A change in volatility or an asymmetry: monetary transmission mechanism in small open European economies during the crisis

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The article analyses the impact of changes in general economic activity during the crisis on the monetary transmission mechanism in small open economies of Czech Rep., Hungary, Poland, and Sweden. The analysis covers the period 2000:1 – 2016:5. The nature of the observed changes is investigated by comparing the goodness-of-fit of the Markov Switching Structural Bayesian Vector Autoregressive models, taking account of systematic changes in the variances of economic processes or in the coefficients of the estimated, or both.

The results seem to confirm that changes in volatilities and the coefficients of the monetary transmission mechanism, reducing the monetary policy efficiency during the crisis, take place in countries characterised by a relatively weak exchange rate transmission channel (Hungary and Sweden). Such changes were not observed in Poland and the Czech Rep., where the exchange rate transmission channel was not closed completely.

Keywords: monetary transmission mechanism, economic crisis, small open economy, Markov Switching Structural Bayesian Vector Autoregression (MS SBVAR)

Subject classification codes: E52.

PRELIMINARY VERSION

1. Introduction

Despite the ongoing development of theoretical and empirical economics, the community of economists is still polarised by many unresolved and widely debated issues. One fundamental problem faced by economic sciences is related to the controversies over the identification of the nature of changes in economic processes that accompany economic crises. Although the leading economists made serious efforts to explain these matters, especially in the aftermath the global economic crisis of 2008, it is still widely disputed whether the crisis should be treated as a period of rapidly increasing volatility of economic processes, an explanation proposed by Stock and Watson (2012) and Sims and Zha (2006b), or as a period of asymmetric reactions from economic entities, as suggested Hubrich and Tetlow (2015) etc. have suggested. This ambiguity bears serious consequences for the formulation of normative economic programs as well as for certain methodological issues caused by fact that we do not know how to properly model crisis periods with the use of standard econometric models.

The above dilemmas affect also the theory of monetary policy, including the analysis of the monetary transmission mechanism (MTM). Because the MTM is potentially dependent on the expectations of economic agents that might differ between the periods of crisis and prosperity increasing the effectiveness of unconventional monetary policies, our knowledge about how monetary policy should be implemented during economic downturns is put into serious question.

The problem of cyclical changes in the MTM is particularly pronounced in the case of small open economies for at least two reasons. Firstly, they are more exposed to economic downturns, because they are more fragile and more easily affected by variations in the global economic conditions; this makes the use of appropriate and efficient anticyclical policies more important for them. Secondly, modelling these economies by means of traditional methods involves more technical problems, because relatively many of them have been or are going through transition processes, which causes that only relatively short data series are available. This problem cannot be bypassed by sample adjustments as it is sometimes done in the case of the developed economies.

The aim of this study is therefore to find more evidence on the nature of MTM changes during a crisis using the case of small open economies (represented by the non-Eurozone Visegrad Group countries – Czech Rep., Hungary, and Poland – and by Sweden that serves as a benchmark) and to determine whether the main source of the changes is volatility of economic processes or changing character of macroeconomic dependencies. The analysis is performed within the Markov Switching Structural Bayesian Vector Autoregression framework following the works of Sims, Wagonner and Zha (2008) and Hubrich and Tetlow (2015)

The article is structured as follows. Part 2 provides an analysis of the current economic theories on the evolution of economic variables during a crisis, giving particular attention to the problem of monetary policy transmission. Part 3 describes the model that will be used to perform empirical analyses. Part 4 explains in detail the specification of the data used in the analysis, as well as introducing issues related to the models' identification issues and the description of estimation techniques. In the last part, the research findings are presented and discussed.

2. Theoretical background

The monetary transmission mechanism (MTM) is relatively well covered in the modern economic literature. MTM analyses were boosted by the introduction of multivariate structural vector autoregressive (SVAR) models in the seminal works by Sims (1972, 1980, 1986). This type of models was found to represent well the relatively complex system of relationships within the MTM due to its inherent feature of overparametrisation, which allows each variable in the system to be studied with respect to its influence on all other variables.

The search for a robust specification of SVAR systems describing the MTM resulted in the introduction of various schemes for identifying monetary policy shocks. Sims (1986), Bernanke and Blinder (1992), Gordon and Leeper (1994), Bernanke and Mihov (1998), Christiano, *et al.* (1999; 2005; 2011), Sims and Zha (2006a), Altig, *et al.* (2011) used different versions of short-run restrictions. Blanchard and Quah (1989) pioneered the use of long-run identification restrictions, which were mainly used in the discussion on the impact of technology shocks on labour (for a critical summary see, e.g.: Chari, *et al.* 2005). Faust (1998) and Uhlig (2005) proposed a scheme based on sign restrictions, which proved especially useful in quadratic programming and Bayesian analysis.

Despite the rapid growth of complex identification schemes utilizing increasingly sophisticated assumptions, no consensus as to the shape of the MTM was reached. As a result, we have recently been able to observe the renaissance of the standard Cholesky identification scheme based on a simple arrangement of the order of variables used in the model. The main source of this renaissance was that researchers realised that complicated identification schemes were hardly justifiable on theoretical grounds and contrasted with the fundamental idea underpinning VAR modelling, which was supposed to be relatively atheoretical as opposed to the traditional structural models of the Cowles' Commission that were followed by the computable and dynamic stochastic general equilibrium models.

The period of the Great Moderation spanning from 1985 and 2007 was the time of observably lower volatility of economic processes in developed western economies. Being attributed to institutional and structural changes implemented in these economies, as well as being considered a permanent feature of the western economic system (Stock and Watson, 2002), the situation resulted in economists' sustained interest in processes and mechanisms governing monetary policy in the "good times", which were easily identifiable by means of traditional econometric methods. The Great Recession of 2007-2010 revived the need to better understand the nature of changes observed in economies affected by decreasing economic activity. Efforts to find an explanation to these phenomena were also evident in MTM analyses. They triggered a new wave of research into this field.

Many articles exploring the issue of changes in the developed economies' MTM during a crisis have been published recently. Researchers who focus their studies on Eurozone countries, e.g. Ciccarelli, *et al.* (2013), Aristei and Gallo (2014) or Leroy and Lucotte (2015), have shown that in a period of crisis monetary policy exerts stronger impact on output. They have pointed to the role of competition in the banking sector and credit availability problems as an important factor affecting the efficiency of monetary transmission via interest rates and bank lending channels. The periods of increased financial stress are characterised by increased competition among banks, as the account balances of firms' and consumers are declining and it is tough for them to find appropriate providers of capital. This entails a decline in the premiums between the actual and market interest rates, which forces banks to react more quickly to monetary policy changes. These observations have been confirmed by Dahlhus (forthcoming), Debes *et al.* (2014), Hubrich and Tetlow (2015), and Fry-Mckibbin and Zheng (2016) for the United States and by Jansen *et al.* (2015) for a group of 20 developed OECD countries.

Hubrich and Tetlow (2015) and Jansen *et al.* (2015) highlight also the role of expectations as a factor in explaining changes observed in the monetary transmission process during a crisis. The concept that the expectations of economic entities have effect on the decisions individuals make at different stages of the business cycle is not new. It was first put forward by Keynes (1936), who analysed the role of "animal spirits" in the context of investment decisions and business cycle dynamics. Modern economics attributes increasing importance to the confidence felt by individuals and uncertainty. Silvia and Iqbal (2011) observed that in periods of low uncertainty and high confidence people work, invest and consume more than in periods when confidence is relatively low, i.e. during economic crisis and military or political unrest. Rising uncertainty makes individuals less confident in the economic growth prospects, as markets are distressed and companies and banks strive to improve their balance sheet positions through savings and employment rationalisation schemes. In this situation, it becomes very probable that consumers will refrain from consumption and investment, especially when having to finance their plans with borrowed funds (Bloom, 2009; Jansen, *et al.*, 2015). It is therefore rational to anticipate that, unless expectations change, the public reaction to the authorities' expansionary monetary policy will be weaker during an economic downturn than during "prosperity times". On the other hand, as Boyarchenko *et al.* (2016) observed, in developed economies the announcements made by monetary authorities tend to boost economic entities' confidence, even if they do not change any decisions. As a result, in countries where the monetary authorities successfully stabilise individuals' expectations through sound actions, expansionary monetary policy might be more efficient during a crisis than in the phase of prosperity (Hubrich, Tetlow, 2015).

Reports on the impact of individuals' confidence on the efficiency of MTM call for a normative use of this relationship. As proposed by Leduc (2010), Hubrich and Tetlow (2015), and Jansen, *et al.* (2015), in the acute phase of a financial crisis the focus of the monetary authorities' efforts should be on mitigating the potentially adverse expectations' spirals, because causing the public to believe that the business cycle will reverse soon may act as a self-fulfilling prophecy and help monetary policy become effective again. According to Nalban (2016), this mechanism resembles the financial accelerator framework: lower interest rates induce confidence and spending, and spending induces optimism. The second and higher-order effects become then a self-winding mechanism, which is crucial for the monetary policy to be effective when the traditional transmission channels are absent.

Relatively little attention has been given so far to changes in the MTM of small open economies during a crisis, even though the economies may differ from the developed economies in several important respects (Nalban, 2016), such as lower credibility of monetary authorities, less developed financial markets, the stabilising role of the exchange rate pass-through, the likelihood of currency mismatches, and procyclicality of capital flows.

Developed economies are relatively stable systems under limited influence of exogenous economic factors. It is therefore relatively easy for monetary authorities to earn the "credibility bonus" underpinning the mechanism described by Boyarchenko, *et al.* (2016). This situation is quite unusual for developing small open economies, where the recollections of hyperinflation episodes are still relatively fresh and exogenous shocks that are hard to neutralise are frequently conclusive for the overall condition of the economy. It is also disputable whether economic shocks increase competition in the financial markets of emerging economies. Because the economies' financial sectors usually depend on capital controlled by foreign-based institutions, it is very probable that declining economic activity and returns will result in capital transfers to countries where both fundamentals and growth prospects are more promising (Corsetti, *et al.*, 1999). Under these conditions, monetary policy in developing economies can be expected to be less effective during crisis than in during prosperity.

According to Frankel (2011), there is solid empirical evidence pointing to a larger role of exchange rate pass-through in small open economies (see e.g. Ca'Zorzi, *et al.*, 2007, Bajo-Rubio, Maria-Dolores, 2011, Mirdala, 2014, Przystupa, Wróbel, 2014 for the assessment of exchange rate pass-through in the Visegrad Group countries). This larger role may additionally stabilise the MTM of developing economies. According to uncovered interest rate parity, the introduction of expansionary monetary policy amounting to the reduction of the domestic interest rate should cause the depreciation of domestic currency following the outflow of capital to countries with relatively high interest rates and increase the exchange rate, thus raising the relative costs of imports. If exchange rate changes are relatively quickly transmitted into imports' prices, then, according to Burstein *et al.* (2003, 2005), consumers will replace imported goods with cheaper local substitutes, thus increasing domestic demand. External demand will also surge, because of relatively lower price of domestic goods abroad. These two effects together may make up for the lower demand of domestic consumers who postpone consumption in response to economic instability, thus narrowing the channel enabling the occurrence of changes in the MTM during a crisis.

The impact of the exchange rate pass-through mechanism may be lessened by the balance sheet effects resulting from currency mismatches. Banks and companies in transition economies quite frequently suffer from inadequate capital funding. To raise capital, they frequently decide to borrow abroad. Their liabilities are then denominated in foreign currency, while their revenues primarily depend on payments in domestic currency. This situation is known as a currency mismatch. Exchange rate increases accompanying the expansionary monetary policy shift may expose these organisations to debt servicing problems, as the total value of their liabilities increases. As a result, they may contribute to negative business cycle effects reducing domestic demand in the wake of employment cuts and bankruptcies, and offsetting positive pass-through effects described above (Krugman, 1999, Frankel, 2011; for the recent account of currency mismatch issues in the Visegrad Group countries see, e.g. IMF, 2015 and Chui, *et al.*, 2016, for analyses concerning Polish economy see e.g. Kapuściński, 2017).

Another major feature differentiating emerging economies from developed ones, closely related to the currency mismatch phenomenon, is the procyclicality of capital flows. In a country that extensively borrows abroad expansive monetary policy launched in the time of economic downturn can, as mentioned in the paragraph above, result in the depreciation of domestic currency and inflate the total value of debt in foreign currency. Such changes may expand the current account deficit and debt-to-GDP ratio, resulting in investors' claims to repay excessive liabilities before new debt is issued. This seems to be easy when the economy is expanding and tax revenues are increasing, but introducing expenditure cuts during economic downturn can be very costly and dramatically reduce economic activity, drawing the current account further down and further counteracting the pass-through effects (Frankel, 2011).

The summing up the existing evidence on the MTM behaviour during a crisis leads to a conclusion that in developed economies monetary policy can be expected to be more efficient during a crisis than in a period of economic upturn for at least two reasons: increasing competition between banks and financial institutions, and the occurrence of "credibility bonus" related to consumers' expectations. As far as emerging economies are concerned, these effects are disputable because their financial markets are less developed and their monetary authorities are less respected. Monetary policy in small open economies can therefore be expected to be less efficient during a downturn than in a period of prosperity due to the retarding impact of expectations on the consumption and investment decisions of economic entities. On the other hand, whether the effect will prevail largely depends on the mix of three factors: the impact of exchange rate pass-through, the occurrence of balance sheet effects due to currency mismatches and the procyclicality of capital flows.

Empirical evidence on the behaviour of MTM during the crisis in small open European economies is still relatively sparse and mixed. Results pointing to a weaker impact of monetary policy on economic variables during economic downturn were presented for the Visegrad Group countries by Darvas (2013), and for Poland by Łyziak, *et al.* (2011). According to some studies, it is deviations in the volatility of the analysed processes that cause changes in the MTM rather than changes in the parameters of the analysed relationships. Other results in that vein have been reported e.g. by Dobešová *et al.* (2015) for the Czech Rep. and Slovakia, and by Rosoiu (2015) for Romania. On the other hand, Franta, *et al.* (2014) and Nalban (2016) have presented evidence confirming the occurrence of structural changes in the MTM, which increased the efficiency of monetary policy during the crisis in the Czech Rep. and Romania. Lastly, Myšková *et al.* (2013) have demonstrated mixed results for the Visegrad Group countries.

This paper contributes to the literature on this subject in at least two ways. Firstly, it presents new empirical evidence about the nature of changes occurring in the MTM of small open economies during the crisis. A hypothesis is tested that the monetary transmission mechanism of small open economies is structurally stable during a crisis. Secondly, we analyse factors that may distinguish emerging small open economies from developed economies and may contribute to the higher stability of MTM in the former, namely: exchange rate pass-through, balance sheet effects related to the currency mismatch, and the procyclicality of capital flows.

3. The model

The recent development of econometric techniques has increased the range of methods that allow for modelling changes in the MTM. As a result, a variety of competing specifications has been recently used in analyses.

From the review of the existing evidence on changes in MTM it follows that the most popular models used to study them are variants of the Threshold Structural Vector Autoregressions (TSVAR). Fry-Mckibbin and Zheng (2016) and Nalban (2016) proposed to use the Threshold Bayesian SVAR (TBSVAR) models, Ciccarelli, *et al.* (2013) and Jansen *et al.* (2015) pointed to the Panel Threshold SVAR models, and Myšková *et al.* (2013) used a standard VAR model estimated for 2 separate subperiods. From the perspective of the analysis presented in this paper, TSVAR models are not the best choice, because their specification assumes successive shifts in volatilities and parameters, which excludes in advance some intermediary specifications and may influence the outcomes. In addition to that, traditional TSVAR models are also vulnerable to arbitrary threshold specification, but this problem can be easily solved by introducing proper Bayesian techniques as Fry-Mckibbin and Zheng (2016) and Nalban (2016) proposed.

Another possibility is to use Markov Switching (Bayesian) SVARs based on heteroscedasticity assumptions developed by Lanne, *et al.* (2010), Netsunajev (2013) and Kulikov and Netsunajev (2016), etc.. This class of models allows researchers to develop agnostic specifications of the MTM, because shocks are identified using assumptions about the heteroscedasticity of the analysed time series, rather than typical assumptions imposed on the matrix of contemporaneous parameters. Woźniak and Dromaguet (2015) proposed an alternative version of the model, in which the standard short-run identifying assumptions are accompanied by the heteroscedasticity assumptions. While presenting an interesting alternative to the standard SVAR models using arbitrary contemporaneous matrix restrictions to identify shocks in the model, SVAR models with heteroscedasticity assumptions exclude in advance some potentially valid specifications, so they can be used as a basis for assessing the nature of MTM changes during a crisis.

Darvas (2013), Franta *et al.* (2014), and Dobešová *et al.* (2015) based their analyses of MTM evolution on the Time-Varying Parameters SVAR (TVP-SVAR) models. With this class of models both the stochastic evolution of parameters and their volatility can be considered, but, as Hubrich and Tetlow (2015) indicate, the parameter drift may be unable to pick-up some high-frequency phenomena affecting the MTM. In spite of this criticism about the use of TVP models for purposes such as adopted for this study, Hubrich and Tetlow (2015) propose, in the vein of Sims, *et al.* (2008), that analyses be based on the Markov Switching Bayesian SVAR (MSBSVAR). This model is flexible enough to account for changes in the volatilities of the analysed processes, parameters of structural relationships, and parameters and volatilities together. Furthermore, because these two types of oscillations are governed by separate Markov chains, it is possible to account precisely for the time structure of changes. Lastly, the mechanism of Markov switching is capable of picking-up even abrupt, discrete shifts in the MTM, which may be necessary when expectations are being taken into account. Therefore, as Hubrich and Tetlow (2015) did, we use the class of MSBSVAR models to investigate the crisis' impacts on the MTM in small open economies.

Following Sims *et al.* (2008), we consider in our analysis an unrestricted *VAR(l, m, n)* model of the form:

$$\boldsymbol{y}_t'\boldsymbol{A_0}(s_t^C) = \sum_{i=1}^{l} \boldsymbol{y}_{t-i}'\,\boldsymbol{A_i}(s_t^C) + \sum_{j=0}^{m} \boldsymbol{z}_{t-j}'\,\boldsymbol{C_j}(s_t^C) + \boldsymbol{\varepsilon}_t'\Xi^{-1}(s_t^V), \tag{1}$$

where: $\boldsymbol{y}$ is a vector of endogenous variables, $\boldsymbol{z}$ is a vector of exogenous variables assumed to be at least predetermined and weakly exogenous, $\boldsymbol{A_0}, \boldsymbol{A_\mathrm{i}}, \boldsymbol{C_\mathrm{j}}$ are the matrices of appropriate state-dependent parameters and s_t^n for $n = \{C, V\}$ is a latent variable describing the current state of an economy separately for parameters, s_t^C and variances, s_t^V.

Let us assume that the state of an economy depends on a set of political, economic, technological and institutional factors sensitive to the influence of independent shocks that may lead to abrupt changes in the character of the observed economic processes. Accordingly, the latent state variables meet the so-called Markov condition and can be modelled as if they were following an irreducible, aperiodic, time-homogeneous and ergodic Markov chain. Because of that, and following Hubrich and Tetlow (2015), variable s_t^n takes values from the set $\{1,2,\dots,h^n\}$ and is governed by the first-order Markov chain given by:

$$\Pr(s_t^n = 1 | s_{t-1}^n = k) = p_{ik}^n \quad i,k = 1,2,\dots,h^n, \tag{2}$$

where p_{ik}^n is the probability that an economy will enter state i provided that in the preceding period it was in state k and the Markov transition probabilities are given by matrix $\boldsymbol{P}$, which is constant in time.

For simplicity, assuming that $\boldsymbol{x}_t = [\boldsymbol{y}'_{t-1}, \dots, \boldsymbol{y}'_{t-l}, \boldsymbol{z}'_t, \dots, \boldsymbol{z}'_{t-m}]$ and $\boldsymbol{A}'_{-}(s_t^n) = [\boldsymbol{A}'_1(s_t^n), \dots, \boldsymbol{A}'_l(s_t^n), \boldsymbol{C}'_0(s_t^n), \dots, \boldsymbol{C}'_m(s_t^n)]$, we obtain the following equation:

$$\boldsymbol{y}'_t \boldsymbol{A_0}(s_t^C) = \boldsymbol{x}'_t \boldsymbol{A}_{-}(s_t^C) + \boldsymbol{\varepsilon}'_t \Xi^{-1}(s_t^V). \tag{3}$$

Further, by imposing the normality restriction on the state-dependent errors using condition:

$$\Pr(\boldsymbol{\varepsilon}_t | \boldsymbol{Y}^{t-1}, \boldsymbol{Z}^t, \boldsymbol{S}^{n,t}, \boldsymbol{A}_0, \boldsymbol{A}_{-}, \Xi) \sim N(\boldsymbol{0}_\eta, \boldsymbol{I}_\eta), \tag{4}$$

where $\boldsymbol{Y}^{t-1}, \boldsymbol{Z}^{t}, \boldsymbol{S}^{n,t}$ are the vectors of variables stacked in the time dimension and $N(\mathbf{0}_{\eta}, \boldsymbol{I}_{\eta})$ is a multivariate normal distribution with a zero mean and unit variance, we arrive at an unrestricted Markov-Switching VAR model that can be estimated using the Bayesian procedure proposed by Sims *et al.* (2008). This class of models was also used for inference in the original article by Hubrich and Tetlow (2015).

4. The data

The following analysis is based on the monthly data from the 2000:1-2016:5 period for three non-Eurozone Visegrad Group (VG 3) countries – the Czech Republic, Hungary, and Poland, all being small open economies with a similar historical background. In the early 1990s they launched transition to a market economy. The first and the most volatile phase of this process ended in 1995, and the whole process was completed with the countries' entry into the European Union on 1 May 2004.

Throughout the period of analysis, all three countries experienced changes in the institutional framework of monetary policy and exchange rates. The dominant strategy of monetary policy that targeted inflation was introduced by the Czech Rep. and Poland in, respectively, January and October 1998, and by Hungary in the summer of 2001. The exchange rate regimes in the Czech Rep. and Poland were also relatively stable, with the free float regimes being in use from June 1997 and March 2000, respectively. Hungary was the only of the three countries where changes in the exchange rate regimes were substantial. In May 2001, a crawling peg in the exchange rate regimes was replaced with a crawling band. In October 2001, another change fixing the exchange rate within a ±15% band was introduced. Finally, the free float currency regime was introduced in February 2008. Changes in the monetary policy strategy and the exchange rate mechanism that the VG3 countries implemented over the sample period are not likely to hinder our analysis, because we estimate a regime switching model.

The fourth of the analysed countries is Sweden, which serves as a benchmark. Sweden is a small open developed economy widely known for its financial and economic stability. In the years under consideration, the Swedish monetary policy was based on a strategy targeting the inflation rate (fully introduced in January 1995), and exchange rates were shaped under a free-float introduced in January 1993. Despite relative economic stability, in February 2015 Sweden hit the so-called "*zero lower-bound*", which led to the occurrence of negative STIBOR rates. According to Gorajski and Ulrichs (2016, p. 14) and some other authors, the outcome of this situation may have been additional non-linearities in the MTM caused by the "*liquidity trap*", etc. Their impact on the results of this analysis can be effectively removed by means of logarithmic transformation, which amounts to the introduction of non-negativity restrictions on the nominal interest rate. This results in the curtailment of the sample and a loss of 16 observations for Sweden spanning the period 2015:2-2016:5,which, however, should have no adverse effect on the overall performance of the estimated models.

In our analysis, we use the time series of industrial production index (IP_t) serving as a proxy for GDP and a consumer price index (CPI_t), both of which were sourced from the Stats.OECD database, short-term interest rates (IR_t) approximated by the 1-month PRIBOR, BUBOR, WIBOR and STIBOR rates obtained from the Eurostat database, the real effective exchange rate index ($REER_t$) based on the data on bilateral exchange rates for 42 leading trading partners, the real effective exchange rate of the Eurozone ($REER_t^f$) approximating the exchange rate of the main trading partner of the analysed economies, both obtained from the Eurostat database, and the world oil prices

(P_t^{oil}), represented by the Brent crude oil 1-month Forward in the EUR index made available by the ECB Statistical Data Warehouse.

Table 1. Correlations between the sentiment indicators and industrial production in the analysed countries

Czech Rep.				Hungary			
Variables	ESI	BCI	IP	Variables	ESI	BCI	IP
ESI	1			ESI	1		
BCI	0.86	1		BCI	0.81	1	
IP	0.62	0.7	1	IP	0.33	0.58	1
Poland				**Sweden**			
Variables	ESI	BCI	IP	Variables	ESI	BCI	IP
ESI	1			ESI	1		
BCI	0.93	1		BCI	0.95	1	
IP	0.67	0.7	1	IP	0.52	0.55	1

ESI - Economic Sentiment Indicator, BCI - Business Confidence Indicator, IP - industrial production.
Source: developed by the author

In addition to the above characteristics of the real economy, we also use in our model data capturing the expectations and sentiments of economic entities that according to the literature review presented in Part 2 can play an important role in the transmission of monetary impulses.

Two alternative measures of sentiment are widely used in the economic literature. The first of them is the Economic Sentiment Indicator (ESI_t), compiled by the Eurostat as an index consisting of the weighted average of 5 sectoral confidence indicators including industry, services, construction, retail trade and private consumption. Enlisted sub-indexes are obtained from a monthly survey of about 125 000 companies and 40 000 consumers in the EU. The second measure is the Business Confidence Indicator (BCI_t) developed by OECD to identify expectations of manufacturing companies. The indicator is presented as an index and is smoothed with an appropriate Hodrick-Prescott filter that removes all cycles shorter than 6 months.

To briefly characterise the data on sentiment indicators let us compare correlations between the indicators, as well as with the data on industrial production. The relevant data are presented in Table 1. In general, the information contain in both sentiment indicators is comparable, because correlations between the ESI and the BCI time series range from 0.81 to 0.95 depending on the country. The BCI also follows closely the output data (correlations between 0.55 and 0.7). The ESI is more informative compared with the data on industrial production (as shown by correlations ranging from 0.35 and 0.67).

Table 2. Standard deviations of sentiment indicators for the analysed countries

Variables	Czech Rep.		Hungary		Poland		Sweden	
	$\sigma(x)$	$\frac{\sigma(x)}{\sigma(y)}$	$\sigma(x)$	$\frac{\sigma(x)}{\sigma(y)}$	$\sigma(x)$	$\frac{\sigma(x)}{\sigma(y)}$	$\sigma(x)$	$\frac{\sigma(x)}{\sigma(y)}$
ESI	0.097	0.604	0.113	0.663	0.086	0.329	0.083	1.299
BCI	0.016	0.101	0.015	0.09	0.011	0.041	0.017	0.261
IP	0.160	1	0.171	1	0.262	1	0.064	1

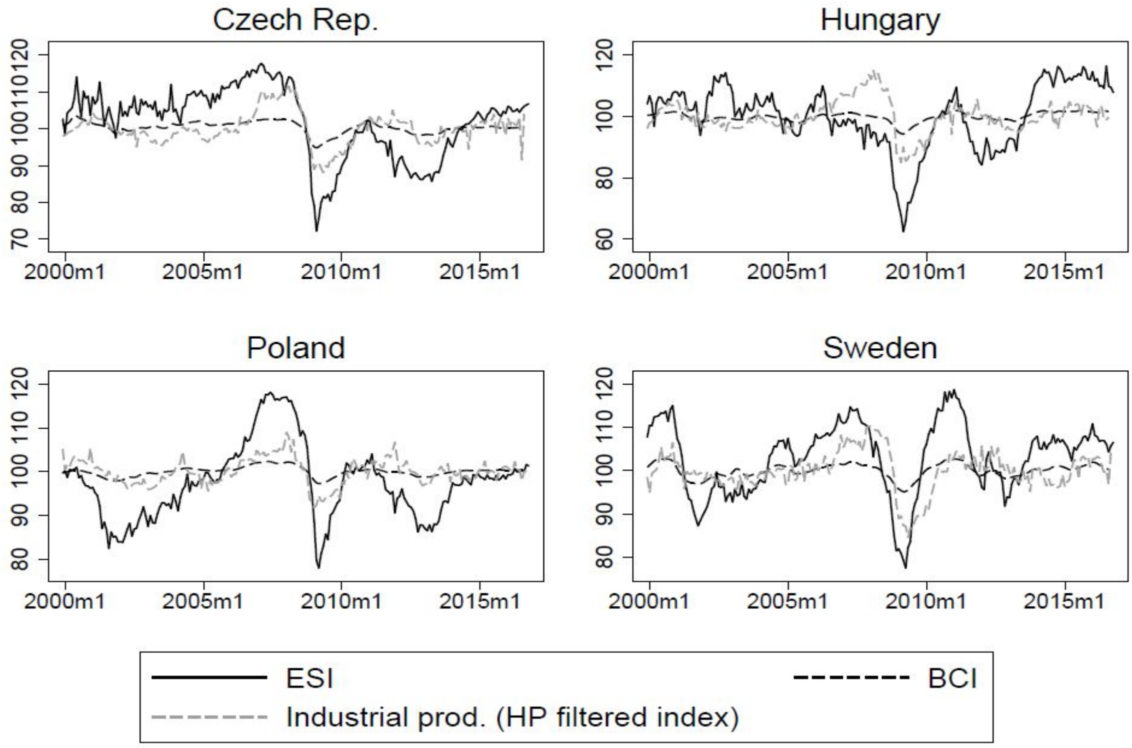
$\sigma(x)$ - standard deviation of a given variable, $\frac{\sigma(x)}{\sigma(y)}$ - standard deviation with regard to standard deviation of industrial production.

Source: calculated by the author

Business cycle characteristics of the analysed economic sentiment indicators can be summarised by their standard deviations and standard deviations in relation to the standard deviation of GDP. The relevant statistics are presented in Table 2. A brief look at the outcomes shows that the ESI is up to 6 times more volatile than the BCI. It is also relatively efficient in approximating output volatility, thus outperforming the BCI as a potential source of information about the expectations of economic entities.

The final argument in favour of using the ESI as an indicator of economic sentiment stems from the fact that, unlike the BCI, it shows real economic phenomena slightly ahead of time, which is especially visible in the Hungarian and Swedish data presented in Figure 1. We can therefore conclude that the ESI contains information that can improve the degree of fit between the model and the data.

Figure 1. Economic Sentiment Indicator, Business Confidence Indicator and the index of industrial production for the analysed countries



Source: Eurostat online database, Stats.OECD.

All time series used in the analyses below have been seasonally adjusted and are expressed as annual rates (12-month log-differences), which are marked with small-case letters.

5. Model identification, estimation and impulse responses

The VAR model of the MTM that we propose for further analysis has 7 variables. The endogenous variables are given by vector $y_t = [ip_t, cpi_t, ir_t, reer_t, esi_t]$. They represent a somewhat standard set of explanatory variables, can be successfully used to model monetary policy transmission in both small open economies and large developed economies, such as US and the Eurozone. In the literature, different variations around this core are proposed. For example, Sims and Zha (2006a) and Hubrich and Tetlow (2015) proposed using a VAR model with a money supply measure instead of an exchange rate to model the US economy, whereas Peersman (2004), and Elbourne and de Haan (2006) considering the Eurozone countries used both money supply data and exchange rates. For the small open economies, similar specifications of the model were proposed by Kapuściński *et al.* (2014), Bogusz *et al.* (2015), Przystupa and Wróbel (2016) and Nalban (2016). The analyses of the last group of economies were additionally extended to different supporting variables, depending on the goals pursued by the authors.

In keeping with our previous considerations, our model includes not only the standard determinants of monetary transmission, but also the measure of economic sentiment. This approach follows closely that adopted by Nalban (2016) and, to some extent, Hubrich and Tetlow's approach (2015), who used the financial stress indicators in their model. It is based on our presumption that the expectations of economic entities may be an important determinant of their decisions and thus an indicator of possible regime switches.

Small open economies are sensitive to changes in external economic conditions. In spite of this, we introduce a vector of exogenous variables z_t, which relates economic activity in the analysed countries to shocks at the global and/or European level. Kim and Roubini (2000) proposed using a vector of exogenous variables made up of the oil price index and foreign interest rates. In our analysis, we use foreign real effective exchange rates instead of foreign interest rates, so $z_t = \left[oil_t, reer_t^f\right]$. There are two reasons for this selection of variables. Firstly, the use of the Eurozone interest rates would make it necessary to reduce the sample, because of the samples taking negative values from February 2015. Secondly, the use of the proposed vector of exogenous variables seems to be justified on theoretical grounds. Commodity prices affect the real economy, which is taken into account by monetary authorities in setting the level of interest rates, and influence the exchange rate. Shocks coming from the exchange rate influence real economies through changes in their levels and in terms of trade. This means that they too should be considered by monetary authorities in formulating their policy.

The determination of how exogenous variables should be entered into the model is somewhat more complicated. The economic literature on this topic shows that consent has not been reached. In their original paper, Kim and Roubini (2000) proposed treating these variables as weakly exogenous

$$\Pr(\boldsymbol{z}_t|\boldsymbol{Y}^{t-1},\boldsymbol{Z}^{t-1},\boldsymbol{S}^{n,t},\boldsymbol{A}_0,\boldsymbol{A}_{-},\Xi) = \Pr(\boldsymbol{z}_t|\boldsymbol{Y}^{t-1},\boldsymbol{Z}^{t-1}), \tag{5}$$

meaning that the exogenous variables are determined not only by their lagged values but also by the lagged values of endogenous variables; as a result, they are influenced, although not simultaneously, by developments in the analysed economy. This assumption may be valid for large economies, e.g. those making up the core EU countries, but it may fail when the transition countries' economies are analysed. Even so, some researchers (e.g. Gorajski and Ulrichs, 2016, Hubrich and Tetlow 2015 and Nalban 2016) propose treating the exogenous variables as strictly exogenous, i.e.:

$$\Pr(\boldsymbol{z}_t|\boldsymbol{Y}^{t-1},\boldsymbol{Z}^{t-1},\boldsymbol{S}^{n,t},\boldsymbol{A}_0,\boldsymbol{A}_{-},\Xi) = \Pr(\boldsymbol{z}_t|\boldsymbol{Z}^{t-1}), \tag{6}$$

Because these variables are solely determined by their lagged values, they are unaffected by changes taking place in the analysed economies. This assumption seems to be reasonable in the case of the small open economies of the Visegrad Group countries, so it will be considered in our model as well.

In order to bring about and analyse impulse responses of the VAR model, we have to impose proper interpretation on the vector of exogenous shocks ε_t'. The most popular method of identifying such shocks consists in the introduction of exclusion restrictions on the matrix of contemporaneous parameters, $\boldsymbol{A}_0$. This is usually performed by means of the Cholesky decomposition, which allows a set of just-identifying restrictions to be obtained through the proper ordering of variables and the introduction of a lower-triangular $\boldsymbol{A}_0$ matrix. The vector of endogenous variables $\boldsymbol{y}_t$ is divided into three blocks $\boldsymbol{y}_t = [\boldsymbol{y}_{1t}, ir_t, \boldsymbol{y}_{2t}]$, where $\boldsymbol{y}_{1t}$ is the vector of variables that concurrently enter information set of monetary authorities, ir_t is an instrument of monetary policy, and $\boldsymbol{y}_{2t}$ consists of all other endogenous variables that are influenced at the same time by decisions made by monetary authorities. The proposed identification scheme has the advantage of being relatively simple, so it allows us to learn about patterns hidden in the data without inflicting too much of *a priori* assumptions.

In keeping with these considerations, the ordering of endogenous variables proposed in our model is given by $\boldsymbol{y}_t = [ip_t, cpi_t, ir_t, reer_t, esi_t]$. This specification takes account of the fact that because of nominal rigidities, real economic variables cannot simultaneously respond to monetary policy changes. At the same time, only the real variables instantaneously affect monetary policy, while the monetary authorities' decisions are quickly discounted by exchange rates and the expectations of economic entities. To account for the openness of the analysed economies in the model, a vector of exogenous variables is introduced and an assumption is made that they simultaneously influence all other variables in the model, which amounts to putting them in front of the vector of endogenous variables. Consequently, the full ordering of the model's variables is given by vector $\boldsymbol{x}_t = \left[oil_t, reer_t^f, ip_t, cpi_t, ir_t, reer_t, esi_t\right]$. This specific identification may lead to the question about which of the exchange rates – domestic or foreign – is targeted by monetary authorities formulating monetary policy. In fact, the proposed ordering of variables implies that it is foreign real exchange rate that is contemporaneously influencing the monetary instrument, while its changes are instantaneously discounted by the domestic real exchange rate. This assumption might be plausible if we took into account that we tend to think in terms of domestic vs. foreign exchange rates rather than about real exchange rates versus the currencies of main trade partners of a given country. As a result, monetary authorities targeting the foreign real exchange rate, which in the case of our model is the Euro real exchange rate, are in fact targeting the exchange rate of its main trade partner's **currency**, which is plausibly close to targeting domestic currency vs. Euro exchange rate pair.

The model proposed in our paper is estimated in `Dynare` using the procedure proposed by Sims, *et al.* (2008). The priors are selected following Hubrich and Tetlow (2015). Specifically, we use for the elements of the VAR model the standard Minnesota priors for the monthly data. The hyperparameters of the priors are given by [0:57; 0:13; 0:1; 1:2; 10; 10]. For the state transition matrix, we use the Dirichlet priors of 5.6 for the two-state chains and 11.9 for the three-state chains, which amounts to assuming that the expected duration of stay in a given regime is equal to 20.3 months. In order to obtain posterior modes, we use 6 million replications as a burn-in and leave every 5th of the next 2.5 million replications, which results in 500 000 posterior draws for further analyses.

To assess the goodness-of-fit of the estimated models, we compare the logarithms of Marginal Data Densities (log MDDs) calculated using the method proposed by Sims, et. al.(2008). Following a widespread practice, we assume that the model is statistically significantly better than the other, if the difference between their log MDDs is higher than 10 orders of magnitude (Kass, Rafterty, 1995). As the strategy may sometimes lead to inconclusive results, we additionally assess the competing models by analysing the plausibility of their regime switches' probabilities and the possibility of explaining these changes through historical data. This empirical strategy is based on the fact that, according to Hubrich and Tetlow (2015), there is a trade-off between volatility changes and the changes of parameters in the class of MSBSVAR models consisting in that the bigger the changes in shock variances the smaller the changes in the parameters of equations, and vice versa. A situation is therefore possible, in which a model explaining both volatility and parameter switches has better goodness-of-fit than a model accounting only for changes in one of these categories. In fact, however, this is a purely statistical phenomenon determined by its parameters moving recursively and hectically between two relatively closely parametrised regimes, which cannot be explained by any historical facts.

6. Empirical results

This part of the paper presents the results of empirical analyses performed using the 2000:1 – 2016:5 data on the non-Eurozone Visegrad Group countries and Sweden. The analysis aims to answer two questions. First, whether the MTM mechanism of the small open economies is relatively stable during the crisis, meaning that shifts are observed in the volatilities of processes but not in the parameters of the models. Second, how do the exchange rate pass-through, balance sheet effects resulting from currency mismatch, and the procyclicality of capital flows contribute to higher stability of the MTM in these countries.

To answer the first of the questions, models allowing for different characteristics of switches observed in the Czech, Hungarian, Polish and Swedish MTMs were estimated. The baseline case is the *1v1c* model, which is a standard Bayesian Structural VAR identified using short-run restrictions and allowing neither for the fluctuations in volatilities of analysed relationships nor for the switches in the structural parameters of the model. The other models take account of changes in the variances of the data (*2v1c* and *3v1c* are models with, respectively, 2 and 3 regimes in variance) and in the model parameters (*1v2c* and *1v3c* are models with, respectively, 2 and 3 regimes in coefficients), as well as changes affecting both the variances and parameters of the model (*2v2c* is a model with 2 regimes in variances and 2 regimes in parameters, while *3v2c* is a model with 3 regimes in variances and 2 regimes in coefficients). For the last case, it is additionally assumed that changes in the variances and coefficients are governed by separate Markov chains so that it can be determined whether or not these two phenomena coincide during the business cycle. The proposed specification and identification of the model yielded estimates capable of recovering a set of impulse response functions, which proved relatively stable and consistent with economic theory. The log MDDs of the estimated models are presented in Table 3.

Table 3. Log MDDs of the estimated MSBSVAR models

Country	Model type						
	1v1c	*2v1c*	*3v1c*	*1v2c*	*1v3c*	*2v2c*	*3v2c*
Czech Rep.	2960.7	3018.2	3042.5	3001.3	3009.2	3046.5	**3063.6**
diff.	-102.9	-45.4	-21.1	-62.3	-54.4	-17.1	-
Hungary	2606	2723.6	2738.8	2713.7	2723.3	2743.8	**2765.8**
diff.	-159.8	-42.2	-27	-52.1	-42.5	-22	-
Poland	3022.6	3054.1	**3070**	3036.7	3040.1	3061.5	3053.2
diff.	-47.4	-15.9	-	-33.3	-29.9	-8.5	-16.8
Sweden	2602.9	2645.3	2661.2	2644.1	2646.5	2665.9	**2675.9**
diff.	-73	-30.6	-14.7	-31.8	-29.4	-10	-

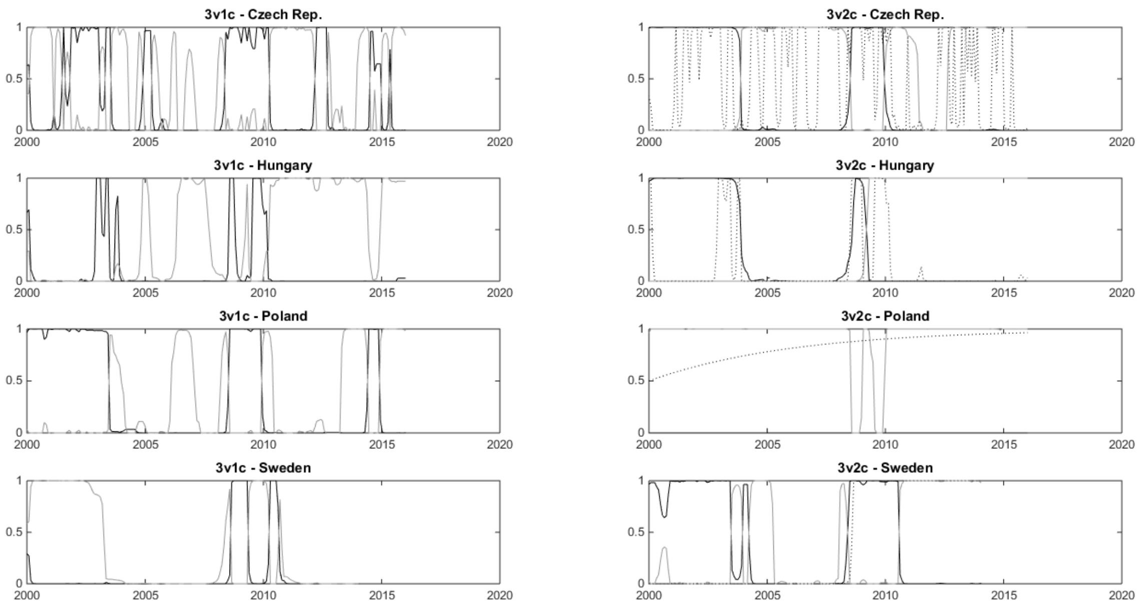
Source: calculated by the author.

An analysis of estimation results presented in Table 3 seems to indicate that the only instance in which the model allowing solely for the changes in volatilities dominates over the other models is observed for Poland. The model with 3 states in variance is statistically significantly better than any other model. As far as the other countries are concerned, the empirical results point to models with switches in both volatilities and coefficients, which are characterised by the highest values of the log

MDDs. In that case the best results are observed within the class of models with 3 regimes in variance and 2 regimes in the coefficients.

In the previous part of the paper we noted that a model with shifts in both volatility and coefficients may outperform models with switches in a single characteristic only, merely due to its bigger potential for adjustments to the dynamic evolution of economic conditions. In spite of that, following Hubrich and Tetlow (2015), we decided to enhance our comparison of the models' goodness-of-fit with an analysis of the estimated state probabilities. The results of the latter are presented in Figure 2, which confronts the probabilities of volatility states obtained with the *3v1c* models (the left hand-side) with the probabilities of volatility (solid line) and coefficient states (dashed line) from the *3v2c* model (the right hand side).

Figure 2. Estimated probabilities of states for the *3v1c* model (left panel) and the *3v2c* model (right panel)



Source: calculated by the author.

In the case of the Czech Rep., both analysed models show relative instability of the MTM, represented by frequent switches between states. When the volatility regime changes are considered on a stand-alone basis, a period of increased instability of economic processes can be observed, probably resulting from the process of accession to the European Union, which was finalised in May 2004. In contrast to the other VG 3 countries, for the Czech Rep. this date does not mark the end of increased volatility – its economy intermittently entered and left a high-variance state until July 2007. The model shows that the global financial crisis affected the Czech economy between the January 2008 and January 2013, but the intensity of its impacts varied: the periods between July 2008 and July 2010 and between July 2012 and January 2013 were less severe. Higher volatility of economic processes can also be observed from the beginning of 2014, probably due to geopolitical situation changing in the region as a result of the war between Russia and Ukraine and the ensuing economic sanctions, etc. The introduction of coefficients' switches into the model does not make the explanation of the analysed processes easier. The model continues to be highly volatile between the states, which seems to suggest that no new information is added. It is also difficult to attribute switches in its parameters to changes in economic expectations represented by the ESI variable. On the other hand, the introduction of coefficient switches seems to stabilise variance changes enabling its clear economic interpretation along the lines mentioned above. We may therefore presume that the main source of changes in the Czech MTM is changes in the volatility of economic processes, and not necessarily swings in the nature of economic relationships.

The results obtained for Hungary reveal 3 periods of increased uncertainty in the course of economic processes. The first of them, resulting from the accession to the European Union, is especially evident towards the end of negotiations, and was at least partially connected with the exchange rate regime switches, which resulted in a need for currency market intervention. The second period of MTM instability emerged during the global economic crisis, which took its toll between July 2007 and January 2012.

Finally, the increased volatility of economic processes during the crisis continued towards 2015 due to the geopolitical reasons. The results of the *3v2c* model show coincidence between changes in volatility, on the one hand, and changes in the model's parameters and decreases in economic sentiment, on the other, thus implying that a structural change may have taken place in the Hungarian economy in those periods.

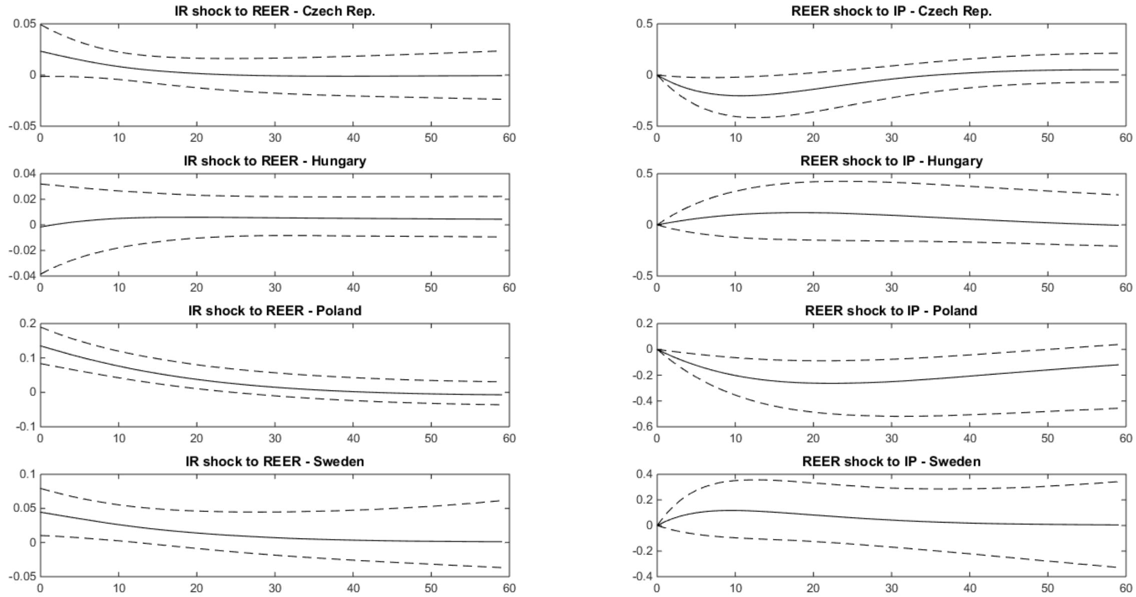
Poland is the only of the analysed countries for which the *3v1c* model proved to be better than the 3*v2c* model, as the comparison of log MDDs showed. We find a confirmation of this result in the state probabilities too. An analysis of the outcomes of model containing only the volatility switches, is an easy way to identify possible reasons of regime changes. According to the estimation results, the EU accession process contributed to increased economic uncertainty between the onset of the sample and May 2004. The effects of the global economic crisis were observed between the spring of 2008 and the fall of 2010. There are also two less pronounced spikes of volatility between January 2006 and July 2007 and from mid-2013 to the end of the sample. The first of them can be easily attributed to political reasons, specifically to the rule of the first cabinet of the party Law and Justice. The second one is a compound of geopolitical and political factors, namely the military unrest in Eastern Europe and the process of political elections, which culminated in the presidential elections in July 2015 and parliamentary elections that led to the formation of the second cabinet of the party Law and Justice. When the results of the *3v2c* model are considered, we can see that despite numerous undertaken attempts it was impossible to obtain proper estimates of the model, as the probabilities for the coefficient changes are degenerate. An inescapable conclusion is that changes in the Polish MTM in the sample period were caused by switches in variances rather than in parameters.

The results on Sweden (Fig. 2), the last of the analysed countries, confirm that its economy was relatively stable. The main factor that affected the Swedish MTM was the global economic crisis of 2008:7-2011:5. Changes in the volatility of economic processes in that period coincide with a swing in the model's parameters and with a deep correction of economic entities' expectations, leading to a structural change in the MTM. Some spikes in volatility of economic processes were also observed towards the beginning of the sample.

The above results can be summed up by concluding that during the sample period, structural changes in the MTM were observed in Sweden and Hungary, whereas volatility swings caused alterations in Polish and up to some extent also Czech MTM. In the next part of the paper, we will attempt to get an insight into the mechanism behind this diversification of economic mechanisms governing the evolution of the MTM in the analysed economies. We will do this along the lines sketched in Part 2 and will assess the role of exchange rate pass-through, balance sheet effects caused by the currency mismatch, and the procyclicality of capital flows ~~in that countries~~. The assessment is based on the evaluation of IRFs yielded by the respective models. We use the *3v2c* model as a basis for further analyses in case of Czech Rep., Hungary and Sweden, whereas for Poland we turn to the results of *3v1c* model. All of these models were proven to fit the available statistical data the best compared with alternative available specifications (Tab.3). The IRFs come from the regimes which were in operation during the financial crisis of 2008-2010, that were marked with black lines and dots in Figure 2 (black line only in case of Poland).

According to the literature review presented in Part 2, the exchange rate-pass through may cushion the negative impact of changes in expectations and economic sentiment during the crisis by causing favourable fluctuations in demand through the depreciation of exchange rates. To investigate this possibility, IRFs depicting the reaction of exchange rates to a monetary policy shock and the industrial production's response to the exchange rate shock are presented in Figure 3.

Figure 3. Exchange rate pass-through in the analysed economies (reactions to positive shocks)

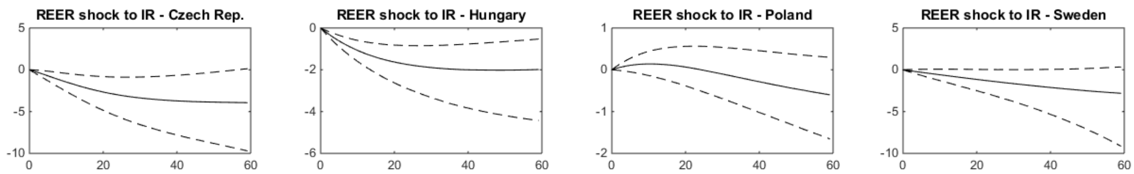


Source: calculated by the author.

Looking at the presented results we find that an expansionary (negative) monetary policy shock results in the depreciation of the real efficient exchange rate in all of the analysed economies. This reaction is the strongest in the case of Poland, while definitely weaker in case of Sweden and the Czech Rep. In case of Hungary it is not only delayed and weak but also statistically insignificant. The remaining IRFs in Figure 3 illustrate the reaction of industrial production to changes in the real effective exchange rates. This feedback is diversified and matches the distinction concerning changes in the MTM. In countries in which structural changes in the MTM occurred during the crisis (Sweden and Hungary), the depreciation of exchange rates is followed by insignificant declines in industrial production. In Poland and the Czech Rep. where the reaction of the MTMs was caused by switches in the volatility of economic processes, industrial production reacts positively to decreases in the exchange rate. Because the power of the exchange rate pass-through depends on the reaction to both shocks, we may infer that the exchange rate pass-through is stronger in Poland than in the Czech Republic.

As already shown, positive exchange rate pass-through effects in the analysed small open economies may be impaired by balance sheet effects resulting from currency mismatch and the procyclicality of capital flows. Both these effects are driven by increasing demand for refinance from both private companies and the state due to the depreciation of domestic currency. Therefore, they should be reflected in the rise of interest rate levels resulting from the depreciation of real effective exchange rates during the crisis.

Figure 4. Reaction of interest rates to the appreciation of the real effective exchange rate



Source: calculated by the author.

IRFs in Figure 4. depict the reaction of interest rates to the real effective exchange rate shock. Analysis shows that in Czech Rep., Hungary and Sweden the depreciation of real effective exchange rates leads to increases in interest rates. The reaction observed for Poland is more problematic as real exchange rates depreciation causes an initial increase of interest rates, however the effect is not statistically significant. This implies that countries in which only volatility changes occurred during the crisis were not affected by balance sheet effects caused by currency mismatch. As such they did not suffered from the phenomenon of the procyclicality of capital flows that may have impaired the monetary transmission mechanism in the sample period.

7. Conclusion

The article presents an analysis of the impact of changes in general economic activity during a crisis on the monetary transmission mechanism in small open economies of Czech Rep., Hungary, Poland, and Sweden. The analysis covers the period from 2000:1 to 2016:5. The nature of the observed changes was investigated by comparing the goodness-of-fit of the Markov Switching Structural Bayesian Vector Autoregressive models allowing for systematic changes in the variances of economic processes, in the coefficients of estimated relationships, or both.

The research results seem to confirm that in the crisis years changes in the volatility of processes underlying monetary transmission occurred in Poland and the Czech Rep., whereas in Sweden and Hungary structural changes in the MTM accompanied the volatility changes. A closer look at the mechanisms leads to a conclusion that the main cause of the diversified response of the analysed economies is the existence and the scope of the exchange rate pass-through mechanism. In countries where this channel of transmission is not fully blocked (Poland and the Czech Rep.), the effects of demand implied by fluctuations in the exchange rate substitute for lower responsiveness of internal demand, thus helping to maintain effective monetary policy during a crisis. In countries where this effect is not present (Hungary and Sweden), structural changes in the MTM and decreasing effectiveness of monetary policy in the period of economic downturn are observed. This leads to a conclusion that the ability of monetary authorities in small open economies to sustain exchange rate pass through may seriously affect their ability to maintain monetary control during a crisis.

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