Beggar-thy-neighbor? The international effects of ECB unconventional monetary policy measures.

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Abstract

The effects that European Central Bank unconventional monetary policy measures have on nine European countries not adopting the Euro are examined with a novel Bayesian mixed frequency Structural Vector Autoregressive technique. The technique accounts for the fact that macro, monetary and financial data have different frequencies. Unconventional monetary policy disturbances generate important domestic fluctuations. The wealth, the risk, and the portfolio rebalancing channels matter for international propagation; the credit channel does not. International spillovers are larger in countries with more advanced financial systems and a larger share of domestic banks. A comparison with conventional monetary policy disturbances and with announcement surprises is provided.

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1 Introduction

In recent years there has been an unprecedented use of so-called unconventional monetary policy (UMP) measures by central banks of advanced economies. These measures have attracted increasing criticisms from leaders of developing and peripheral countries. Most notably, the United States' tapering policy has led to condemnations from Turkey, India, Brazil and South Africa (Kynge, 2014). In addition, concerns have been voiced that UMP measures could lead to 'beggar-thy-neighbor' effects. Brazilian President Rousseff remarked in 2012: *"Quantitative easing policies (...) have triggered (...) a monetary tsunami, have led to a currency war and have introduced new and perverse forms of protectionism in the world."*

For Europe, where non Euro members are linked to the Euro area, either through membership in the European Union or through significant trade and financial ties, concerns that recent Quantitative Easing (QE) measures could lead to large appreciation pressures, to increased financial volatility, and to perverse real effects are widespread. The economic implications of these spillovers can be severe, as demonstrated by the recent example of Switzerland, who was forced to abandon its peg to the Euro in January 2015 in anticipation of QE measures. For both academic and policy purposes, it is therefore crucial to understand if these international spillovers exist and, if so, to measure the repercussions on foreign real economies.

This paper sheds light on these issues using an empirical model which combines slow-moving monthly macroeconomic variables, weekly monetary policy variables, and fast-moving daily financial variables. To handle the frequency mismatch we employ a Bayesian mixed-frequency Vector Autoregressive (VAR) model. The setup is advantageous in many respects: it accounts for macroeconomic–financial linkages without generating those time-aggregation biases which are present when lower-frequency data are used; it circumvents policy endogeneity problems; and it enables us to give a structural interpretation to the spillovers - such an interpretation is impossible when only high-frequency financial data is used.

We focus our investigation on three questions. First, do European Central Bank (ECB) UMP measures generate important 'beggar-thy-neighbor' effects in European countries not adopting the Euro? Second, does the degree of financial integration matter? In particular, is it true that larger financial market integration led to more significant international real comovements in response to UMP disturbances? Third, which channel of international transmission is operative? What is the relative importance of trade and financial spillovers in propagating UMP shocks?

In recent years, a new literature emerged analyzing the domestic effects of UMP measures (see Cecioni et al. (2011) for a review). For the Euro area, there is evidence that UMP measures had positive output and inflation effects (Lenza et al., 2010, Gambacorta et al., 2012 and Darracq Paries and De Santis, 2013); but that real responses were slower, less significant than those induced by conventional monetary policy measures (Peersman, 2012). In terms of financial market responses, many high frequency/ (quasi) event studies find a reduction in market spreads following a UMP announcement (Abbassi and Linzert, 2011; Angelini et al., 2011; Beirne et al., 2011) and a significant fall in the term premia and government bonds yields, especially when intra-day data are used (see Ghysels et al., 2013). The International Monetary Fund (2013b) claims that, after UMP measures, the gap between lending rates and the policy rate is still large. Borstel et al. (2015) find that the interest rate pass-through to bank lending has not changed during the last few years. Thus, the liquidity increases that UMP measured produced had marginal effects on banks' mark-ups.

A number of studies have also began investigating the international consequences of US UMP measures for emerging markets and found that QE caused the US dollar to depreciate, foreign stock prices to rise and CDS spreads to decrease (see e.g. Neely, 2010; Chinn, 2013; Chen et al. (2012); Fratzscher et al. (2013)). Moessner (2014) observes that international effects for advanced and emerging countries are similar, while Chen et al. (2012) claims that the impact in emerging countries is stronger and that exchange rate responses are quite heterogeneous (see also Aizenman et al., 2014). Lim (2014) claims that at least 5% of financial inflows between 2000 to 2013 to the average developing country are due to US UMP.

For Euro area UMP measures, Boeckx et al. (2014) show that, after a liquidity increase, countries with less capitalized banks have smaller bank lending and output effects, while Lo Duca et al. (2014) find that confidence and asset prices improve. Since the effects on yields are small, they conclude that UMP policies only have limited international impact. However, because the high frequency nature of the study, macroeconomic spillovers are not investigated.

In this paper, we simultaneously look at the effects of ECB UMP measures on financial and macroeconomic variables in a structural framework; examine the pairwise transmission between the Euro area and nine European countries not adopting the Euro; and try to disentangle channels of domestic and international transmission of UMP disturbances.

We document that UMP shocks generate important domestic financial market responses. Contrary to the literature, we find sizable macroeconomic responses and no major difference in terms of timing and persistence relative to conventional monetary policy shocks; time aggregation biases might thus be responsible for the additional stickiness found in the literature. We also show that while UMP disturbances induce significant inflation dynamics, conventional monetary policy disturbances primarily affect output. Announcement surprises produce financial market responses which are similar to those of conventional policy shocks, but output and inflation effects are weaker.

Internationally, there is no generalized beggar-thy-neighbor effects: some countries benefit and others loose from ECB UMP actions. Advanced economies, which are more financially integrated with the Euro area and have a larger share of domestic banks, tend to have output and inflation dynamics which are qualitatively similar but generally stronger than those in the Euro area. For financially less developed countries, which have a larger share of foreign banks, the macroeconomic effects may differ. International transmission occurs both via trade (the exchange rate channel) and via financial markets (wealth, risk and portfolio rebalancing channels). However, contrary to the popular view, the exchange rate rate channel does not seem to shape the responses of foreign macroeconomic variables to Euro area UMP shocks. This is in sharp contrast to the international transmission of conventional policy shocks, where exchange rate movements are crucial to understand foreign output and foreign inflation dynamics.

The paper is structured as follows: Section 2 gives an overview of the channels that may induce domestic and international spillovers following UMP measures. Section 3 describes the estimation methodology, the identification strategy, and the data. Section 4 presents domestic responses. Section 5 discusses international spillovers. Section 6 investigates why international macro-financial linkages are heterogeneous. Section 7 examines the robustness of the results. Section 8 concludes. The Appendices present an overview of the unconventional monetary policy actions by the ECB, the details of the mixed frequency algorithm we use, and additional results.

2 Channels of international transmission

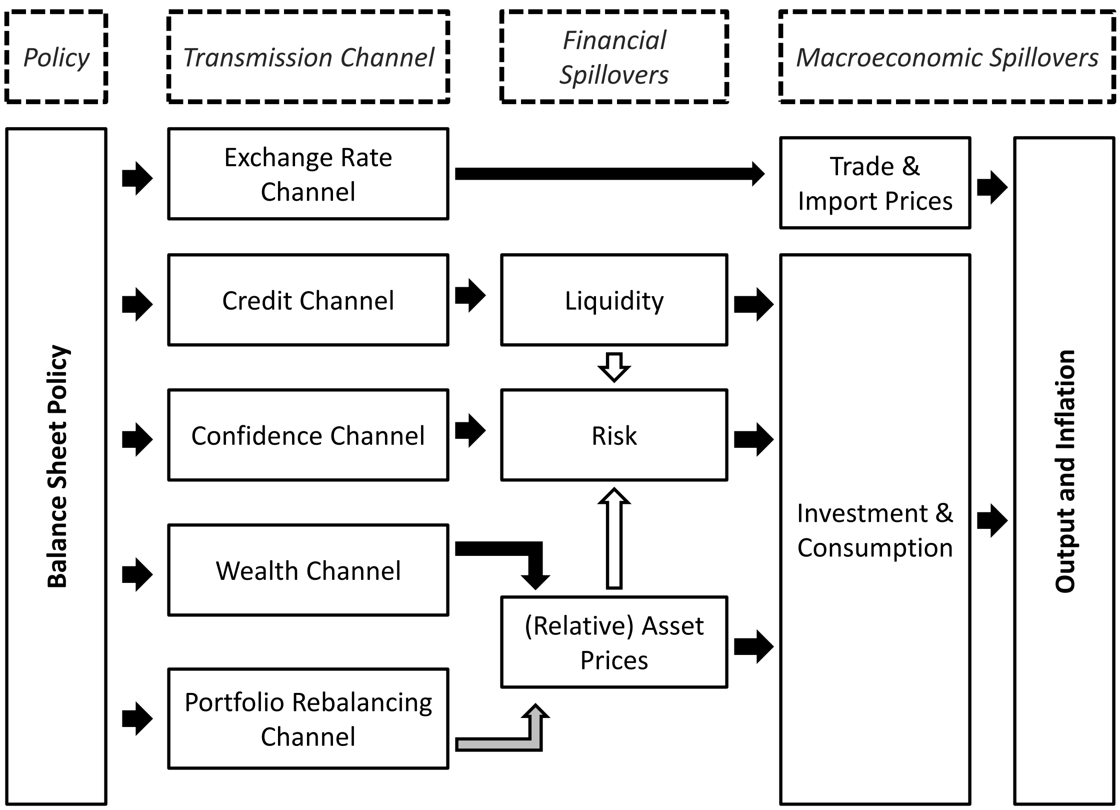
There is a large literature analyzing the mechanics of domestic monetary policy transmission (see e.g. Krishnamurthy and Vissing-Jorgensen, 2011). As far as conventional monetary policy is concerned, three channels have been emphasized: the expectation, the exchange rate, and the interest rate channels (e.g. Russell, 1992). Basic to the idea that monetary policy affects the economy is the notion that central bank decisions influence (a) price level expectations and thus the domestic aggregate supply, via price and wage settings; (b) expectations of future short term interest rate, which feeds into long term interest rates. Because long term interest rates matter for investment and consumption decisions, the domestic aggregate demand is also altered.

These aggregate demand and aggregate supply effects could be reinforced when monetary policy alters the value of the domestic currency. Exchange rates variations influence both the quantity and price of import and exports; price changes then feed into the aggregate supply, and quantity changes into the aggregate demand. Finally, monetary policy tilts the term structure of interest rates and thus consumption and investment decisions. The interest rate channel has been identified as the main transmission mechanism for conventional monetary policy in Europe before the introduction of the Euro (Angeloni, 2012).

When discussing unconventional monetary policy measures, two other channels are considered as potentially relevant: the wealth and the confidence channel. UMP measures may alter asset prices if they change the cost of capital (*wealth channel*); and reduce uncertainty and financial risk perceptions (*confidence channel*). This latter stabilization purpose has been heavily emphasized during the recent financial crisis.

Figure 1 depicts the channels of international transmission the literature finds relevant when discussing unconventional monetary policy measures: the exchange rate, the credit, the confidence, the wealth, and the portfolio rebalancing channels [1]. The latter four mechanisms influence financial markets first - by changing liquidity, risk, and asset prices - and then the macroeconomy, through changes in investment and consumption.

Figure 1: Channels of International Unconventional Monetary Policy Transmission



Note: The gray arrow indicates an indirect effect. The white arrows indicate contemporaneous effects on risk.

UMP measures alter the bilateral nominal (real) exchange rate, which affects net trade and import prices for the partner country (*exchange rate channel*). In turn, these variations affect foreign prices, production, and consumption. The relative magnitude of the changes in foreign inflation and output depends on substitution and income effects (Mishkin, 2001).

Interest in the financial channels of international transmission has emerged since the onset

[1] While this study is silent on the *signaling channel*, we account for signaling effects in the empirical analysis.

of the financial crisis. The *credit channel* comprises the bank lending and the balance sheet sub-channels. The bank lending channel refers to the effect that UMP measures have on bank reserves when the amount of market liquidity changes (recall that banks are the main financial institutions in the Euro area). The balance sheet channel refers to variations in the net worth of banks (and firms) due to changes in the value of the collateral and of cash flows. These two sub-channels alter credit conditions by affecting the quantity and quality of loans. In economies which are financially integrated, global credit conditions may also be affected.

UMP measures may change the relative cost of capital. This change may have an effect on the relative price of stocks, bonds, houses, and land which in turn may lead to international capital flows (*wealth channel*). Both the wealth and the credit channels feed into financial risk, investment and consumption decisions. While these channels are present also when conventional monetary policy actions are undertaken, an expansion or change in the composition of the balance sheet of the central banks also activates the *portfolio rebalancing channel* (Krishnamurthy and Vissing-Jorgensen, 2011). It has been argued (e.g. Bernanke, 2010; Gagnon et al., 2011) that balance sheet policies may reduce private portfolio's duration risk. Thus, yields on long-term securities should decline, long-term borrowing increase, and the portfolios of investors shift towards shorter-term assets. As a consequence, aggregate demand and financial risk should be altered. Besides a duration (temporal) effect, the *portfolio rebalancing channel* could lead to an international (spatial) rebalancing between UMP and non-UMP countries, as investors seek higher yields or lower risk. Finally, the *confidence channel* influences perceptions of uncertainty and risk. Changes in liquidity and asset prices may also have an indirect effect on risk, as they influence the confidence of investors, and thus investment and consumption decisions.

According to the financial accelerator theory (Bernanke et al., 1998), financial markets could be a powerful amplifier of real and financial disturbances: firms need to borrow and lenders require a guarantee of repayment, usually in the form of collaterized assets. Asset prices deteriorations alter firms' balance sheet, their net worth, their ability to borrow, and thus investment and economic activity. In turn, with reduced economic activity, asset prices fall, leading to a further financial and real economic downturn. These feedback dynamics could have international repercussions as firms, households or even governments may borrow abroad. UMP measures are typically employed to improve weak financial market conditions. With increasing asset prices and firms' ability to borrow reestablished, investment and real activity should recover faster.

3 The Mixed frequency methodology

Due to the high-frequency nature of financial variables and the slow reporting of macroeconomic variables, applied economists typically face a frequency mismatch when trying to jointly examine macro-financial linkages in response to shocks. The most common solution is to aggregate high-frequency data into a lower-frequency, but valuable information is lost in the process. Furthermore, the frequency of the data typically influences the conclusions one obtains (see Rogers et al., 2014 and Ghysels et al., 2013). Alternatively, one may discard low-frequency data and focus on event studies that look at financial variables around policy announcement dates (see Krishnamurthy and Vissing-Jorgensen, 2011). Unfortunately, this approach is also sub-optimal since it ignores the real effects of UMP measures. Another problem that event studies face is the high volatility of daily or intra-daily data, so that the conclusions may be driven by noise.

In this paper we provide a mixed-frequency compromise (see Foroni and Marcellino, 2013 for a survey of mixed-frequency methods): key macro variables are converted from monthly to weekly-frequency using an augmented Gibbs sampler technique; financial variables are aggregated from daily to weekly frequency by taking averages. Because ECB unconventional policy data is reported weekly, a weekly frequency balances the desire to smooth some of the noise without discarding too much information. The empirical model we consider is a VARX

$$y_t = \mathbf{A} y_{t-1} + \mathbf{B} \omega_t + \epsilon_t, \;\; \epsilon_t \sim N(0, \Sigma), \tag{1}$$

where $\omega_t = [\mathbf{1}, \omega_{\mathbf{t}}^*]$ is a vector of weakly exogenous variables, $y_t = (z_t,\, x_t)$ is a vector of endogenous variables containing the lower-frequency data, z_t, and the higher-frequency data, x_t. z_t has missing observations: with monthly data reported as averages, we only observe a mid-month weekly value, z_t^i - the values of the other weeks of the month remain latent.

3.1 Mixed frequency with irregular spacings

Researchers trying to combine weekly with monthly data face an additional problem, fairly neglected in the literature. Because of the irregular nature of weeks (some months contain four, others five weeks), the Gibbs sampler can not be used mechanically and needs to be augmented by an additional step that draws the missing, irregularly spaced observations. The approach we employ here is similar to Chiu et al. (2011) and Qian (2013), allows us to use a Bayesian setting, and differs from the usual Kalman filter (Carter and Kohn, 1994) employed in the literature. In fact, rather than being predicted and smoothed, missing data is sampled directly from a constrained multivariate normal distribution.

Direct drawing is advantageous in many respects. First, and most importantly, unlike the Kalman filter, the procedure is easily implementable with irregularly spaced data. Second, the Kalman filter often produces non-linear and non-Gaussian likelihood functions, which could be costly to evaluate - especially in large models. Third, while the Kalman filter works sequentially, we can block sample, which significantly increases the computational speed. There are two main drawbacks of the approach: the dependence of the Gibbs draws increases- we avoid this by appropriately thinning the chains; the number of nodes at which the distribution needs to be evaluated increases and this may affect the tightness of the standard errors.

Apart from having to deal with irregularly spaced weeks, we also need to solve a time aggregation problem in estimation. As monthly data is reported as a mid-point average, we need to take this into account when drawing missing data. Unlike with end-of-the-period sampling, where one draws the latent variables from a unconstrained multivariate normal distribution, we need to draw all missing variables simultaneously from a constrained multivariate normal distribution. The constraint is introduced because the draws must satisfy the monthly average. The algorithm we employ to estimate the parameters is described in details in Appendix B.

To avoid imposing too much a prior information which in unjustified, given our ignorance about the properties of UMP shocks, we will use flat priors on all VARX coefficients.

3.2 Identification of UMP shocks

Since the countries we pair with the Euro area are relatively small open economies, they are likely to have little influence on the Euro area, while the latter has presumably a larger impact on them. Hence, there is a natural block exogeneity in the VAR system with the Euro are block coming first. The block exogeneity assumption has been used quite a lot in the empirical international literature, see e.g. Cushman and Zha (1997), Mackowiak (2007) or Dungey and Pagan (2009). It is stronger than the one employed by Kim and Roubini (2000) - block exogeneity there is imposed only on the contemporaneous matrix. The estimates we compute are equivalent to those obtained with the two steps approach of Canova (2005).

For each country pair we consider, the structural system is

$$\mathbf{A_{0,11}} y_{1t} = \mathbf{A_{1,11}}(\mathbf{L}) y_{1t-1} + \mathbf{B}_1 \omega_t + \epsilon_{1t}, \quad \epsilon_{1t} \sim N(0, \Sigma_1) \tag{2}$$

$$\mathbf{A_{0,21}} y_{1t} + \mathbf{A_{0,22}} y_{2t} = \mathbf{A_{1,21}}(\mathbf{L}) y_{1t-1} + \mathbf{A_{1,22}}(\mathbf{L}) y_{2t-1} + \mathbf{B}_2 \omega_t + \epsilon_{2t}, \quad \epsilon_{2t} \sim N(0, \Sigma_2) \tag{3}$$

The endogenous variables of the small open economy are $y_{2t} = [IP_t, \pi_t, e_t, sp_t, l_t, risk_t]'$, while the endogenous variables of the Euro area are $y_{1t} = [IP_t^*, \pi_t^*, UMP_t^*, sp_t^*, l_t^*, risk_t^*]'$. The weakly exogenous variables are $\omega_t^* = [News_{t-1}, i_t, i_t^*, PC_t]$. $IP_t(IP_t^*)$ is output, $\pi_t(\pi_t^*)$ is inflation, UMP_t* is the unconventional monetary policy variable,e_t is the nominal exchange rate, $sp_t(sp_t^*)$ is stock prices, $l_t(l_t^*)$ is a liquidity variable, and $risk_t(risk_t^*)$ is a measure of risk. $News_{t-1}$ is a dummy variable capturing UMP announcements; the conventional monetary policy tool (the interest rate) is denoted by $i_t(i_t^*)$. Finally, PC_t is the first Principal Component of a number of control variables and it is described in more detail in the next subsection. It is important to have both the conventional monetary policy tool and the UMP announcements as controls to avoid to confound their effects with those of the shocks which are of interest.

The set of variables included in the VAR is chosen so as to be able to examine the transmission channels discussed in Section 2. The exchange rate channel is operative if UMP shocks generate significant exchange rate movements; significant responses of the liquidity variable, on the other hand, would indicate that credit channel is important; a strong and significant response of stock prices would suggest the presence of a wealth channel; finally, a strong and significant response of the risk variable would indicate that the confidence channel matters.

Because theory is, by and large, silent regarding the features of UMP shocks, we identify them in an agnostic way. That is, we assume that output and inflation matter for UMP decisions within a week, but that the UMP variable reacts to financial variables only with a week delay. Note that these restrictions have to hold only for a week and, thus, are weaker than similar restrictions imposed on a monthly or a quarterly VAR.

The justification for choosing these identifying assumptions is that while unconventional monetary policy reacts to financial factors, it is unlikely to do so on a weekly basis. This is especially true for the Long Term Refinancing Operation programs (LTRO) that make up the largest proportion of UMP measures in our sample. For the Security Market program (SMP) Lo Duca et al. (2014) point out that some of the decisions were taken at an intra-daily frequency. The ordering of the variables within the financial block is arbitrary. We have stock prices before the liquidity spread, since we assume they react more slowly to monetary policy than liquidity in the interbank market due to transaction costs. The risk variables appear last, since risk perceptions react fast and take all available information into account. In Section 7 we examine the robustness of the conclusions when different identification assumptions are employed.

3.3 Data

All data comes from Datastream. The sample spans from 18th December 2008 until 10th May 2014. The starting date has deliberately been chosen in order to (a) avoid major structural breaks, (b) avoid the high volatility period following the Lehman crisis, and (c) have a time period where UMP were frequently used. The end date has been chosen to avoid the period of negative interest rates, which were applied by the ECB in June 2014.

The analysis focuses on nine European countries, some of which are EU members and some which are not. We choose them since they have the largest trade and financial linkages with the Euro area, and are therefore most likely to be influenced by the ECB's policies. The majority of countries have floating currency regimes (Czech Republic, Hungary, Poland, Romania, and Sweden, Norway). In addition to these six countries we include Denmark and Bulgaria, whose currencies are pegged to the Euro, and Switzerland which is a hybrid case, since the Swiss Central Bank switched from a floating regime to a fixed regime in September 2011.

The monthly Industrial Production index is used as output measure and the monthly IMF Consumer Price Index is used to compute inflation. The weekly policy variables is calculated summing up LTRO, SMP and Covered Bond Purchase Programmes (CBP) (I and II). The daily financial variables are the bilateral nominal exchange rate, the liquidity spread, measured by the difference between the 3-month and overnight interbank rates (e.g. EURIBOR-EONIA for Euro area), stock market indices, and CDS spreads. The CDS for the Euro area are computed weighting individual Euro members' CDS using Eurostat weights.

The announcement dummy, $News_t$, sums up the event dummies for LTROs, collateral changes, SMP, CBP I and II. Because UMP announcements took place roughly 1–2 weeks before the actual implementation (see Lo Duca et al., 2014), the news variable enters the VAR lagged. Appendix A provides an overview of ECB unconventional measures during the sample.

Apart from using the nominal interest rate and the announcement dummy of Euro area UMP measures, we use as control variable a principal component (PC) indicator for global factors, computed using US and UK (conventional and unconventional) policy variables; global real economy indicators, oil prices, Eastern European and EU (excluding EA) financial indicators, global trade price, and global equity indicators.

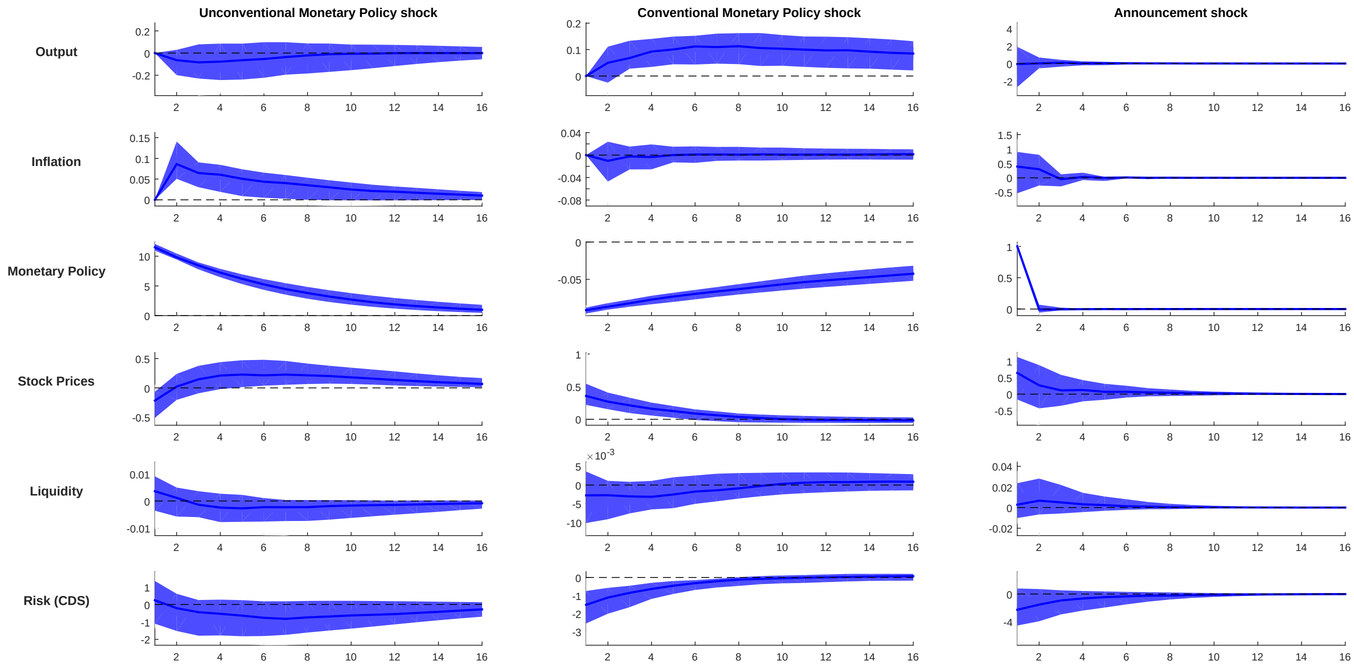
Since VAR data is used as conditioning set to draw the latent variables, it is essential that all variables (and in particular the higher-frequency ones) exhibit an approximately normal distribution. Thus, all macroeconomic variables enter the VAR in log-growth rates. As in Stock and Watson (2012), we use first differences of financial variables, except interest rates. The financial data transformed this way show less skewness and almost no kurtosis. Note that, while long run relationships will be lost, our transformation helps to have the data on a similar scale, making the Gibbs sampler more efficient, and economic interpretation easier.

4 Domestic transmission

We first present the dynamics produced by UMP shocks in the Euro area. We do so to compare our results with those present in the literature, which were derived without a mixed-frequency methodology, and to provide a benchmark to understand international dynamics. The first column of Figure 2 reports the responses of the six Euro area variables. For comparison, the figure also reports the responses obtained following an expansionary conventional monetary policy shock (second column) and a UMP announcement (third column).

There are a few interesting features of the dynamics which are worth commenting upon. First, a UMP shock is somewhat persistent and has a half life of about 6 weeks. Second, while inflation significantly and persistently increases, output responses are negative on impact and then insignificant. This is in contrast to what researchers have found in the US and UK.

Figure 2: Responses of Euro area variables to shocks



Note: The shaded regions report pointwise 68% credible intervals. The x-axis reports weeks, the y-axis monthly growth rates for all but the liquidity spread, the interest rate (for conventional monetary policy) and the announcement dummy.

However, while central banks in these countries engaged in large asset purchase programs to drive up yields and aggregate demand, the UMP measures adopted by the ECB were aimed primarily at providing liquidity for the interbank market. Thus, for output effects to materialize, this liquidity needed to be transmitted to the real economy via bank lending and there is little evidence that this has happened (Borstel et al., 2015). In addition, since Euro area members differ substantially in their bank lending responses, imbalances within the region may have jeopardized any positive output gains (Santis and Surico, 2013).

Third, the responses of financial variables are in line with expectations. Stock prices initially fall and then persistently increase and the responses are generally significant; liquidity spread responses are positive but insignificant in the short and turn significantly negative in the medium run; the responses of the risk variable are generally negative but insignificant. Thus, while the wealth channel is operative, the liquidity and the confidence channels seem weak and this may explain why output responses are also muted.

Fourth, contrary to previous studies, see e.g. (Peersman, 2012), we find that the responses to UMP disturbances are sizable and significant and no additional stickiness is present when compared to conventional monetary policy disturbances. Thus, a mixed frequency approach seems necessary to avoid aggregation biases.

Fifth, while UMP disturbances primarily induce important inflation dynamics, conventional monetary policy disturbances significantly and persistently displace output from its stationary state - the largest effect occurs after 8-10 weeks. In addition, risk perceptions persistently decrease. The dynamics of liquidity and stock price variables are both quantitatively and qualitatively in line with what is known in the Euro area (see e.g. Christoffel et al., 2008). The weak response of inflation and the strong decrease in risk are a feature of our sample period, which only starts in 2008, and includes both the financial and the European sovereign debt crises.

Finally, a UMP announcement surprise does not have measurable effects on output or inflation. The responses of financial variables, although less significant, resemble to those produced by a conventional policy disturbance (see also Szczerbowicz, 2015). Note that the effects of announcement shocks are probably underestimated because we have averaged daily financial variables. Ghysels et al. (2013) and Rogers et al. (2014) have argued that to properly measure the effects of announcements, higher-frequency data, ideally intra-daily, should be used.

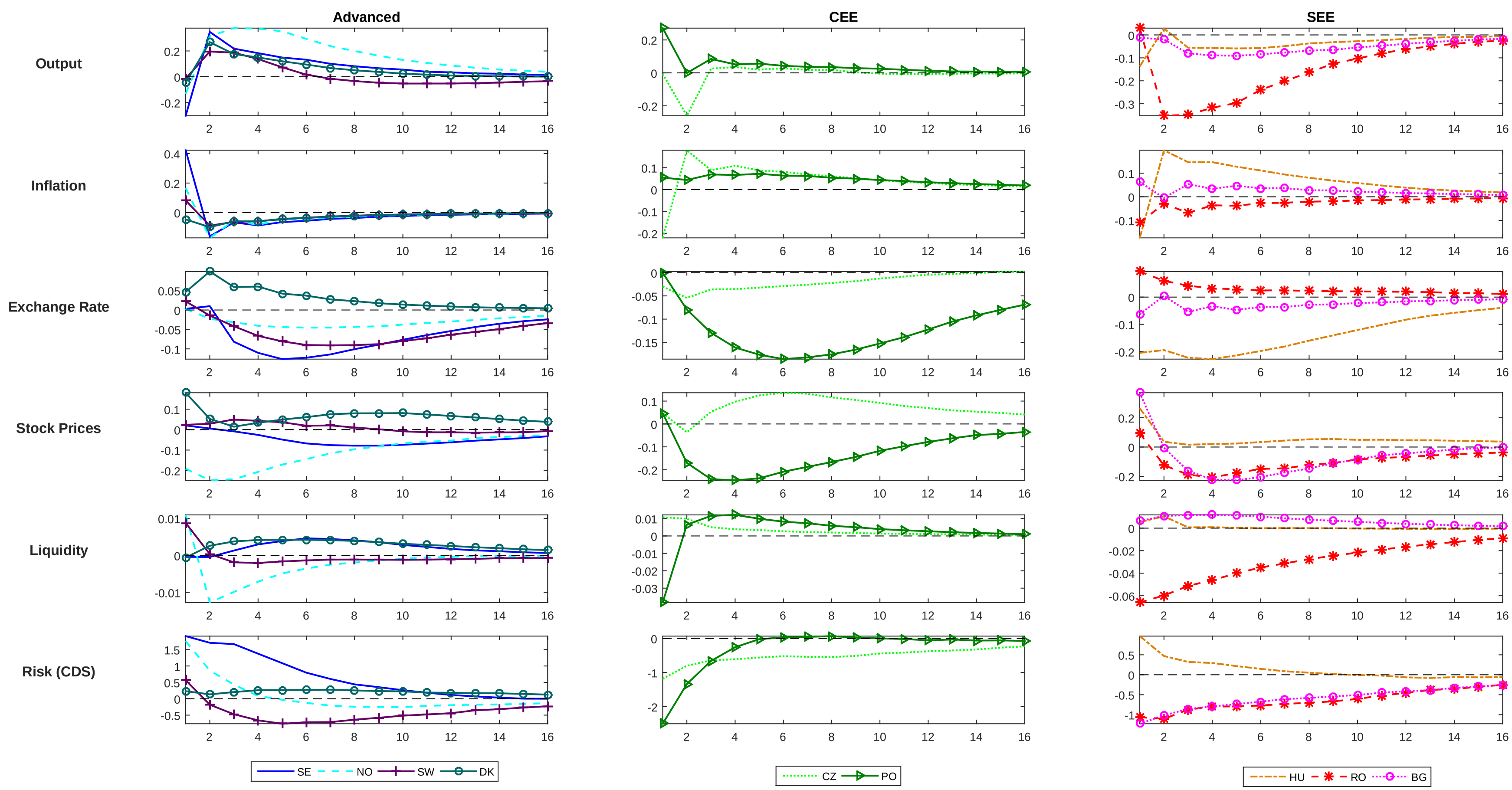
Overall, our model gives a coherent view of the domestic propagation of monetary policy disturbances and thus seems suited to analyze international transmission.

5 International transmission

Figure 3 shows the median posterior responses of the variables of the nine foreign economies to UMP shocks in the Euro area, in deviations from the responses obtained in the Euro area (except for the exchange rate which is plotted in level). Thus, positive and significant responses of, say, output would indicate that a UMP shock generates foreign output responses which are significantly larger than those obtained in the Euro area. For easy of interpretation, responses are grouped into different country groups: (a) Advanced countries - Sweden, Norway, Denmark and Switzerland, (b) Central Eastern European countries (CEE) - Poland and the Czech Republic, and (c) Southern Eastern European countries (SEE) - Hungary, Romania and Bulgaria. Figure C.1 in the Appendix reports group average responses with the associated posterior credible sets.

Output responses to Euro area UMP shocks are quite heterogeneous. While in advanced countries, responses are persistently positive and significantly larger than in the Euro area after two weeks, those in the CEE countries are insignificant, and those in SEE countries are persistently negative and significantly smaller than in the Euro area after about two weeks. Thus, Euro area UMP shocks make some countries better off and some countries worse off in terms of real economic activity. Inflation responses are positive for CEE and SEE countries, generally after about 2 or 3 weeks, while they are negative for advanced countries.

Figure 3: Responses to a Euro area UMP shock, foreign countries



Note: The lines report the pointwise posterior median responses in deviations from Euro area responses. The x-axis reports weeks, the y-axis monthly growth rates for all variables but the liquidity spread. The size of the shock is 10% of UMP.

Why are macroeconomic responses so different across countries? One possibility is that certain countries are insulated from foreign shocks while others are not because of different exchange rate regimes. Such an explanation does not seem to fly: for example, in the advanced countries group there are floaters and peggers. Another related explanation could be that different real exchange rate dynamics lead to different trade gains across country groups. Again, this explanation seems incapable to account for the heterogeneities we find: real exchange rate responses are all negative (the local currency appreciate versus the Euro) [2]. Lo Duca et al. (2014) also find a (nominal) appreciation versus the Euro using an event study approach and much higher frequency data. In addition, exchange rate responses are very sluggish - the real exchange rate has not returned to its steady state after 4 months. Thus, while there is some evidence that the exchange rate channel is activated following UMP disturbances, differential exchange rate dynamics do not explain the pattern of differential cross-country output responses we obtain.

Stock prices responses are significantly different from those obtained in the Euro area. Stock prices initially increase for all countries but Norway, and then fall for up to 8 weeks - Denmark is the exception here. Note that the responses for CEE and SEE countries are slightly more persistent than in advanced countries. These patterns are consistent with the presence of both wealth and portfolio re-balancing channels: at least on impact stock prices increase more than in the Euro area by a significant amount. In the medium run, stock prices of all countries either increase by less than in the Euro area or fall.

There is considerable heterogeneities in the responses of the risk variable: it declines relative to the Euro area for CEE and SEE countries (with the exception of Hungary), while it increases for advanced countries. Note that risk responses are large in absolute value, despite the fact that we are using the CDS spread to infer risk - country risk usually serves as a floor for domestic financial risk. Thus, the true risk effects may be even larger.

The credit channel, on the other hand, seems to be absent. Except for Romania and perhaps Poland, the liquidity spread is not responding significantly to Euro area UMP disturbances. This is in line with Taylor and Williams (2008), who find that the LIBOR-OIS spread did not react to the FED's QE1.

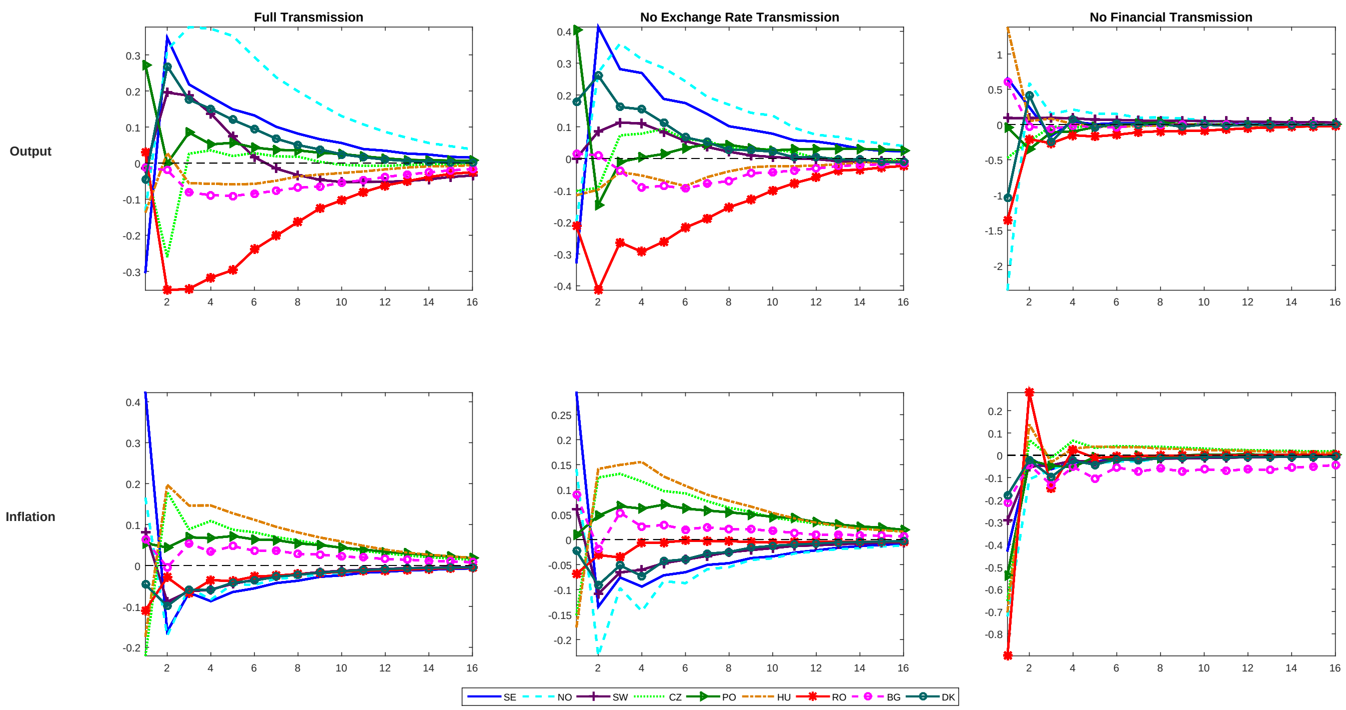
To quantify the relative importance of financial vs. trade channels in transmitting UMP disturbances we perform a counterfactual exercise. That is, we trace out the dynamics of the foreign variables to a Euro area UMP shock holding constant either stock prices, liquidity and risk, or the exchange rate. Thus, in the former case international links are generated via the exchange rate; in the latter case only financial transmission will take place. Figure 4 presents the results of our exercise. In the first panel, we report the benchmark output and inflation

[2] Note that the small response of the bilateral Euro-Swiss franc real exchange rate should be interpreted with care, since in the middle of the sample a nominal peg was introduced.

responses we had in Figure 3; in the second, the responses obtained switching off the exchange rate channel; in the third, the responses obtained switching off the financial channels.

Eliminating the exchange rate channel slightly alters the magnitude but does not change the shape of the responses. Overall, exchange rate movements seem to slightly reduce output responses and slightly amplify inflation responses. Thus, the trade effects that exchange rate variations may induce are minor in the case of UMP disturbances. In contrast, shutting off financial channels has major effects on foreign output and inflation responses: output responses are now insignificant except on impact and display no persistence; inflation now drops on impact. Note also that output and inflation responses are now homogenous. Since the dynamics of the financial variables are relative homogeneous also in the baseline case, cross country differences in financial-macro linkages are likely to be the reason for the cross country heterogeneity of the output and inflation responses we discover.

Figure 4: Counterfactual output and inflation responses to a Euro area UMP shock, foreign countries



Note: The lines report the pointwise posterior median impulse responses in deviations from the Euro area responses. The x-axis reports weeks, the y-axis monthly growth rates.

In Appendix C we present the international responses obtained when conventional monetary policy shocks and announcement surprises are considered. With conventional MP shocks, the Euro depreciates relative to most other currencies. Perhaps more importantly, we find that after a couple of weeks, foreign output and inflation responses are similar in sign and magnitude to those of the Euro area. Instantaneously, some countries loose from a monetary expansion in the Euro area with relative output, relative stock prices decreasing and the liquidity spread, and relative risk increasing. In our sample, peggers show the largest financial losses.

Announcement surprises produce macroeconomic responses which are similar to those obtained in the Euro area. The exchange rate and the financial responses resemble those obtained with a conventional monetary policy shock - Denmark is the exception here. However, exchange rate responses are far less persistent. Also, the credit channel seems to play a more significant role in the international transmission.

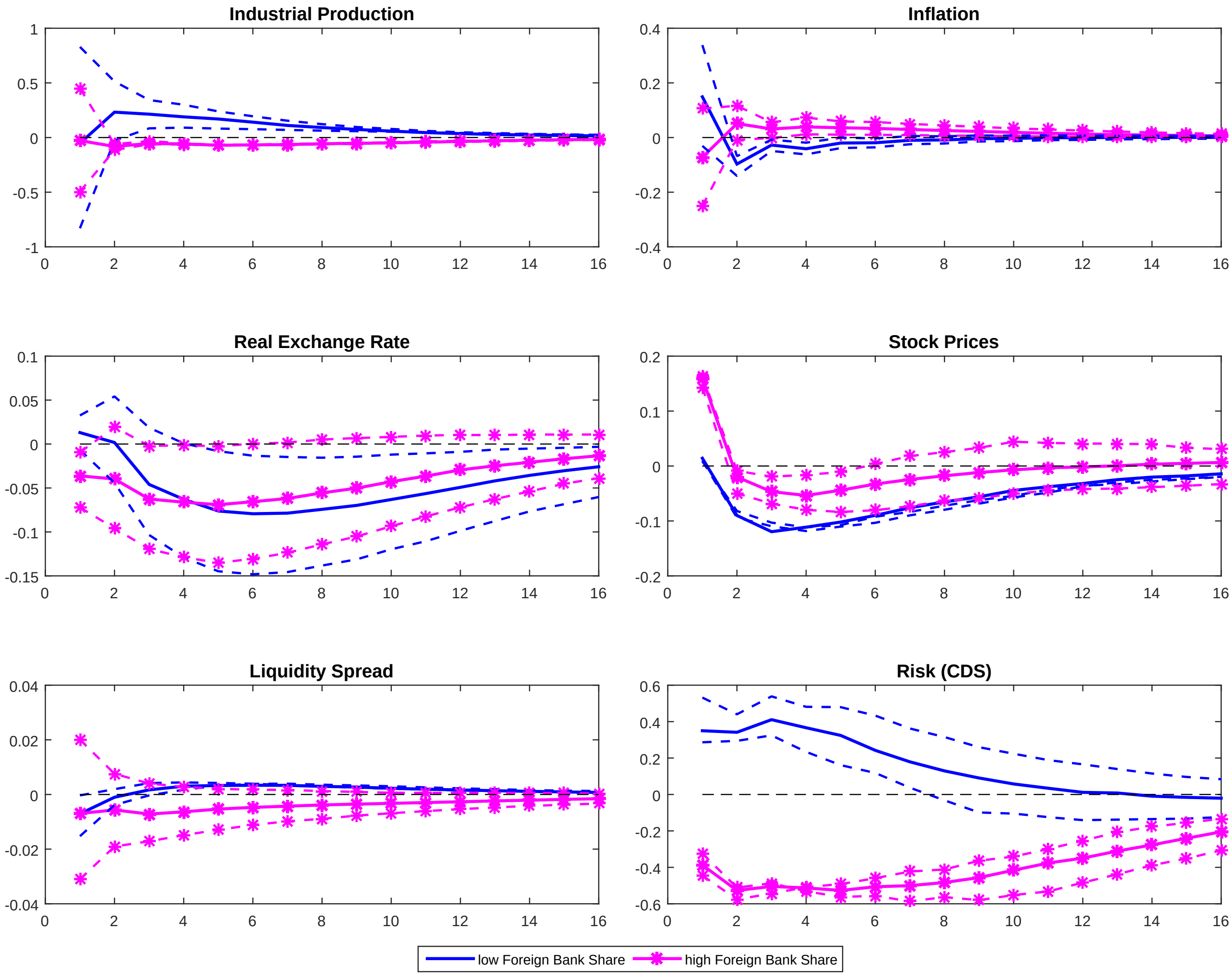
In sum, the evidence suggests that the exchange rate, wealth, risk and portfolio re-balancing channels spill Euro area UMP shocks to foreign countries. However, we fail to find a generalized beggar-thy-neighbor effect. Advanced economies, which are more financially integrated with the Euro area, tend to have output and inflation dynamics which look like those of the Euro area, even though output effects are larger and inflation effects smaller. For the remaining countries the macroeconomic consequences seem to differ. Finally, the exchange rate channel does not seem to shape the responses of foreign macroeconomic variables. In fact, international transmission of UMP disturbances primarily goes through financial channels. This is in sharp contrast with the international transmission of conventional monetary policy shocks, where exchange rate movements are crucial to determine foreign output and inflation dynamics.

6 Why are foreign macroeconomic responses heterogeneous?

As we have seen, positive financial spillovers from UMP disturbances do not necessarily translate into positive real transmission. Instead, it appears that while financial market responses are somewhat similar across countries, real responses are quite heterogeneous. In this section, we examine why this may occur.

The IMF (2013a) states that between 70-90% of assets in CEE and SEE countries is held by foreign banks and claims that these assets amount to, at least, 50% of domestic GDP. Since foreign banks, which in the countries under consideration are mostly from the Euro area, have access to the cheap ECB liquidity, they may invest into foreign financial markets what they borrow from the ECB rather than lend it to domestic agents. This would positively affect foreign asset prices, reduce in foreign risk, but would not lead to positive real spillovers, as foreign loans would not be affected by the additional liquidity banks obtain. Hence, if countries are heterogeneous in the composition of their banking sector, similar financial market responses may lead to different real effects. In particular, in countries featuring a large share of foreign banks, global liquidity increases should have the smallest pass-through to the real economy.

Figure 5: Comparative Impulse Responses to a UMP shock



Note: The lines report the pointwise average posterior median responses in deviations from the Euro area responses. The dotted line represents the 68% pointwise credible sets. Low foreign bank share countries are Sweden (52%), Norway (58%), Poland (63%) and Denmark (61%); high foreign bank shares countries are Switzerland (72%), Czech Republic (92%), Hungary (100%), Romania (72%) and Bulgaria (81%). Data on foreign bank shares comes from the Bank of International Settlement and is for 2012.

To examine this hypothesis we group countries according to the foreign bank share. Figure 5 reports the responses for countries with low foreign bank share (at least 1/3 of banks are domestic) and high foreign ownership. Confirming our intuition, we find no significant difference in the dynamics of the liquidity spread across groups, but we observe a stark difference in the response of stock prices and risk. Countries with high share of foreign bank ownership experience an increase in stock prices and a reduction in risk relative to the Euro area; countries with a lower share of foreign banks, feature declining stock prices and increasing risk. In addition, while the former display falling relative real output growth, the latter show a relative output increase, which is significantly positive a few weeks after the Euro area UMP shock.

To provide further evidence that the structure of domestic financial markets is crucial to understand the international macroeconomic effects of UMP disturbances, we group countries according to the level of financial development (as provided by the World Economic Forum,2012) and the credit-to-GDP ratio. With these two alternative classifications, the grouping remains unchanged except for Poland and Switzerland which switch groups. The financially advanced, high credit-to-GDP ratio countries (Sweden, Norway, Denmark) behave like the low foreign bank share countries, while the less financially advanced, low credit-to-GDP economies (CEE and SEE) show the same responses as the high foreign bank share countries. These results agree with Aizenman et al. (2015), who claim that higher levels of financial development can mitigate the negative effects of a foreign UMP shock and that financially more open but potentially less developed small economies are more sensitive to foreign UMP shocks. They also agree with Dedola et al. (2015), who shows that spillovers of a US monetary shock are largest for emerging economies whose level of financial development is generally low; and with Ongena et al. (2015) who point out that local lending in foreign currencies, which is common among the high foreign bank share countries, leads to a stronger international bank lending channel and weaker domestic policy transmission.

7 Robustness

The results presented so far are derived under the identification assumption that a UMP shock has no weekly effect on output and inflation and that the UMP variable does not respond within a week to financial variables. While the first assumption is hard to dispute, the second could be debatable. Furthermore, the ordering of variables within the financial block is somewhat arbitrary. In this section we discuss what happens when we alter identification assumption. The responses for these cases are reported in Appendix C.

7.1 Changing the ordering of Euro area financial variables

We considered three alternative orderings of the variables of the Euro area block; two where financial variables are permuted (R1: output, inflation, UMP, liquidity, stock prices, and risk; R2: output, inflation, UMP, risk, stock prices, and liquidity); and one where the policy variable reacts within a week to macro and financial variables, meaning that the ECB monitored financial markets on a weekly basis when deciding UMP which, as mentioned, seem to have occurred with the Securities Market Programme - roughly 10% of the UMP in our sample (R3: output, inflation, stock prices, liquidity, risk and UMP).

No major differences are noticeable between the baseline and the R1 and R2 schemes, except for the kink in the liquidity spread responses for Romania. Thus, the order of the variables within the financial block is inconsequential for the transmission properties of UMP shocks.

Some changes appear when the R3 scheme is used. The responses for Euro area variables are qualitatively similar, even though stock prices and risk responses are less significant. Internationally, the most notable change is in the dynamics of peggers countries:the responses of inflation and of the liquidity spread are now stronger; those of stock prices and of risk are weaker. Thus, the relative importance of the wealth and portfolio channels depends somewhat on whether we allow the UMP variable to react to financial variables or not.

7.2 Identification of UMP via sign and zero restrictions

While we have argued that with weekly data and the variables we employ, the identification scheme for Euro area UMP shocks we have used is relatively weak, we also examined for robustness the dynamics with an identification scheme which mixes of sign and zero restrictions. In particular, we still assume that output and inflation do not react to UMP shocks within a week, but impose that a positive UMP shock increases the UMP variable and makes the liquidity spread non-positive for one period. Restrictions of this type have been used by Gambacorta et al. (2012) and Carrera et al. (2015), and seem reasonable since the main goal of several UMP measures was to increase the liquidity of financial markets.

Since this scheme identifies a set rather than a point in the space of contemporaneous matrices, responses are generally more uncertain. Qualitatively speaking, the responses for the exchange rate, the liquidity spread, and risk are as in the baseline, while the response of stock prices is, on average, more negative. Interestingly, the dynamic responses of output and inflation are similar to those of the R3 scheme for most countries. Thus, the idea that unconventional monetary policy may react to liquidity on a weekly basis finds additional support.

7.3 Identification via Heteroskedasticity

The use higher-frequency data makes us less sensitive to the issue of policy endogeneity but still imposes some restrictions on financial variables. As a further check on the robustness of our conclusions, we use volatility changes to identify UMP shocks as in Rigobon (2003). The method requires that there are a minimum of two regimes with different volatilities (e.g. low and high), assumes that shocks are uncorrelated, and that the contemporaneous impact matrix and the parameters of the VAR are stable. While the restrictions such an identification scheme imposes are weak, one should also remember that regimes are often arbitrarily chosen and that shocks identified this way have very little economic interpretation (Kilian, 2011).

We check for the presence of different regimes/structural breaks in the reduced form VAR residuals informally. There is a decrease in volatility in a number of the equations roughly corresponding to Mario Draghi's famous 'whatever it takes' speech on the 26th July 2012. This decrease is marked in the liquidity and UMP equations for the Euro area, and in the exchange rate, liquidity, and risk equations for some countries.

To estimate the system, we condition the Gibbs sampler on the variances for the two regimes as Kulikov and Netsunajev (2013). We divide the sample in pre-Draghi speech, s_1, and post-Draghi speech state, s_2 and assume that the variance of the structural errors is state-dependent

$$\varepsilon_t(s_j)|s_t \sim Normal(0, \mathbf{D}(s_t)),$$

The diagonal matrix, $\mathbf{D}(s_2)$, is employed to determine the short-run run matrix $\mathbf{A_0}$, once posterior variances are computed using $\mathbf{\Sigma^{-1}}(1) = \mathbf{A_0'A_0}$, $\mathbf{\Sigma^{-1}}(2) = \mathbf{A_0'D(s_2)^{-1}A_0}$, where $D(s_1) = I$.

Since not all countries display volatility changes around the chosen breakpoint, general conclusions are difficult to draw. While responses are not very significant, the majority of the conclusions we have obtained are unchanged: output responses vary across countries with advanced countries displaying strong positive responses while responses in CEE and SEE countries are negative; the real exchange rate appreciates for most countries; the credit channel is weak.

8 Conclusion

This paper examined the international transmission of Euro area UMP disturbances. We contributed to the literature in two ways. From a methodological point of view, we provide a way to combine low-frequency macroeconomic data with high-frequency financial data, minimizing time-aggregation and policy endogeneity biases. From an economic point of view, we provide insights into the effect of unconventional ECB measures using a framework where macro-financial linkages are properly accounted for and an international perspective is adopted.

We address three questions. First, do European Central Bank UMP measures generate important 'beggar-thy-neighbor' effects in European countries not adopting the Euro? Second, does the degree of financial integration matter? In particular, is it true that larger financial market integration led to more significant international real comovements in response to UMP disturbances? Third, which channel of international transmission is operative? What is the relative importance of trade and financial spillovers in propagating UMP shocks?

We document that UMP shocks generate important domestic financial market responses.

Contrary to the literature, we find sizable macroeconomic responses and no major difference in terms of timing and persistence relative to conventional monetary policy shocks; time aggregation biases might thus be responsible for the additional stickiness found in the literature. We also show that while UMP disturbances induce significant inflation dynamics, conventional monetary policy disturbances primarily affect output. Announcement surprises produce financial market responses which are similar to those of conventional policy shocks, but much weaker output and inflation effects.

Internationally, there is no generalized beggar-thy-neighbor effects: some countries benefit and others loose from ECB UMP actions. Advanced economies, which are more financially integrated with the Euro area and have a larger share of domestic banks, tend to have output and inflation dynamics which are qualitatively similar to those of the Euro area. For financially less developed countries, which have a larger share of foreign banks, the macroeconomic effects may differ. International transmission occurs both via trade (the exchange rate channel) and via financial markets (wealth, risk and portfolio rebalancing channels). However, contrary to the popular view, the exchange rate rate channel does not seem to shape the responses of foreign macroeconomic variables to Euro area UMP shocks. This is in sharp contrast to the international transmission of conventional monetary policy shocks, where exchange rate movements are crucial to understand foreign output and foreign inflation dynamics.

The current work can be extended in various ways. For example, one could study announcement effects in more detail. While we controlled for them in the estimation, we excluded from the analysis any potential anticipatory effect that announcements can generate. Taking expectations into account might give the credit channel a better chance to matter. In addition, since the UMP adopted by the ECB fall into two classes (liquidity and sovereign bond policies) it may be worth to distinguish disturbances to different types of policy instruments. Because of the relative short sample, we decided to look at the whole set UMP measures, but this means our results are likely driven by the largest instrument in the package (LTROs). Finally, we have assumed that structural parameter are stable in the sample. Ciccarelli et al. (2013) suggested that time variations could play an important role in international policy transmission. Investigations of this type are likely to improve our understanding of how UMP measures are transmitted, both domestically and internationally, and give policymakers a more solid ground to decide which policy to implement.

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Appendix A: ECB Unconventional Monetary Policy measures

Table A.1: Timeline of ECB unconventional monetary measures

Date	Tool	Total size in Bn of € (outstanding)
Dec. 2007-ongoing	Reciprocal Currency Agreement	271.6
Mar. 2008-May 2010	6-month Long term refinancing operations	66
May–Dec. 2009	12-month Long term refinancing operations	614
Jun. 2009-Jun. 2010	Covered Bond Purchase Programme	45
May 2010-Aug. 2012	Securities Market Programme	195
Aug. 2011	12-month Long term refinancing operations	49.8
Oct. 2011	13-month Long term refinancing operations	57
Nov. 2011-Oct. 2012	Covered Bond Purchase Programme 2	15
Dec. 2011	36-month Long term refinancing operations	489
Feb. 2012	36-month Long term refinancing operations	530
Jul. 2012	Draghi's "Whatever it takes speech"	
Aug. 2012-ongoing	Outright Monetary Transaction	
Jul. 2013	Forward Guidance	

Source: ECB weekly Financial Statements; ECB Statistical Warehouse; Cecioni et al. (2011).

Two main policy categories can be identified summarizing most 'unorthodox' policies adopted by the ECB: liquidity policies and sovereign debt policies. Liquidity policies were conducted as a reaction to the financial crisis; sovereign bond policy appeared later on.

According to Trichet (2009) ECB's unconventional tool box included five liquidity policy measures to aid the interbank market. The first of these tool was introduced in October 2008 - the new fixed-rate full allotment tender procedure - and designed to ensure that the high demand for liquidity, which reached a peak of 95 billion Euros during the crisis, could be met. The policy allow credit institutions to acquire an unlimited amount of Euros in an auction at a fixed rate. The second, also introduced in October 2008, expanded the list of assets that were accepted as collateral. These two tools together ensured an almost unlimited refinancing to the 2200 credit institutions which had access. The third tool allowed lengthening of the maturities of the longer term refinancing operations (LTROs) from three months to up to three years. In March and July 2008, the first six-month full allotments were announced and twelve-month LTROs were introduced in June 2009. In December 2011 and then again in February 2012, LTROs with a maturity of three years were introduced to provide more long term liquidity and to ease interbank market tensions. The fourth tool ensured enough liquidity of foreign currency, particularly of the US Dollar. This was conducted by a direct swap line with the Federal Reserve. The final measure, covered bond purchases (CBPs), introduced in 2009, allowed the ECB to purchase of debt securities issued by banks. This allowed banks to have even longer-term funding than through refinancing operations following the complete shut down of the covered bond market during the financial crisis [3]. In November 2011, a second round of CBPs was introduced. These five tools make up what we term (in-)direct liquidity policy.

As far as sovereign debt policy is concerned, a measure was introduced in May 2010 that allowed the ECB to purchase public and private debt securities - the Security Market Programme (SMP). The official objective of the SMP is to provide more liquidity to 'dysfunctional' market segments to ensure that transmission channels for monetary policy are properly operating. The ECB conducted sterilizing operations to re-absorb the excess liquidity. The composition of the SMP consisted of 47% Italian debt, 22% Spanish, 16% Greek and the remaining percent on Irish and Portuguese debt. The final measure was announced in August 2012, when the SMP was aborted - the Outright Monetary Transactions (OMT). Similarly to the SMP, the OMT is the sterilized purchase, conditional on certain domestic economic conditions, of 1 to 3 year maturing government debt. The aim of the policywas to restore confidence in the Euro and to lower long-term yields for troubled economies.

[3] CBPs are different from asset backed securities. The risk associated with covered bonds stays with the originator, so that the ECB was not necessarily subjected to more risk and the issuing institution still had an incentive to constantly evaluate credit risk. This is in contrast to the US and the UK, where the Fed started buying asset-backed securities, commercial papers and direct obligation of mortgage backed securities and the BoE introduced an asset purchase facility, to ease the non-bank credit market. Since banks are the biggest holders of covered bonds in Europe, such a measure was designed to improve interbank market conditions.

Appendix B

This appendix describes the algorithm used to draw sequences for the posterior distribution of the missing variables and of the parameters - see also Qian, 2013.

Let $z_{\setminus t}$ be the vector of all missing observations and let (z, x) represent all recorded observations. The algorithm works as follows:

1. Define a matrix of data Y (missing observations are indicated by NaN).

2. Analyze the aggregation structure (if data comes as sum, average, end-of-period) and define a matrix, M, indicating which observations are missing. For example, if we have two variables, one monthly average which we observe once in the final week, and one weekly which we observe four times, we construct $\overrightarrow{M}$, vectorizing $\underset{kxT}{M}$ column by column, so that $\overrightarrow{M} = [0, 0, 0, 1, 1, 1, 1, 1]'$.

3. Transform the averaged data into summed data, where the average is $\overline{z}_{a,b} \equiv \frac{1}{b-a+1} \sum_{t=0}^{b-a} \hat{z}_{\setminus t+a}$, and the sum $z_b = (b - a + 1)\overline{z}_{a,b}$.

4. Specify a normal prior for the coefficients, A, B, and an inverted Wishart prior the variance Σ.

5. Draw initial values for the coefficients, A, B, and for the variance Σ.

6. Specify initial values for the latent data by substituting missing values with sums computed from Step 3.

7. Construct the matrix $\underset{Tk\times Tk}{T}$ that will account for time-aggregation. In our case $T = 262$ and $k = 12$. Initially, $\underset{3144\times 3144}{T}$ is an identity matrix. Using the matrix M, we scan each row,i, and column,j, for missing values, m. In the previous example, we have $m = 1, 2, 3$ in $i = 1$ right before $j = 4$. We add one for every missing variable to the transformation matrix in row $(j-1)k + i$ and column $(j-1)k + i - mk$. The transformation matrix is then:

$$\underset{8\times 8}{T} = \begin{pmatrix} 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 \\ 1 & 0 & 1 & 0 & 1 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 \end{pmatrix}.$$

8. Transform the data using $\overrightarrow{M}Y$, so that we have both, a latent disaggregated block and an observed block.

9. Start the Gibbs sampler:

   (a) Estimate the VAR coefficients and draw parameter estimates from $f(A^i, B^i|\hat{Y}^i, \Sigma^{i-1})$.

   (b) Estimate the variances of the VAR and draw the variance estimates from $f(\Sigma^{i-1}|\hat{Y}^i, A^i, B^i)$.

   (c) Compute the covariance matrix of the VAR using draws for the coefficients, $\hat{A}, \hat{B}$, and the variance $\hat{\Sigma}$.

   (d) Constrain the multivariate normal (MVN) distribution using the transformation matrix A, so that $y_t \sim MVN(A\eta,\, A\Omega A') = MVN(\mu,\, \Sigma)$. The distribution for the latent variables is

   $$z_{\setminus t}|z, x \sim MVN(\mu_0 + \Sigma_{01}\Sigma_{11}^{-1}((z,x)' - \mu_1), \Sigma_{00} - \Sigma_{01}\Sigma_{11}^{-1}\Sigma_{10}),$$

   where Σ_{01} is a submatrix of Σ representing the covariances between the missing and the observed observations. Σ_{00} is the variance of the missing observations and Σ_{11} is the variance of the observed data.

   (e) Sample missing data from the conditional constrained MVN described in Step 9.d (in blocks). That is, for all $t = 1, .., T$, we draw missing data from $f(\hat{z}_t^i|x, \hat{z}_{\setminus t}^{i-1}, A^i, B^i, \Sigma^i)$.

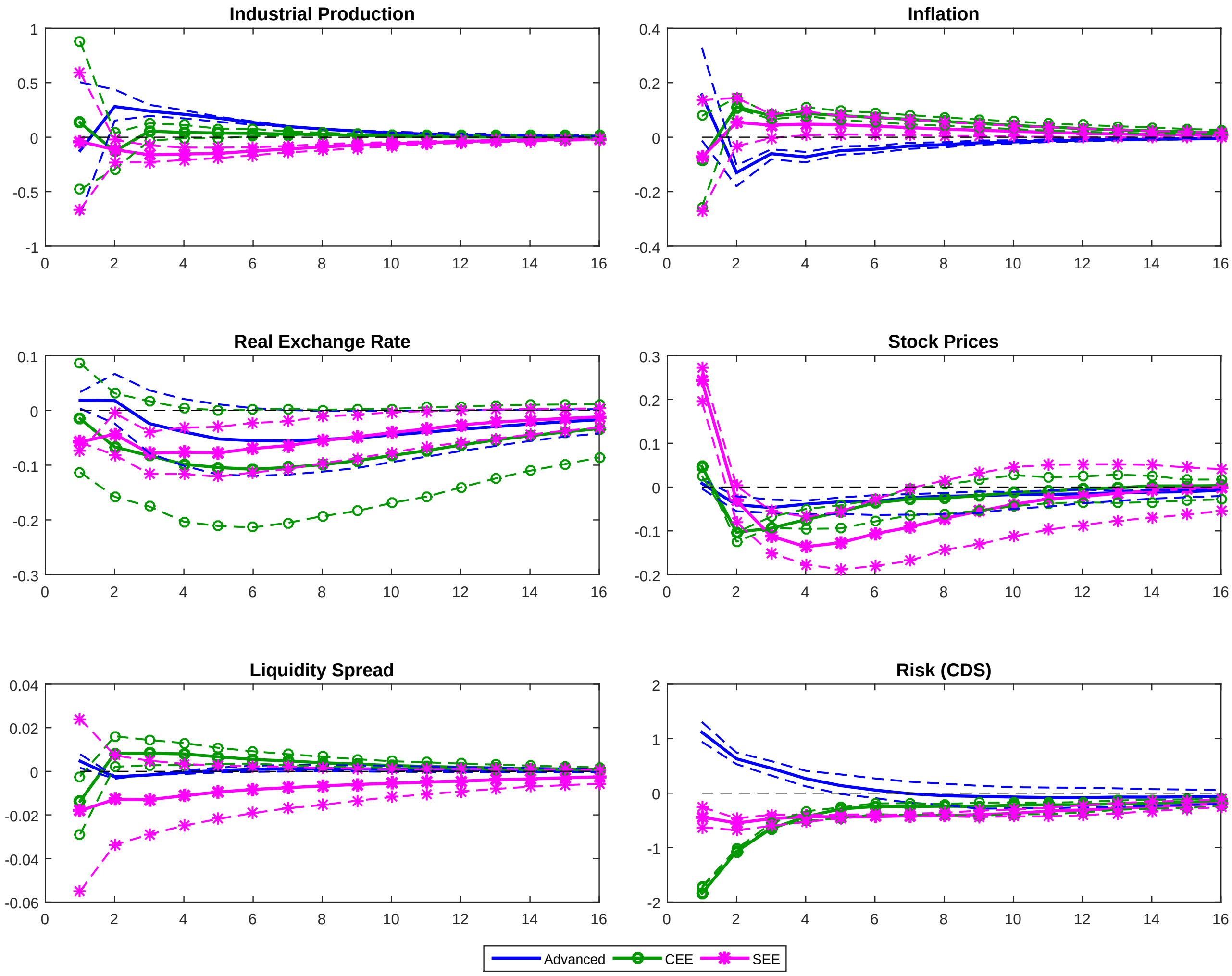
   (f) Repeat steps (a) through (e).

10. Examine convergence using e.g. CUSUM statistics.

The results we present are based on 12500 draws: we discard the first 2500 as burn-in, and retain every 20th draw to reduce serial correlation. Inference is based on 500 saved draws.

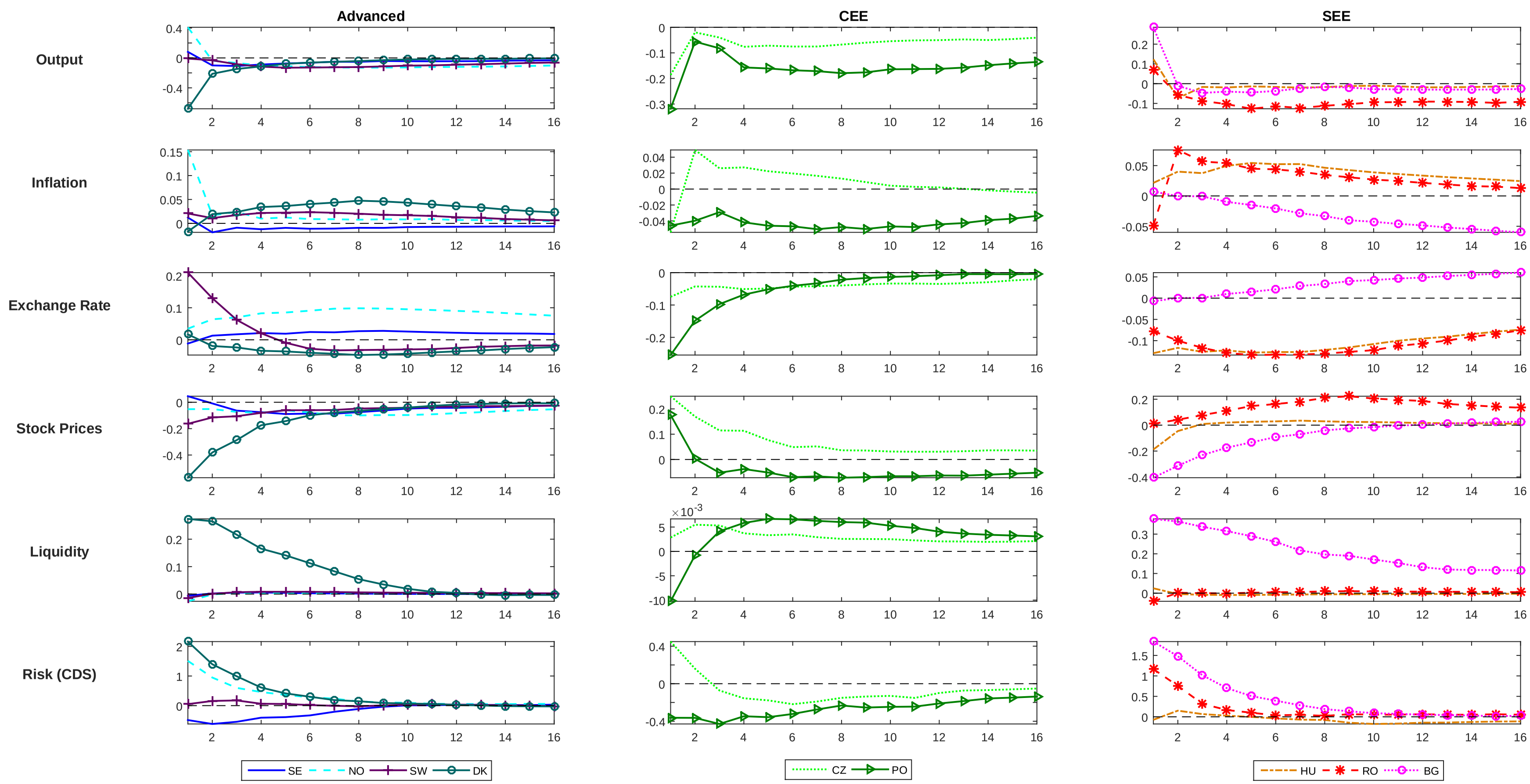
Appendix C: Additional Results

Figure C.1: Group responses to Euro area UMP shocks



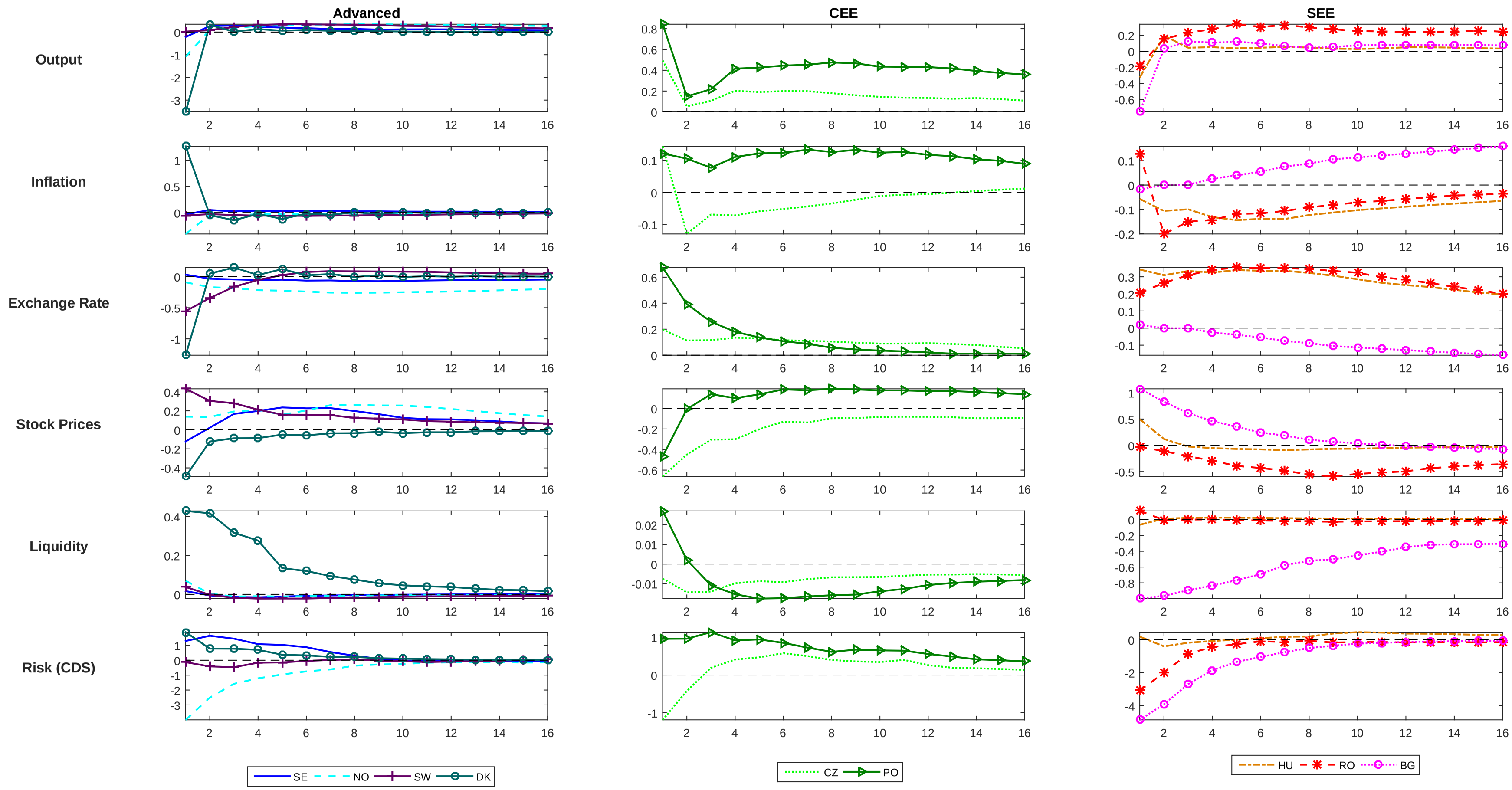
Note: The solid lines report pointwise average posterior median responses in deviations from Euro area responses. The dotted lines pointwise 68% credible intervals. The x-axis reports weeks, while the y-axis monthly growth rates for all variables but the liquidity spread.

Figure C.2: Foreign responses to conventional Euro area interest rate shocks



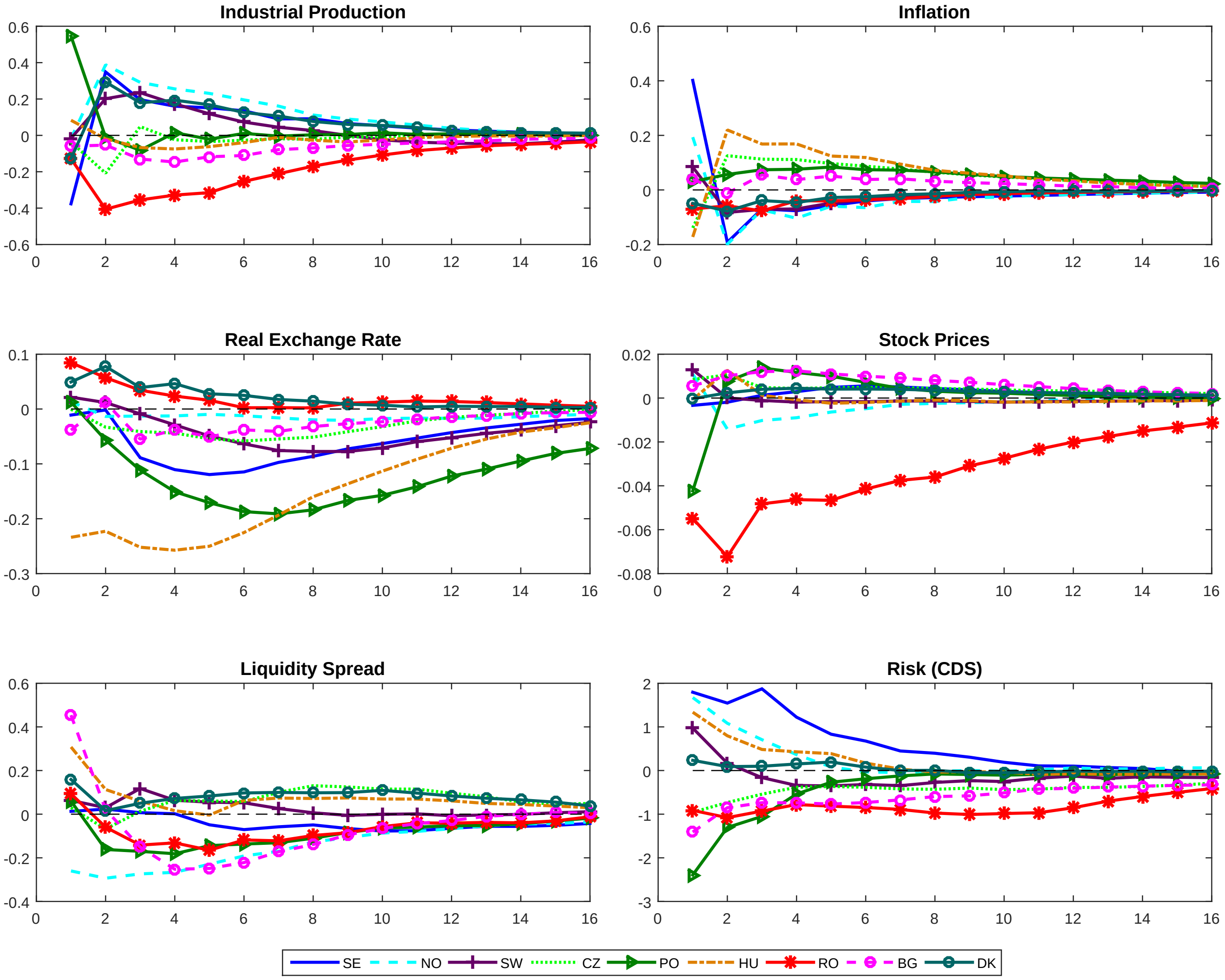
Note: The lines report pointwise posterior median responses in deviations from Euro area responses. The x-axis reports weeks, the y-axis monthly growth rates for all variables but the liquidity spread. The size of the shock corresponds to 10 monthly basis points.

Figure C.3: Foreign responses to Euro area announcement shocks



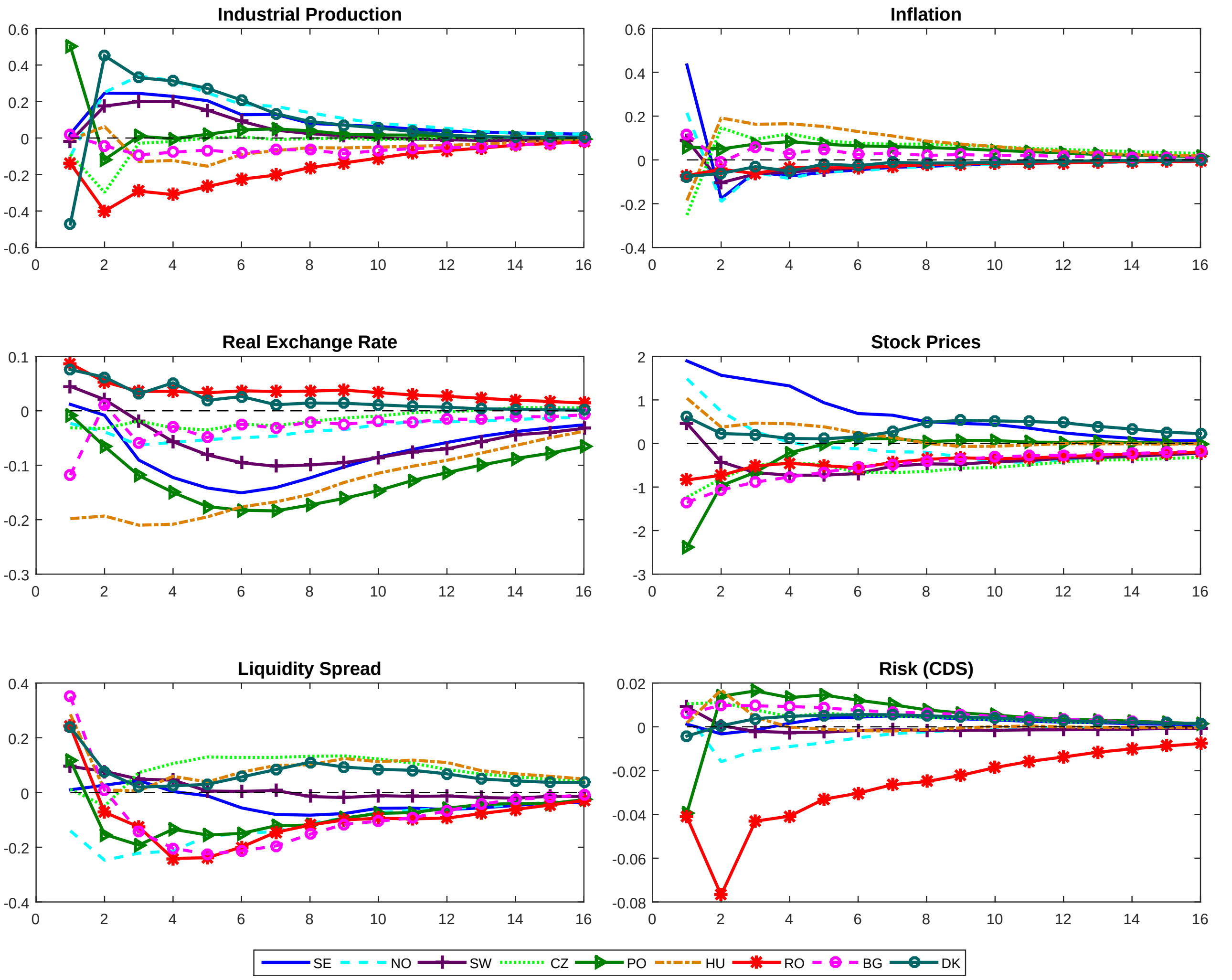
Note: The lines report pointwise posterior median responses in deviations from Euro area responses. The x-axis reports weeks, the y-axis monthly growth rates for all variables but the liquidity spread. The size of the shock is one policy announcement.

Figure C.4: Foreign responses to Euro area UMP shocks: Identification R1



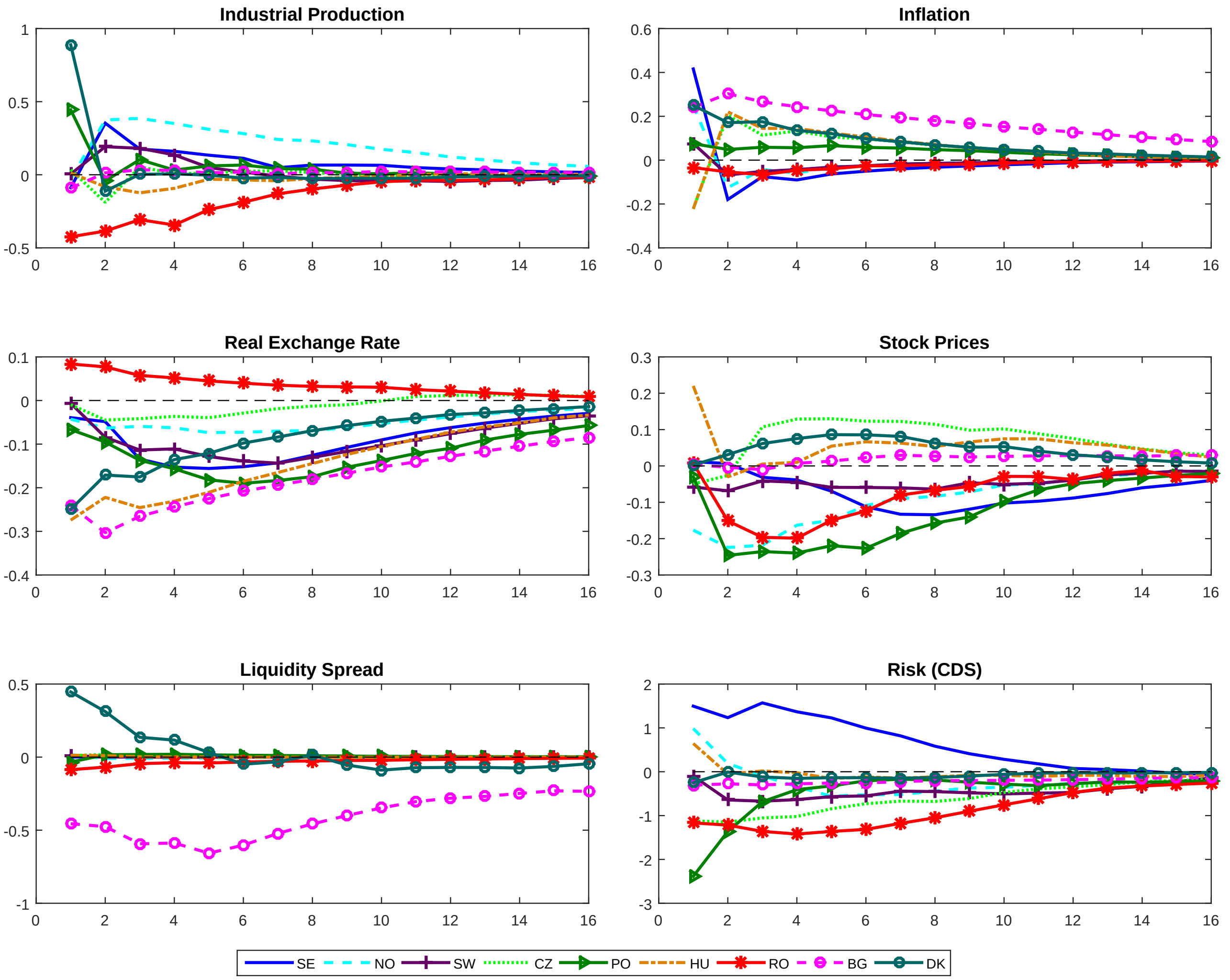
Note: The lines report pointwise posterior median responses in deviations from Euro area responses. The x-axis reports weeks, the y-axis monthly growth rates for all variables but the liquidity spread. The size of the shock is one standard deviation of UMP growth (a 10% monthly increase in the quantity of UMP).

Figure C.5: Foreign responses to Euro area UMP shocks: Identification R2



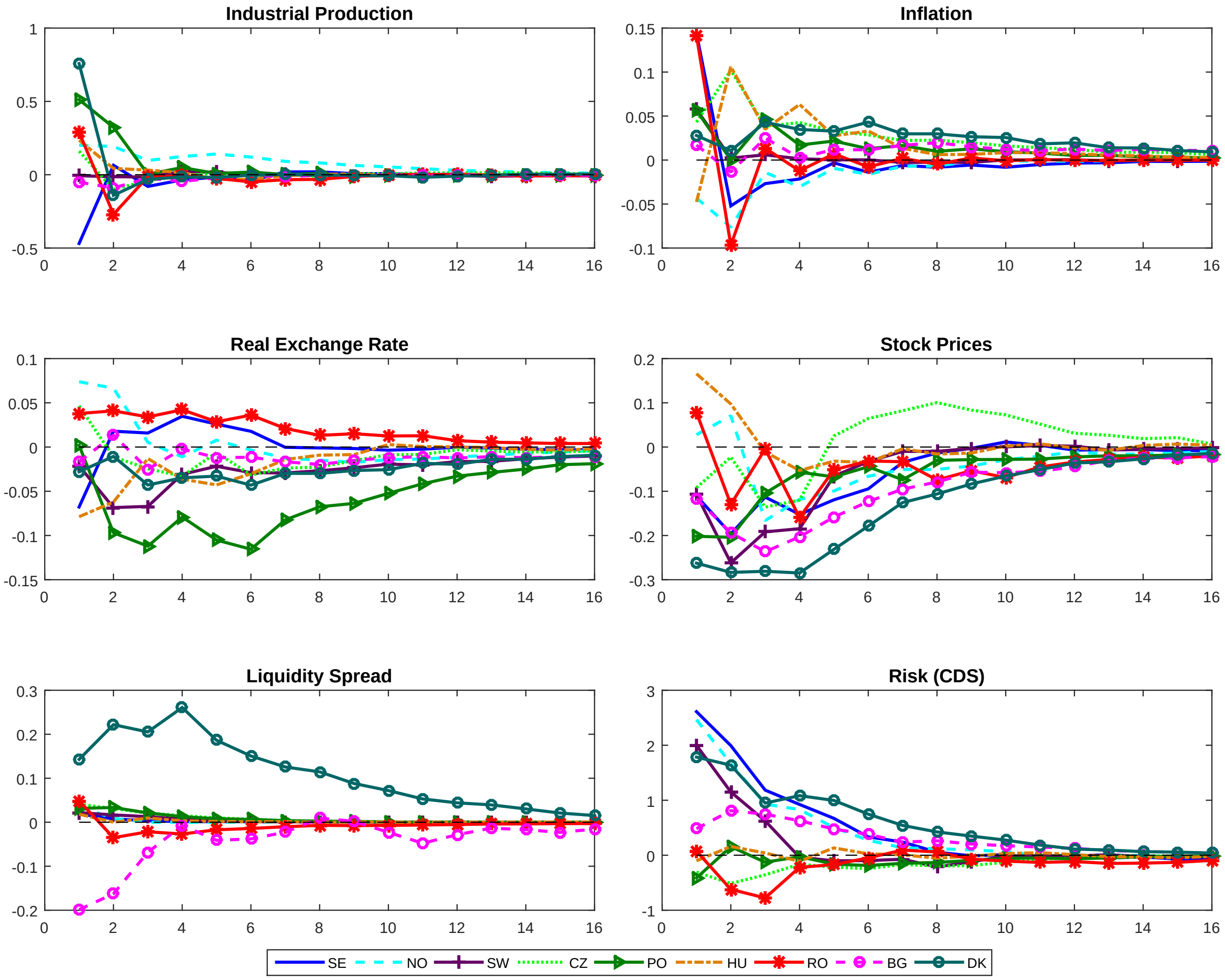
Note: The lines report pointwise posterior median responses in deviations from Euro area responses. The x-axis reports weeks, the y-axis monthly growth rates for all variables but the liquidity spread. The size of the shock is one standard deviation of UMP growth (a 10% monthly increase in the quantity of UMP).

Figure C.6: Foreign responses to Euro area UMP shocks: Identification R3



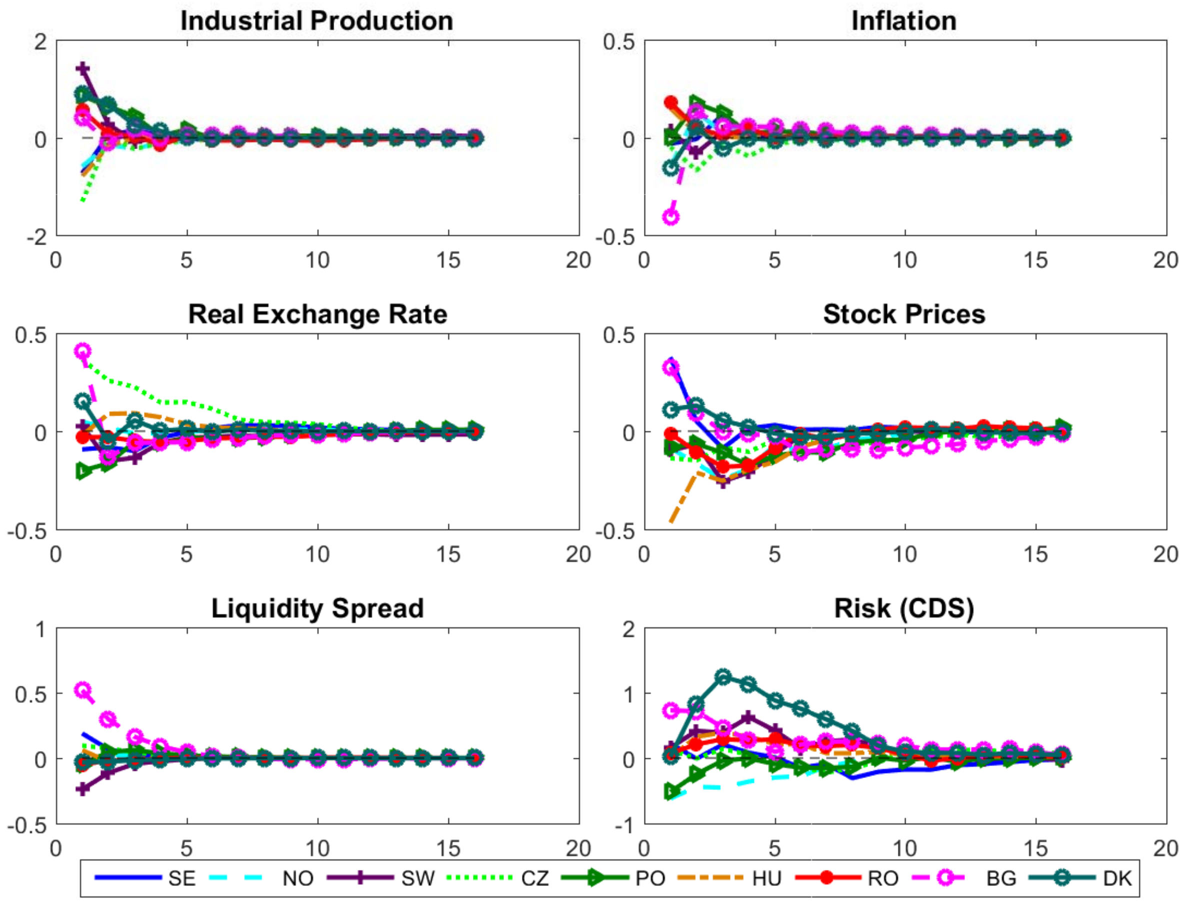
Note: The lines report pointwise posterior median responses in deviations from Euro area responses. The x-axis reports weeks, the y-axis monthly growth rates for all variables but the liquidity spread. The size of the shock is one standard deviation of UMP growth (a 10% monthly increase in the quantity of UMP).

Figure C.7: Foreign responses to Euro area UMP shocks: Identification via zero and sign restrictions



Note: The lines report pointwise posterior median responses in deviations from Euro area responses. The x-axis reports weeks, the y-axis monthly growth rates for all variables but the liquidity spread. The size of the shock is one standard deviation of UMP growth (a 10% monthly increase in the quantity of UMP).

Figure C.8: Foreign responses to Euro area UMP shocks: Identification via heteroskedasticity



Note: The lines report pointwise posterior median responses in deviations from Euro area responses. The x-axis reports weeks, the y-axis monthly growth rates for all variables but the liquidity spread. The size of the shock is one standard deviation of UMP growth (a 10% monthly increase in the quantity of UMP).