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Global financial crisis-driven mutations affecting the transmission mechanism customized to monetary policy strategies. A VAR, SVAR and BVAR approach

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Abstract. *This paper analyzes the transmission mechanisms of monetary policy in the Central and Eastern European (CEE) countries on the road to euro adoption depending on the monetary policy strategies used by the national central banks (CBs). The scientific construction of the paper is based on three methods: vector autoregressive (VAR), structural vector autoregressive (SVAR) and Bayesian techniques-estimated vector autoregressive (BVAR). The main results have indicated: 1) lack of similarity of the transmission mechanism, a high degree of heterogeneity in the transmission of monetary policy impulses indicated in all three cases subject to analysis: speed, persistence and amplitude, 2) an increase in the speed of monetary policy shocks transmission, a decrease in the amplitude of monetary policy shock impact and a reduction (or the maintaining at a similar level) of the persistence of monetary policy shock effects subsequent to the global financial crisis, regardless of the monetary policy strategy used.*

Keywords: monetary policy; transmission mechanism; autoregressive vector; impulse response functions; Central and Eastern Europe.

JEL Classification: E52, E43, C58, P48.
REL Classification: 8J.

1. Introduction

Currently, there are at least three important reasons to study monetary transmission mechanism in the economies of Central and Eastern Europe on the road to euro adoption. First, a real, accurate understanding of the measure, speed, and persistence of a change in CBs short-term nominal interest rate on inflation is a central element of the inflation targeting (IT) strategy due to the fact that the IT is a popular monetary strategy among states in the region.

Second, monetary policy transmission mechanism has a number of implications for the currency area entry and the proper functioning of the monetary union. The relevance of the transmission mechanism from the euro adoption perspective occurs when the effects of domestic monetary policy on inflation and economic activity are significant and substantially different from the ones identified in the EZ, because given such a context, the cost of monetary policy independence loss could be considerable. Third, the identification of mutations in the monetary policy transmission mechanism as a result of the global financial distress are especially important in shaping the monetary policy decision in the new environment characterized by a high degree of uncertainty.

Closely related to the above, we focus on providing an empirical analysis of the monetary policy shocks consequences on real economic aggregates and prices for CEE countries acceding to the euro area compared to the EZ states, using three methods: vector autoregressive (VAR), structural vector autoregressive (SVAR) and Bayesian techniques-estimated vector autoregressive (BVAR). Hence, we proposed to identify the impact of a contractionary monetary policy shock, customized according to the various types of strategies used by central banks in CEE countries and the EZ, respectively.

Model specification is different for each case, partly because we intend to capture as well a number of distinctive features that characterize each of the strategies applied in selected countries. Specific objectives aimed at three levels: 1) identifying the effects generated by a monetary policy shock both in the aggregate EZ and in the CEE states on the road to euro adoption, depending on the monetary strategies used by their national CBs; 2) compare the impact of monetary policy across countries in the area that apply the same strategy of monetary policy; between countries using different strategies and compare the outcomes identified with those available for the EZ and 3) determine the consequences of the international turmoil on the monetary policy transmission mechanism promoted by the European Central Bank and the monetary authorities of the selected states.

The proposed approach for pursuing our objectives brings several novelty elements: first, the specification of different models for various monetary policy strategies applied in the countries subject to analysis to better capture their

specific features; second, determining the consequences of monetary policy through the Bayesian techniques-estimated vector autoregressive (BVAR), as there is only a scarce literature of individual and comparative studies using the method in the context of CEE states acceding to the euro area; third, to determine the implications of the recent financial crisis on the transmission mechanism in the region, because currently there are only limited non-unitary researches treating CEE countries separately.

2. The application of vector autoregressive models in the analysis of the monetary policy transmission mechanism in Central and Eastern Europe

Vector autoregression models (VAR) introduced by Sims (1980) are considered 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 the data-based approach and the coherent approach based on economic theory.

The analysis of the monetary policy effects on key macroeconomic variables using VAR models has been extended to the emerging markets of Central and Eastern Europe. In the case of these states we identify both studies targeted at the individual level, as well as comparative analyses performed for different groups of countries to underline the relative peculiarities of the monetary policy impact on the economy and for making comparisons between these and the euro area.

Regarding individual level analyses, we note the presence of an important number of papers on CEE countries that use or have used until the euro adoption an inflation targeting strategy (Hurník and Arnoštová (2005), Morgese and Horváth (2008) in the case of the Czech Republic; Lyziak et al. (2008), Demchuk et al. (2012) for Poland; Antohi et al. (2003), Andries (2008) on Romania, Kucserová (2009), Horváth and Rusnák (2009) for Slovakia; Coricelli et al. (2006) for Slovenia; Vonnák (2005, 2007) for Hungary.

However, considering the CBs in CEE countries that use or have used, until the single currency adoption, an exchange rate targeting strategy, the number of individual studies focused on identifying the effects of monetary policy is low (especially those based on vector autoregression), because of their inability to promote an active monetary policy, with interest rates determined in the money market and not by a rule or a discretionary decision of central banks and must, in theory, closely follow the path of the anchor currency/ country (in this case, of the ECB). Several examples can be identified at Minea and Rault (2008, 2011) for Bulgaria; Lättemäe (2003) for Estonia; Bitans et al. (2003) in the case of Latvia, Vetlov (2003) for Lithuania.

Of particular importance for our analysis are the researches comparing the effects of monetary policy through the vector autoregression method in different groups of CEE countries against other advanced economies (Ganev et al., 2002; Creel and Levasseur; 2005; Héricourt, 2005; EFN 2005; Elbourne and de Haan, 2006; Anzuini and Levy, 2007; Jarocinski, 2008; Darvas, 2009). These works present a myriad of specific features of the monetary policy transmission mechanism in the new EU member states in Central and Eastern Europe against the old Member States. Such particularities include several aspects, as follows: 1) financial systems relatively much less developed than that of the 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 may lead to higher lag price responses, 3) growing inflation with implications for monetary policy transmission mechanism because in an environment of increased inflation agents adjust their prices more frequently and thus, prices are less rigid, 4) prevalence of exchange rate channel over the other two traditional channels of monetary policy transmission mechanism (interest rate channel and credit channel).

An analysis of the most representative studies focused on identifying the effects of monetary policy in CEE emerging countries can be found at Coricelli et al. (2006) and more recently at Egert and MacDonald (2009).

Presently, we note a new wave of interest towards the study of the recent economic and financial crisis implications on the monetary policy transmission mechanism based on VAR techniques (e.g., Boivin et al. 2010; Cecioni and Neri, 2010).

Research in the case of the CEE region is still at the beginning. We mention the study by Lyziak et al. (2011), which highlights the impact of the recent worldwide distress on the effectiveness of monetary policy transmission mechanism in Poland through a VAR model and a small structural model, pointing out that it depends on both the monetary policy and the structural characteristics of the economy. The financial turmoil, which affected both components, has led to a change in the monetary policy rule and to a significant decrease in the effectiveness of monetary policy. On the same line, Demchuk et al. (2012) emphasized that during the recent crisis, the monetary policy transmission mechanism in a small, open economy such as Poland suffered extensive disruption, with the interest rate channel being the most affected.

Carare and Popescu (2011) performed an analysis of the monetary policy implications in Hungary through a large-scale Bayesian estimated VAR model (BVAR) for the period 2001:6 - 2010:9 and outlined that despite the significant degree of euroisation, high share of foreign capital in the banking and corporate sectors, exponential levels of public debt, altogether likely to diminish the

effectiveness of monetary policy, the decline in economic activity due to the manifestation of a contractionary monetary policy shock appears as obvious and much faster than in advanced economies.

Popescu (2013) underlined the lack of similarities of the transmission mechanisms between all CEE countries on the road to EZ accession and the Eurozone at the aggregate level, which might lead to the manifestation of clear and strong asymmetries at the time of monetary area entry. Cocriş and Nucu (2013) researched the effectiveness of monetary policy applied by the monetary authorities in the region in ensuring financial stability and emphasize that the effectiveness of changes in short-term nominal interest rates on asset prices differ according to the type of monetary policy strategy used.

Based on a structural VAR, Pelinescu (2012) studied the measures taken by the National Bank of Romania at the beginning of the financial turmoil, and underlined 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) analyzed the functioning of monetary policy transmission mechanism in Romania through a Bayesian techniques estimated VAR model (BVAR). The key findings highlighted by authors stress the importance of the exchange rate channel, which significantly influences the evolution of real economic variables, and the rising importance of the interest rate channel, which over recent years has become more consistent. It should be noted that the authors included in the analysis a real estate market development index, reflecting domestic currency appreciation and the evolution of broad money as decisive factors that have led to these asset prices boom prior to the emergence of the financial crisis.

3. Methodology and data

Depending on the peculiarities of central banks' monetary policy strategies we specify one model for each strategy separately. The attachment of a distinct pattern for each type of monetary policy strategy applied by the CBs in CEE countries, and the specific monetary strategy of the ECB, respectively, aims to best highlight their distinguishing features. We use a recursive (VAR), structural (SVAR) and Bayesian techniques estimated (BVAR) approach for each model.

3.1. Recursive VAR model

Given the below system:

$$AxY_t = C(L)xY_{t-1} + D(L)xX_t + Bx\varepsilon_t \quad (1)$$

where: the A matrix includes all coefficients describing simultaneous relationships between variables, the C(L) matrix includes all coefficients that describe relations between variables lags, 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 the residuals. By multiplying the VAR system with the inverse of the A matrix, we obtain the followings:

$$Y_t = A^{(-1)}xC(L)xY_{t-1} + A^{(-1)}xD(L)xX_t + A^{(-1)}xB\varepsilon_t \quad (2)$$

That can be re-written as:

$$Y_t = axY_{t-1} + bxX_t + \mu_t \quad (3)$$

where:

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

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

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

Equation (1) describes the structural model and equation (3) is the reduced form of the model; the latter can be empirically observed.

Thus, the considered VAR model has the following representation in the reduced form:

$$Y_t = axY_{t-1} + bxX_t + \mu_t$$

where: Y_t is the vector of endogenous variables, X_t is the vector of exogenous variables, μ_t is the vector of the residual terms (white noise), a is a matrix comprising coefficients that describe the relationship between all the variables, and b is an endogenous matrix comprising all the coefficients that model the relationships between endogenous and exogenous variables.

Hence, for the euro area the recursive VAR (VAR 1) would have the representation shown in equation (4):

$$\text{VAR(1):} \begin{bmatrix} gdp\_r\_ez \\ cpi\_ez \\ m3\_ez \\ ir\_ez \\ reer\_ez \\ pc\_ez \\ pp\_ez \end{bmatrix} = ax \begin{bmatrix} gdp_{t-1}\_r\_ez \\ cpi_{t-1}\_ez \\ m3_{t-1}\_ez \\ ir_{t-1}\_ez \\ reer_{t-1}\_ez \\ pc_{t-1}ez \\ pp_{t-1}\_ez \end{bmatrix} + bx \begin{bmatrix} wcpi \\ gdp\_r\_us \\ ir\_us \end{bmatrix} + \mu_t^{ez} \quad (4)$$

In this case, the vector of exogenous variables includes the followings: global resource prices index (wcpi), U.S. real gross domestic product (gdp_r_us) and short-term interest rate in the U.S. (ir_us). The vector of endogenous variables for the Eurozone comprises the real gross domestic product (gdp_r_ez), consumer price index (cpi_ez), M3 monetary aggregate (m3_ez), short-term interest rate (ir_ez), the real effective exchange rate (reer_ez), private credit (pc_ez) and real estate prices (pp_ez).

For states that use an inflation targeting strategy, the recursive VAR model (VAR 2) is specified according to relation (5):

$$\text{VAR(2):} \begin{bmatrix} gdp\_r\_n \\ cpi\_n \\ reer\_n \\ ir\_n \\ m3\_n \\ pc\_n \\ pp\_n \end{bmatrix} = ax \begin{bmatrix} gdp_{t-1}\_r\_n \\ cpi_{t-1}\_n \\ reer_{t-1}\_n \\ ir_{t-1}\_n \\ m3_{t-1}\_n \\ pc_{t-1}\_n \\ pp_{t-1}\_n \end{bmatrix} + b \begin{bmatrix} gdp\_r\_ez \\ cpi\_ez \\ ir\_z \end{bmatrix} + \mu_t^n \quad (5)$$

where *n* successive = CZ (the Czech Republic), HU (Hungary), PL (Poland), RO (Romania).

Exogenous variables vector for the euro area in this case includes: real gross domestic product (gdp_r_ez), consumer price index (cpi_ez) and short-term interest rate (ir_ez) and the vector of endogenous variables comprises the real gross domestic product in the selected state (gdp_r_n), consumer price index (cpi_n), real effective exchange rate for the country in question (reer_n), short-term interest rate (ir_n), the size of the national M3 monetary aggregate (m3_n), private credit (pc_n) and real estate market prices (pp_n).

For central banks using a strategy of exchange rate targeting, recursive VAR (VAR 3) will have the representation in equation (6):

$$\text{VAR(3):} \begin{bmatrix} ir\_ez \\ gdp\_r\_n \\ cpi\_n \\ m3\_n \\ ir\_n \\ pc\_n \\ pp\_n \end{bmatrix} = ax \begin{bmatrix} ir_{t-1}\_ez \\ gdp_{t-1}\_r\_n \\ cpi_{t-1}\_n \\ m3_{t-1}\_n \\ ir_{t-1}\_n \\ pc_{t-1}\_n \\ pp_{t-1}\_n \end{bmatrix} + bx \begin{bmatrix} reer\_n \\ gdp\_r\_ez \\ cpi\_ez \end{bmatrix} + \mu_t^n \quad (6)$$

where *n* successive = BG (Bulgaria), LV (Latvia), LT (Lithuania).

The exogenous variables vector include: the real effective exchange rate for the selected country (reer_n), real GDP in the euro area (gdp_r_ez) and), consumer price index in the EZ (cpi_ez). In turn, in this case, the vector of endogenous variables comprises the short-term interest rate in the euro area (ir_ez), real gross

domestic product in the country in question (gdp_r_n), consumer price index (cpi_n), the expanded national monetary aggregate (m3_n), short-term interest rate (ir_n), private credit (pc_n) and real estate prices in the considered state (pp_n).

Exogenous variables are included to control the evolution of foreign demand and inflation. The inclusion of these variables helps solve the so-called *price puzzle* referring to current empirical results identified in the VAR literature stating that an increase in the interest rate leads to rising price levels. Treating these variables as exogenous implicitly presumes that there is no impact of endogenous to exogenous variables. At the same time, it allows for a contemporary impact of exogenous variables on endogenous factors.

In the case of recursive VAR, the identification of shocks implies imposing zero restrictions on the A and B matrices coefficients in the relation $\mu = A^{(-1)}B\varepsilon$ is achieved through a Cholesky decomposition. In the case of recursive identification, the Cholesky A matrix has a triangular structure, with elements above the main diagonal equal to zero. Given that, we note that the ordering of variables as highlighted by relations (4), (5) and (6) requires implicit assumptions about: (1) what to consider when setting the monetary policy and (2) which variables respond or not respond simultaneously to monetary policy decisions.

Thus, for the Eurozone recursive VAR model (VAR 1), a monetary policy shock is identified by a standard Cholesky decomposition with variables ordered as in (4). The shock identification scheme is reflected by equation (7).

$$\text{VAR(1):} \begin{bmatrix} \varepsilon_t^{gdp\_r\_ez} \\ \varepsilon_t^{cpi\_ez} \\ \varepsilon_t^{m3\_ez} \\ \varepsilon_t^{ir\_ez} \\ \varepsilon_t^{reer\_ez} \\ \varepsilon_t^{pc\_ez} \\ \varepsilon_t^{pp\_ez} \end{bmatrix} = \begin{bmatrix} 1 & 0 & 0 & 0 & 0 & 0 & 0 \\ a_{21} & 1 & 0 & 0 & 0 & 0 & 0 \\ a_{31} & a_{32} & 1 & 0 & 0 & 0 & 0 \\ a_{41} & a_{42} & a_{43} & 1 & 0 & 0 & 0 \\ a_{51} & a_{52} & a_{53} & a_{54} & 1 & 0 & 0 \\ a_{61} & a_{62} & a_{63} & a_{64} & a_{65} & 1 & 0 \\ a_{71} & a_{72} & a_{73} & a_{74} & a_{75} & a_{76} & 1 \end{bmatrix} x \begin{bmatrix} \mu_t^{gdp\_r\_ez} \\ \mu_t^{cpi\_ez} \\ \mu_t^{m3\_ez} \\ \mu_t^{ir\_ez} \\ \mu_t^{reer\_ez} \\ \mu_t^{pc\_ez} \\ \mu_t^{pp\_ez} \end{bmatrix} \quad (7)$$

The ordering used implies that when deciding the monetary policy, the authorities consider the current level of production, prices and monetary developments. At the same time, the implicit assumption is that an unexpected monetary policy shock has no contemporaneous impact on the output, prices and monetary aggregates, but it can have an immediate effect on the real effective exchange rate, private credit and property prices. However, the interest rate does not respond simultaneously to changes in the real effective exchange rate, private credit and real estate prices.

We consider such an assumption to be appropriate, as the aggregate euro area is on the one hand, a large and relatively closed economy, and on the other hand, characterized by the absence of clear guidelines to prevent unsustainable credit growth and asset price bubble formation. Such ordering in the endogenous vector of variables (except for private credit and real estate market prices) is widely used in the literature starting with Peersman and Smets (2001).

For the recursive VAR model in the context of the states using an inflation targeting strategy (VAR 2), a monetary policy shock is identified by a standard Cholesky decomposition with the variables ordered as in (5). The scheme of identifying the shock is illustrated by equation (8).

$$\text{VAR(2):} \begin{bmatrix} \varepsilon_t^{gdp\_r\_n} \\ \varepsilon_t^{cpi\_n} \\ \varepsilon_t^{reer\_n} \\ \varepsilon_t^{ir\_n} \\ \varepsilon_t^{m3\_n} \\ \varepsilon_t^{pc\_n} \\ \varepsilon_t^{pp\_n} \end{bmatrix} = \begin{bmatrix} 1 & 0 & 0 & 0 & 0 & 0 & 0 \\ a_{21} & 1 & 0 & 0 & 0 & 0 & 0 \\ a_{31} & a_{32} & 1 & 0 & 0 & 0 & 0 \\ a_{41} & a_{42} & a_{43} & 1 & 0 & 0 & 0 \\ a_{51} & a_{52} & a_{53} & a_{54} & 1 & 0 & 0 \\ a_{61} & a_{62} & a_{63} & a_{64} & a_{65} & 1 & 0 \\ a_{71} & a_{72} & a_{73} & a_{74} & a_{75} & a_{76} & 1 \end{bmatrix} x \begin{bmatrix} \mu_t^{gdp\_r\_n} \\ \mu_t^{cpi\_n} \\ \mu_t^{reer\_n} \\ \mu_t^{ir\_n} \\ \mu_t^{m3\_n} \\ \mu_t^{pc\_n} \\ \mu_t^{pp\_n} \end{bmatrix} \quad (8)$$

This means a contemporary impact of the national gross domestic product, consumer price index and the real exchange rate on the short term rate variable. On the other hand, there is no immediate effect of the monetary policy shock on extended money supply, private credit and real estate market prices. This type of ordering of endogenous variables (except for private credit and real estate prices) can be found at Peersman and Mojon (2001).

Finally, in the case of the recursive VAR model for the CEE states subject to analysis that use an exchange rate targeting strategy (VAR 3), the monetary policy shock is identified by a standard Cholesky decomposition with the variables ordered as in (6). Such identification scheme is presented in equation (9).

$$\text{VAR(3):} \begin{bmatrix} \varepsilon_t^{ir\_ez} \\ \varepsilon_t^{gdp\_r\_n} \\ \varepsilon_t^{cpi\_n} \\ \varepsilon_t^{m3\_n} \\ \varepsilon_t^{ir\_n} \\ \varepsilon_t^{pc\_n} \\ \varepsilon_t^{pp\_n} \end{bmatrix} = \begin{bmatrix} 1 & 0 & 0 & 0 & 0 & 0 & 0 \\ a_{21} & 1 & 0 & 0 & 0 & 0 & 0 \\ a_{31} & a_{32} & 1 & 0 & 0 & 0 & 0 \\ a_{41} & a_{42} & a_{43} & 1 & 0 & 0 & 0 \\ a_{51} & a_{52} & a_{53} & a_{54} & 1 & 0 & 0 \\ a_{61} & a_{62} & a_{63} & a_{64} & a_{65} & 1 & 0 \\ a_{71} & a_{72} & a_{73} & a_{74} & a_{75} & a_{76} & 1 \end{bmatrix} x \begin{bmatrix} \mu_t^{ir\_ez} \\ \mu_t^{gdp\_r\_n} \\ \mu_t^{cpi\_n} \\ \mu_t^{m3\_n} \\ \mu_t^{ir\_n} \\ \mu_t^{pc\_n} \\ \mu_t^{pp\_n} \end{bmatrix} \quad (9)$$

This identification allows for an output shock to simultaneously affect production, prices, monetary developments, domestic short-term interest rate, private credit and real estate prices; a price level shock to affect the price level, monetary

developments, domestic short-term interest rate, private credit and real estate prices; a shock of monetary aggregates to affect monetary aggregates, domestic short-term interest rate, private credit and real estate prices; changes in domestic short term interest rates to simultaneously affect domestic short-term interest rate, private credit and housing market prices; a private credit shock to impact real estate prices, while changes in market prices affect exclusively the real estate market prices.

The first position of the short term interest rate in the euro area implies that it does not allow for a contemporary impact of shocks in the other endogenous variables on its levels. An ordering of this type of endogenous variables, in the context of CBs targeting the exchange rate (except for private credit and real estate prices) is found in European Forecasting Network (2004).

3.2. Structural VAR model (SVAR)

The optimal highlighting of the three monetary policy strategies distinctive characteristics through recursive VAR models is strongly constrained by the specific rigidity of Cholesky orthogonalization shock identification method. To remove this disadvantage, structural VAR models have been custom built to the three types of monetary policy strategy with the same representation as the recursive ones, differing by shock identification techniques.

Thus, while for VAR recursive models the innovation decomposition is performed by Cholesky identification technique, for VAR structural models, the identification of shocks is a structural process, with zero restrictions freely distributed. Compared to the Cholesky orthogonalization method, the latter allows for a more accurate description of the variables interdependencies, and a greater flexibility of the relationships between them.

For the structural VAR model in the context of the euro area (SVAR 1) the number of zero restrictions imposed is 21 (the system is exactly identified), with the proposed scheme of shock identification given by relation (10).

$$\text{SVAR(1):} \begin{bmatrix} \varepsilon_t^{gdp\_r\_ez} \\ \varepsilon_t^{cpi\_ez} \\ \varepsilon_t^{m3\_ez} \\ \varepsilon_t^{ir\_ez} \\ \varepsilon_t^{reer\_ez} \\ \varepsilon_t^{pc\_ez} \\ \varepsilon_t^{pp\_ez} \end{bmatrix} = \begin{bmatrix} 1 & 0 & 0 & 0 & 0 & 0 & 0 \\ a_{21} & 1 & 0 & 0 & 0 & 0 & 0 \\ a_{31} & a_{32} & 1 & a_{34} & a_{35} & a_{36} & a_{37} \\ a_{41} & 0 & a_{43} & 1 & 0 & a_{46} & 0 \\ a_{51} & a_{52} & a_{53} & a_{54} & 1 & a_{56} & 0 \\ a_{61} & a_{62} & a_{63} & 0 & 0 & 1 & a_{67} \\ 0 & 0 & a_{73} & 0 & 0 & a_{76} & 1 \end{bmatrix} \text{x} \begin{bmatrix} \mu_t^{gdp\_r\_ez} \\ \mu_t^{cpi\_ez} \\ \mu_t^{m3\_ez} \\ \mu_t^{ir\_ez} \\ \mu_t^{reer\_ez} \\ \mu_t^{pc\_ez} \\ \mu_t^{pp\_ez} \end{bmatrix} \quad (10)$$

The first two equations represent the slow reaction of the real sector (GDP and prices) to shocks in the monetary sector (broad money, interest rate and exchange

rate) and shocks from private credit and real estate prices. There is no contemporary impact of monetary policy shocks, M3, exchange rate, private credit and real estate market prices on production and consumer price index.

M3 monetary aggregate is influenced by contemporary innovations of all other endogenous variables. The monetary authority sets the interest rate taking into account contemporary innovations in production (a_{41} can be interpreted as an indicator of excess demand pressure), extended monetary aggregate innovation and private credit (a_{43} and a_{46} interpreted as expression of using the information provided by the monetary analysis pillar line as a distinctive feature of the ECB monetary policy strategy), but it does not simultaneously respond to shocks in the price level (price data available only with some lag), exchange rate (considering the EZ as a large and relatively closed economy) and property prices (assuming that monetary policy conducted by the ECB has not been directed towards preventing the formation of bubbles in asset prices specific to this market) .

Exchange rate, as the price of an asset, immediately reacts to all the innovations of the other variables, except for shocks of the property prices. Private credit is influenced by contemporary production shocks, price level, broad money and asset prices in the housing market. Finally, real estate prices respond simultaneously to innovation of the broad money and private credit.

$$\text{SVAR(2):} \begin{bmatrix} \varepsilon_t^{gdp\_r\_n} \\ \varepsilon_t^{cpi\_n} \\ \varepsilon_t^{reer\_n} \\ \varepsilon_t^{ir\_n} \\ \varepsilon_t^{m3\_n} \\ \varepsilon_t^{pc\_n} \\ \varepsilon_t^{pp\_n} \end{bmatrix} = \begin{bmatrix} 1 & 0 & 0 & 0 & 0 & 0 & 0 \\ a_{21} & 1 & 0 & 0 & 0 & 0 & 0 \\ a_{31} & a_{32} & 1 & a_{34} & a_{35} & a_{36} & 0 \\ a_{41} & 0 & a_{43} & 1 & 0 & 0 & 0 \\ a_{51} & a_{52} & a_{53} & a_{54} & 1 & a_{56} & a_{57} \\ a_{61} & a_{62} & 0 & 0 & a_{65} & 1 & a_{67} \\ a_{71} & 0 & 0 & 0 & a_{75} & a_{76} & 1 \end{bmatrix} \text{x} \begin{bmatrix} \mu_t^{gdp\_r\_n} \\ \mu_t^{cpi\_n} \\ \mu_t^{reer\_n} \\ \mu_t^{ir\_n} \\ \mu_t^{m3\_n} \\ \mu_t^{pc\_n} \\ \mu_t^{pp\_n} \end{bmatrix} \quad (11)$$

$$\text{SVAR(3):} \begin{bmatrix} \varepsilon_t^{ir\_ez} \\ \varepsilon_t^{gdp\_r\_n} \\ \varepsilon_t^{cpi\_n} \\ \varepsilon_t^{m3\_n} \\ \varepsilon_t^{ir\_n} \\ \varepsilon_t^{pc\_n} \\ \varepsilon_t^{pp\_n} \end{bmatrix} = \begin{bmatrix} 1 & 0 & 0 & 0 & 0 & 0 & 0 \\ a_{21} & 1 & 0 & 0 & 0 & 0 & 0 \\ 0 & a_{32} & 1 & a_{34} & 0 & 0 & 0 \\ a_{41} & a_{42} & a_{43} & 1 & a_{45} & a_{46} & 0 \\ a_{51} & a_{52} & a_{53} & a_{54} & 1 & a_{56} & 0 \\ a_{61} & a_{62} & 0 & a_{64} & a_{65} & 1 & 0 \\ a_{71} & a_{72} & 0 & 0 & a_{75} & a_{76} & 1 \end{bmatrix} \text{x} \begin{bmatrix} \mu_t^{ir\_ez} \\ \mu_t^{gdp\_r\_n} \\ \mu_t^{cpi\_n} \\ \mu_t^{m3\_n} \\ \mu_t^{ir\_n} \\ \mu_t^{pc\_n} \\ \mu_t^{pp\_n} \end{bmatrix} \quad (12)$$

For considered structural VAR models specific to IT strategies (SVAR 2) and exchange rate targeting (SVAR 3), identification schemes proposed are expressed by equations (11) and (12). Similar to the euro area, these schemes have been constructed aiming at a more accurate description of interdependencies between variables given the country-specific factors for each monetary policy strategy

used. Interpretation of interdependencies between variables amid the strategies particularities can be realized based on the general guidelines detailed above, in the case of the euro area.

3.3. Bayesian VAR model (BVAR)

In order to illustrate the framework of BVAR, the reduced form of the VAR model expressed by the relationship (3) with the extraction of exogenous variables vector (Ko-Ko Minnesota prior distribution used for the estimation does not allow the inclusion of exogenous variables) is refined by introducing the following matrix notations in a compact form:

$$Y_{TXm} = X_{Tx(mp+1)} x B_{(mp+1)xm} + E_{Txm}\,, \quad E \sim N(0, \Sigma) \tag{13}$$

where: $X = \begin{bmatrix} x_1 \\ \vdots \\ x_T \end{bmatrix}$, $x_t = \begin{bmatrix} 1 & y_{t-1} & \dots & y_{t-p} \end{bmatrix}$, $B = \begin{bmatrix} a_0 \\ A_1 \\ \vdots \\ A_p \end{bmatrix}$, $\beta = vec(B)$,

Therefore, in this case, Y is defined as an array (Txm) incorporating the T observations for each dependent variable. This approach allows to easily obtain the posterior distribution required by the Bayesian techniques. It should be noted that the estimation cannot be performed equation by equation, as in the reduced version, because this time the dependent variable is not a vector, but a matrix (Txm).

To formally describe how to build the Bayesian estimation, the model expressed by equation (13) is implemented as relation (14):

$$Y_t = x_t x \beta + \varepsilon_t\,, \quad t = 1, \dots, T \tag{14}$$

with β and Σ the unknown parameters of the model.

The analysis of Bayesian VAR models requires the knowledge of the distribution properties to estimate parameters. If we note the unknown parameters θ = (β, Σ) and consider π (θ ∣ Y) and π (θ) the posterior and prior distribution, and L (Y ∣ θ) a data distribution function, according to Bayes theorem, the posterior distribution is given by (15):

$$\pi(\theta \mid Y) = \frac{L(Y \mid \theta) x \pi(\theta)}{\int L(Y \mid \theta) x \pi(\theta) d\theta} \tag{15}$$

Given the definition of conditional likelihood, the combination of data density function and the parameters π (β, Σ, Y) can be written as in (16):

$$\pi(\beta, \Sigma, Y) = L(Y \mid \beta, \Sigma) x \pi(\beta, \Sigma) = \pi(\beta, \Sigma \mid Y) x \pi(Y) \tag{16}$$

When given π (β, Σ, Y), conditional marginal posterior distribution of data can be obtained based on the relation (17):

$$\pi(\Sigma \mid Y) = \int \pi(\beta, \Sigma \mid Y) d\beta \;\; şi \;\; \pi(\beta \mid Y) = \int \pi(\beta, \;\; \Sigma \mid Y) d\Sigma \tag{17}$$

Under these conditions, the main purpose of the Bayesian estimation is to identify posterior distribution moments for the parameters of interest.

The choosing of prior information for the model parameters has always been an important issue in the Bayesian analysis, as this option is the essential step for model specification. The literature has proposed various types of prior information (Sims-Zha, Koop-Koroblis, Diffuse), with selection depending on the specific economic problem subject to analysis, data samples and parameters determination procedure.

In the present paper, we use a Ko-Ko Minnesota priors distribution developed by Koop and Korobilis (2010). The simplicity of the approach derives from the fact Σ is assumed to be known. Prior information for β appears as $\beta \sim N(\beta_0, V_0)$, with an average of $\beta_0 = 0_{mpx1}$ and covariance in the form of $V_0 \neq 0$. Koop and Korobilis have specified the V_0 prior covariance matrix as a diagonal matrix with elements $v_{ij,l}(l = 1, \ldots, p)$, according to the relation (18).

$$v_{ij,l} = \begin{cases} \frac{a_1}{p^2} \text{ for own lags coefficients} \\ \frac{a_2 \sigma_i}{p^2 \sigma_j} \text{ for } i \neq j \text{ variable lags coefficients} \\ a_3 \sigma_i \text{ for exogeneous variables coefficients} \end{cases} \tag{18}$$

where σ_i^2 is the *i* diagonal element of Σ.

Priors information (values of a_1, a_2, a_3 and β_0 hyper-parameters) can be determined either by using their values from previous studies or by choosing those that reduce the forecast errors. a_1 and a_2 hyper-parameter values have been set based on state-specific data, while for a_3 și β_0 we used values of 100 and 0. To determine the a_1 and a_2 hyper-parameters we searched the $(a_1, a_2) \in ([0,1],[0,1])$ peers that minimizes the root mean square error (RMSE) calculated for country-specific data samples for the selected period in each case. A summary of the hyper-parameter values is shown in Table 1.

Table 1. *Hyper-parameter values used in estimating the BVAR*

Hyper-parameter / Country/ Region	a_1	a_2	a_3	β_0
Bulgaria	0.3	0.1	100	0
The Czech Republic	0.9	0.9	100	0
Latvia	0.1	0.1	100	0
Lithuania	0.1	0.2	100	0
Poland	0.9	0.9	100	0
Romania	0.9	0.9	100	0
Hungary	0.1	0.1	100	0
The euro area	0.1	0.1	100	0

Source: authorial calculations.

3.4. Data

The sample used is restricted, including data from the time central banks have adopted the monetary policy strategy currently in application. It should be noted that such a restriction allows us both to achieve the objective of identifying the effects of monetary policy customized to various types of strategies adopted by CBs, and at the same time, as pointed out in the literature, offers the possibility to remove one of the causes that lead to the manifestation of puzzles between different variables (identification of counterintuitive results, contrary to the fundamental theoretical relationships between variables). Furthermore, this approach also facilitates the avoidance to some extent of the Lucas critique (Lucas, 1976), as the transition from the use of a monetary policy strategy to another represents without any doubt a regime change.

Such an aim focused on a time horizon that starts with the adoption of the CB monetary policy strategy was hampered by the availability of real estate prices development data series. Given quarterly data frequency, the application of the two restrictions above mentioned leads to the following intervals for the baseline scenario: Bulgaria: 1997q1: 2013q1; the Czech Republic: 2004q1: 2013q1; Latvia: 2000q1: 2013q1; Lithuania: 1998q4: 2013q1; Poland: 2002q4: 2013q1; Romania: 2005q3: 2013q1; Hungary: 2001q4: 2013q1; the Eurozone: 1999q1: 2013q1. For the scenario that covers the period subsequent to the international financial crisis, the time span is 2008q4: 2013q1.

The variables included in the analysis are the gross domestic product (gdp) as a fixed-base index (2005 = 100) of real GDP in the euro area, the US and each of the selected countries; consumer price index (cpi) as fixed base index (2005 = 100) of consumer prices for the euro area and for each of the states subject to analysis; broad money (m3) as a fixed-base index (2005 = 100) for euro area M3 monetary aggregate and in each country in the sample; the short term interest rate (ir) with 3M EURIBOR as proxy for the EZ and its equivalents for other countries, respectively; the real effective exchange rate (reer) as fixed-base index (2005 = 100) of real effective exchange rate (taking into account the 27 trading partners) for the euro area and the selected states; global resource prices index (wcpi) as fixed-base index (2005 = 100); private credit (pc) as fixed-base index (2005 = 100) of private credit in the euro area and in analyzed countries and real estate price (pp) as a fixed base index (2005 = 100).

Most data is provided by Eurostat, except for the world resources price index retrieved from the World Bank, the size of monetary aggregates taken from monthly bulletins published on the websites of selected CBs, private credit and the price of real estate, where the data comes from the Bank for International Settlements database.

All series except for short-term interest rate and real effective exchange rate has been adjusted to remove seasonal factors using the X12 procedure applied by the U.S. Census Bureau. Also, all series except for short-term interest rates are logarithmic.

We test the variables stationarity by using Augmented Dickey – Fuller test and Phillips – Perron that returned negative results (non-stationary variables). Most variables are integrated of order 1 (I (1)), and some of order 2 (I (2)).

The variables supporting the VAR analysis should not, however, be stationary. Sims (1980), *inter alia,* argued against differentiation, even if the series contain a unit root, because differentiation causes information losses. What matters for the robustness of VAR results is the overall system is the stationarity of the VAR results for the robustness of the overall system (Lütkepohl, 2006). Moreover, the use of variables in levels and not as first order differences has the ability to maintain long-term relationships (if present) and do not affect the statistical inference (Sims et al., 1990).

Cointegration testing based on the methodology developed by Johansen shows the existence of a number of cointegration equations, r, so that $0 < r <$ endogenous variable number (in this case 7), at a significance threshold of 0.05 (results based on both the Trace test and the Maximum Eigenvalue test). This outcome, in conjunction with those obtained from stationarity tests highlights the possibility of model estimation with level-expressed variables.

The choice of lags number was based on Schwartz informational evaluation criteria, suggesting in all cases the selection of a single lag. We verified the results by applying the lag exclusion test to eliminate lags that are not significant. The Lag Exclusion Wald test confirmed the number of lags indicated by the Schwartz criterion. In case of the Bayesian techniques-estimated VAR models we selected two lags due to the fact that the use of a single lag would not allow the accurate determination of the coefficients.

3.5. The soundness of analysis

VAR, SVAR and BVAR considered models are confirmed if they are stable and the residuals are white noise. We verified the stability of the model by applying AR root tests, with results indicating the stability of all VAR models, subunit inverse roots, non-exceeding the circle of unit radius, respectively. Residual serial non-correlation hypothesis testing is based on *Portmanteau test*; we checked for the normal distribution of errors with the help of *Jarque - Bera test*, and for the residuals homoscedasticity by applying the *White test* statistic. The findings revealed a normal, homoscedastic distribution of errors, a number of small problems related to the existence of a serial correlation of residuals; overall, the

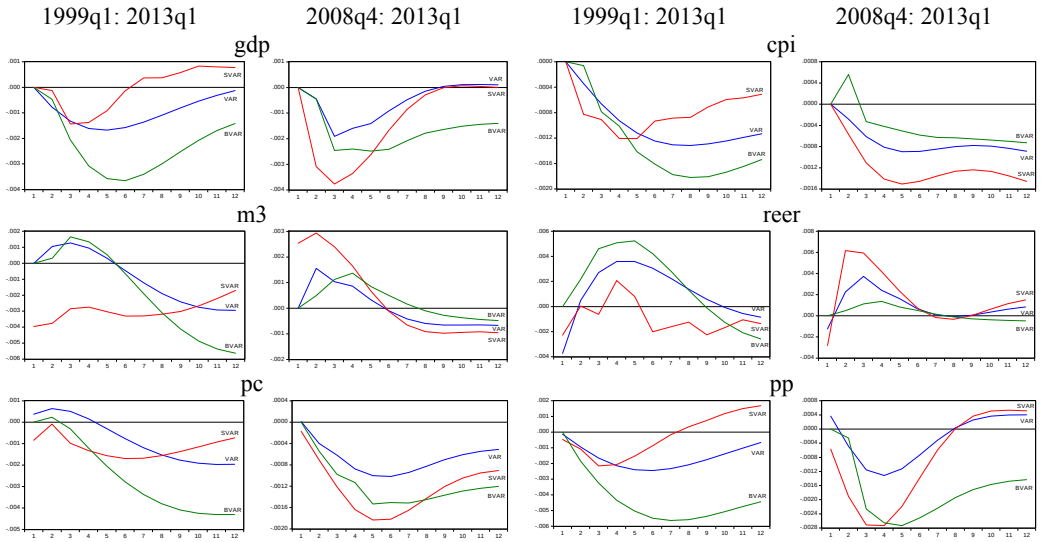
models are able to provide a good picture of the dynamics of variables interactions. The results of the above mentioned tests can be obtained on request from the author.

4. Estimation results

Analyses based on vector autoregression models returned two important results: the impulse response function and variance decomposition. The present paper addresses only the response functions to a monetary policy shock as illustrated in the graphs below, with a confidence interval of 95%, where the shock is represented by a standard deviation and time on the horizontal axis is expressed in quarters.

4.1. The euro area case

In the context of an unexpected event of contractionary monetary policy (sudden increase in short-term interest rate) in the EZ, the variables responses for the two given intervals can be identified in Graph 1.



Source: authorial calculations.

Graph 1. *The response of variables to a contractionary monetary policy shock - the euro area*

A summary of the monetary policy transmission mechanism characteristics in the euro area for the selected intervals considered is indicated in Table 2. The effects caused by a contractionary monetary policy shock on macroeconomic variables

are quantified in terms of three basic characteristics: speed (S), amplitude (A) and persistence (P). *Speed* refers to the number of quarters from the shock emergence until it reaches the peak, *the amplitude* relates to the maximum impact of the shock on the interest variable, quantified as a percentage of the standard deviation (shock being represented by a standard deviation) and *the persistence* is the number of quarters affected by the shock manifestation.

Table 2. *Characteristics of the monetary policy transmission mechanism in the euro area*

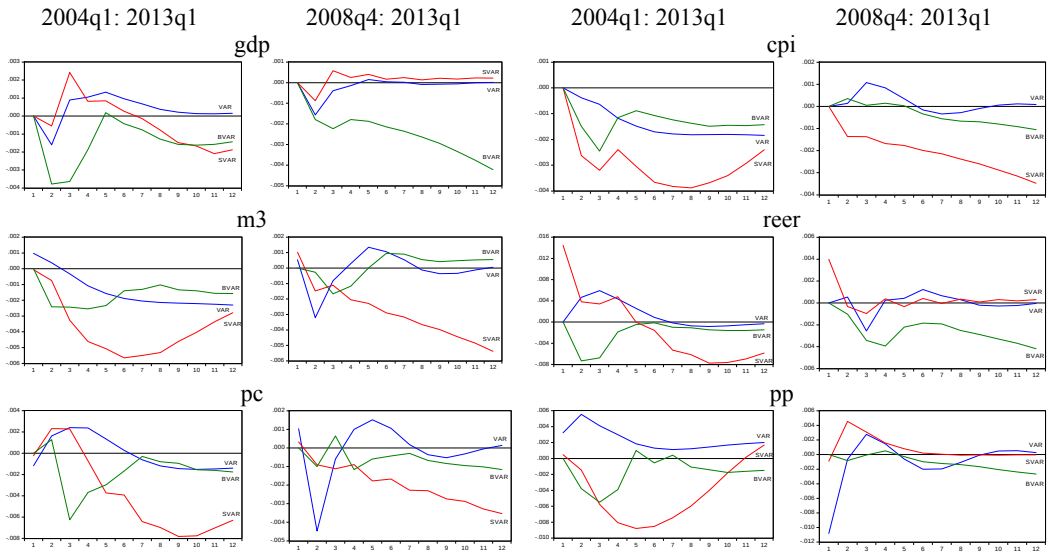
1999q1:	*gdp*			*cpi*			*m3*			*reer*			*pc*			*pp*		
2013q1	S	A	P	S	A	P	S	A	P	S	A	P	S	A	P	S	A	P
VAR	5	0.18	7	7	0.13	12+	C			1	0.4	2	C			6	0.20	12
SVAR	3	0.15	12	4	0.12	12+	1	0.4	12+	1	0.2	2	6	0.18	12	2	0.20	7
BVAR	6	0.35	12+	8	0.18	12+	C			C			C			6	0.55	+12
2008q4:	gdp			cpi			m3			reer			pc			pp		
2013q1	S	A	P	S	A	P	S	A	P	S	A	P	S	A	P	S	A	P
VAR	2	0.18	8	4	0.08	12+	C			1	0.1	1	5	0.08	12+	3	0.12	7
SVAR	2	0.35	8	4	0.13	12+	C			1	0.3	1	5	0.18	12+	2	0.26	7
BVAR	2	0.20	12+	C			C			C			5	0.15	12+	4	0.26	12+

Source: authorial calculations.
Note: S – speed of reaching the shock peak (quarters), A – shock effects amplitude (% of a standard deviation;) P – shock impact persistence maintaining (quarters); C – a result contrary to macroeconomic theory.

The comparative approach of the impact of an unexpected contractionary monetary policy shock for the two selected time horizons indicates a higher speed and amplitude, but a lower persistence on real activity for the period subsequent to the global financial crisis. In the same interval, the monetary policy shock is likely to cause a more rapid, with a similar persistence, but with a lower power impact on inflation expressed by the consumer price index. *Ex post* turmoil, the exchange rate reacts with a similar speed, but less powerful and for a shorter time to the unexpected increase in short-term nominal interest rate, while the reaction of private credit to monetary policy shock occurs with relatively close features from the perspective of all the elements of comparison. Regarding the impact on prices in the housing market, it appears to be faster, but of lower amplitude and persistence.

4.2. The Czech Republic case

For the Czech Republic, an unanticipated contractionary monetary policy shock (sudden increase in short-term interest rate) generates responses of the variables of interest for the two considered intervals that can be traced in Graph 2.



Source: authorial calculations.

Graph 2. *Response of variables to a contractionary monetary policy shock - The Czech Republic*

The main features of the Czech monetary policy transmission are summarized in Table 3. The comparative analysis of the transmission mechanism on the two temporal horizons covers the same key elements, namely speed and persistence of effects generated by the manifestation of an unanticipated contractionary monetary policy shock.

Table 3. *Characteristics of the monetary policy transmission mechanism in the Czech Republic*

2004q1:	gdp			cpi			m3			reer			pc			pp		
2013q1	S	A	P	S	A	P	S	A	P	S	A	P	S	A	P	S	A	P
VAR	2	0.15	3	5	0.18	12+	C			C			1	0.10	1	C		
SVAR	2	0.05	3	7	0.38	12+	6	0.58	12+	C			C			5	0.9	11
BVAR	2	0.38	12+	3	0.25	12+	2	0.25	12+	2	0.7	12+	C			3	0.5	4
2008q4:	gdp			cpi			m3			reer			pc			pp		
2013q1	S	A	P	S	A	P	S	A	P	S	A	P	S	A	P	S	A	P
VAR	2	0.15	3	C			C			C			C			2	1.1	2
SVAR	2	0.05	3	2	0.35	12+	C			C			12	0.10	12+	C		
BVAR	3	0.20	12+	C			3	0.15	5	4	0.40	12+	1	0.10	2	2	0.1	2

Source: authorial calculations.

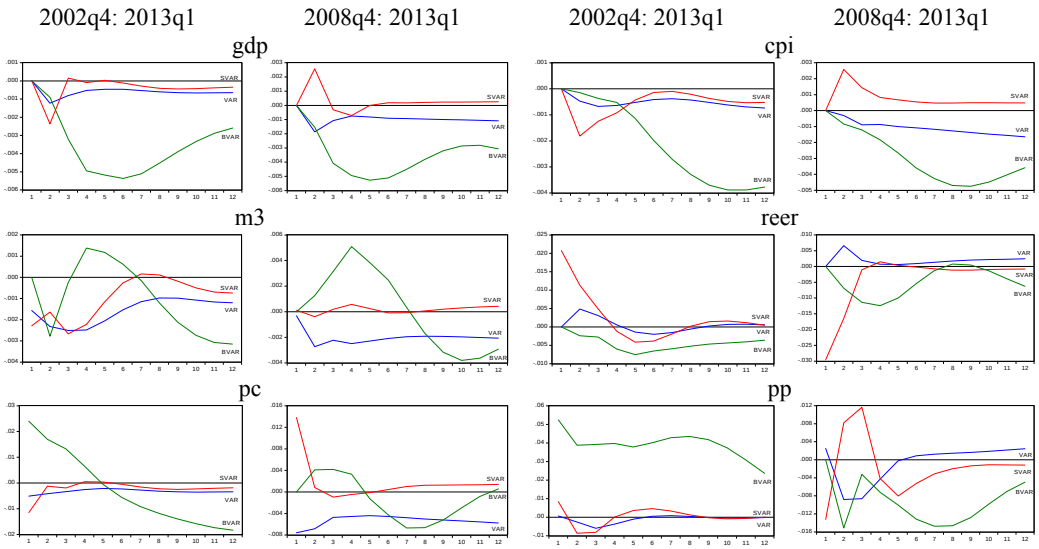
Note: S – speed of reaching the shock peak (quarters), A – shock effects amplitude (% of a standard deviation;) P – shock impact persistence maintaining (quarters); C – a result contrary to macroeconomic theory.

Compared to the extended timeframe, within the range 2008q4: 2013q1, the impact of a monetary policy shock on real output appears to be less powerful but of a higher persistence, while the transmission speed seems to maintain its level. The effect on inflation reveals a similar persistence, but it turns out to be more extensive and manifests more rapidly. At the same time, the decrease in the broad money supply in response to short-term nominal interest rate is characterized by

lower speed, amplitude and persistence, while the exchange rate reaction becomes more faster and lengthy, but less intense. The impact of monetary policy shocks on private credit is slower, but turns stronger and lengthy, and real estate price impulse occurs faster with a higher amplitude, but only limited persistence.

4.3. The case of Poland

As indicated by VAR, SVAR and BVAR models, in Poland, a contractionary monetary policy shock impact on macroeconomic variables leads to a number of effects that can be identified in Graph 3.



Source: authorial calculations.

Graph 3. *Response of variables to a contractionary monetary policy shock - the case of Poland*

The implications of the monetary policy shock in terms of speed, strength and duration are summarized in Table 4.

Table 4. *Characteristics of the monetary policy transmission mechanism in Poland*

2002q4:	gdp			cpi			m3			reer			pc			pp		
2013q1	S	A	P	S	A	P	S	A	P	S	A	P	S	A	P	S	A	P
VAR	2	0.10	12+	3	0.05	12+	3	0.20	12+	C			1	0.50	12+	3	0.50	5
SVAR	2	0.25	3	2	0.2	12+	3	0.20	7	C			1	1.00	3	C		
BVAR	6	0.55	12+	10	0.50	12+	2	0.25	3	1	2.00	12+	C			C		
2008q4:	gdp			cpi			m3			reer			pc			pp		
2013q1	S	A	P	S	A	P	S	A	P	S	A	P	S	A	P	S	A	P
VAR	2	0.0	12+	3	0.05	12+	2	0.30	12+	C			1	0.50	12+	C		
SVAR	C			C			2	0.02	2	1	3.00	3	C			1	1.50	1
BVAR	4	0.50	12+	8	0.50	12+	C			4	1.50	7	C			2	1.50	12+

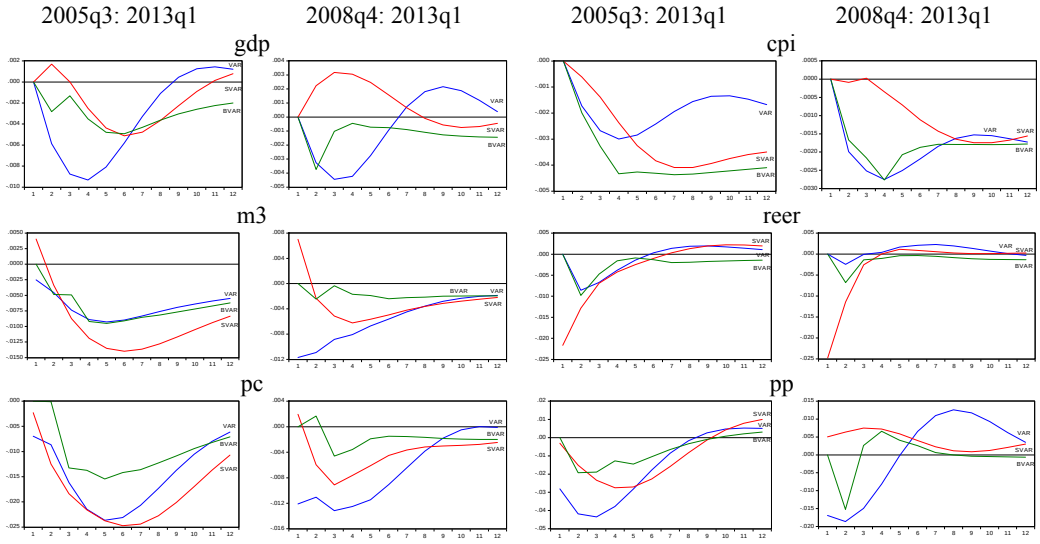
Source: authorial calculations

Note: S – speed of reaching the shock peak (quarters), A – shock effects amplitude (% of a standard deviation;) P – shock impact persistence maintaining (quarters); C – a result contrary to macroeconomic theory.

Comparing the impact caused by an unanticipated contractionary monetary policy shock on selected macroeconomic variables in the two intervals indicates *ex post* the global financial crisis the following results: first, a similar persistence, but an increase in speed and intensity of the shock effects on the economic real activity real and inflation; second, a negative faster reaction, but less powerful and complex of broad money to short-term nominal interest rate rising; third, rising rapidity, persistence and magnitude of the exchange rate impulse to an unexpected change in real interest rate; fourth, the increase in the intensity of monetary policy shocks on private credit and fifth, a decrease in the speed, duration and amplitude of the overall effect on housing market prices.

4.4. The case of Romania

In the context of an unexpected contractionary monetary policy shock (sudden increase in short-term interest rate) in Romania, the impulse responses of the macroeconomic variables indicated by VAR, SVAR and BVAR models are shown in Graph 4.



Source: authorial calculations.

Graph 4. *Response of variables to a contractionary monetary policy shock - the case of Romania*

Based on the results captured in Graph 4, the identification of the impact of a monetary policy shock and of mutations manifested *ex post* the international turmoil, in terms of speed, amplitude and persistence, are summarizes in Table 5.

Table 5. *Characteristics of the monetary policy transmission mechanism in Romania*

2005q3:	gdp			cpi			m3			reer			pc			pp		
2013q1	S	A	P	S	A	P	S	A	P	S	A	P	S	A	P	S	A	P
VAR	3	0.90	9	4	0.30	12+	5	0.90	12+	2	0.80	5	5	2.30	12+	2	4.50	8
SVAR	C			7	0.40	12+	C			1	2.20	7	6	2.50	12+	3	2.50	9
BVAR	5	0.40	12+	4	0.45	12+	5	0.90	12+	2	1.00	12+	6	1.50	12+	2	2.00	9
2008q4:	gdp			cpi			m3			reer			pc			pp		
2013q1	S	A	P	S	A	P	S	A	P	S	A	P	S	A	P	S	A	P
VAR	3	0.45	8	4	0.28	12+	1	1.00	12+	2	0.20	2	3	1.40	10	2	1.80	5
SVAR	C			8	0.18	12+	C			1	2.50	4	C			C		
BVAR	2	0.40	12+	4	0.28	12+	2	0.50	12+	2	0.70	5	C			2	1.50	2

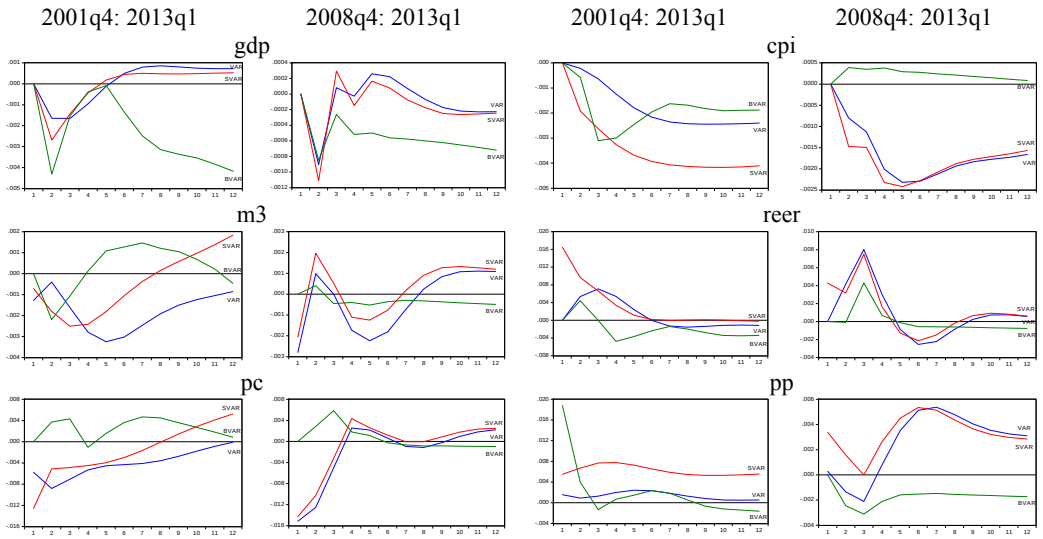
Source: authorial calculations.
Note: S – speed of reaching the shock peak (quarters), A – shock effects amplitude (% of a standard deviation;) P – shock impact persistence maintaining (quarters); C – a result contrary to macroeconomic theory.

Compared to the horizon 2005q3: 2013q1, *ex post* the emergence of the financial crisis, the monetary policy shock impact on the real economic activity appears to be more rapid, but less intense. Persistence of the increase in short-term nominal interest rate on real output appears to be similar to that associated to the extended time interval. A lower shock impact amplitude has also been identified in the case of inflation, which suggests a diminished power of monetary policy in achieving its fundamental objective.

In terms of speed and duration, the effect of a contractionary shock on inflation appears to be relatively identical to that shown in the expanded timeframe. Reduction of the broad monetary aggregate as a result of rising interest rates occurs faster, with similar persistence and amplitude. The real exchange rate reacts with a lower intensity to the shock impact, and also is much diminished in length. Private credit shock impulse response induced by changing short-term nominal interest rate manifests at a higher speed, but has a much reduced intensity and duration. At the same time, the unanticipated contractionary monetary policy shock leads to consequences of limited intensity and persistence on property prices.

4.5. The case of Hungary

In the case of Hungary, an unexpected contractionary monetary policy shock drives responses of the variables of interest that can be identified in Graph 5.



Source: authorial calculations.

Graph 5. *Response of variables to a contractionary monetary policy shock - the case of Hungary*

The analysis of impulse response functions from the perspective of the three defining selected characteristics speed, amplitude and duration of effects induced by the monetary policy shock returned the results summarized in Table 6.

Table 6. *Characteristics of the monetary policy transmission mechanism in Hungary*

2001q4: 2013q1	gdp			cpi			m3			reer			pc			pp		
	S	A	P	S	A	P	S	A	P	S	A	P	S	A	P	S	A	P
VAR	2	0.15	5	6	0.25	12+	5	0.35	12+	C			2	0.80	12	C		
SVAR	2	0.25	5	6	0.40	12+	3	0.25	7	C			1	1.20	7	C		
BVAR	2	0.45	5	3	0.30	12+	2	0.20	3	C			C			C		
2008q4: 2013q1	gdp			cpi			m3			reer			pc			pp		
	S	A	P	S	A	P	S	A	P	S	A	P	S	A	P	S	A	P
VAR	2	0.08	3	4	0.23	12+	1	0.25	1	C			1	0.15	3	3	0.20	3
SVAR	2	0.08	3	4	0.24	12+	1	0.20	1	C			1	0.15	3	C		
BVAR	2	0.10	3	C			C			C			C			3	0.30	12+

Source: authorial calculations.
Note: S – speed of reaching the shock peak (quarters), A – shock effects amplitude (% of a standard deviation;) P – shock impact persistence maintaining (quarters); C – a result contrary to macroeconomic theory.

The results presented in Table 6 allow for a comparative approach of the monetary policy transmission mechanism features in Hungary for the two time intervals considered. Hence, for the 2008q4: 2013q1 horizon, a contractionary

monetary policy shock determines a negative response of output, characterized by a reduced intensity and duration against the extended time range. At the same time, the shock impact on inflation appears to be faster, but of lower amplitude.

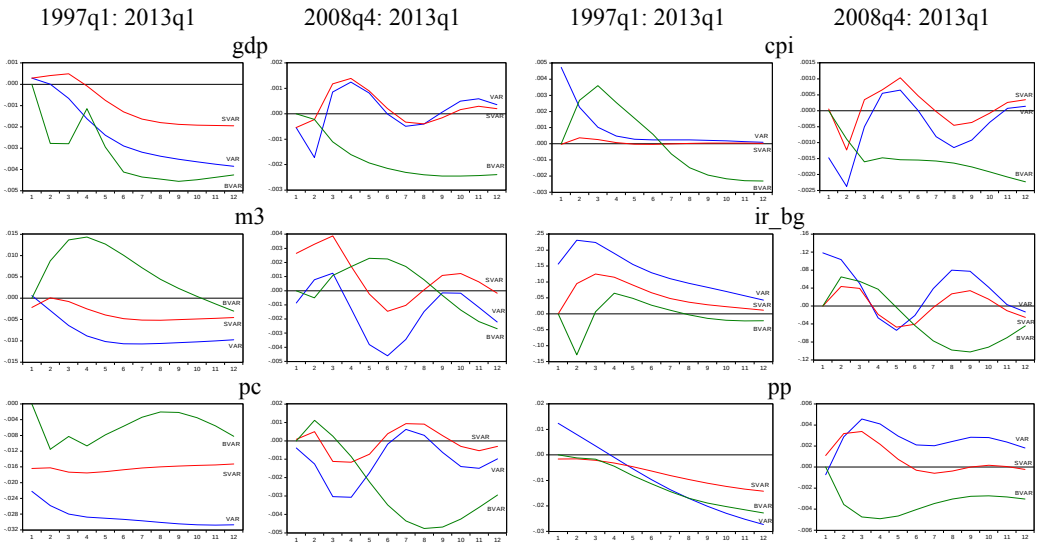
Broad monetary aggregate reaction shows a similar magnitude; it gains rapidity, but loses persistence. The exchange rate behavior seems to be counterintuitive in all estimated scenarios for both periods. The reverse impulse response of private credit is also characterized by a decrease in the intensity and persistence. The comparison of the effects induced by an increase in short-term nominal interest rate on real estate prices cannot be achieved, as the results for the extended interval proved to be counterintuitive.

4.6. The case of Bulgaria

The analysis of the transmission mechanism in CEE countries that currently apply a strategy of exchange rate targeting (Bulgaria, Latvia and Lithuania) presents additional difficulties. In fact, the literature widely recognizes that there is only limited knowledge (at least yet) on monetary transmission within currency boards, and on other versions of such a monetary policy strategy, respectively. The reason lies in their inability to use an active monetary policy (exogenous changes in interest rates or the money supply are not generated by the national monetary policy, both indicators being solely influenced by developments in the domestic economy).

The interest rate in these countries is determined in the money market and not by a rule or a discretionary decision of central banks, with the national rate closely following the trajectory of related anchor currency/country (in this case, the ECB), according to the theory. Thus, in the context of an exchange rate targeting strategy (especially of a currency board), attention is focused on the amplitude, speed and persistence of external shocks transmission (in the ECB interest rate) on domestic savings.

Given the currency board in Bulgaria, VAR, SVAR and BVAR models reveal that an unexpected rise in short-term nominal interest rate in the EZ (which is, as previously shown, endogenous for countries that apply an exchange rate targeting strategy) determines variables response shown in Graph 6.



Source: authorial calculation.

Graph 6. *Response of variables to a contractionary monetary policy shock –the case of Bulgaria*

The main features of the monetary policy transmission mechanism in Bulgaria in the two intervals in terms of speed, amplitude and persistence of the effects caused by a contractionary monetary shock can be identified in Table 7.

Table 7. *Characteristics of the monetary policy transmission mechanism in Bulgaria*

1997q1:	gdp			cpi			m3			ir_bg			pc			pp		
2013q1	S	A	P	S	A	P	S	A	P	S	A	P	S	A	P	S	A	P
VAR	C			C			4	1.00	12+	2	25	12	9	3.00	12+	C		
SVAR	C			C			6	0.50	12+	3	10	12	2	1.60	12+	11	1.00	12+
BVAR	8	0.45	12+	C			C			C			2	1.20	12+	11	2.00	12+
2008q4:	gdp			cpi			m3			ir_bg			pc			pp		
2013q1	S	A	P	S	A	P	S	A	P	S	A	P	S	A	P	S	A	P
VAR	2	0.15	3	2	0.25	3	1	0.10	1	2	12	3	3	0.30	6	C		
SVAR	1	0.05	2	2	0.10	2	C			2	4	3	C			C		
BVAR	7	0.25	12+	11	0.15	12+	2	0.05	2	2	6	5	C			3	0.50	12+

Source: authorial calculations

Note: S – speed of reaching the shock peak (quarters), A – shock effects amplitude (% of a standard deviation); P – shock impact persistence maintaining (quarters); C – a result contrary to macroeconomic theory.

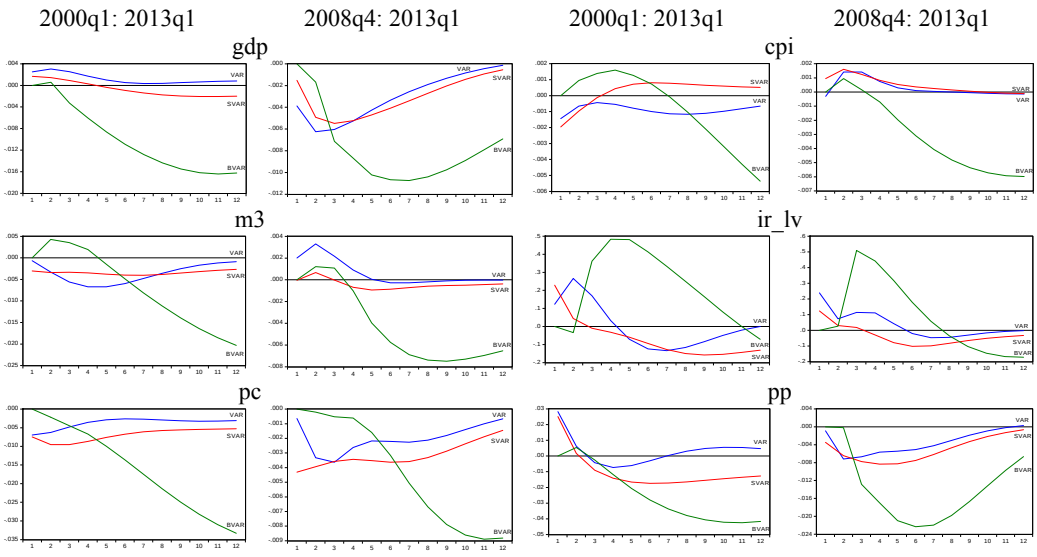
Relative to the expanded time horizon, *ex post* the global crisis manifestation, an unexpected contractionary monetary policy shock in the euro area appears to have

a quick impact, but a lower intensity on real national activity. A comparison between the two periods in terms of inflation reaction to the monetary policy shock cannot be achieved, as VAR, SVAR and the BVAR models analysis identify results contrary to the macroeconomic theory. The negative relationship between the interest rate in the area of the anchor currency and money supply is a finding specific to a currency board manifested much rapidly subsequent to the crisis in Bulgaria, but of diminished intensity and persistence.

The positive relationship between the two interest rates, another result particular to countries that use an exchange rate targeting strategy appears to lose persistence and amplitude. Moreover, under the monetary policy shock, private credit reacts slower, less intensely, with an impact that greatly diminishes over time. The negative impact generated by the short-term nominal interest rate rising in the euro area on the national real estate market prices seems to gain speed and lose intensity.

4.7. The case of Latvia

In the context of Latvia, where there is a conventional fixed exchange rate against the European single currency, a contractionary monetary policy shock, defined as an unanticipated increase in the interest rate of the ECB, has led VAR, SVAR and BVAR models to return responses of selected macroeconomic variables as illustrated in Graph 7.



Source: authorial calculations.

Graph 7. *Response of variables to a contractionary monetary policy shock – the case of Latvia*

The main characteristics of the monetary policy transmission mechanism in Latvia, for the two timeframes in terms of speed, intensity and duration of effects induced by a monetary policy shock on macroeconomic variables of interest are presented in Table 8.

Table 8. *Characteristics of the monetary policy transmission mechanism in Latvia*

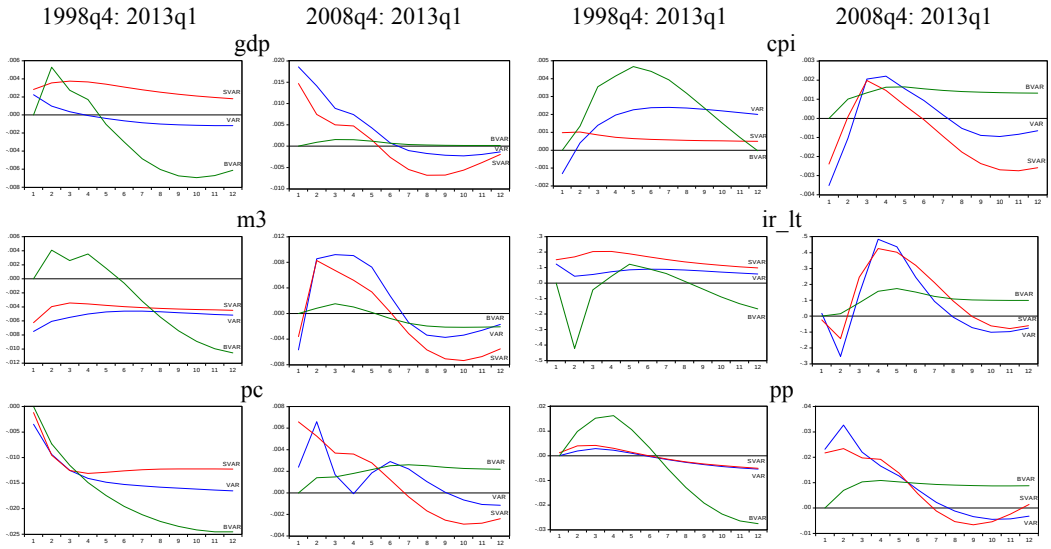
2000q1:	gdp			cpi			m3			ir_lv			pc			pp		
2013q1	S	A	P	S	A	P	S	A	P	S	A	P	S	A	P	S	A	P
VAR	C			1	0.15	12+	4	0.50	12+	2	28	6	1	0.80	12+	C		
SVAR	C			1	0.20	3	5	0.30	12+	1	25	2	2	1.00	12+	C		
BVAR	C			C			C			C			12	3.50	12+	C		
2008q4:	gdp			cpi			m3			ir_lv			pc			pp		
2013q1	S	A	P	S	A	P	S	A	P	S	A	P	S	A	P	S	A	P
VAR	2	0.60	12	C			C			1	25	6	3	0.40	12+	2	0.70	11
SVAR	2	0.50	12	C			C			1	15	2	1	0.45	12+	4	0.80	11
BVAR	6	1.10	12+	C			C			2	50	7	12	0.90	12+	6	2.20	12+

Source: authorial calculations.
Note: S – speed of reaching the shock peak (quarters), A – shock effects amplitude (% of a standard deviation); P – shock impact persistence maintaining (quarters); C – a result contrary to macroeconomic theory.

A comparative analysis of the monetary policy transmission mechanism in Latvia given the three characteristics researched faces additional difficulties, most selected variables reacting contrary to the macroeconomic theory in at least one of the two time intervals. VAR, SVAR and BVAR analysis revealed possible interpretable results only in the case of domestic interest rates and private credit. The effect of an unanticipated increase in the short-term nominal interest rate in the EZ on domestic interest rate seems to be more persistent, *ex post* the global turmoil, while the impulse reaction of private credit to the monetary shock loses intensity.

4.8. The case of Lithuania

Following the impact of an unanticipated contractionary monetary policy shock, defined as an unexpected rise in short-term nominal interest rate in the euro area, the responses of macroeconomic variables of interest are illustrated in Graph 8.



Source: authorial calculations.

Graph 8. *Response of variables to a contractionary monetary policy shock – the case of Lithuania*

The main features of the monetary policy transmission mechanism in Lithuania for the selected time intervals in terms of speed, amplitude and persistence of the monetary policy shock effects can be identified in Table 9.

Table 9. *Characteristics of the monetary policy transmission mechanism in Lithuania*

1998q4:	gdp			cpi			m3			ir_lt			pc			pp		
2013q1	S	A	P	S	A	P	S	A	P	S	A	P	S	A	P	S	A	P
VAR	C			1	0.20	2	1	0.80	12+	1	5.00	12+	3	1.50	12+	C		
SVAR	C			C			1	0.60	12+	3	20.00	12+	3	1.20	12+	C		
BVAR	C			C			C			C			12	2.50	12+	C		
2008q4:	gdp			cpi			m3			ir_lt			pc			pp		
2013q1	S	A	P	S	A	P	S	A	P	S	A	P	S	A	P	S	A	P
VAR	C			1	0.20	2	1	0.60	1	C			C			C		
SVAR	C			1	0.25	1	1	0.40	1	C			C			C		
BVAR	C			C			C			2	15.00	12+	C			C		

Source: authorial calculations.
Note: S – speed of reaching the shock peak (quarters), A – shock effects amplitude (% of a standard deviation); P – shock impact persistence maintaining (quarters); C – a result contrary to macroeconomic theory.

As in the case of Latvia, VAR and BVAR SVAR analysis has led in many cases to counter-response functions; the achievement of results contrary to the macroeconomic theory is otherwise a popular finding in the literature addressing the transmission mechanism of monetary policy under fixed exchange rates regimes through vector autoregression models.

Despite all aspects mentioned, we can identify a number of results that allow for a comparative approach on the selected time intervals. Thus, in the aftermath of the global financial crisis, the impact of a monetary policy shock on inflation appears to be characterized by a higher intensity. Also, extended monetary aggregate decrease under the influence of rising ECB short-term nominal interest rate has lost persistence and amplitude, while the contractionary shock effect on the domestic interest rate is delayed and diluted.

4.9. The comparative study of monetary policy transmission mechanisms features and of the mutations caused by the recent financial crisis

Regarding the impact of an unexpected contractionary monetary policy shock on inflation in the case of selected states that apply an IT strategy, the analysis yielded results consistent with the macroeconomic theory. The same cannot be said about CEE countries that use a strategy of targeting the exchange rate; in this case, the VAR models usually identified the presence of a price puzzle (except for Latvia).

From the standpoint of the transmission speed of the monetary policy shock on inflation in most countries in the region where CBs apply an IT strategy, the impact is faster compared to the situation in the Eurozone. A number of significant differences also occur from the point of view of the magnitude of short-term nominal interest rate shock impact on inflation, which indicates a high degree of heterogeneity in the transmission of monetary impulses. From the perspective of impact persistence, the analysis has revealed a more homogeneous context.

The focus of attention on states practicing a strategy of targeting the exchange rate, yielding counter-intuitive results, has allowed for the highlighting of some characteristics similar to the euro area in the transmission of monetary impulse on inflation from the perspective of impact persistence, but not from the point of view of amplitude and speed.

Mixed results have also been identified in case of aggregate output impulse response to rising short-term nominal interest rate, with GDP puzzle phenomenon sometimes present. In addition, the heterogeneity of real activity responses to a contractionary monetary policy shock appears obvious in terms of all features: speed, persistence and amplitude.

A high degree of heterogeneity compared to the situation in the euro area could be observed for both countries in the region that use an IT strategy and those that target the exchange rate relative to the impact of the monetary policy shock on the broad monetary aggregate, private credit, property prices and exchange rate.

All the above mentioned aspects underline the lack of similarity of the transmission mechanisms between all the CEE countries on the road to the euro adoption and the Eurozone as a whole, which can drive the emergence of clear and powerful asymmetry at the time of currency area entry.

The study of the international turmoil impact on the monetary policy transmission mechanism promoted by the ECB and the monetary authorities of selected states has led to the results summarized in Table 10.

Table 10. *Changes in the effects generated by a monetary policy shock ex post the global financial crisis*

	gdp			cpi			m3			reer/ir_n			cp			pp		
	S	A	P	S	A	P	S	A	P	S	A	P	S	A	P	S	A	P
ez	+	=	-	+	-	=	n.a.	n.a.	n.a.	=	-	-	+	=	=	+	-	-
cz	+	-	=	+	-	=	+	-	-	-	-	=	-	=	+	+	-	-
pl	+	-	=	+	=	=	+	-	-	-	-	-	=	=	=	+	+	+
ro	+	-	=	=	-	=	+	-	=	=	-	-	+	-	-	=	-	-
hu	=	-	-	+	-	=	+	-	-	n.a	n.a	n.a	+	-	-	n.a	n.a	n.a
bg	+	-	=	n.a.	n.a.	n.a.	+	-	.-	+	-	-	+	-	-	+	-	=
lv	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	+	-	=	=	-	=	n.a.	n.a.	n.a.
lt	n.a.	n.a.	n.a.	=	=	=	=	-	-	=	-	=	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.

Source: authorial calculations.

Note:

1) The signs "+", "-" and "=" indicate an increase / decrease / maintaining of effects generated by the monetary policy shocks on selected macroeconomic variables between 2008q4: 2013q1 compared with extended time range specific to each country/area y;

2) n.a. - The comparison is not possible based on the results;

3) reer – in the case of inflation targeting states and the euro area; ir_n - for countries targeting the exchange rate;

4) EZ – the Eurozone; CZ – the Czech Republic; PL – Poland; RO – Romania; HU – Hungary; BG – Bulgaria; LV – Latvia; LT - Lithuania.

A first result highlighted in Table 10 identifies an increase in the speed of transmission of monetary policy shocks on macroeconomic variables both in the EZ and in CEE countries acceding to the currency area, regardless of the monetary policy strategy applied. This translates into a faster achievement of the impact peak driven by the monetary policy shock on inflation, the real economic activity, the money supply, private credit and property prices. The only exception concerns the exchange rate for countries where the monetary authority uses a strategy of inflation targeting, which speed of the unanticipated change in the interest rates reaction seems to be diminished by the crisis.

A second result reveals a decrease in the amplitude of the monetary shock impact on the variables subject to analysis under the empire of the global economic downturn, a result valid for all states in the region and for the EZ. This is equivalent to a reduction in the ability of monetary policy to influence the selected macroeconomic variables, or a diminishing in the efficiency of thee monetary policy in the aftermath of the turmoil.

Third, because of the international financial distress, the study based on vector autoregression has found a decrease or the maintaining of the monetary policy shock implications persistence. This means a shorter (or similar) duration of the impact in the aftermath of the crisis.

5. Conclusions

The analysis of the monetary policy transmission mechanism in the CEE countries on the road to the euro adoption compared to the EZ, based on three methods-vector autoregression (VAR), structural vector autoregression (SVAR) and Bayesian techniques estimated vector autoregression (BVAR) with emphasis on monetary policy strategies used by the CBs in selected countries-has led to the obtaining of two important conclusions.

First, the identification of the effects generated by a monetary policy shock and the comparison of monetary policy effects across countries in the CEE region separately, depending on the types of monetary strategies applied by their central banks has underlined the absence of transmission mechanism similarly among all CEE states acceding to the euro area and that found in the case of the aggregate EZ, which may lead to the manifestation of clear, strong asymmetries at the time of the currency area entry. A high degree of heterogeneity in the transmission of monetary policy impulses has been identified from all three perspectives analyzed: speed, persistence and amplitude.

Second, the assessment of the impacts of the international financial crisis on the monetary policy transmission mechanism promoted by the European Central Bank and the monetary authorities of the CEE selected states has led to the following outcome: an increase in the speed of the monetary policy shock transmission, a decrease in the effects amplitude and a reduction (or the maintaining) in the persistence of the monetary policy shock implications *ex post* the worldwide distress, regardless of the applied monetary policy strategy.

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