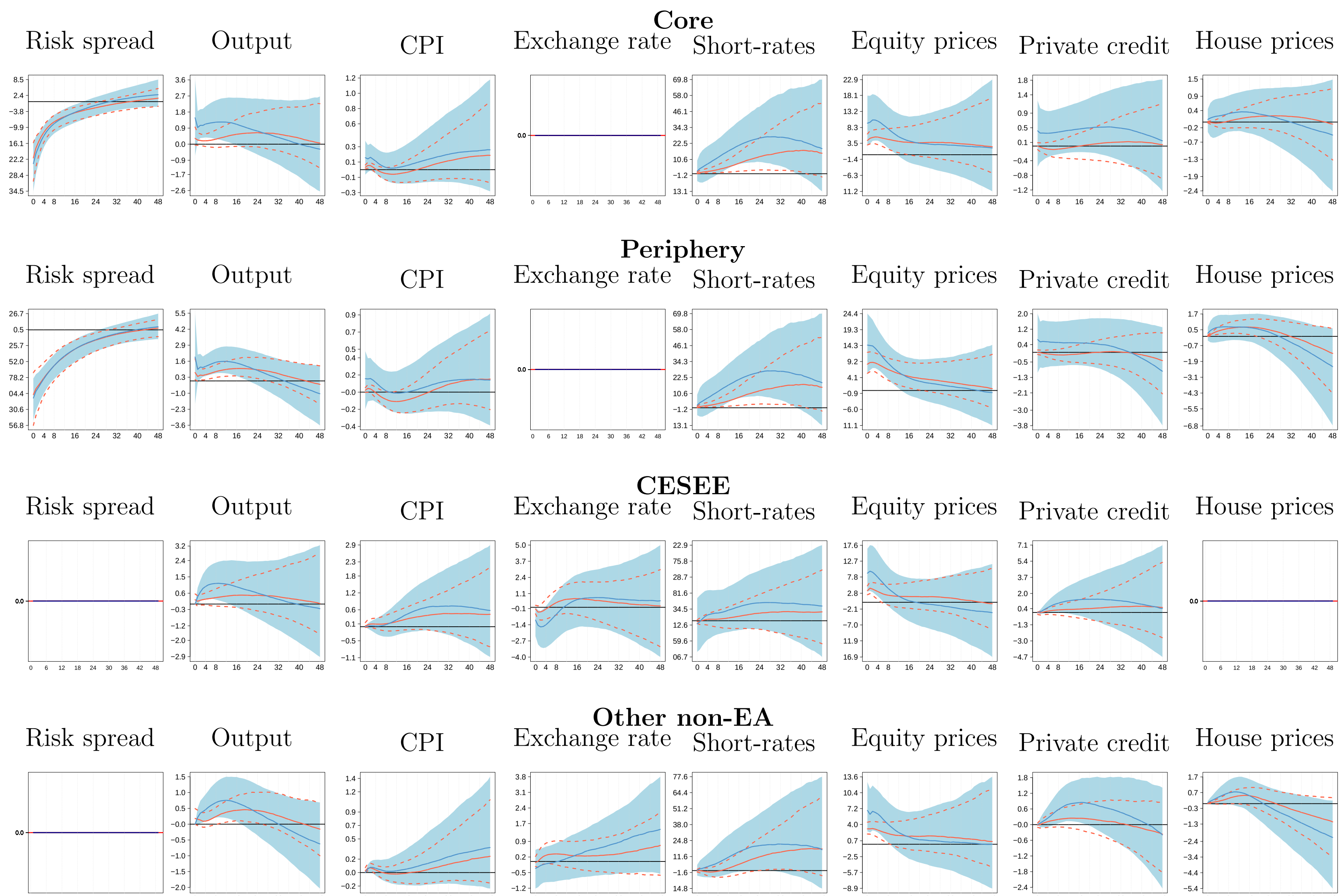

Notes: The plot shows median impulse responses based on 30 random permutation of the variable orderings in the fast ($\boldsymbol{x}_t^{\mathrm{FI}}$) and slow moving ($\boldsymbol{x}_t^{\mathrm{RA}}$) variable blocks. For comparison, in black solid median response of the baseline model from section 5. Results on long-term yields available upon request.

**Fig. B.3:** Comparison Identification - Term spread shock




Notes: In blue zero sign restrictions as proposed in section 4, in orange identification follows Eickmeier and Ng (2015) with a minimum of restrictions imposed on euro area countries. 68% credible sets.

**Fig. B.4:** Comparison Identification - Risk spread shock




Notes: In blue zero sign restrictions as proposed in section 4, in orange identification follows Eickmeier and Ng (2015) with a minimum of restrictions imposed on euro area countries. 68% credible sets. Results for long-term interest rates available upon request.