The Transmission of Euro Area Monetary Shocks to the Czech Republic, Poland and Hungary: Evidence from a FAVAR Model

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We analyze the effects of euro area monetary policy on three Central and Eastern European non-euro area EU countries: the Czech Republic, Poland and Hungary. We employ an open economy version of the factor-augmented vector autoregression model (FAVAR) to estimate the cross-border effects of a contractionary monetary policy of the ECB. We find significant and sizeable effects of euro area monetary policy in these small and highly open economies, with economic activity variables being primarily affected through the impact of increased interest rates and reduced foreign demand – thus leading to a contraction of GDP – and exchange rate effects being important for price reactions.

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1 Introduction

The euro area accounts for more than 16% of world GDP at purchasing power parities and for 75% of EU GDP. With the exception of the U.K., all non-euro area EU members are small in comparison to the euro area as a whole. Representing 3% of total EU GDP in 2009, Poland is the second largest non-euro area EU country. Taking into account the importance of trade and financial linkages between non-euro area EU countries and the euro area, the monetary policy of the euro area is likely to have sizable effects on the small and open non-euro area EU countries. Although there is an abundant literature on monetary policy spillovers for countries within the sphere of influence of the U.S.A., there has been little empirical research on the transmission of monetary policy from the euro area to other EU members. One obvious explanation relates to the fact that the euro area was created only a relatively short time ago. The effects of monetary policy are usually studied within the framework of time series models and therefore require long time series. Clearly, the first studies based on observed data for the euro area were devoted to analyzing the workings of monetary policy within the euro area itself, taking into account the particular feature of different economies sharing a common monetary policy (see for example Peersman and Smets, 2001, and Peersman, 2004). Those studies that look in particular at the Central and Eastern European (CEE) EU member countries mostly focus on domestic monetary policy transmission channels in the context of these countries' transition from centrally planned to market economies (see for example Elbourne and de Haan, 2006, and Golinelli and Rovelli, 2005).

We aim to fill the gap of research on monetary policy spillovers in the European context by putting the focus explicitly on the effects of euro area monetary

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policy on three small and highly open EU member countries with flexible exchange rates: the Czech Republic, Poland, and Hungary.[3] Shedding some light on the impact of the ECB's decisions on these countries is of utmost importance, not only in view of future euro adoption in the region, but also in light of the recent unconventional monetary policy measures taken by the ECB to overcome the financial and economic crisis.

The existing literature on cross-border effects of monetary policy is vast, but inconclusive to date. The transmission of a monetary shock from a foreign country to the domestic economy can occur through different channels: The change in the foreign country's interest rate has an indirect effect on a small country, since the large foreign country can influence the global interest rate. An additional, direct interest rate effect can occur via domestic borrowing in foreign currencies, which may be of particular relevance in Central and Eastern European countries (CEECs). In general, the interest rate effects will be positively correlated between the two countries. Further, changes in foreign demand trigger an output response in the same direction in both countries. Another effect works through exchange rate movements, which cause effects on foreign and domestic output with opposing signs. Transmission can also occur through financial markets, as monetary growth abroad can trigger capital flows with an ambiguous net effect on the domestic liquidity situation. We apply a factor-augmented vector autoregression model (FAVAR), which seems highly appropriate in this context as it takes into account the largest possible amount of data series which may influence an economy's reaction to a monetary policy shock. This method has been developed first by Bernanke, Boivin and Eliasz (2005) to study the domestic effects of U.S. monetary policy. It was extended to the open economy case by Boivin and Giannoni (2008) and Mumtaz and Surico (2009), thus allowing the incorporation of international monetary policy transmission.

We find sizable effects of euro area monetary policy on the Czech Republic, Poland and Hungary overall. An unexpected increase in the euro area interest rate results in a contraction of all three economies, leading us to conclude that the foreign demand and interest rate effects (the latter being reinforced through foreign currency loans in these countries) dominate the reaction of real economic activity variables, while the exchange rate effect is important for price reactions, leading to higher export and import deflators. The reaction is strongest in Hungary, followed by the Czech Republic, and considerably smaller in Poland, the largest of the three economies.

The paper proceeds as follows: In section 2 we explain the various transmission channels and review the relevant literature. Section 3 describes the FAVAR model and applies it to the open economy. The database and the results of the factor analysis are given in section 4. Section 5 describes the effects of a contractionary monetary policy in the euro area and in each of the three countries, and section 6 concludes.

[3] *Our sample was determined by data considerations. Since we need roughly 200 time series over the whole observation period, we restrict the analysis to these three countries. We also focus on countries with a flexible exchange rate regime. The form of monetary policy transmission and hence the interpretation of the results for EU members which have pegged their currency to the euro is quite distinct and would go beyond the scope of this study.*

2 Cross-Border Effects of Monetary Policy

Open economy models do not offer a clear prediction about the effect of foreign monetary policy on domestic economic activity and prices. On the one hand, a restrictive monetary policy shock abroad will decrease foreign activity and, as a result, lower the demand for domestic products. This limits domestic output as do higher world interest rates and higher interest rates on foreign currency borrowing. On the other hand, according to the standard Mundell-Fleming framework, monetary restriction abroad will lead to a depreciation of the domestic currency under a floating exchange rate regime and will redirect demand from foreign goods toward domestic products. Thus, monetary policy affects foreign countries through a positive foreign demand and interest rate effect and a negative exchange rate effect with an ambiguous net outcome. The sign and the size of cross-border monetary policy transmission depend on many factors, such as country size, openness to international trade, the monetary policy regime and in particular the flexibility of the exchange rate, structural issues such as different degrees of wage and price stickiness, and the like.

In the particular case of Central, Eastern and Southeastern European countries, yet another factor comes into play: Loans in foreign currency are of great importance in these countries (Beckmann, Scheiber and Stix, 2011; Fidrmuc, Hake and Stix 2011), especially in Hungary and, to a lesser extent, in Poland. As a result, euro area monetary policy has an additional direct effect on these countries through a traditional interest rate channel.

During the last decade many empirical studies focused on the question of the cross-border effects of monetary policy, primarily studying the effect of U.S. monetary policy on other countries. Perhaps the most popular method of investigating the outcome of a foreign monetary policy shock is the structural VAR (SVAR) approach. Kozluk and Mehrotra (2009) broadly classify such papers into two categories. Papers from the first category estimate a VAR model for a large foreign economy augmented by some external variables for the domestic economy (Kim, 2001; Mackowiak, 2006), while papers from the second category estimate the model for a small domestic economy augmented by foreign variables (Kim and Roubini, 2000; Sousa and Zaghini, 2008; Kozluk and Mehrotra, 2009). However, there are papers which are difficult to classify into any of the above-mentioned groups as the set of domestic and foreign variables is about equal in size (Mojon and Peersman, 2003; Canova, 2005; Miniane and Rogers, 2007; Mumtaz and Surico, 2009). Some of these papers follow Cushman and Zha (1997) and apply the block-recursive structure of the two-country model, which assumes a unidirectional effect from the large economy to the small one. A recent theoretical contribution is given by Boivin, Giannoni and Mojon (2009), who aim to shed light on the evolution of the transmission mechanism by setting up a stylized two-country model. The calibrated model compares monetary transmission in the pre-EMU and the EMU periods. The model predicts significant benefits for a country joining a monetary union. In particular, a foreign interest hike results in a more contained domestic (short- and long-term) interest rate increase, boding well for consumption and thereby stabilizing output.

Several papers report a positive effect from foreign monetary expansion on activity in the domestic country, although in some cases the effect of the depreciating foreign currency outweighs the positive spillover effects. Kim and Roubini

(2000) find significant effects of U.S. monetary policy shocks on output levels of non-U.S. G7 economies. The output response is mixed. In the comparatively small G7 economy Canada, where the interest rate reacts strongly to the U.S. rate, output falls significantly in response to a U.S. rate increase. In large economies like Japan and Germany, the exchange rate depreciates more, and the output response to a higher Federal Funds Rate is positive. In Kim (2001) an expansionary monetary policy shock in the U.S.A. is shown to increase real GDP in the remaining G7 countries, with changes in the trade balance seeming to be too small to explain this boom. He concludes that the increase in world aggregated demand triggered by the lower world real interest rate is the important channel in the transmission. Schmidt (2006) offers an alternative explanation for these positive effects of U.S. monetary expansion, namely the asymmetry in the price-setting behavior of firms which arises as a result of dollar pricing in international exports. Canova (2005) finds that U.S. monetary policy shocks have important effects on Latin America, with U.S. contractionary monetary disturbance boosting domestic production with a time lag due to increased capital inflows.

Mackowiak (2006) finds that an expansionary monetary policy in Japan increases real output in Japan and depreciates the yen against the U.S. dollar. As the expansionary monetary policy causes a decrease in Japanese net exports and increases net exports of Japan's neighbors in the short run, positive spillover effects dominate. Similar findings for China are reported in Kozluk and Mehrotra (2009): A monetary expansion in China leads to an increase in real GDP (temporary) and the price level (permanent) in a number of economies in East and Southeast Asia, most notably in Hong Kong and the Philippines.

Mumtaz and Surico (2009) use the more sophisticated FAVAR approach for a panel comprising 17 industrial countries to investigate the international transmission mechanism. They conclude that an expansionary shock to monetary policy in the foreign block causes the nominal exchange rate of the pound sterling to appreciate. The growth rate of GDP and consumption increase temporarily but significantly, CPI and GDP deflator inflation reach their maximum values in the third year after the shock.

While the literature on the international transmission of monetary policy is abundant, there is – to our knowledge – very little research that looks into the specific effects of euro area monetary policy on non-euro area Eastern European EU members. Peersman (2004) looks at the effects of ECB monetary policy on individual euro area members, finding largely similar effects in individual member countries. In an earlier study, Peersman and Smets (2001) focus on euro area-wide effects of the common euro area monetary policy based on a synthetic sample from 1980 to 1998. They find stable effects comparable to those for the U.S.A. Another strand of the literature with a European focus analyzes the effects of monetary policy during the transition of Eastern Europe. Golinelli and Rovelli (2005) show that even though monetary policy followed different paths in the Czech Republic, Poland and Hungary, it was successful in achieving disinflation. Elbourne and de Haan (2006) look at the link between financial structures and monetary policy, finding little evidence for such a link.

Jiménez-Rodriguez, Morales-Zumaquero and Égert (2010) specifically look at the impact of international monetary shocks on Central, Eastern and Southeastern Europe. Using a rather long sample period, starting in the early 1990s, and a near-VAR analysis, they find evidence for structural breaks, including the global

crisis. They further find a weak but contractionary response of industrial production to a positive euro area interest rate shock (with the exception of the Czech Republic and Slovenia) and a fall in prices in almost all countries reviewed, while the effects on interest rates and effective exchange rates are mixed across countries.

3 Description of the Methodology

3.1 The Main Idea of a FAVAR Model

A vast body of monetary research has been devoted to uncovering monetary policy effects on macroeconomic variables. A conventional tool to explore and account for these effects is a vector autoregression model (VAR). Yet, standard VAR models can capture only a small number of variables, since a larger number leads to a substantial loss of degree of freedom. This is an especially severe limitation for CEECs, for which typically relatively short data series are available. However, according to Bernanke, Boivin and Eliasz (2005), two potential problems arise from such a small set of variables: First, the small number of variables is unlikely to span the dataset that central banks use to make their policy decisions. As a result, the measurement of policy shocks in this way is likely to be affected by an omitted-variable bias. Second, using standard VAR analysis, we can observe impulse responses only for variables that are included in the given framework, and a large number of economic variables that we are interested in are left out.

Bernanke, Boivin and Eliasz (2005) propose the solution to these problems by using the VAR analysis for a small number of unobservable factors which are extracted from a large dataset and represent different dimensions of the set of explanatory variables (factor-augmented vector autoregression, FAVAR). These latent factors account for the common dynamics of hundreds of macroeconomic variables and summarize the bulk of information about the whole economy in a small number of factors. Impulse responses of key macroeconomic variables are then constructed using the impulse responses of factors and corresponding factor loadings.

The main idea of FAVAR is to consider the joint dynamics of latent factors that span most of the economic variables and the observable monetary policy variables that have comprehensive effects throughout the economy. The joint dynamics of factors is assumed to be defined by a structural VAR as

$$\Phi_0 \begin{bmatrix} F_t \\ R_t \end{bmatrix} = \Phi(L) \begin{bmatrix} F_{t-1} \\ R_{t-1} \end{bmatrix} + \varepsilon_t \qquad (1)$$

where R_t is a $(M \times 1)$ vector of observable policy variables that affect the economy, F_t is a $(K \times 1)$ vector of unobservable factors excluding the above-mentioned policy variables, $\Phi(L)$ is a lag polynomial of finite order p, and ε_t is a vector of shocks assumed to be iid with mean zero and covariance matrices Q. The monetary policy shock is identified using a Cholesky identification scheme assuming that the monetary policy variable has only a lagged impact on unobservable factors.

The vector F_t is unobservable, and equation (1) cannot be estimated directly, although the information on latent factors could be extracted from a large set of observable economic variables. It is assumed that the $(N \times 1)$ vector X_t consisting of macroeconomic time series can be represented as a linear combination of the latent factors and the observable policy variables so that

$$X_t = \Lambda^F F_t + \Lambda^R R_t + e_t \tag{2}$$

where Λ^F and Λ^R are factor-loading matrices with $(N \times K)$ and $(N \times M)$ elements respectively, residuals e_t are allowed to be serially and weakly correlated across indicators. The number of unobservable factors and policy variables is much smaller than the number of macroeconomic time series $(N>>K+M)$.

3.2 FAVAR Analysis for a Small and Open Economy

As we are interested in the transmission of euro area monetary policy to the Czech Republic, Hungary and Poland, we need to extend the general FAVAR model to the case of two countries. We follow the approach of Boivin and Giannoni (2008) and assume that in each country, the state of the economy can be summarized by a vector of common factors. Since we are interested in the international policy spillover effect, we further restrict the analysis to the case where only the vector of foreign common factors contains a monetary policy variable. In this paper we estimate a model containing one large foreign and one small domestic economy, assuming that the CEEC of interest is the small economy, while the euro area is the large economy.

These assumptions seem to be well justified. Poland, by far the largest of the three economies, accounted for 3.5% of euro area GDP in 2010, according to Eurostat data based on exchange rates; this ratio increased recently due to Poland's outstanding economic performance compared to that of other EU members during the economic crisis. The GDP of the Czech Republic represents 1.5% of euro area GDP, while the figure for Hungary is 1%. Further, a clear asymmetry is reflected in trade relations. The euro area represents the most important trading partner for all three countries. Euro area imports ranged between 54% of total imports in Hungary and 60% in the Czech Republic in 2010. This share has fallen somewhat after a sharp upward spike in the accession year 2004, when euro area imports accounted for 70% of total Czech imports. On the export side, the euro area is even more important, with the respective trade shares coming to 56% for Hungary and Poland and to 66% for the Czech Republic. In contrast, euro area exports to these three countries have been rising steadily and accounted for 5.6% of total exports in 2010. The importance of these three countries for the euro area is identical on the import side.

Both small and large economies can be described by the respective vector of common factors $Z_t=[\hat{F}_t]'$ and $Z^*_t=[\hat{F}^*_t \; R^*_t]'$, where the large foreign economy (i.e. the euro area) is denoted by *. Unobservable factors $\hat{F}_t$ and $\hat{F}^*_t$ are separately extracted from a large set of macroeconomic variables X_t and X^*_t accordingly, using the algorithm fully described in the appendix[4] to this paper. In this asymmetric case, where we are interested in foreign monetary policy shocks only, this is reduced to the extraction of factors by principal components for the small economy.[5]

[4] *The appendix is available online only (see www.oenb.at).*

[5] *Since we are not interested in the effects of domestic monetary policy – a strand of the literature that has been extensively researched – there is no need to include separate domestic policy rates in the model (on the contrary, the strong correlation of the Czech domestic interest rate with the EURIBOR might introduce additional noise in the estimation). To corroborate this point, the share of interest rate variance explained by the first three common factors is rather low in all three countries under consideration (40.8% for the Czech Republic, 9.3% for Hungary, 34.3% for Poland). We take this as an indication that the influence of domestic interest rates is small for the purpose of our analysis.*

We follow the approach introduced by Cushman and Zha (1997) and subsequently used by Mojon and Peersman (2003) and Canova (2005) and assume a unidirectional causality from the large economy to the small one. In other words, we impose zero restrictions on some FAVAR coefficients in order to identify the inability of a small open economy to influence economic developments in a large foreign economy:

$$\begin{bmatrix} Z_t^* \\ Z_t \end{bmatrix} = \begin{bmatrix} \phi_{1,1}(L) & 0 \\ \phi_{1,2}(L) & \phi_{2,2}(L) \end{bmatrix} \begin{bmatrix} Z_{t-1}^* \\ Z_{t-1} \end{bmatrix} + u_t \tag{3}$$

The lag polynomials $\varphi_{1,1}(L)$ and $\varphi_{1,2}(L)$ show the impact of the large economy on itself and on the small economy respectively. Lag polynomial $\varphi_{1,2}(L)$ is of major interest to us as it identifies the transmission of a monetary shock in the euro area to CEECs. In our FAVAR model we assume that $\varphi_{2,1}(L)$ is equal to zero, so there is no effect from CEECs on the euro area at any lags. The null hypothesis that lagged values of CEECs have zero coefficients in the euro area block is not rejected for any of the three CEECs in our analysis.

In this paper, we use an identification scheme which is very similar to the standard Cholesky decomposition (a recursive identification scheme was also used by Bernanke, Boivin and Eliasz, 2005, and Blaes, 2009). The variables are ordered as follows: $(F_t^*, R_t^*, F_t)'$. Thus, the euro area's factors contemporaneously determine the movements in the CEECs' factors but not vice versa. The order of variables also assumes that monetary policy variables react contemporaneously to factor movements but not otherwise. The additional restriction we implement concerns the impact of the large country's monetary policy shock on the small economy. In the Cholesky decomposition we already assumed that the large country's interest rate does not affect unobservable factors of the large country, which is a quite traditional and realistic assumption, as real activity variables and prices have a lot of inertia and react to monetary policy with a lag. Consequently, we also assume that it has no influence on the small economy's latent factors. Hence, we end up with the following over-identified restriction scheme:

$$\begin{bmatrix} 1 & 0 & 0 \\ -\alpha_{R^*,F^*} & 1 & 0 \\ -\alpha_{F,F^*} & 0 & 1 \end{bmatrix} \begin{bmatrix} u_t^{F^*} \\ u_t^{R^*} \\ u_t^{F} \end{bmatrix} = \begin{bmatrix} \gamma_{F^*} & 0 & 0 \\ 0 & \gamma_{R^*} & 0 \\ 0 & 0 & \gamma_F \end{bmatrix} \begin{bmatrix} \varepsilon_t^{F^*} \\ \varepsilon_t^{R^*} \\ \varepsilon_t^{F} \end{bmatrix} \tag{4}$$

The order of unobservable factors coincides with their order in the principal component extraction, which may be subject to criticism, as these factors have no economic interpretation. However, the first factor is usually associated with economic activity, which is largely predetermined in the current period. Also, we experiment with changing the order of unobservable common components in the Cholesky decomposition, which, however, does not affect our results significantly.

4 Database and Extracted Factors

4.1 Data Description

As regards the observable monetary policy instrument variable, changes in the 3-month EURIBOR are used as a reference rate for the European money market response to the ECB's monetary policy change. Although the money market rate is not set by the ECB (unlike the main refinancing rate or the rate on the marginal lending facility), the EURIBOR is an even better indicator of the euro area monetary policy in the current circumstances. During the recent financial turmoil, the ECB along with other central banks used non-standard measures to provide additional liquidity to the market. An excellent description of these measures and their effects can be found in Lenza, Pill and Reichlin (2010), who argue that the non-standard measures have resulted in a significant increase in the monetary base, which, however, has not translated into an increase in broad money. The main effect on the real economy was the one passed on through interest rates. Lenza, Pill and Reichlin (2010) stress three channels of transmission via interest rates. First, non-standard measures may influence the level of very short-term interest rates. Second, non-standard measures may affect the spreads in the money market (e.g. 3-month EURIBOR and 3-month overnight interest swap). Third, non-standard measures may manage expectations and affect the slope of the money market yield curve. To sum up, the 3-month EURIBOR rate contains both standard and non-standard measures and can be used as a good indicator of the ECB's monetary policy.

In order to determine common unobservable components for the euro area, the Czech Republic, Hungary and Poland in the FAVAR model, we use an unbalanced panel of data that comprises about 170 to 200 time series for each economy. We collect a rather broad set of macroeconomic variables consisting of national accounts' data on volumes, prices and employment, consumer and producer prices, hard data on industry, trade, exports and imports, financial data and soft data on consumer and business confidence.[6] When constructing the database we aim to keep a reasonable balance between real activity, price, external trade and financial indicators. The composition of indicators is almost identical for all countries and the euro area. More information on the dataset is given in the online appendix.

We use quarterly data for the period from the second quarter of 1999 to the third quarter of 2010 (46 observations). The sources of our data are Eurostat and IMF databases. The choice of the beginning of the sample was driven by two factors. First, the beginning of 1999 was the date of the euro introduction and marks the creation of the euro area. Second, and even more importantly, statistical data for the Czech Republic, Hungary and Poland are rather scarce for prior periods.

Where seasonally-adjusted data were not available from the statistical database, we use the standard X12 adjustment procedure (except for interest rates and exchange rates). All variables are transformed in logs with the exception of interest rates, confidence indicators and fiscal variables. These latter variables are measured in percent to GDP. Non-stationary variables are differentiated to obtain stationary

[6] *Our data set contains traditional activity and price variables. Due to data limitations (especially for Hungary and Poland), we put less emphasis on labor market variables than Bernanke, Boivin and Eliasz (2005) but include soft data on economic sentiment.*

time series. Several outliers are removed from the data. For example, for all three CEECs, external trade data are removed for the second quarter of 2004 because the statistical methodology changed due to these countries' accession to the EU. Observations for the first quarter of 2001 are removed from several national accounts variables in the euro area due to the inclusion of Greece in this quarter. As long as the number of missing observations does not exceed 4 for one variable, we fill the gap using a usual Expectation Maximization (EM) algorithm (see Stock and Watson, 2002b).

The size of the dataset is an important issue. As was argued by Boivin and Ng (2006), the use of more series can actually lead to less useful results, as some important factors may be dominant in the large database. Also, this problem tends to arise when the idiosyncratic errors are cross-correlated. However, our results appear to be quite robust to the size of the database. Therefore we keep this set of variables, which allows us to calculate impulse response functions for a large number of macroeconomic variables.

4.2 Unobservable Factors

First, we need to determine the number of unobservable factors for each region. According to the traditional Bai/Ng criteria (Bai and Ng, 2002), the number of unobservable factors is 3 for the euro area and Poland, and 4 for the Czech Republic and Hungary. However, we should take into account that these criteria perform badly when the number of observations is small. Moreover, as pointed out by Bernanke, Boivin and Eliasz (2005), Bai/Ng criteria do not address the question of how many factors should be included in the VAR. We experiment with different numbers of latent factors and find that FAVAR results are qualitatively unchanged as long as the number of factors for all regions is not smaller than 2. Taking into account the very short sample period, a smaller number of unobservable factors is preferable. In addition, this also narrows the confidence bands of impulse responses. In contrast, a larger number of factors maximizes the fraction of variance explained by common factors and therefore also improves the validity of impulse responses. In order to keep a good balance between a small number of variables in the VAR and a high fraction of common variance we extract 3 unobservable factors for each country or region following the methodology described in section 3.2. These factors are depicted in chart 1.

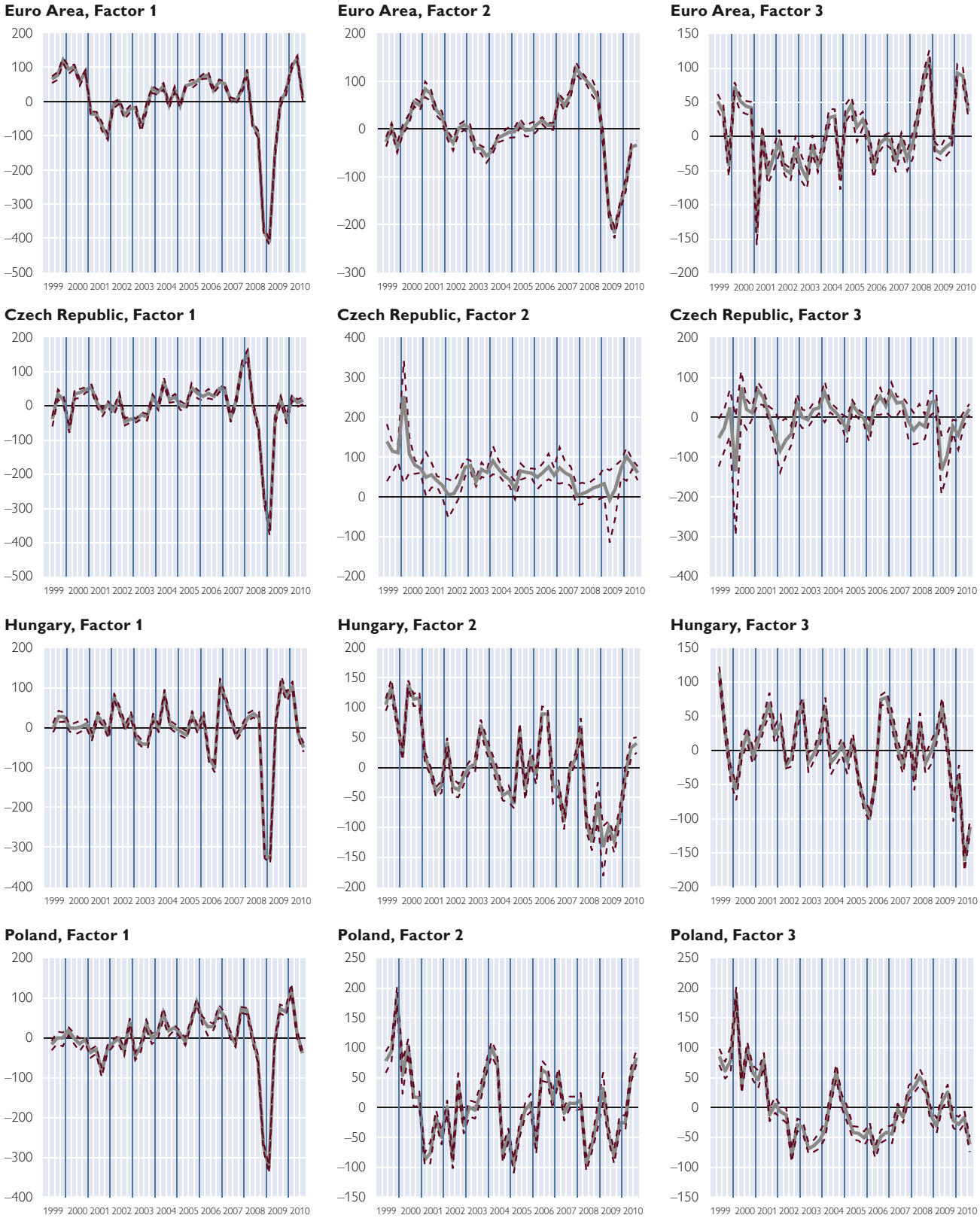
In order to give individual factors a precise economic meaning, we would need to apply a rotation method which increases the correlation between a factor and a particular group of observable macroeconomic variables. However, since we are more interested in the monetary shock transmission to an individual variable, which can be retrieved from the effects on all defined common factors, we skip this step and provide only the approximate and intuitive definition of obtained unobservable factors.

For all four regions the first factor can be interpreted as an "activity" factor. The highest loadings for the first factor are observed in industry, external trade and confidence variables. In each region, the first factor indicates the boom periods in 2006–07 and the financial crisis in 2008–09. Also, some activity moderation in 2001–02 is captured for the euro area and Poland. "Activity" factors are highly correlated between the euro area and all three countries s (the correlation is around 0.75–0.8), which mainly comes from the similar dynamics during the

Chart 1

Unobservable Factors for the Euro Area, the Czech Republic, Hungary and Poland

%, with 70% confidence bands



Source: Authors' calculations.

Note: Unobservable factors estimated using equation (A2) in the online appendix, confidence intervals calculated using bootstrap method.

financial crisis. Before 2008, this correlation was not so pronounced (below 0.4). As to the second and third factors, the interpretation is more ambiguous, although factor loadings can give us some clues. For the euro area, the second factor shows some similarities to price dynamics (high inflation in 2007–08 and low inflation in 2009–10) and changes in monetary aggregates, while the third factor is likely to be correlated with exchange rate movements. In the Czech Republic, Hungary and Poland, the second and third unobserved factors have the highest loadings for several price indices, i.e. HICP, PPI and trade deflators.

Table 1

Explanatory Power (R^2) for Selected Macroeconomic Variables

	Euro area	Czech Republic	Hungary	Poland
Real GDP	0.885	0.586	0.744	0.51
Real consumption	0.384	0.155	0.356	0.188
Real capital formation	0.7	0.3	0.162	0.147
Real exports	0.911	0.573	0.649	0.126
Real imports	0.903	0.448	0.633	0.301
Employment	0.661	0.184	0.318	0.149
Exports of goods	0.901	0.777	0.823	0.77
Imports of goods	0.918	0.741	0.85	0.855
Manufacturing production	0.905	0.498	0.785	0.767
Retail trade turnover	0.799	0.598	0.607	0.491
HICP	0.522	0.222	0.59	0.905
PPI in manufacturing	0.787	0.798	0.845	0.686
GDP deflator	0.419	0.321	0.269	0.386
Consumption deflator	0.674	0.219	0.303	0.593
Capital formation deflator	0.689	0.229	0.572	0.301
Export deflator	0.813	0.768	0.883	0.184
Import deflator	0.774	0.575	0.887	0.479
Confidence (ESI)	0.898	0.529	0.774	0.757
NEER	0.796	0.814	0.915	0.891
REER	0.793	0.702	0.886	0.88
3-month interest rate	1	0.408	0.093	0.343

Source: Authors' calculations.

Note: R^2 for equations (A3) and (A4) in the online appendix.

Table 1 reports the fraction of variance explained by the common unobservable factors and the policy variable for selected variables (see equations (4a) and (4b)). It shows a high *R2* in most of the cases, meaning that the variables of interest are well described by common factors. Comparing different regions, the explanatory power is high for the euro area: The fraction of common variance is below 50% only for real consumption, the GDP deflator and M1, while for other variables *R2* is typically above 70%. The fit is not as good in the Czech Republic, Hungary and Poland, obviously due to more volatile data, although on average it exceeds 50%. As for differences among variables, activity indicators are explained better than price indices. The factor model is good in fitting export and import data, industry production, real GDP, confidence and exchange rates. On the other hand, price indicators, especially the deflators of GDP, private consumption and capital formation as well as financial variables are not as well approximated by common factors.

5 Results of the FAVAR Model

In this section we present the estimated impulse responses of the selected macroeconomic variables to a euro area monetary policy shock, with a special focus on comparisons between reactions in the Czech Republic, Hungary and Poland to reactions in euro area variables. In all models we define the monetary policy shock as an unexpected 50 basis point increase in the 3-month EURIBOR (restrictive monetary policy). Note that we use changes in the EURIBOR as the monetary policy variable in our model. Thus the shock will have a permanent effect on the level of the EURIBOR, while the effect on the changes is non-permanent. When denoting the shock as an unexpected one, we draw on standard macroeconometric terminology, while we are well aware of the fact that the euro area is always very keen to inform the markets in advance. In the context of our model, which is based on quarterly data, the assumption of an unexpected shock is appropriate, since the timeliness of informing the markets could only be captured by high frequency (i.e. daily) data.

The size of the shock was chosen to be similar to the one in Blaes (2009) for the ease of comparability. However, the responses to other sizes of the monetary shock as well as an expansionary shock could easily be obtained as the model is linear and symmetric.

The number of lags in the FAVAR model was chosen according to Akaike and Schwarz information criteria, and in all three cases it was indicated to be one quarter. The FAVAR model involves two types of uncertainty: the uncertainty of factors and FAVAR estimates. In order to overcome bias problems in determining confidence intervals of a small sample that are usually present in traditional parametric estimation methods, we apply the bootstrap method (nonparametric approach) to obtain confidence intervals for common factors and impulse responses of FAVAR. The traditional regression bootstrap approach is used to determine confidence bands for the estimated common latent factors. For confidence intervals of FAVAR impulse responses, we follow the bootstrap-after-bootstrap approach proposed by Kilian (1998). The 70% confidence intervals are calculated using 10,000 replications.[7]

5.1 Transmission of Euro Area Monetary Policy Shocks in the Euro Area

First we shortly discuss the estimated impulse responses of the euro area variables to a euro area monetary policy shock (see chart A1 in the online appendix). Overall, almost all the variables of interest respond statistically significantly and with the expected signs: Activity and prices react negatively, while exchange rates react positively (meaning an appreciation of the euro). An unexpected increase in the short-run interest rate by 50 basis points results in a gradual decrease in real GDP, which reaches its peak after 1.5 years, and the cumulative decline after five years is 0.35% compared to the baseline (note that all impulse responses described subsequently are cumulative ones). Our results are well in line with those of Cecioni and Neri (2010) and lie between the ones obtained by Barigozzi, Conti and Luciani (2011) and Blaes (2009) regarding the magnitudes of the responses.

[7] *A 70% confidence band is quite traditional for FAVAR models, see e.g. Boivin and Giannoni (2008) or Blaes (2009). The reasoning for smaller confidence bands may be given by an increased uncertainty due to the large amount of data series underlying the analysis as compared to traditional VAR analysis.*

All three studies follow different empirical approaches, with the latter one being most closely in the vein of ours and therefore constituting our benchmark. Blaes (2009) shows that a monetary policy shock by 50 basis points reduces real GDP by 0.2% after seven years, which is approximately half as much as in our case. The different response could come from differences in the underlying sample period. Blaes (2009) analyzes the period from 1986 to 2006.

The reaction of all real GDP components to the unexpected monetary tightening is also negative and statistically significant. However, in contrast to Blaes (2009), there is a pronounced difference in the size of responses. The weakest reaction was shown by real private consumption, which decreases by 0.13% after five years. The reaction of real capital formation is more pronounced – about 0.70% – which is in line with the usual results of macroeconomic models. The most significant reaction to the restrictive monetary policy stance is observed in real exports and imports – 1.24% and 1.08% respectively. Such a high sensitivity could be explained by the fact that euro area real exports and imports include also intra-euro area trade. Therefore, the reaction of external trade variables is boosted by various foreign demand effects within the euro area. A similar effect can be observed in the response of merchandise exports and imports. The response of manufacturing production is also quite strong and exceeds that of retail trade turnover, as industrial production is closely linked to external activities.

We do not find any evidence of a "price puzzle"[8] for any price indices, except for the GDP deflator. Prices respond a bit more slowly than activity variables, e.g. the HICP response reaches its maximum two years after the monetary contraction and decreases by 0.09% after five years. This result is lower than the one obtained by Blaes (2009), who reports a 0.15% decline in the HICP after seven years in response to a 50 basis point monetary policy shock, although the response is much more delayed in this case. A comparison of different price indices shows the strongest reaction for the deflators of exports and imports. To some extent this could be driven by a tighter link to exchange rate movements. Our results show an appreciation of the euro effective exchange rate in response to an unexpected increase in short-term interest rates, which is in line with theoretical expectations. This response, however, is not statistically significant, perhaps due to the small part of exchange rate variation, which is explained by common factors.

5.2 Transmission of Euro Area Monetary Policy Shocks to the Czech Republic, Hungary and Poland

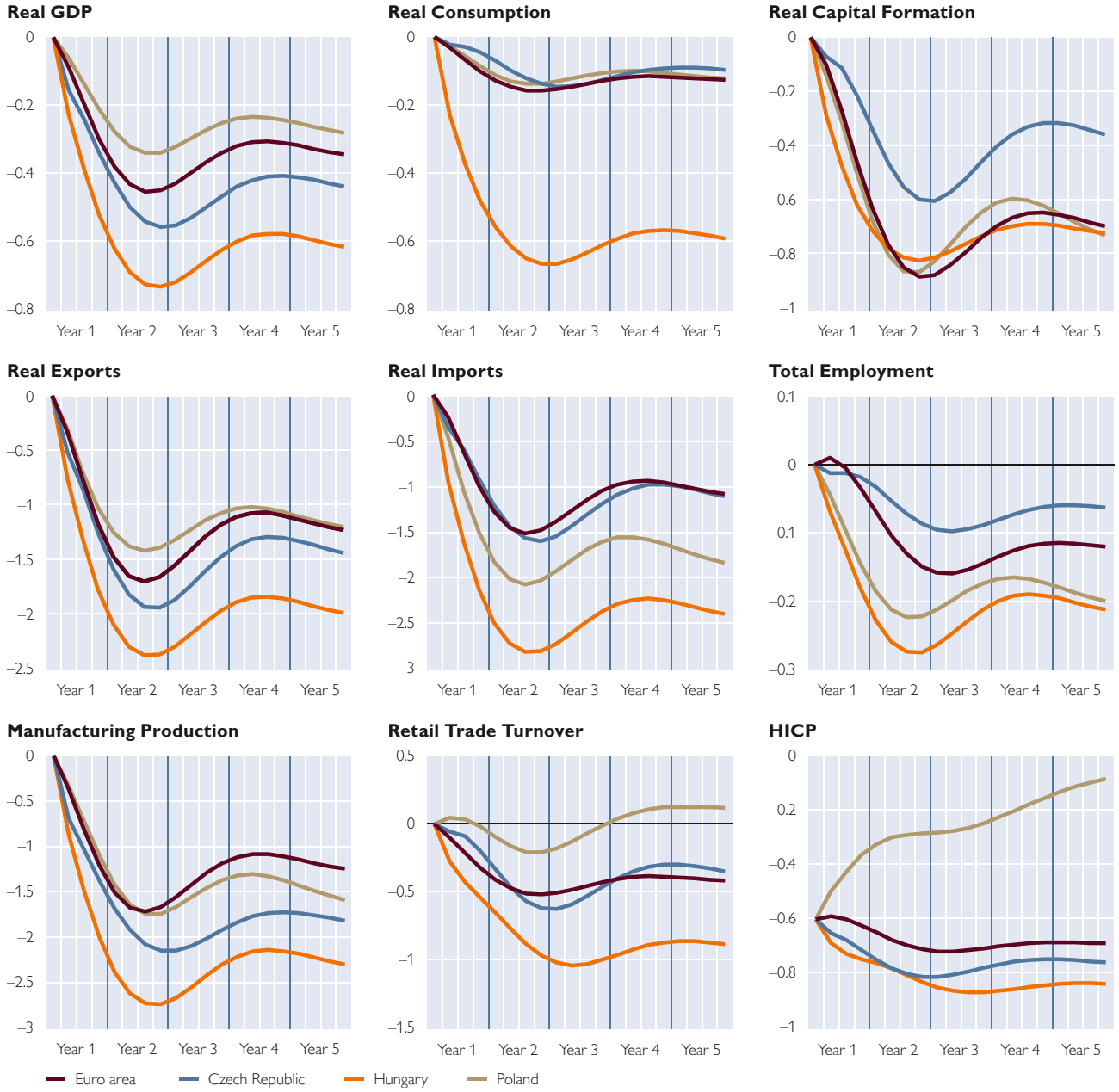
Now we can turn to the results for the three CEECs and compare the transmission of euro area monetary policy to the Czech Republic, Hungary and Poland (see chart 2). In all three *s* the response of real GDP to an unexpected increase in the euro area short-term interest rate by 50 basis points is negative and statistically significant (see charts A.2, A.3, A.4 in the online appendix). The strongest reaction is observed for Hungary, where real GDP declines by 0.60% after five years, while Poland shows the smallest contraction, by 0.29% after five years. The response of real GDP in the Czech Republic is about 0.42% after five years.

[8] *According to Sims (1992), the tightening of monetary policy in traditional VAR models leads to an initial increase of price levels, which contradicts the macroeconomic (monetarist) theory.*

Chart 2

Comparison of Impulse Responses to a Euro Area Monetary Shock

Cumulative deviation from the baseline in % in response to a 50 basis points increase in changes of the 3-month EURIBOR



Source: Authors' calculations.

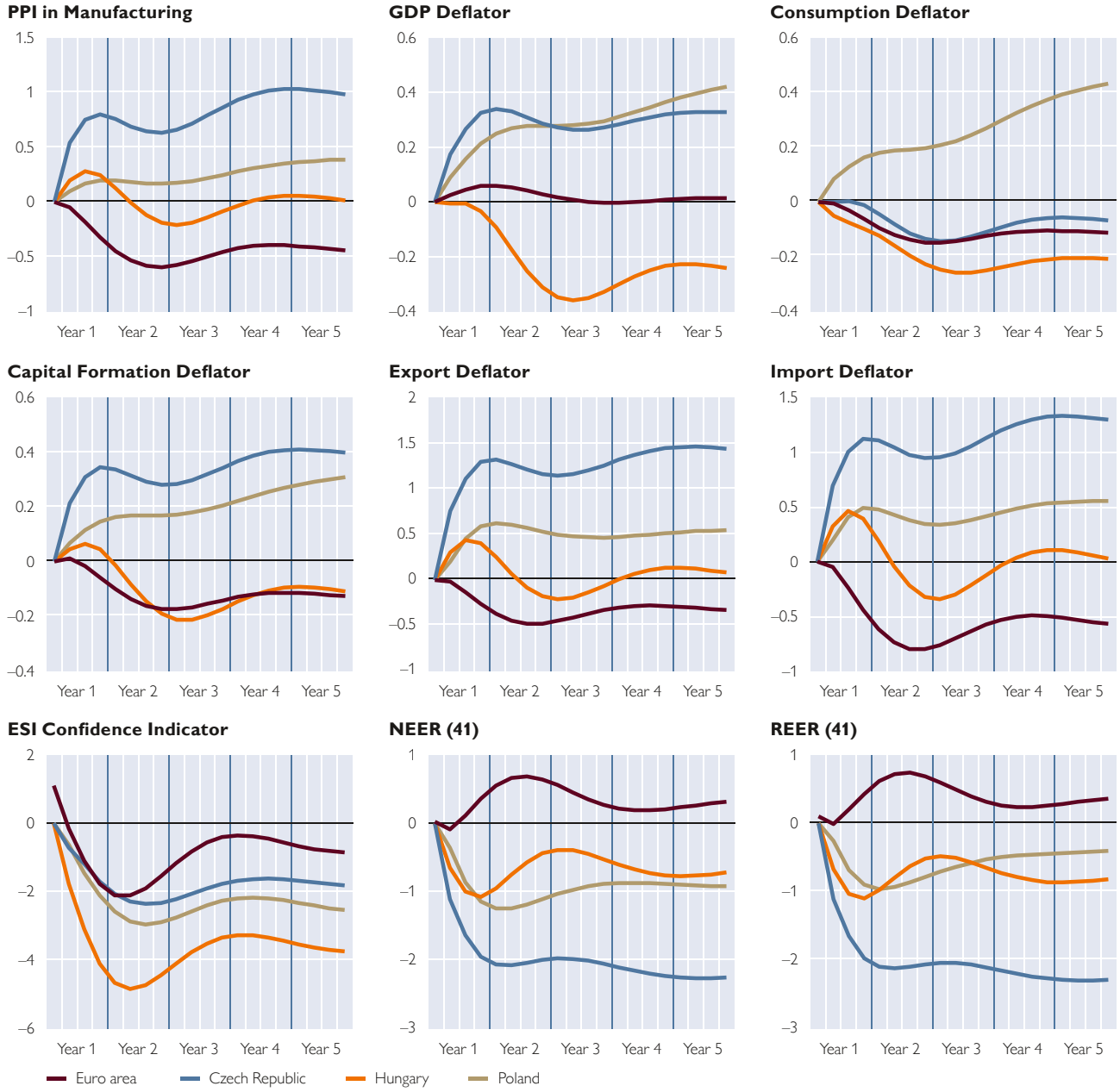
Note: See equations (3) and (4). Confidence bands calculated using bootstrap-after-bootstrap method, see Kilian (1998).

Several conclusions can be drawn from these results. First, as monetary tightening in the euro area contracts real activity in the Czech Republic, Hungary and Poland, we can conclude that foreign demand and interest rate effects are stronger than the impact from a depreciation of the local currency vis-à-vis the euro and therefore outweigh the exchange rate effect. This is not surprising given the fact that external demand in these countries is dominated by the euro area coupled with an

Chart 2 (continued)

Comparison of Impulse Responses to a Euro Area Monetary Shock

Cumulative deviation from the baseline in % in response to a 50 basis point increase in changes of the 3-month EURIBOR



Source: Authors' calculations.

Note: See equations (3) and (4). Confidence bands calculated using bootstrap-after-bootstrap method, see Kilian (1998).

overall high degree of openness. This is further reflected in a strong reaction of external trade variables in all three countries. Second, country size matters indirectly. The weakest response to foreign monetary policy is observed in Poland, the largest economy among the three. Finally, we should not forget about the direct interest rate effect of the euro area monetary policy on these economies via loans issued in foreign currencies (euro among them). This can explain the strong

decline in Hungary's real GDP, as the share of loans granted in foreign currencies is highest in Hungary. A large fraction of these loans is denominated in Swiss francs, but a comparison of the ratio of euro-denominated foreign currency credit to GDP in the three countries shows that in Hungary, the ratio is still almost four times higher than in the Czech Republic and Poland. Moreover, the negative response of real consumption in Hungary is by far more pronounced compared to the other two countries and the euro area, which could be explained by the high share of household loans in foreign currency as well as a lower quality of loan portfolios. In contrast, there is no significant reaction of real consumption in the Czech Republic, where foreign currency consumer loans are practically non-existent (not least because of the negligible interest rate differential to the euro area).

Although foreign demand and interest rate effects clearly dominate in the case of real activity, it does not mean that the exchange rate channel is not operative. The unexpected increase in the short-term euro area interest rates depreciates the effective exchange rates of all three countries in the medium term, which transmits further to the economy. The most obvious effect is seen in the reaction of the export and import deflators. Monetary tightening in the euro area induces an increase in both deflators, obviously following the depreciation of the domestic currency (with the exception of Hungary, where deflators increase only temporarily). The reaction of other prices is ambiguous: In producer prices and capital formation deflators, the exchange rate channel seems to dominate, while for consumer prices decreasing demand is more important.

Our results are comparatively stronger than those reported by Jiménez-Rodríguez, Morales-Zumaquero and Égert (2010), who simulate a larger foreign interest shock and obtain often insignificant (for Poland) or small effects in the magnitude of 0.4% to 0.5%. Furthermore, they report a positive but significant reaction of domestic output for the Czech Republic. However, their focus is on the identification and consideration of structural breaks in the underlying time series. Therefore they use a sample which starts in the early 1990s. This might deliver one explanation for these surprisingly small effects and – in the Czech case – opposing results compared to our analysis. Further, the use of structural break dummies in their analysis may alter the results and thus explain the differences from our exercise.

5.3 Robustness of Results

Finally, we conduct some robustness checks to the FAVAR model, changing the set of variables, the number of unobservable factors, the number of lags, the alternative Cholesky ordering etc. First, we exclude certain blocks of variables from the factor analysis, such as trade turnover, exports and imports of goods, sentiment indicators, etc. The results are qualitatively unchanged as long as we keep a set of activity variables (GDP or industrial production) and price variables. Second, we look at the sensitivity of the results with respect to the number of common factors. As reported above, the results are again robust. When using only two factors instead of three, the results for activity remain more or less unchanged; however, we obtain some differences in the price responses. Since the overall fit of this model is lower, we opt for the model with three factors. On the other hand, increasing the number to four common factors (as suggested by the Bai/Ng criteria for the Czech Republic and Hungary) results in wide confidence bands, rendering

most of the results insignificant. Third, the results appear to be robust to changes in the number of lags used, therefore we keep the lag length of one quarter as suggested by the Akaike and Schwarz information criteria. Given the rather small sample size of 46 time periods, this also minimizes the degree of freedom loss in the model. Fourth, we add the rest of the world as a third regional block to the model in order to account for the influence of exogenous factors, which otherwise would erroneously be ascribed to the foreign monetary policy. This does not change the results, but results in a reduction of the degrees of freedom. Fifth, we change the order of unobservable common factors in the Cholesky decomposition, which has a minor effect on our results. Sixth, although the null hypothesis that lagged values of the variables for the Czech Republic, Hungary and Poland have zero coefficients in the euro area block is not rejected for any of the three countries in our analysis, we relax the Cushman and Zha (1997) assumption that the small country does not affect the large country. The effect of euro area monetary policy remains qualitatively unchanged, although the size of the confidence bands increases due to fewer degrees of freedom in the euro area equations. Seventh, we use the EONIA and main refinancing operation interest rates instead of the EURIBOR. The direction of the responses remains unchanged while the magnitude of the EURIBOR responses are typically less pronounced compared to the ones of the other two interest rates.[9] Finally, we also assess possible changes in the cross-border monetary transmission process during the financial crisis by excluding the years 2008 to 2010 from the sample period. This task was complicated by the extremely short sample period (the number of observations was reduced to 35) and wide confidence bands of the resulting impulse response functions, therefore any conclusions should be drawn with caution. However, we still see the negative response of activity variables in the Czech Republic, Hungary and Poland to a contractionary monetary policy in the euro area; moreover, the magnitude of the reaction is comparable to the full-sample results.

6 Conclusions

We use a FAVAR model to study cross-border effects of monetary policy in three Central and Eastern European EU member countries – the Czech Republic, Hungary and Poland. This method allows us to consider the largest possible number of economic variables, thus eliminating a potential omitted-variables bias in the sense of mistaking the reactions of monetary policy to economic variables for independent policy shocks. It further allows us to analyze the impact of monetary policy on a large number of time series.

The bulk of research on international monetary spillovers focuses on the U.S.A. Both the formation of the euro area in 1999 and the expansion of the EU in 2004 raised the interest in monetary policy spillovers from the euro area. While early studies on the euro area were mainly concerned with the transmission channels among euro area members, a nascent stream of the literature has also focused on the future EU members in Central, Eastern and Southeastern Europe. However, this part of the literature is not abundant to date, which may be due to the fact that the euro was introduced only a relatively short time ago and due to

[9] *The only significant difference is in inflation in Poland, which shows a different reaction when we use main refinancing operation rates or the EONIA instead of the EURIBOR. The results are available from the authors upon request.*

the even shorter period for which CEECs have been EU members. Nevertheless, this field of study is of utmost importance given the strong interlinkages between the euro area and these economies and these countries' plans to adopt the euro. Also, during the recent financial and economic crisis, the euro area took strong and supportive monetary action, thereby proving a large and dominant neighbor for the Czech Republic, Hungary and Poland (see Lenza, Pill and Reichlin, 2010, for the effectiveness of ECB monetary policy in the recent recession).

Based on a data set spanning roughly 170 to 200 variables for each region (the euro area and each of the three CEECs) over 46 periods (from the first quarter of 1999 to the third quarter of 2010), we first establish that the reactions of euro area variables to a contractionary ECB monetary policy shock show the expected signs and are of plausible magnitude.

Our analysis then shows that euro area monetary policy is a significant factor for all three CEECs. The response of real GDP to an unexpected increase in the euro area short-term interest rate by 50 basis points is negative and statistically significant. Thus, the overall economic reaction is similar in all three economies under consideration. This is not surprising given their homogeneity with respect to their openness to foreign capital flows and the degree of flexibility of their labor and consumer markets. Further, in recent years all three countries have adopted a similar monetary policy framework (inflation targeting). As monetary tightening in the euro area contracts real activity in the three CEECs, we can conclude that foreign demand and interest rate effects are dominant in the exchange rate channel for activity variables, although exchange rate movements are important for price indices. An unexpected increase in short-term euro area interest rates leads to a depreciation of the effective exchange rate in all three CEECs in the medium term, resulting in higher export and import deflators.

Nevertheless, we observe some heterogeneity in the individual responses. The strongest reaction is observed for Hungary, while we see the smallest contraction for Poland, the country whose trade links with the euro area are not as close as those of the other two countries. For economic activity variables, these differences relate only to the magnitude of the response and are particularly pronounced with respect to the trade variables. Hence, we conclude that differences in the degree of trade openness (which is of course also related to differences in country size) are mainly responsible for this finding. A potential direct interest rate effect may materialize in Hungary due to strong foreign currency borrowing in this country. Also, not taking account of Swiss franc-denominated loans and looking only at the ratio of euro-denominated loans to GDP, Hungary surpasses the other two countries by a factor of almost four. This compounds the foreign demand and general interest rate effects mentioned above and may explain the strong reaction of the Hungarian variables (especially private consumption) to the foreign shock. Thus, just as monetary policy in the euro area is likely to have supported economic activity not only within the euro area, but also in the neighboring CEE EU members, the ongoing and future exit from the loose policy stance back to a normalization of monetary policy is again likely to have considerable dampening effects on these countries. As such, the small and open CEE economies will have to monitor and analyze the design, timing and implementation of euro area monetary policy carefully in order to be able to react timely and sufficiently to the repercussions on their domestic economies.

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Appendix

Estimating Unobservable Factors

The dynamic factor model approach is commonly employed to extract common unobservable factors from a large set of variables. As in Bernanke, Boivin and Eliasz (2005) and Boivin and Giannoni (2008), we employ the less restrictive form of a dynamic factor model (DFM) – the approximate DFM (equation 2), obtaining common factors by the principal components method. Stock and Watson (2002a) prove that principal components are consistent estimates of common factors in an approximate DFM.

During the first step of the estimation of $\hat{F}_t$, the common factors $\hat{C}_t$ are estimated using the first K principal components of X_t. However, these common factors cannot be used in equation (1) directly. The Cholesky ordering often used[10] to identify the monetary shock assumes that latent factors do not respond to a monetary policy shock in the same period. Therefore one needs to eliminate the immediate effect of any monetary policy variable from $\hat{C}_t$ in a second step.

One way of doing so is to draw out the effect of policy variables directly from observable macroeconomic variables, as was done in Boivin and Giannoni (2008). The original paper of Bernanke, Boivin and Eliasz (2005) follows a slightly different route by splitting observable macroeconomic variables into "slow-moving" and "fast-moving" ones. "Slow-moving" variables are assumed to be largely predetermined in the current period and thus do not react to the monetary policy shock immediately, while "fast-moving" variables react instantly to a contemporaneous monetary shock.

[10] *See Bernanke, Biovin and Eliasz (2005) or Blaes (2009).*

Akin to Bernanke, Boivin and Eliasz (2005) we estimate "slow-moving" factors $\hat{F}_t^s$ as the principal components of X_t^s, the subset of "slow-moving" variables. By construction these factors are not immediately affected by the monetary policy shock. Regressing the common factors $\hat{C}_t$ on the set of extracted slow-moving factors and controlling for the policy rate (equation (A1)), we can extract the proportion of variance explained by slow-moving factors (equation (A2)).

$$\hat{C}_t = \beta_s \hat{F}_t^s + \beta_R R_t + \upsilon_t \tag{A1}$$

$$\hat{F}_t = \hat{\beta}_s \hat{F}_t^s + \hat{\upsilon}_t \tag{A2}$$

The system summarized by equations (1)-(2) can now be estimated by replacing the true unobservable factors F_t with their estimates $\hat{F}_t$ from equation (A2).

We make one slight modification to this classical Bernanke, Boivin and Eliasz (2005) methodology. Equation (2) states that all macroeconomic series from X_t are determined by a small number of unobservable factors as well as the current value of the observable policy instrument, irrespective of being "slow-moving" X_t^s or "fast-moving" X_t^f. Here we imply an additional restriction on Λ^R to be zero for "slow-moving" variables:

$$X_t^s = \Lambda^{F,s} \hat{F}_t + e_t^s \tag{A3}$$

$$X_t^f = \Lambda^{F,f} \hat{F}_t + \Lambda^{R,f} R_t + e_t^f \tag{A4}$$

This additional restriction does not alter the results when $T \to \infty$, as estimates of Λ^R for "slow-moving" variables should converge to zero if the assumption of no immediate effect of monetary policy is true. However, our additional restriction should ensure the consistency of results in short samples.

Table A1

Number and Grouping of Variables

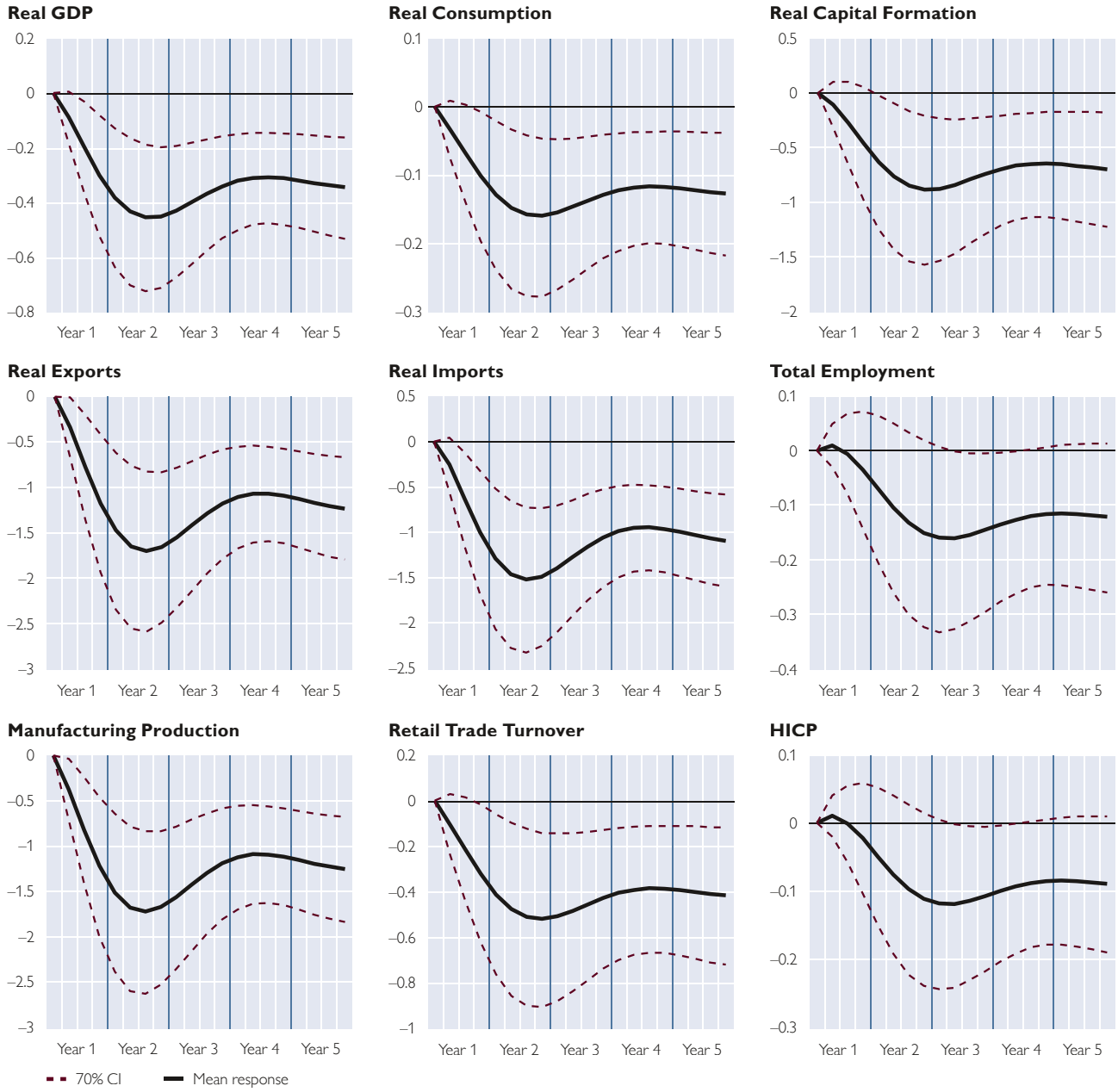
Variable block	Type	Number of variables			
		Euro area	Czech Republic	Hungary	Poland
Real GDP (expenditure side)	Slow	7	7	7	7
Employment by production sectors	Slow	8	8	2	1
Industry production index by sectors	Slow	32	30	32	32
Trade turnover by categories	Slow	29	20	16	16
Exports and imports of goods	Slow	20	20	20	20
Business and consumer confidence indicators	Fast	46	39	39	26
HICP by main categories	Slow	13	13	13	13
Industry producer price index by sectors	Slow	18	32	33	34
GDP deflator (expenditure side)	Slow	7	7	7	7
Exchange rates, nominal and real	Fast	7	9	9	9
Interest rates	Fast	2	2	2	2
Monetary aggregates	Fast	3	0	3	3
Deposits and loans	Fast	6	0	0	0
Total "slow-moving" variables	Slow	134	137	130	128
Total "fast-moving" variables	Fast	64	50	53	42
Total		198	187	183	170

Source: Authors' calculations.

Chart A1

Euro Area: Comparison of Impulse Responses to a Euro Area Monetary Shock

Cumulative deviation from baseline in % in response to a 50 basis point increase in changes of the 3-month EURIBOR, with 70% confidence bands



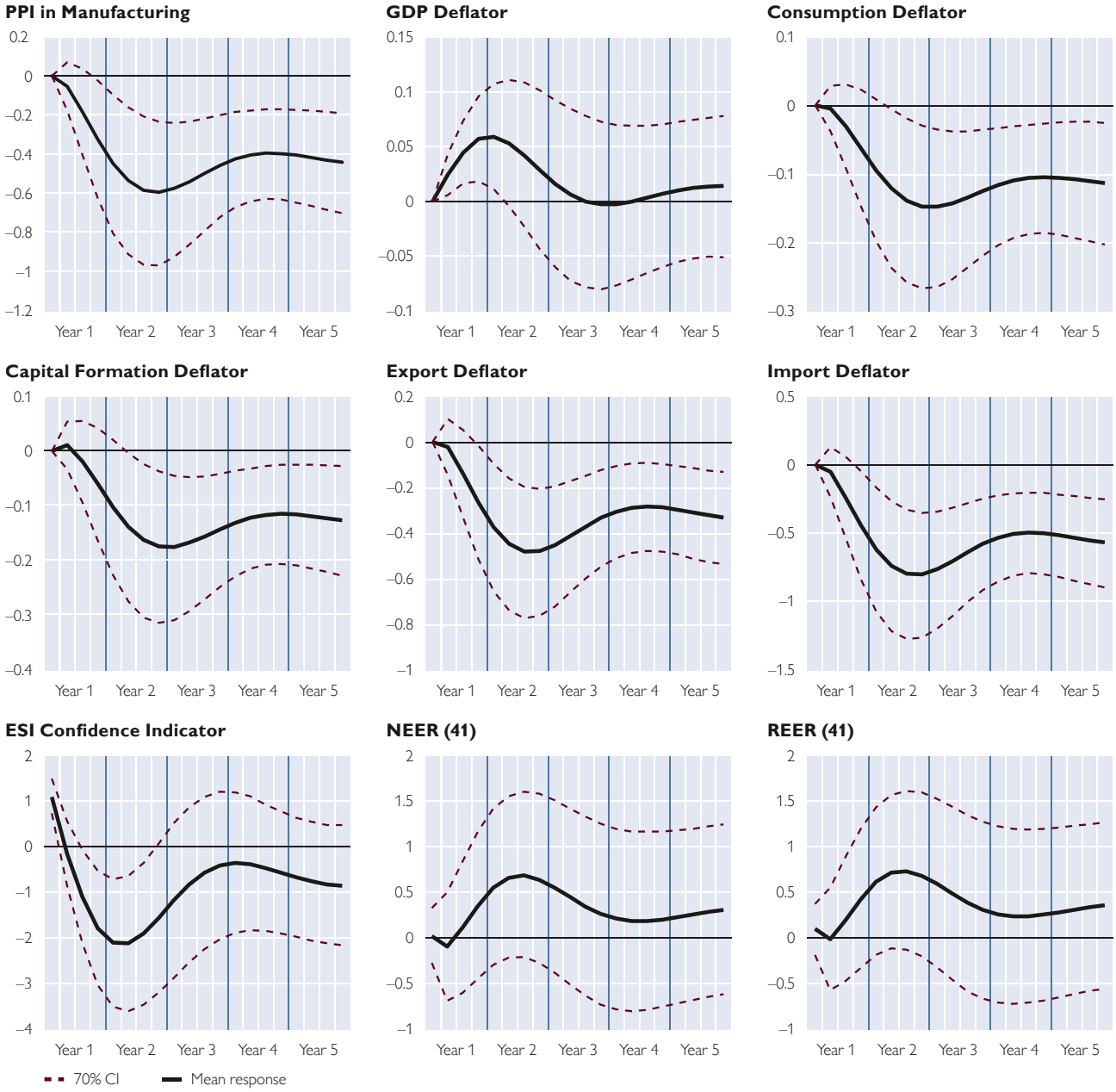
Source: Authors' calculations.

Note: See equations (3) and (4). Confidence bands calculated using bootstrap-after-bootstrap method, see Kilian (1998).

Chart A1 (continued)

Euro Area: Comparison of Impulse Responses to a Euro Area Monetary Shock

Cumulative deviation from baseline in % in response to a 50 basis point increase in changes of the 3-month EURIBOR, with 70% confidence bands



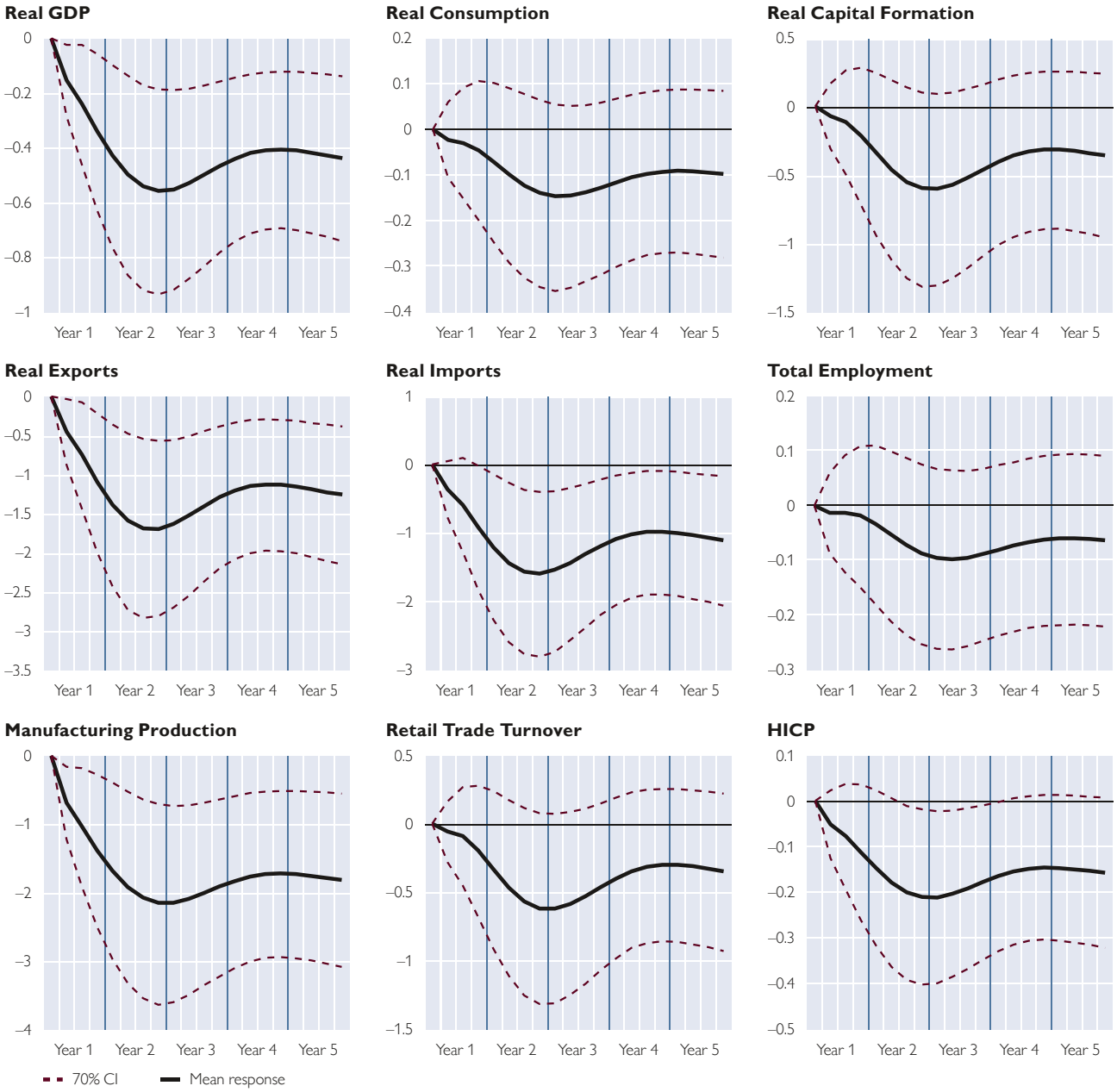
Source: Authors' calculations.

Note: See equations (3) and (4). Confidence bands calculated using bootstrap-after-bootstrap method, see Kilian (1998).

Chart A2

Czech Republic: Comparison of Impulse Responses to a Euro Area Monetary Shock

Cumulative deviation from baseline in % in response to a 50 basis point increase in changes of the 3-month EURIBOR, with 70% confidence bands



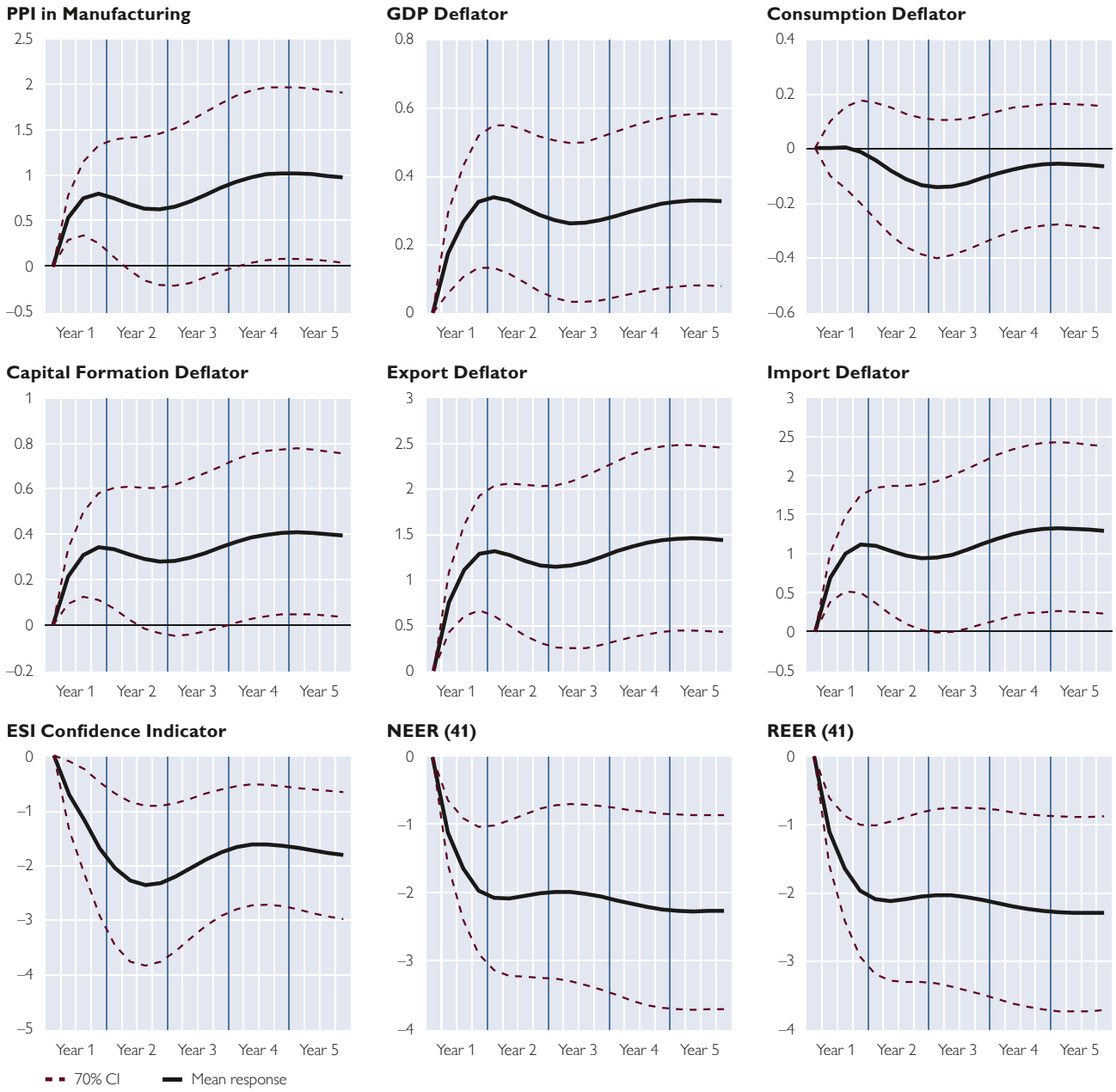
Source: Authors' calculations.

Note: See equations (3) and (4). Confidence bands calculated using bootstrap-after-bootstrap method, see Kilian (1998).

Chart A2 (continued)

Czech Republic: Comparison of Impulse Responses to a Euro Area Monetary Shock

Cumulative deviation from baseline in % in response to a 50 basis point increase in changes of the 3-month EURIBOR, with 70% confidence bands



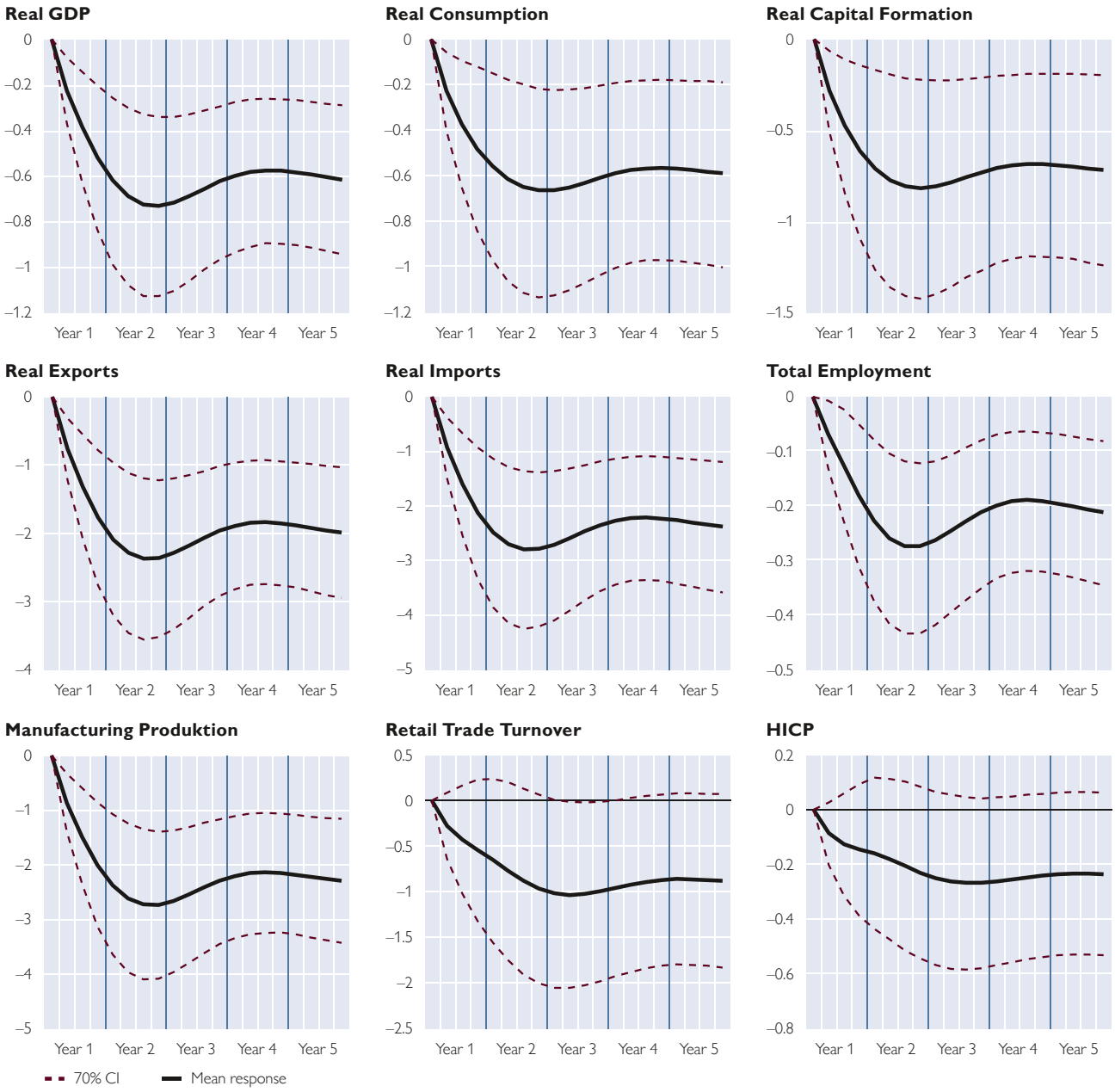
Source: Authors' calculations.

Note: See equations (3) and (4). Confidence bands calculated using bootstrap-after-bootstrap method, see Kilian (1998).

Chart A3

Hungary: Comparison of Impulse Responses to a Euro Area Monetary Shock

Cumulative deviation from baseline in % in response to a 50 basis point increase in changes of the 3-month EURIBOR, with 70% confidence bands



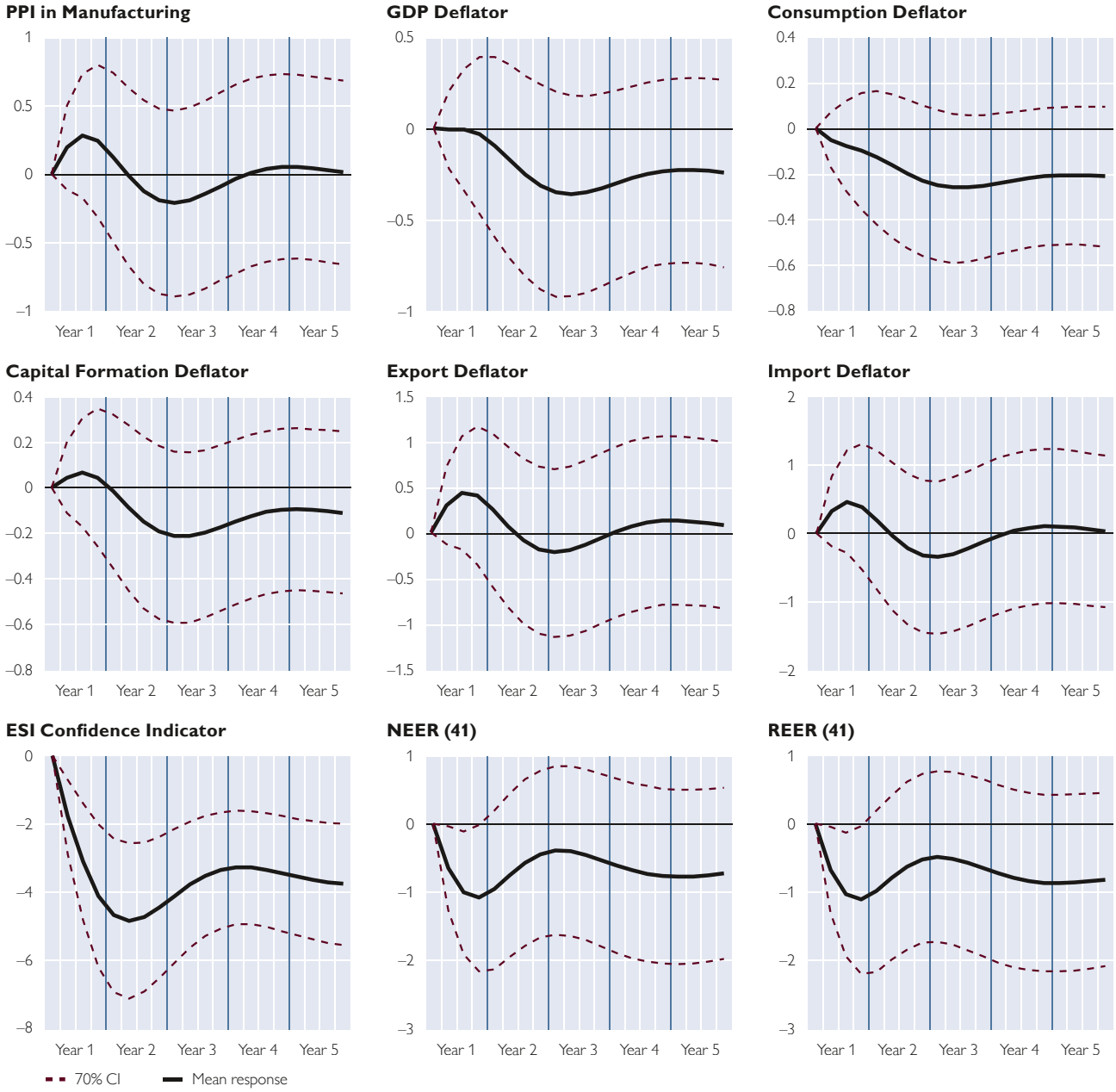
Source: Authors' calculations.

Note: See equations (3) and (4). Confidence bands calculated using bootstrap-after-bootstrap method, see Kilian (1998).

Chart A3 (continued)

Hungary: Comparison of Impulse Responses to a Euro Area Monetary Shock

Cumulative deviation from baseline in % in response to a 50 basis point increase in changes of the 3-month EURIBOR, with 70% confidence bands



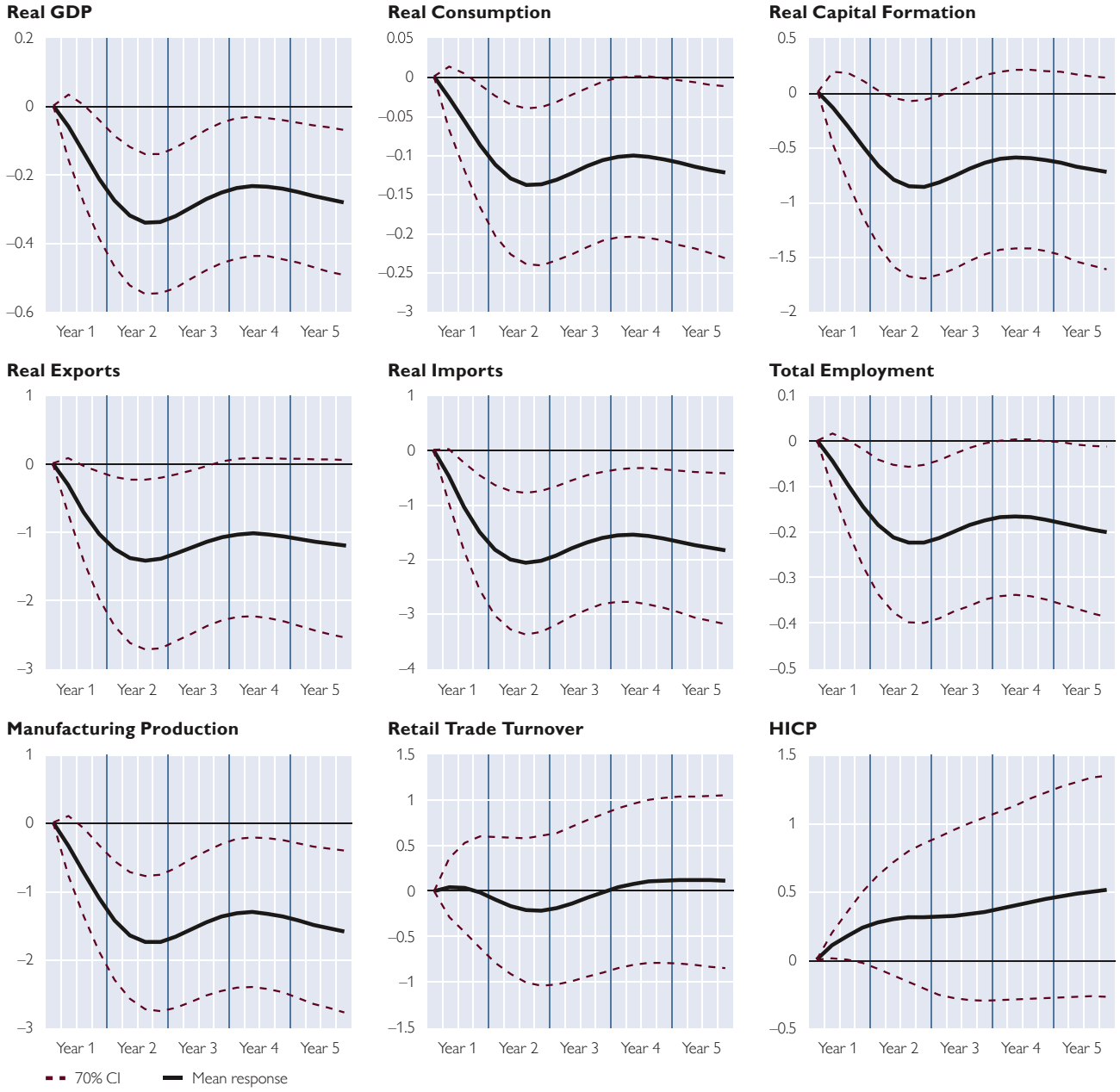
Source: Authors' calculations.

Note: See equations (3) and (4). Confidence bands calculated using bootstrap-after-bootstrap method, see Kilian (1998).

Chart A4

Poland: Comparison of Impulse Responses to a Euro Area Monetary Shock

Cumulative deviation from baseline in % in response to a 50 basis point increase in changes of the 3-month EURIBOR, with 70% confidence bands



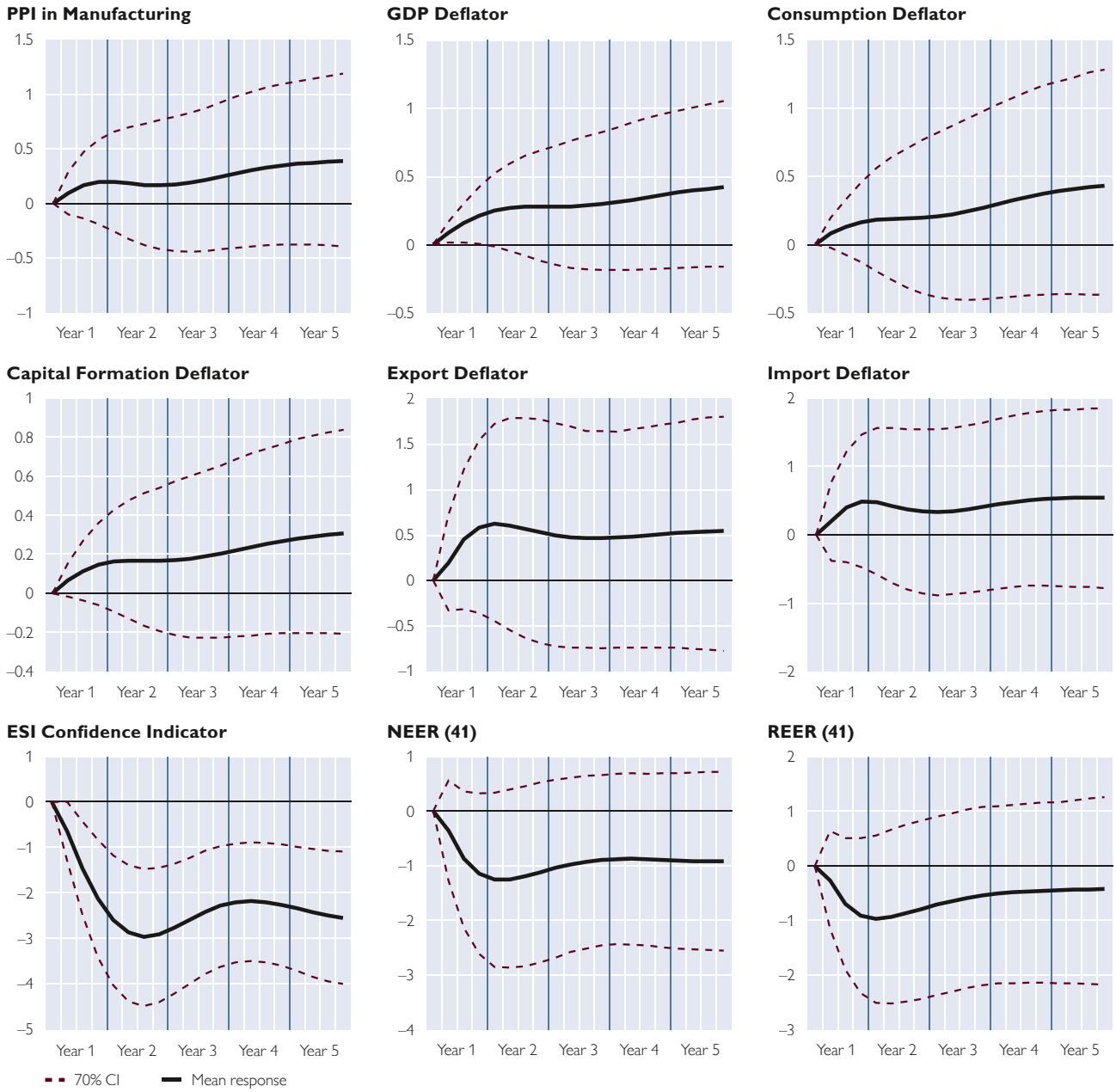
Source: Authors' calculations.

Note: See equations (3) and (4). Confidence bands calculated using bootstrap-after-bootstrap method, see Kilian (1998).

Chart A4 (continued)

Poland: Comparison of Impulse Responses to a Euro Area Monetary Shock

Cumulative deviation from baseline in % in response to a 50 basis point increase in changes of the 3-month EURIBOR, with 70% confidence bands



Source: Authors' calculations.

Note: See equations (3) and (4). Confidence bands calculated using bootstrap-after-bootstrap method, see Kilian (1998).