The analysis of monetary policy effects with emphasis on monetary policy strategy types. A VAR approach

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This paper proposes an empirical analysis of monetary policy shocks effects on the real economic aggregates and prices with the help of vector autoregressive (VAR) in the context of Central and Eastern European countries. Model specification is different for each type of monetary policy strategies applied by central banks in the region with the scope of best capturing a series of CEE states distinctive features. Our main results identify a relatively high degree of heterogeneity between the transmission of an unexpected contractionary monetary policy shock (in terms of speed, amplitude and impact persistence) under different monetary policy strategies, which could create major problems for the proper functioning of a monetary union.

Keywords: monetary transmission mechanism, vector autoregressions, Cholesky decomposition, impulse response function, CEECs.

JEL Classifications: E31, E52, E58, C32.

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Introduction

Determination of monetary policy impact, of the effects generated by the evolution of the price levels and the real economic activity is circumscribed to the review of the monetary policy transmission mechanism with a key role in the process of conducting monetary policy.

The transmission mechanism of monetary policy has a number of implications for the adoption of the euro and the proper functioning of the monetary union. The relevance of the transmission mechanism from the perspective of single currency implementation occurs when the effects of domestic monetary policy on inflation and economic activity are significant and very different from the impact identified in the euro area, because in that case, the cost of the loss of monetary policy independence could be considerable.

Vector Autoregressive Models (VAR), introduced by Sims (1980), are treated as the reference in econometric modeling of the monetary policy transmission mechanism. Fry and Pagan (2005) argue that this class of models offers the ideal combination between data-based approach and the economic theory-based coherent perspective.

The study of monetary policy implications on key macroeconomic variables using VAR models spread to the emerging markets of Central and Eastern Europe. In their case we can identify a number of works that analyze and compare the effects of monetary policy through vector autoregressive in different groups of CEE countries against other advanced economies (Ganev et al., 2002, Creel and Levasseur, 2005; Hericourt, 2005, EFN, 2005, Elbourne and de Haan, 2006; Anzuini and Levy, 2007; Jarocinski, 2008, Darvas, 2009). These studies reveal a number of specific features of the monetary policy transmission mechanism in the new EU member states in Central and Eastern Europe compared to the old Member States.

These particularities include a number of aspects such as: 1) *financial systems* relatively much less developed than that of old EU Member

States, which could lead to a weaker impact of monetary policy on the economy, 2) *additional difficulties* in anchoring inflation expectations, which could involve lagged price responses 3) a *higher inflation rate* with implications for monetary policy transmission mechanism because in a rising inflation environment agents adjust their prices more frequently and as such, prices display a lower rigidity in these countries, 4) *prevalence of the exchange rate* channel to the other two traditional channels of monetary policy transmission mechanism (interest rate and the credit channels).

An analysis of the most representative studies aimed at identifying the effects of monetary policy in Central and Eastern European emerging countries is provided by Coricelli et al. (2006) and more recently by Egert and MacDonald (2009).

Presently, there is a new wave of interest towards the identification and analysis of *implications of the recent financial and economic crisis* harsh transmission mechanism of monetary policy using VAR models (e.g., Boivin et al. (2010), Cecioni and Neri (2010)).

Researches of the topic in emerging countries of Central and Eastern Europe are still at the beginning. In this regard we note the study of Lyziak et al. (2011), which highlighted the impact of the global turmoil on the monetary policy transmission mechanism efficiency in Poland through a VAR and a small structural model, pointing out that it depends on both the monetary policy and the structural characteristics of the economy. The financial crisis, which affected the two components, has led to a change in the monetary policy rule and to a significant decrease in the effectiveness of monetary policy. In the same line, Demchuk et al. (2012) argued that during the recent international tensions, the transmission mechanism of monetary policy in a small open economy such as Poland suffered extensive disruption, with the interest rate channel being the most affected.

Cărare and Popescu (2011) performed an analysis of monetary policy effects in Hungary through a large-scale Bayesian VAR model (BVAR)

for the period 2001:6 - 2010:9 and outlined that despite the high degree of euroisation, the high share of foreign capital in the banking and corporate sectors, large levels of public debt, all likely to diminish the effectiveness of monetary policy, the decline in economic activity due to the manifestation of a contractionary monetary policy shock appears to be obvious and much faster compared to advanced economies.

In the case of Romania, Pelinescu (2012) analyzed with the help of a structural VAR the measures taken by the National Bank at the beginning of the global economic and financial crisis, emphasizing the importance of the interest rate channel, the complex impact of the exchange rate channel and the key role of the need for and implementation of appropriate measures to stimulate demand. Using monthly frequency data for the period 2001 to 2010, Spulbăr et al. (2012) studied the functioning of monetary policy transmission mechanism in Romania based on a Bayesian estimated VAR model (BVAR). The most important findings highlighted the role of the exchange rate channel that significantly influences the evolution of real economic variables, as well as the raising importance of the interest rate channel, which in recent years has become more consistent. It should be noted that mentioned authors included in the analysis a real estate market development index, showing the appreciation of the national currency and broad monetary aggregate evolution as key factors that have led to the assets price boom prior to the financial crisis.

Model specification

We consider the following system:

$$AY_t = C(L)Y_{t-1} + D(L)X_t + B\varepsilon_t \quad (1)$$

where: the A matrix A includes all coefficients describing the simultaneous relationships between variables, the C(L) matrix includes all coefficients describing relationships between lagged variables, the D (L) matrix includes all coefficients describing relationships between

endogenous and exogenous variables, the B matrix is a diagonal matrix and the ε vector includes error terms. By multiplying the VAR system with the inverse of A matrix we obtain:

$$Y_t = A^{(-1)}C(L)Y_{t-1} + A^{(-1)}D(L)X_t + A^{(-1)}B\varepsilon_t \quad (2)$$

which can be rewritten as:

$$Y_t = aY_{t-1} + bX_t + \mu_t \quad (3)$$

where:

$$a = A^{(-1)}C(L)$$

$$b = A^{(-1)}D(L)$$

$$\mu = A^{(-1)}B\varepsilon$$

Equation (1) describes the structural model and equation (3) is a simplified form, empirically observable. Therefore, the VAR model has the following reduced representation:

$$Y_t = aY_{t-1} + bX_t + \mu_t$$

where: Y_t is the vector of endogenous variables, X_t is the vector of exogenous variables, μ_t is the vector of residual terms (white noise), a is a matrix that includes all coefficients describing relationships between endogenous variables and b is the matrix of all coefficients describing relationships between endogenous and exogenous variables. Depending on the specific monetary policy strategies used by central banks, we will build a VAR model for each type of strategy in hand. Thus, for the euro area the considered VAR model considered (VAR 1) will have the following representation:

$$\begin{bmatrix} pib\_r\_ze \\ ipc\_ze \\ m3\_ze \\ rd\_ze \\ reer\_ze \end{bmatrix} = a \begin{bmatrix} pib_{t-1}\_r\_ze \\ ipc_{t-1}\_ze \\ m3_{t-1}\_ze \\ rdt_{t-1}\_ze \\ reer_{t-1}\_ze \end{bmatrix} + b \begin{bmatrix} wcpi \\ pib\_r\_sua \\ rd\_sua \end{bmatrix} + \mu_t^{ze} \quad (4)$$

In this case, the exogenous variables vector includes the following factors: global index of resource prices (wcpi), U.S. real gross domestic product (pib_r_sua) and short-term interest rate in the U.S. (rd_sua). Endogenous variables vector comprises the real GDP in the euro area (pib_r_ze), the consumer price index in the Eurozone (ipc_ze), EZ M3 monetary aggregate (m3_ze), EZ short-term interest rates (rd_ze) and the real effective exchange rate EUR / USD (reer_ze).

For states that use (or used until the adoption of the euro) a strategy of inflation targeting, the VAR model has the following specification form (VAR 2):

$$\begin{bmatrix} pib\_r\_n \\ ipc\_n \\ reer\_n \\ m3\_n \\ rd\_n \end{bmatrix} = a \begin{bmatrix} pib_{t-1}\_r\_n \\ ipc_{t-1}\_n \\ m3_{t-1}\_n \\ rdt_{t-1}\_n \\ reer_{t-1}\_n \end{bmatrix} + b \begin{bmatrix} pib\_r\_ze \\ ipc\_ze \\ rd\_ze \end{bmatrix} + \mu_t^n \qquad (5)$$

where *n* succesiv = CZ (the Czech Republic), HU (Hungary), PL (Poland), RO (Romania), SI (Slovenia), SK (Slovakia).

If central banks use (or used until the common currency adoption) a strategy of targeting the exchange rate, the VAR model will have the following representation (VAR 3):

$$\begin{bmatrix} rd\_ze \\ pib\_r\_n \\ ipc\_n \\ m3\_n \\ rd\_n \end{bmatrix} = a \begin{bmatrix} rd_{t-1}\_ze \\ pib_{t-1}\_r\_n \\ ipc_{t-1}\_n \\ m3_{t-1}\_n \\ rd_{t-1}\_n \end{bmatrix} + b \begin{bmatrix} reer\_n \\ pib\_r\_ze \\ ipc\_ze \end{bmatrix} + \mu_t^n \qquad (6)$$

where *n* succesiv = BG (Bulgaria), EE (Estonia), LV (Latvia), LT (Lithuania).

Exogenous variables vector include: real effective exchange rate for the country subject to analysis (reer_n), real gross domestic product in the Eurozone (pib_r_ze) and), and the consumer price index in the euro area (ipc_ze). In turn, in this case, the vector of endogenous

variables comprises the short term interest rates in the EZ (rd_ze), real gross domestic product for the country subject to analysis (pib_r_n), the consumer price index (ipc_n) national monetary aggregate M3 (m3_n), and domestic short-term interest rate (rd_n).

Data used

The sample used is restricted, including data since the moment central banks have adopted the current monetary policy strategy until the end of 2012. The data frequency is quarterly. The analysis variables are expressed as fixed-base indexes (2005 = 100), excluding short-term interest rate. The data source is Eurostat, except for the world commodity price index (wcpi) retrieved from the World Bank database and for the size of monetary aggregates taken from the monthly bulletins published on the websites of central banks.

All series except the short-term interest rate and real effective exchange rate have been adjusted to remove seasonal factors using the X12 procedure of the U.S. Census Bureau. Also, all series except from short-term interest rates are logarithmic. We verify the variables stationarity with the help of Augmented Dickey - Fuller test and Phillips - Perron, which revealed non-stationary series. Most variables are integrated of order 1 (I (1)), and some of order 2 (I (2)*)*. Variables used in the VAR analysis should not, however, be stationary. Sims (1980), among others, argued against differentiation, even if the series contain a unit root, because it leads to the loss of information. What matters for VAR results robustness is the general stationarity of the system (Lütkepohl, 2006).

The testing of cointegration was supported by the methodology developed by Johansen, and highlighted the existence of a number of cointegration vectors, *r*, so that 0 <r <number of endogenous variables (in our case 5), at a significance level of 0.05 (results based both on trace test and the Maximum Eigenvalue Test). This result corroborated with those obtained from stationarity underlines the possibility of model estimation with leveled variables. The number of

lags was chosen based on the Schwartz criterion of information content, which usually indicates one lag and in rarer cases two lags.

The identification of schocks

The present work uses Cholesky decomposition to identify shocks. In this respect it is worth noting that the ordering of variables in the highlighted versions of relations (4), (5) and (6) requires implicit assumptions about: (1) factors monetary authority considers in the policy making, and (2) which variables respond or not respond simultaneously to monetary policy decisions.

Thus, in case of the euro area VAR model (VAR 1), a monetary policy shock is identified by a standard Cholesky decomposition with variables ordered as in (4). The ordering implies that monetary authorities' decisions take into account the current level of production, prices and monetary developments. At the same time, the implicit assumption is that unexpected monetary policy shock has no contemporaneous impact on output, prices and monetary aggregates, but it may have an immediate effect on real effective exchange rate. However, the interest rate does not instantly respond to changes in the real effective exchange rate. We consider this as an appropriate hypothesis, as the Eurozone, seen as a whole defines a large and relatively closed economy. This variables ordering in the vector of endogenous factors is widely used in the literature, starting with Peersman and Smets (2001).

For the VAR model applied in the context of states that use (or used until the adoption of the euro) a strategy of inflation targeting (VAR 2), a monetary policy shock is identified by a standard Cholesky decomposition with variables ordered as in relation (5). This means that it allows for a contemporary impact of all endogenous variables on short-term interest rate. On the other hand, there is no immediate effect of a monetary policy shock on the other endogenous factors. This variables ordering approach has been used by Mojon and Peersman (2001).

Finally, if specified VAR model for states that use (or used until the common currency adoption) a strategy of targeting the exchange rate (VAR 3), the monetary policy shock is identified by a standard Cholesky decomposition variables ordered as in relation (6). Under this identification, an output shock simultaneously affects production, prices, monetary developments and domestic short-term interest rate; a price level shock affects prices, monetary developments and domestic short-term interest rate; a shock of monetary aggregates affects domestic short-term interest rate and monetary aggregates, while changes in domestic short-term interest rate simultaneously influence only domestic short-term interest rate. EZ short-term interest rate top ranking means that it does not allow for a contemporary impact of other endogenous variables shocks. Such an ordering of endogenous variables, in the context of central banks applying the exchange rate targeting, is observable for the European Forecasting Network (2004).

Analysis robustness

VAR models are confirmed if they are stable and the residuals are white noise. We verify the stability of the model by applying AR roots tests, which returned a stable VAR model in all cases, the roots inverse are under par and do not exceed the circle of unit radius. We check the serial non-correlation hypothesis with the help of Portmanteau test; we verify the normal distribution of errors based on the Jarque-Bera test and the homoscedasticity of error terms with the support of the White test. The results indicate the absence of autocorrelation, the normal distribution of errors and their homoscedasticity, so that the models have the ability to offer a good image on the interactions dynamics between variables. Results of the tests can be obtained from the author.

The estimation results

The VAR analysis returned three important results: *shock response function* (impulse response), *variance decomposition* (dispersion) and

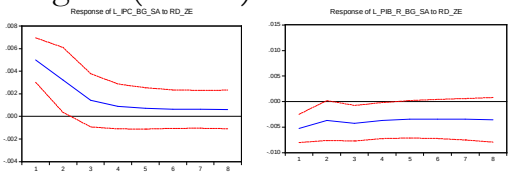
Granger causality. In this paper, considering the scale, we deal only with impulse response function.

Response functions to shocks presents the results on the effects of monetary policy shock on economic variables of interest to the monetary authority, providing information on both the response sign (positive or negative) and on the amplitude, speed and persistence impact of different shocks. Responses of three endogenous VAR variables to an unexpected contractionary monetary policy shock are shown in Figure 1 (full results can be obtained on request from the author). In the graphs presented, the confidence interval is 95%, the shock is one standard deviation and time on the horizontal axis is expressed in quarters.

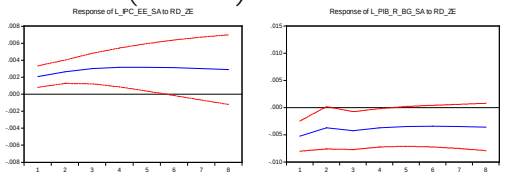
Figure 1

Figure no. 1. Inflation and aggregate output response to a contractionary monetary policy shock in the Euro Area and Central and Eastern European countries

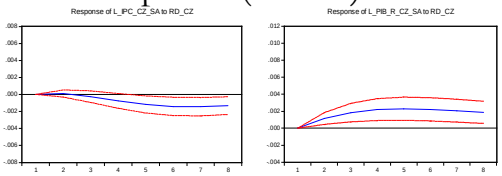
Bulgaria (VAR 3)



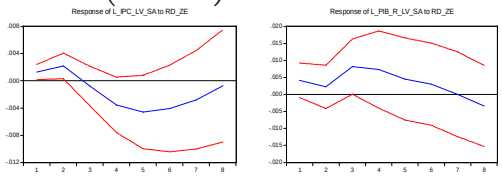
Estonia (VAR 3)



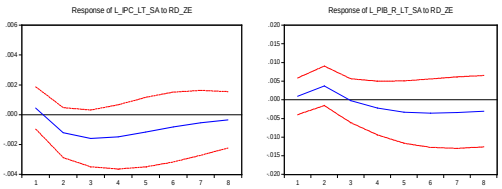
Czech Republic (VAR 2)



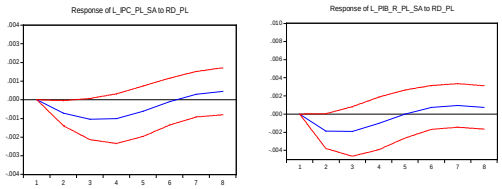
Latvia (VAR 3)



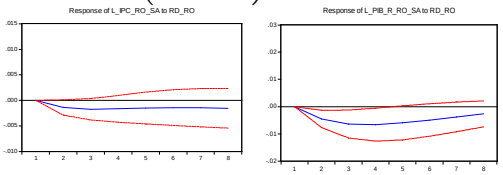
Lithuania (VAR 3)



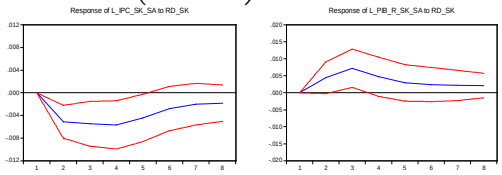
Poland (VAR 2)



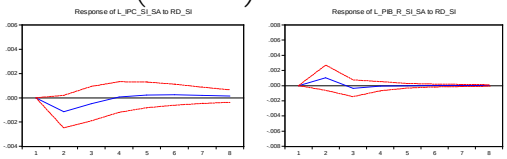
Romania (VAR 2)



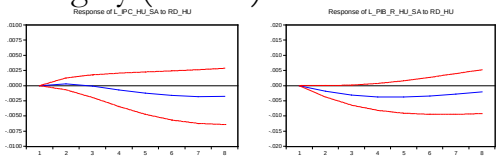
Slovakia (VAR 2)



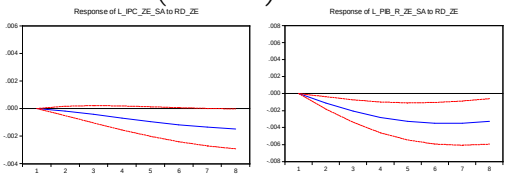
Slovenia (VAR 2)



Hungary (VAR 2)



Euro area (VAR 1)



Source: authorial calculations

To summarize, based on the analysis of individual countries, we identified that in most cases, impulse response functions observed for Central and Eastern European countries are, in terms of response sign, in accordance to the results obtained for the euro zone, meaning that an unexpected increase in short-term interest rate leads to a temporary reduction in the price level and output. From the perspective of a contractionary monetary policy shock impact on the general price level within analyzed economies where central banks are geared towards inflation targeting or used such a monetary policy strategy until the common currency adoption, the outcomes are consistent with the macroeconomic theory, revealing no counterintuitive answers in any case.

However, in these countries, the effects of domestic monetary policy on inflation present some significant differences from those identified

in the euro area, especially in terms of the magnitude and speed of shock impact (but not in its persistence).

As for the of the time elapsed since the event of contractionary monetary policy shock until the onset of maximum corresponding response of price level, for the case of the Eurozone we identify the passing of 8 quarters. In contrast, in most states in the region applying a direct inflation targeting strategy, a short-term nominal interest rate shock affects inflation reaching the impact peak much faster (usually after 3-4 quarters since its manifestation). In this line, linked to the rapid transmission of monetary policy shocks, the case of the Czech Republic appears to be more similar to the euro zone, where the most intense reaction occurs in the prices after the 7 quarters.

In terms of impact persistence we can highlight a more homogeneous situation. Thus, reduced consumer price level maintains for a horizon exceeding 8 quarters, both for the euro area and in the Czech Republic, Romania, Slovakia and Hungary. We note a lower persistence of the monetary policy shock in Poland, where the effect disappears after 5 quarters and also in Slovenia, until the adoption of the European single currency (4 quarters).

A number of differences between both the euro area and countries that use an inflation targeting strategy and between the latter showing a significant heterogeneity in monetary policy impulses, are also visible in terms of the amplitude of short term interest rate shock impact on inflation. Such a comparison makes it possible to determine the magnitude differences of the monetary policy effect on its final objective. Thus, from the perspective of inflation impact, the impulse response functions show a stronger monetary policy in Slovakia (until the euro adoption) and Hungary against the European Central Bank one. However, monetary policy in the Eurozone appears to be more solid than its counterparts in the Czech Republic, Poland, Romania and Slovenia (in that order). Maximum amplitude of the impact occurs at a 8 quarters horizon for the euro area viewed as a whole, while in

the case of selected countries, with monetary authorities aiming at inflation targeting, the most intense effects of the monetary policy on consumer price levels are felt more quickly, i.e. after 2 -3 quarters.
While the analysis of the impact generated by a contractionary monetary policy shock on the evolution of the price level in countries that apply an IT strategy has led to results consistent with the macroeconomic theory, the same cannot be said for the countries in the region with central bank using an exchange rate targeting strategy. Thus, both in Bulgaria and Estonia (until the accession to the euro area) and Latvia results indicate the presence of a price puzzle (current empirical results identified by VAR literature arguing that a rise in interest rates leads to increases in the price level). However, it should be noted that, although less numerous, most studies aimed at analyzing the transmission mechanism of monetary policy using vector autoregressive applied in the case of Bulgaria and the Baltic countries also reveal a counterintuitive result. Of these, only in Latvia, the increase in the short-term nominal interest rate of the European Central Bank (monetary policy shock considered for countries that apply an exchange rate targeting strategy) led to a drop in the price level. The impact of the contractionary monetary policy shock identified for Latvia has similar characteristics in terms of persistence to that manifesting in the euro area, but not in terms of the magnitude and speed of transmission (faster but less extensive, comparable to those in the Czech Republic, Poland, Romania and Slovenia, all applying an inflation targeting strategy.
The focus on the effects generated by a monetary policy shock on real economic activity evolution reveals counterintuitive results in the shape of a GDP puzzle in both CEE countries where the national monetary authorities use or have used until joining the euro area an IT strategy (the Czech Republic, Slovakia, Slovenia) and for some central banks that target the exchange rate (Latvia, Lithuania).

A comparative analysis of the impact of higher short-term nominal interest rate on real GDP in the euro area as a whole and in countries in the region following a strategy of inflation targeting reveals a certain similarity of responses in terms of effects persistence (findings recorded for inflation, as argued above). Instead, from the perspective of the unexpected contractionary shock manifestation and its impact amplitude we note a certain degree of heterogeneity. Thus, the rapid transmission of monetary shocks on real activity appears to be smaller in the Eurozone against countries that use an inflation targeting strategy (6 quarters to 3-4 for the latter). Meanwhile, in Romania and Hungary the amplitude of real economy activity drop in response to increased short-term nominal interest rate proves to be higher compared to the situation in the euro area, while Poland appears to be the opposite end.

In the states where we identified the exchange rate targeting as the monetary policy strategy, real GDP decrease due to higher short-term nominal interest rate set by the European Central Bank appears to be stronger compared to the euro area decrease and comparable in size with the process occurred in Romania and Hungary. Also, in terms of speed and persistence effects, the results are close to that found in countries that practice inflation targeting. As for the peak reaction, the situation is heterogeneous. Estonia recorded a maximum decrease in real activity in a timeframe comparable to the euro area, while in Bulgaria the decrease peak occurs immediately, with the first quarter of the contractionary shock manifestation.

Conclusions

The analysis of the monetary policy transmission mechanism in Central and Eastern European countries, based on the vector autoregressive with Cholesky identification customized on types of monetary policy strategies used in the region and the comparison to the corresponding monetary policy strategy of the European Central Bank revealed some mixed results.

Regarding the impact of an unexpected contractionary monetary policy shock on inflation in the case of selected states that apply or have applied until the euro adoption an inflation targeting strategy, we have obtained results consistent with macroeconomic theory. The same cannot be said for countries in the region that target the exchange rate, as we identified the presence of a price puzzle (except for Lithuania).

In terms of transmission speed of monetary policy shocks in most CEE countries that apply an inflation targeting strategy, it is much faster than compared to the euro area. We also note a number of significant differences from the perspective of short-term nominal interest rate shock impact amplitude on inflation, which indicates a high degree of heterogeneity in monetary policy impulses. As for the persistence level, the impact analysis revealed a more homogeneous context.

The focus on countries that apply an exchange rate targeting strategy, for which the outcomes were found to be counterintuitive, allowed the highlighting of some characteristics similar to those of the euro area monetary impulses in terms of impact persistence, but not in terms of the magnitude and speed of transmission.

We also found different results for aggregate output response to increased short-term nominal interest rate, as the GDP puzzle phenomenon is present in some cases. In addition, the heterogeneity of real activity responses to contractionary monetary policy shock is obvious from all three perspectives analyzed: *speed, persistence and amplitude.*

All this highlights the lack of similarity of transmission mechanisms between all Central and Eastern European countries on the road to adopting the euro and the EZ as a whole, which could cause strong evidence of obvious asymmetry when entering the European Monetary Union.

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