The impact of the recent global crisis on the prioritization of central banks final objectives. A structural approach in the context of Central and Eastern European states

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Abstract

This paper aims to identify the actual objectives of monetary authorities in Central and Eastern Europe (CEE) that promote an independent monetary policy. In this sense we consider the study of central banks (CBs) behavior in the Czech Republic, Poland, Romania and Hungary in establishing short-term nominal interest rate by estimating a Taylor-type monetary policy rule, with new features in terms of elements aimed at exploring the interactions between the monetary policy and financial stability. We estimate the monetary policy rule based on a dynamic stochastic general equilibrium model (DSGE). The main results revealed the strong stance of the selected monetary authorities towards their fundamental objective of price stability, but in parallel, towards stabilizing the exchange rate and real economic activity and the existence of specific elements indicating a leaning against the wind orientation of the monetary policy in countries under analysis. Following the emergence of international turmoil our analysis has identified the maintaining of a strong orientation towards the primary objective of monetary policy, a similar relative stance of monetary policy relative to the stabilization of the real activity alongside a decrease in the focus of stabilizing the exchange rate, while the accentuated focus on financial stability does not appear to be achieved through monetary policy.

Keywords: DSGE models, Taylor rules, monetary policy, Bayesian methods, Central and Eastern Europe

JEL Classification: C11, E52, F41

1. Introduction

Identifying the behavior of central banks in setting interest rates may provide a conclusive picture on both their objectives and on their attached importance. A standard approach in this respect is the estimation of the CBs reaction function as a Taylor rule.

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Since the formulation of its original version, the Taylor-type monetary policy rule has undergone a number of changes and extensions designed to better reflect the central bank's monetary policy decisions. Given the current specific of CEE countries, all small and open economies, a first extension is to include the exchange rate in the Taylor-type monetary policy rule.

In addition, we introduce into the rule specific to these states additional variables financial stability-related in order to investigate how monetary authorities subject to analysis have approached the asset prices in the conduct of their monetary policy. All these appear as an objective necessity, due to the extensive discussions on the optimality of 'cleaning' or 'mopping-up' approach versus 'leaning against the wind' (cleaning effects after asset price bubble burst or intervention in an early stage to avoid their creation) amid the recent financial crisis consequences.

The estimation of the Taylor-type monetary policy rule including exchange rate changes, private credit and property prices fluctuations is supported by a Neo-Keynesian model for a small open economy in which the central bank reaction function is one of the model equations (along with those of aggregate demand, aggregate supply and exchange rate dynamics). The model is a dynamic stochastic general equilibrium-type (DSGE), following the general lines developed by Lubik and Schorfheide (2007). The mentioned model has been chosen as reference due to the fact that it has been previously used to estimate monetary policy rules with different specifications, including for the states subject to our analysis (Caraiani, 2011a; 2013), so that a comparative study is relevant.

The model estimation for CEE countries following a direct inflation targeting strategy (the Czech Republic, Poland, Romania and Hungary) is based on Bayesian techniques that offer the advantage of robust results in the context of small samples sizes. Estimation is performed using Matlab and Dynare, a widely used program both by central banks and academia arena to solve, simulate and estimate DSGE models.

The remainder of the paper presents as follows. The first part consists of an overview of the literature, the second part describes the model, the third is focused on methodology and data sources, while the estimation results are summarized in the fourth part. The fifth section concludes.

2. Literature review

While existing evidence reveal that CBs monetary policy in the major developed countries can be described by a reaction function (Clarida et al., 1998), the studies for emerging countries, including Central and Eastern Europe members are much narrower. A number of estimates of Taylor-type monetary policy rules in different specifications and using different methods (usually GMM) can be found in the works of: María Dolores (2005), Angeloni et al. (2007), Frömmel and Schobert (2006; 2011), Vašíček (2008), Orlowski (2008; 2010).

As for exploring interactions between monetary policy and financial stability, a first representative paper that takes into account a number of emerging economies (the Czech

Republic, Poland and Hungary) is the one of Munoz and Schmidt-Hebbel (2012). The authors analyze the monetary policy decisions on a group of 28 emerging and developed countries, between 1994 and 2011 by inserting into the Taylor rule alongside the exchange rate of two financial variables, namely the development of private credit and stock prices, following their actions towards the avoidance of asset prices bubbles formation. Munoz and Schmidt-Hebbel (2012) identified specific items that indicate a 'leaning against the wind' orientation of monetary policy in CEE countries.

From a structural perspective, of the dynamic stochastic general equilibrium models, existing evidence of Taylor-type monetary policy rules estimates in the case of CEE is even more limited. Of course, over time, central banks in the region have developed complex structural DSGE models including estimates of monetary authority's reaction function, as shown by a number of recent examples: Andrle et al. (2009) in the case of the Czech Republic; Grabek et al. (2011) for Poland; Copaciu (2013) on Romania and Szilágyi et al. (2013) for Hungary.

To compare, a common estimate of a Taylor-type monetary policy rule within a DSGE model is to be found in Caraiani (2013) for the Czech Republic, Poland, and Hungary and by using the same model in Caraiani (2011a) in the case of Romania. The author' model is close to Lubik and Schorfheide (2007) framework. The results retuned by the Bayesian estimation have illustrated that central banks subject to analysis reacted to exchange rate changes, which have generally led to a similar monetary policy, characterized by a high level of conservatism and a moderate or low gradualism.

Eschenhof (2009) used a comparable model to determine the role of the exchange rate in monetary policy of the euro area. The Taylor-type monetary policy rule specifications in three different forms, taking into account the GDP, the output gap and inflation expectations simultaneously with the output gap, allowed the identification of clear evidence regarding the ECB's reaction to exchange rate fluctuations. The monetary policy rule that includes the output gap and inflation expectations proved to fit best with the ECB conduct.

The estimation of the model is based on Bayesian techniques, which are considered the most appropriate for estimating DSGE models (An and Schorfheide, 2007), in Dynare, an array of programs that allow to solve, simulate and estimate models including rational expectations. The algorithm supporting Dynare can be found in Juillard (1996), a description of it in Juillard (2004) and an initiation into its use in Griffoli (2008).

3. The Model

The model broadly follows the framework developed by Lubik and Schorfheide (2007), which, in turn, is an improved version of the DSGE model built by Gali and Monacelli (2005). The Neo-Keynesian context underlying the model includes four equations. The first equation is the aggregate demand curve described by an IS curve for an open economy that comprises forward-looking items. The second equation is the aggregate supply as a Phillips curve for an open economy with forward-looking components. Monetary policy is introduced by setting the interest rate according to a Taylor-type rule and the exchange rate is indirectly inserted by assuming uncovered interest rate parity (PPP). In addition, the terms of trade, private credit and real estate prices are introduced into the model by specifying certain development laws of motion on their dynamics as exogenous AR (1) processes. Due to the fact that the model is outlined for an open economy, foreign output, foreign inflation and technology are modeled as exogenous AR (1) processes.

The model is presented in log-linearized form. Solving the problem of maximizing the utility of households expressed by the Euler consumption equation leads to the IS curve with forward-looking elements as described in relation (1).

$$y_t = E_t y_{t+1} - [\tau + \alpha(2-\alpha)(1-\tau)](r_t - E_t\pi_{t+1}) - \rho_z z_t - \alpha[\pi + \alpha(2-\alpha)(1-\tau)]E_t\Delta q_{t+1} - \\ -\alpha(2-\alpha)\frac{1-\tau}{\tau}E_t\Delta y^*_{t+1} \tag{1}$$

where: y_t is domestic production, π_t domestic inflation expressed by the consumer price index (CPI), r_t short-term nominal interest rate, E_t expectations operator and Δ is the difference operator. All other variables in equation (1) are considered to be exogenous: z_t is the technology growth rate internationally, Δq_t changes in the terms of trade (relative prices difference of exports and imports at time t and t-1), the differentiation operator being the result of the fact that inflation is affected only by changes in relative prices and not by the relative price itself, and y^*_t the foreign output. In the context of an open economy α ($0 < \alpha < 1$) is the share of imports, while τ is the inter-temporal substitution elasticity.

The price setting by domestic producers is described by a Phillips curve for an open economy with forward-looking components in the form of relation (2):

$$\pi_t = \beta E_t\pi_{t+1} + \alpha\beta E_t\Delta q_{t+1} - \alpha\Delta q_t + \frac{\kappa}{\tau + \alpha(2-\alpha)(1-\tau)}(y_t - \bar{y}_t) \tag{2}$$

where: $\bar{y}_t = [-\alpha(2-\alpha)(1-\tau)/\tau]y^*_t$ is potential GDP assuming the absence of nominal rigidities and the κ parameter (Phillips curve slope coefficient, with $\kappa > 0$) is a structural parameters function depending on the model specification.

To introduce changes in the nominal exchange rate Δe_t consumer price inflation (CPI) is defined according to the relation (3):

$$\pi_t = \Delta e_t + (1-\alpha)\Delta q_t + \pi^*_t \tag{3}$$

where: π^*_t is the foreign inflation. Relation (3) implies uncovered interest rate parity functionality (PPP), with inflation depending on changes in the nominal exchange rate, terms of trade and foreign inflation.

The model is closed by specifying a monetary policy rule as a Taylor-type rule that takes into account both the deviation of GDP (real GDP - potential GDP) and inflation expectations. Besides, as a novelty in the Taylor rule we considered the insertion of private credit and real estate market prices changes to capture the behavior of selected monetary authorities geared towards financial stability, pursuing, in fact, the extent to which they include asset price developments in their monetary policy decision. Relation (4) presents the Taylor rule:

$$r_t = \rho_r r_{t-1} + (1-\rho_r)\left[\psi_1 E_t \pi_{t+1} + \psi_2 (y_t + \frac{\alpha(2-\alpha)(1-\tau)}{\tau} y_t^*) + \right.$$
$$\left. + \psi_3 \Delta e_t + \psi_4 \Delta pc_t + \psi_5 \Delta pp_t \right] + \varepsilon_t^r \tag{4}$$

where: ρ_r is the coefficient of interest rate inertia, Δpc_t private credit variation and Δpp_t the housing market price changes. According to Lubik and Schorfheide (2007) the output gap in equation (4) is modeled as a combination of domestic and foreign production.

The model is complemented by a series of equations that describe the behavior of exogenous variables, i.e. the terms of trade, the technology growth rate international, inflation and foreign output and the changes in the private credit and property prices. All variables are modeled as AR (1) processes according to relations (5) - (10).

Terms of trade shocks:

$$\Delta q_t = \rho_q \Delta q_{t-1} + \varepsilon_t^q \tag{5}$$

Technology shocks:

$$z_t = \rho_z z_{t-1} + \varepsilon_t^z \tag{6}$$

Shocks of foreign inflation:

$$\pi_t^* = \rho_\pi \pi_{t-1}^* + \varepsilon_t^{\pi^*} \tag{7}$$

Shocks in foreign production:

$$y_t^* = \rho_y y_{t-1}^* + \varepsilon_t^{y^*} \tag{8}$$

Private credit shocks:

$$\Delta pc_t = \rho_{pc} \Delta pc_{t-1} + \varepsilon_t^{pc} \tag{9}$$

Shocks in the prices of real estate assets:

$$\Delta pp_t = \rho_{pp} \Delta pp_{t-1} + \varepsilon_t^{pp} \tag{10}$$

The model is solved and estimated by Bayesian techniques using Matlab and Dynare.

4. Methodology and data

The model is estimated with quarterly frequency data for the four CEE countries in the process of convergence towards the euro area that apply an inflation targeting strategy: the Czech Republic, Poland, Hungary and Romania. The intention of an analysis for a time horizon that starts with the date of adopting inflation targeting strategy by the four countries has been heavily restricted by the availability of data series on the development of real estate prices. Therefore, data samples cover the following ranges: the Czech Republic - 2004q1:2013q1; Poland - 2002q4:2013q1; Romania - 2005q3:2013q1; Hungary - 2001q4:2013q1. Estimates for the period subsequent to the global financial crisis cover the interval 2008q4:2013q1. All data is provided by Eurostat database, except for private credit and the price of real estate, where the data comes from the database of the Bank for International Settlements.

The data series include the quarterly national GDP in constant prices (2005) expressed as volume of national currency; quarterly domestic inflation measured as the difference between national consumer price indices as monthly quarterly average and multiplied by 400 to obtain annualized inflation interest rate; quarterly interest rate as short-term nominal interest rates set by central banks; quarterly exchange rate given by the average quarterly nominal exchange rate against EUR; foreign quarterly GDP as quarterly GDP in the euro area in constant prices (2005) expressed as volume in the European single currency, foreign quarterly inflation as the Eurozone inflation for the same time horizon, similar to national inflation; quarterly internal private credit as a fixed base index (2005 = 100) and quarterly properties price in real estate markets as fixed base index (2005 = 100). All series except for the interest rates were logarithmic. Subsequently, all series have been seasonally adjusted and filtered through a Hoddrik-Prescott filter.

The study of the literature reveals two main methods of evaluating DSGE models: calibration and econometric estimation. The calibration method was widely used until a few years ago, when its popularity positioned on a downward trend. However, calibration should be considered a fundamental aspect in the model construction and estimation, contributing essentially, for example, in the learning of model properties (Tovar, 2008). Regarding the econometric estimates, this can be achieved by various methods such as the estimation of equilibrium relationships based on the generalized method of moments (GMM), the maximum likelihood method and Bayesian methods (see Canova (2007), An and Shorfheide (2007), Ruge-Murcia (2007) and Favero (2001) for details of the various approaches).

The Bayesian techniques are presently considered the best way of estimating such models and consist in adding to the probability function of early information (priors).

Bayesian estimates are actually a bridge between the calibration method and maximum likelihood method. Tradition of calibration models is included in the Bayesian estimates by specifying a priori information (priors). Maximum likelihood approach is the result of the estimation based on the model-data comparison. Priors can be seen as weights within the probability function in order to give greater importance to certain areas of the parameter subspace. These two blocks, priors and maximum likelihood, are linked together by Bayes's theorem.

Given the vector ψ (6 x 1) of the monetary policy rule parameters:

$$\psi = \left[\rho_r, \psi_1, \psi_2, \psi_3, \psi_4, \psi_5\right] \tag{11}$$

vector θ (17 x 1) containing the other parameters and standard deviations of the shocks:

$$\theta = \left[\alpha, r, \kappa, \tau, \rho_q, \rho_z, \rho_{pc}, \rho_{pp}, \rho_{y^*}, \rho_{\pi^*}, \sigma_R, \sigma_q, \sigma_z, \sigma_{pc}, \sigma_{pp}, \sigma_{y^*}, \sigma_{\pi^*}\right] \tag{12}$$

vector Y^T (7 x 1) of observable variables:

$$Y^T = \left[4R_t, 4\pi_t, \Delta y_t + z_t, \Delta e_t, \Delta q_t, \Delta pc_t, \Delta pp_t\right] \tag{13}$$

a random distribution with density $p(\psi,\theta) = p(\psi)p(\theta)$ and a probable distribution function of data $L_D(\psi,\theta / Y^T)$ with $Y^T = \{Y_1,...,Y_7\}$ then the posterior density $p_D(\psi,\theta / Y^T)$ of the model parameters is given by Bayes' theorem:

$$p_D(\psi,\theta / Y^T) = \frac{L_D(\psi,\theta / Y^T)p(\psi)p(\theta)}{\int L_D(\psi,\theta / Y^T)p(\psi)p(\theta)d(\psi,\theta)} \tag{14}$$

Distribution type is based on the allowable ranges for the parameter values and random information on mean and standard deviation as in Lubik and Schorfheide (2007), Eschenhof (2009), Caraiani (2011a; 2013). Posterior distribution of the parameters is determined by the Metropolis-Hastings algorithm.

Before the Bayesian approach, a number of coefficients are calibrated using results from the literature. β discount factor is calibrated at 0.99, its reference value in the literature ($\beta = \exp(-r/400)$), ρ_{π^*} at 0.69, ρ_{y^*} at 0.92 with standard deviations of 0.5 and respectively 0.3 (Caraiani 2008; 2011b). $\rho_z, \rho_{pc}, \rho_{pp}$ parameters and shocks standard deviations are calibrated similar to external variables coefficients given that they are considered AR (1) processes. Parameters estimates, as in fact the Dynare code we used (mod. file) and Matlab files (m. files) can be obtained on request from the author.

The final set of parameters to be estimated is reflected by the following array:

$$\{\alpha, \kappa, \tau, \rho_r, \psi_1, \psi_2, \psi_3, \psi_4, \psi_5\} \tag{15}$$

5. Estimation results

5.1 The Czech Republic case

The estimation was based on 2 Metropolis-Hastings chains of 50,000 extractions each, with final acceptance rates of 28.08% and 28.17%, indicating a high quality of the estimation given that the literature recommends an optimal acceptance rate between 20% and 40%.

Results of univariate and multivariate Brooks-Gelman (1998) convergence statistics presented in Annex 1 reveal convergence after a reasonable number of iterations. Priors and posterior distributions are illustrated in Annex 2. The estimation findings in terms posterior distributions can be found in Table 1.

The estimation results indicate a ψ_1 value of 1.9384, which emphasizes a stabilizing monetary policy. A coefficient of inflation gap greater than one shows the viability of the Taylor principle, a stabilizing monetary policy assuming an increase in the nominal interest rate to a greater extent (more than proportionally) than inflation.

However, such a high value returned by the Bayesian estimates for inflation coefficient compared to parameters related to other macroeconomic variables in the monetary policy rule underlines a strong orientation towards maintaining the price stability.

Table 1: Results of the Bayesian estimation - the case of the Czech Republic (2004q1:2013q1)

Parameters	Prior mean	Posterior mean	Confidence interval	Confidence interval	Prior distribution	Domain	Standard deviation
τ	0.5000	0.1689	0.1419	0.1964	beta	[0,1)	0.1500
α	0.5000	0.6967	0.5972	0.7997	beta	[0,1)	0.1000
κ	0.5000	0.3767	0.2377	0.5129	gamma	R^+	0.1000
ρ_r	0.7000	0.2638	0.1270	0.3997	beta	[0,1)	0.1500
ψ_1	1.5000	1.9384	1.5414	2.3261	gamma	R^+	0.3000
ψ_2	0.2500	0.1381	0.0773	0.1969	gamma	R^+	0.1250
ψ_3	0.2500	1.6436	1.2967	1.9812	gamma	R^+	0.1250
ψ_4	0.2500	0.2510	0.0620	0.4391	gamma	R^+	0.1250
ψ_5	0.2500	0.2496	0.0571	0.4319	gamma	R^+	0.1250
ρ_q	0.4000	0.4767	0.2420	0.7226	beta	[0,1)	0.1500

Source: author's estimation

For the output gap coefficient (ψ_2) the findings point out a value of 0.1381 that shows a rather low orientation of monetary policy towards the stabilization of the real activity.

The importance attached by national monetary authorities to the exchange rate stability is evidenced by the ψ_3 value. The high coefficient value (1.6436) emphasizes a strong orientation of CBs towards the stabilization of the exchange rate through short-term nominal interest rate.

The estimation results for the variables coefficients introduced into the monetary policy rule to identify the behavior towards financial stability through monetary policy, respectively ψ_4, related to changes in private credit and ψ_5, corresponding to real estate price trends, are 0.2510 and 0.2496.

The parameters significant values reveal the presence (though not very strong) of a 'leaning against the wind' monetary policy approach of the national CBs. The analysis of central bank behavior in setting the interest rate in order to ensure financial stability shows that it has taken into account to some extent both private credit developments and the evolution of real estate prices. Besides, the monetary policy stance of ensuring financial stability can be determined even by simply identifying the importance attributed to the exchange rate in the monetary policy rule, believed to be high. Such an approach seems to be justified if we consider the high degree of euroisation and currency mismatch of financial institutions assets and liabilities, a distinctive feature of selected economies, because the depreciation of national currencies severely affects the financial stability.

ρ_r coefficient of inertia (interest rate smoothing) resulting from the estimation returns a value of 0.2638, which indicates a relatively low degree of inertia in adjusting interest rates. The value of the parameter expresses the position of national monetary authority towards the compromise between less aggressive changes in the interest rate not to cause instability in financial markets, on the one hand, and strengthening the credibility of monetary policy (which would automatically imply fast and powerful interest rates reactions, with a lower level of inertia) on the other hand.

The focus on the recent financial crisis subsequent period has led to results that can be identified in Table 2. Given this range, the final acceptance rates for the 2 Metropolis - Hastings chains of 50,000 extractions each retuned values of 33.79% and 33.94% respectively, with a corresponding quality of estimation and Brooks and Gelman convergence univariate and multivariate statistics highlighting convergence achievement after a reasonable number of iterations.

Table 2: Results of the Bayesian estimation - the case of the Czech Republic (2008q4:2013q1)

Parameters	Prior mean	Posterior mean	Confidence interval	Confidence interval	Prior distribution	Domain	Standard deviation
τ	0.5000	0.1491	0.1157	0.1830	beta	[0,1)	0.1500
α	0.5000	0.6519	0.5336	0.7698	beta	[0,1)	0.1000
κ	0.5000	0.4009	0.2555	0.5422	gamma	R^+	0.1000
ρ_r	0.7000	0.3816	0.2030	0.5645	beta	[0,1)	0.1500
ψ_1	1.5000	1.8535	1.4744	2.2324	gamma	R^+	0.3000
ψ_2	0.2500	0.1389	0.0515	0.2219	gamma	R^+	0.1250
ψ_3	0.2500	0.8516	0.3577	1.3244	gamma	R^+	0.1250
ψ_4	0.2500	0.2481	0.0592	0.4335	gamma	R^+	0.1250
ψ_5	0.2500	0.2489	0.0554	0.4324	gamma	R^+	0.1250
ρ_q	0.4000	0.4175	0.1673	0.6561	beta	[0,1)	0.1500

Source: author's estimation

The comparative approach of the two intervals has indicated similar values for the ψ_1, ψ_2 coefficients included in the monetary policy rule, which emphasizes the maintaining of monetary policy stance towards the basic objective of price stability and a similar orientation of monetary policy relative to the stabilization of real economic activity in the post-crisis period. Significantly close values for the parameters can also be identified in the case of ψ_4 and ψ_5, which emphasizes that in the aftermath of the international turmoil the increased focus towards financial stability has not been achieved through monetary policy. Instead, the ψ_3 coefficient of exchange rate retuned lower values, reflecting a decrease in the monetary policy stance towards the stabilization of the exchange rate subsequent to the crisis.

5.2 The case of Poland

The model is estimated based on two Metropolis Hastings chains of 50,000 extractions each, with acceptance rates between 27.90% and 27.96%, and appropriate quality estimation. Convergence statistics supported by Brooks-Gelman (1998) approach presented in Annex 1 have highlighted convergence both in univariate and multivariate terms. Annex 2 includes the a priori and posterior distributions and differences between them. The estimation results are illustrated by Table 3.

Table 3: Results of the Bayesian estimation - the case of Poland (2002q4:2013q1)

Parameters	Prior mean	Posterior mean	Confidence interval	Confidence interval	Prior distribution	Domain	Standard deviation
τ	0.5000	0.1784	0.1507	0.2052	beta	[0,1)	0.1500
α	0.5000	0.6970	0.5938	0.7993	beta	[0,1)	0.1000
κ	0.5000	0.3587	0.2205	0.4937	gamma	R^+	0.1000
ρ_r	0.7000	0.2374	0.1134	0.3570	beta	[0,1)	0.1500
ψ_1	1.5000	2.8952	2.1544	3.6340	gamma	R^+	0.3000
ψ_2	0.2500	0.3352	0.2584	0.4083	gamma	R^+	0.1250
ψ_3	0.2500	1.5676	1.1375	1.9812	gamma	R^+	0.1250
ψ_4	0.2500	0.2503	0.0579	0.4330	gamma	R^+	0.1250
ψ_5	0.2500	0.2508	0.0596	0.4383	gamma	R^+	0.1250
ρ_q	0.4000	0.4137	0.1610	0.6530	beta	[0,1)	0.1500

Source: author's estimation

Inflation coefficient in the monetary policy rule (ψ_1) is estimated at 2.8952, a high value both per se and compared with the corresponding parameters of the other variables taken into account in deciding the monetary policy rule, which firstly confirms the pursuit of price stability objective in full accordance with the inflation targeting strategy.

Such a monetary policy strategy is not applied under a strict form, leaving room for the stabilization of real activity and the exchange rate. The estimated coefficient for the output gap (ψ_2) is 0.3352, which indicates the stance of monetary policy towards the aggregate output stabilization, while the ψ_3 real exchange rate change parameter returns an estimated value of 1,5676, underlining the high importance attributed to exchange rate stability in the monetary policy decision. This evidence, however, is not likely to jeopardize the inflation target priority, as ψ_2 and ψ_3 values are much smaller than those of ψ_1.

Besides the high importance of exchange rate developments, monetary policy stance geared to financial stability can be identified based on the results for the coefficients of changes in private credit (ψ_4) and changes in real estate prices (ψ_5). The estimated values of 0.2503 and respectively 0.2508 emphasize a not very wide, but constant concern of the CBs monetary policy to prevent excessive credit growth and the formation of asset price bubbles in the housing market.

The estimation results indicate a value of 0.2374 for the interest rate inertia coefficient (ρ_r) showing the absence of a high gradualism in implementing the monetary policy.

The analysis of the period following the emergence of the international financial crisis has led to the results illustrated in Table 4. From the technical point of view, the quality of estimation in this case appears to be appropriate for the rates of acceptance of the two Metropolis Hastings chains, returning values of 34.09% and 33.97%, respectively. In addition, we found univariate and multivariate convergence after a reasonable number of iterations, according to Brooks-Gelman approach.

Table 4: Results of the Bayesian estimation - the case of Poland (2008q4:2013q1)

Parameters	Prior mean	Posterior mean	Confidence interval	Confidence interval	Prior distribution	Domain	Standard deviation
τ	0.5000	0.1517	0.1175	0.1860	beta	[0,1)	0.1500
α	0.5000	0.6398	0.5183	0.7632	beta	[0,1)	0.1000
κ	0.5000	0.4086	0.2625	0.5500	gamma	R^+	0.1000
ρ_r	0.7000	0.3380	0.1699	0.5013	beta	[0,1)	0.1500
ψ_1	1.5000	2.4130	1.7659	3.0390	gamma	R^+	0.3000
ψ_2	0.2500	0.2671	0.1485	0.3827	gamma	R^+	0.1250
ψ_3	0.2500	0.7299	0.2472	1.2051	gamma	R^+	0.1250
ψ_4	0.2500	0.2487	0.0580	0.4329	gamma	R^+	0.1250
ψ_5	0.2500	0.2513	0.0596	0.4361	gamma	R^+	0.1250
ρ_q	0.4000	0.4006	0.1480	0.6381	beta	[0,1)	0.1500

Source: author's estimation

The comparison of the two periods in the case of Poland suggests a slight decrease in the monetary policy stance towards price stability and stabilization of real economic activity. The very similar values obtained for the coefficients of private borrowing and asset prices in the housing market indicates a further disengagement of monetary policy in ensuring financial stability after the crisis. An obvious reduction occurs for the exchange rate associated coefficient indicating a dilution in monetary policy authorities' efforts to stabilize the exchange rate in the aftermath of the financial turmoil.

5.3 The case of Hungary

The Metropolis-Hastings algorithm with two chains of 50,000 extractions on data for Hungary resulted in acceptance rates of 32.78% for the first chain, and 32.84% for the second. Brooks-Gelman univariate and multivariate convergence statistics presented in Annex 1 indicates convergence after a reasonable number of iterations. The differences between a priori and posterior distributions are shown in Annex 2. Estimation results can be found in Table 5.

Table 5: Results of the Bayesian estimation - the case of Hungary (2001q4:2013q1)

Parameters	Prior mean	Posterior mean	Confidence interval	Confidence interval	Prior distribution	Domain	Standard deviation
τ	0.5000	0.1788	0.1520	0.2064	beta	[0,1)	0.1500
α	0.5000	0.6433	0.5307	0.7510	beta	[0,1)	0.1000
κ	0.5000	0.3350	0.1942	0.4678	gamma	R^+	0.1000
ρ_r	0.7000	0.2772	0.1434	0.4115	beta	[0,1)	0.1500
ψ_1	1.5000	2.1531	1.7357	2.5796	gamma	R^+	0.3000
ψ_2	0.2500	0.6947	0.6525	0.7370	gamma	R^+	0.1250
ψ_3	0.2500	1.6186	1.2422	1.9812	gamma	R^+	0.1250
ψ_4	0.2500	0.2557	0.0616	0.4455	gamma	R^+	0.1250
ψ_5	0.2500	0.2535	0.0594	0.4391	gamma	R^+	0.1250
ρ_q	0.4000	0.4761	0.2292	0.7190	beta	[0,1)	0.1500

Source: author's estimation

The estimation result for inflation coefficient within the monetary policy rule (ψ_1) indicates a value of 2.1531, highlighting the strong orientation of the NCB towards its primary objective of maintaining the price stability.

Inflation targeting strategy seems to be applied in a flexible manner, as the stabilization of the real economic activity and exchange rate represents a concern of the monetary authority in setting short-term nominal interest rate, as evidenced by the values of ψ_2 and ψ_3 coefficients (0.6947 and 1.6186 respectively). Comparative values of the three parameters emphasize the efforts of the monetary policy to stabilize aggregate production and exchange without affecting the primary objective of price stability.

The values obtained for parameters corresponding to the variables in the Taylor-type rule to identify the conduct of monetary policy in ensuring financial stability (ψ_4 and ψ_5) reveal a 'leaning against the wind' approach, a monetary policy that reacts to some extent to unsustainable credit growth and the formation of a real estate asset price bubbles.

ρ_r interest rate smoothing coefficient is estimated at 0.2772, which translates into a relatively low level of gradualism in adjusting interest rates, partly explained by the CB intent to increase the credibility of its monetary policy.

The estimation results for the period subsequent to the international financial crisis can be identified in Table 6. The acceptance rates resulting from the application of Metropolis Hastings algorithm with two chains of 50,000 extractions each are 34.37% and 34.38%, respectively, in the context of a sound estimation quality. Convergence achievement is ensured both in terms of univariate and multivariate statistics.

The comparison of results for the period 2008q4: 2013q1 with those of the 2001q4: 2013q1 time horizon suggests a relative decrease in the orientation of the monetary authority towards the fulfillment of the primary objective and the post-crisis stabilization of aggregate production.

Table 6: Results of the Bayesian estimation - the case of Hungary (2008q4:2013q1)

Parameters	Prior mean	Posterior mean	Confidence interval	Confidence interval	Prior distribution	Domain	Standard deviation
τ	0.5000	0.1519	0.1169	0.1867	beta	[0,1)	0.1500
α	0.5000	0.6065	0.4805	0.7332	beta	[0,1)	0.1000
κ	0.5000	0.3920	0.2489	0.5343	gamma	R^+	0.1000
ρ_r	0.7000	0.2900	0.1215	0.4513	beta	[0,1)	0.1500
ψ_1	1.5000	1.8691	1.4890	2.2377	gamma	R^+	0.3000
ψ_2	0.2500	0.5746	0.5014	0.6487	gamma	R^+	0.1250
ψ_3	0.2500	0.7518	0.2888	1.2151	gamma	R^+	0.1250
ψ_4	0.2500	0.2501	0.0571	0.4322	gamma	R^+	0.1250
ψ_5	0.2500	0.2533	0.0598	0.4431	gamma	R^+	0.1250
ρ_q	0.4000	0.4121	0.1672	0.6589	beta	[0,1)	0.1500

Source: author's estimation

A second result identifies the maintaining to a certain extent of the leaning against the wind orientation of monetary policy, while the focus on the exchange rate appears significantly lower after the recent financial crisis.

5.4 The case of Romania

In this case also the Bayesian approach is based on two Metropolis-Hastings chains with 50,000 extractions each, with acceptance rates of 28.08% and 27.75%. Convergence both in terms of univariate and multivariate Brooks-Gelman statistics is present, as illustrated by Appendix 1, while priors and posterior distributions can be found in Appendix 2. Bayesian estimation results are displayed in Table 7.

Inflation coefficient in the monetary policy rule (ψ_1) returned by the estimation model is 2.0117, indicating in this case also the principle of Taylor and the strong orientation of the national monetary authority towards the primary objective of price stability. From this point of view, of inflation stabilization magnitude, the CB's monetary policy appears to be well behind the realities of Poland and Hungary, but superior to the monetary authority measures applied by the Czech Republic.

The output gap coefficient (ψ_2) is at 0.2253, emphasizing efforts, to some extent, of the monetary authorities to stabilize the real economic activity. From the perspective of stabilizing the aggregate production, as objective hierarchically subordinate to the primary aim of ensuring a low and stable inflation, the monetary policy of the Central Bank of Romania appears to over perform the monetary policy of the Czech central bank, but it is less efficient than the one implemented in Poland. Hungary appears to be the CEE country with an inflation targeting strategy involving the NCB focus primarily in the real economic activity.

Table 7: Results of the Bayesian estimation - the case of Romania (2005q3:2013q1)

Parameters	Prior mean	Posterior mean	Confidence interval	Confidence interval	Prior distribution	Domain	Standard deviation
τ	0.5000	0.1616	0.1303	0.1937	beta	[0,1)	0.1500
α	0.5000	0.5538	0.4247	0.6829	beta	[0,1)	0.1000
κ	0.5000	0.3673	0.2206	0.5061	gamma	R^+	0.1000
ρ_r	0.7000	0.3540	0.1979	0.5072	beta	[0,1)	0.1500
ψ_1	1.5000	2.0117	1.5999	2.4187	gamma	R^+	0.3000
ψ_2	0.2500	0.2253	0.0738	0.3777	gamma	R^+	0.1250
ψ_3	0.2500	1.3344	0.8304	1.8904	gamma	R^+	0.1250
ψ_4	0.2500	0.2516	0.0544	0.4330	gamma	R^+	0.1250
ψ_5	0.2500	0.2505	0.0622	0.4389	gamma	R^+	0.1250
ρ_q	0.4000	0.4086	0.1562	0.6504	beta	[0,1)	0.1500

Source: author's estimation

In Romania, the real exchange rate changes coefficient in the monetary policy rule (ψ_3) indicates a value of 1.3344, which means the strong orientation of the NCB to stabilize the exchange rate through interest rate policy. Moreover, for the real exchange rate parameter estimation results showed high values for all selected states, the Czech Republic and Hungary examples revealing a solid focus of the monetary policy authorities on ensuring the external balance.

For the variables parameters in Taylor-type rule used to test the concerns of central banks to ensure financial stability through monetary policy (ψ_4 and ψ_5), estimates on Romania are similar to those obtained for all other CEE countries subject to analysis, highlighting the same limiting trend (not very strong, but there), through the monetary policy, of uncontrolled private credit expansion and the formation of a real estate price bubble.

For the interest rate inertia degree, the estimated coefficient indicates a higher value compared to the other CEE countries (0.3540), showing a moderate gradualism of monetary policy implemented by the national CBs.

The focus on the post-crisis period has led to estimation results presented in Table 8. The forecasting quality is found to be better for this temporal interval, with acceptance rates of the two Metropolis Hastings chains of 33.84% and 33.97%, respectively. The achievement of convergence after a reasonable number of iterations is evidenced by both univariate and multivariate Brooks-Gelman statistics.

The comparative approach of the two time intervals subject to analysis indicates, similar to Poland and Hungary, a slight decrease of the monetary policy stance towards ensuring price and real economic activity stability. Similar values obtained for the coefficients of variables introduced to test the monetary policy stance relative to financial stability highlight, similar to the other three countries analyzed, additional non-involvement of monetary policy.

Table 8: Results of the Bayesian estimation - the case of Romania (2008q4:2013q1)

Parameters	Prior mean	Posterior mean	Confidence interval	Confidence interval	Prior distribution	Domain	Standard deviation
τ	0.5000	0.1647	0.1263	0.2025	beta	[0,1)	0.1500
α	0.5000	0.6055	0.4784	0.7373	beta	[0,1)	0.1000
κ	0.5000	0.3934	0.2441	0.5357	gamma	R^+	0.1000
ρ_r	0.7000	0.3817	0.1959	0.5630	beta	[0,1)	0.1500
ψ_1	1.5000	1.8466	1.4692	2.2252	gamma	R^+	0.3000
ψ_2	0.2500	0.1942	0.0545	0.3310	gamma	R^+	0.1250
ψ_3	0.2500	0.8781	0.3840	1.3733	gamma	R^+	0.1250
ψ_4	0.2500	0.2479	0.0611	0.4323	gamma	R^+	0.1250
ψ_5	0.2500	0.2461	0.0601	0.4288	gamma	R^+	0.1250
ρ_q	0.4000	0.4014	0.1538	0.6457	beta	[0,1)	0.1500

Source: author's estimation

Another result close to the other three selected countries revealed diluted efforts of the monetary policy authorities to stabilize the exchange rate in the aftermath of the international financial turmoil.

6. Conclusion

The estimation of CBs reaction functions as Taylor rules is a useful tool both for identifying the objectives of central banks and for getting a conclusive picture on their importance for monetary authorities.

To accurately identify the factors considered by the monetary authorities in setting short-term nominal interest rate we estimated a Taylor-type monetary policy rule that includes the exchange rate. In addition, amid extensive discussion generated by the recent financial crisis on the optimality of cleaning or mopping-up approach versus leaning against the wind (cleansing effects after asset price bubble burst or intervention in an early stage to avoid their formation), we inserted into the monetary policy rule two variables (private credit developments and property prices) in order to identify the behavior of selected central banks to financial stability through the monetary policy.

We estimated the monetary policy rule based on a dynamic general stochastic equilibrium model (DSGE) through Bayesian techniques, currently believed to be the best estimation tool.

Monetary policy rule estimation results within the model with explicit micro-elements showed the strong orientation of CEE states towards fulfilling their goal of price stability.

Inflation targeting strategy does not appear, however, to be used in its strict version, in parallel leaving room for the stabilization of real economic activity. In addition, the high values of changes in the real exchange rate coefficients point out the significant efforts of national monetary authorities to support the exchange rate through short-term nominal interest rate. Such evidence, however, is not likely to jeopardize the inflation target priority, as the corresponding parameters identified for aggregate production and changes in the real exchange rate are much lower than those related to inflation.

The interest rate inertia (interest rate smoothing) values indicate in all states a relatively low degree of inertia in adjusting interest rates. Such a limited gradualism in modifying short-term nominal interest rate can be attributed to the purpose of increasing the credibility of the central bank's monetary policy.

The stance of CBs monetary policy to ensuring financial stability in the CEE region has been primarily identified on the basis of high importance attributed to the exchange rate in the monetary policy rule, because the national currency depreciation poses major problems for financial stability due to the characteristics of these economies in terms of high degree of euroisation and currency mismatch of financial institutions assets and liabilities.

As for the coefficients of variables explicitly introduced in the monetary policy rule to determine the behavior of central banks efforts to enhance financial stability through monetary policy, the results reveal a diluted, but present trend of limiting uncontrolled private credit expansion and the formation of a real estate price bubble. In other words, the estimation allowed the identification, to some extent, of a ‘leaning against the wind’ monetary policy orientation of selected monetary authorities.

Orientation of attention to the period following the emergence of the financial crisis has emphasized a strong stance of monetary policy towards the fundamental objective of ensuring price stability (though slightly decreased compared to the extended time period including Romania, Poland and Hungary). If the Czech Republic was found to maintain a similar orientation of monetary policy towards the real activity in post-crisis period, the other three countries subject to analysis reveal a moderate decrease in the monetary policy efforts to stabilize this sector. However, in the aftermath of the global financial crisis, accentuated orientation towards financial stability has not been achieved through monetary policy.

Additional lack of involvement of monetary policy in ensuring financial stability after the crisis was identified in all four countries considered.

Another common result is the change in the monetary policy orientation relative to the exchange rate following the emergence of the turmoil, highlighting limited efforts to stabilize the exchange rate in the post-crisis period.

Acknowledgment

This work was partially supported from the European Social Fund through Sectoral Operational Programme Human Resources Development 2007-2013, project number POSDRU/159/1.5/S/142115 ‘Performance and excellence in doctoral and postdoctoral research in Romanian economics science domain’.

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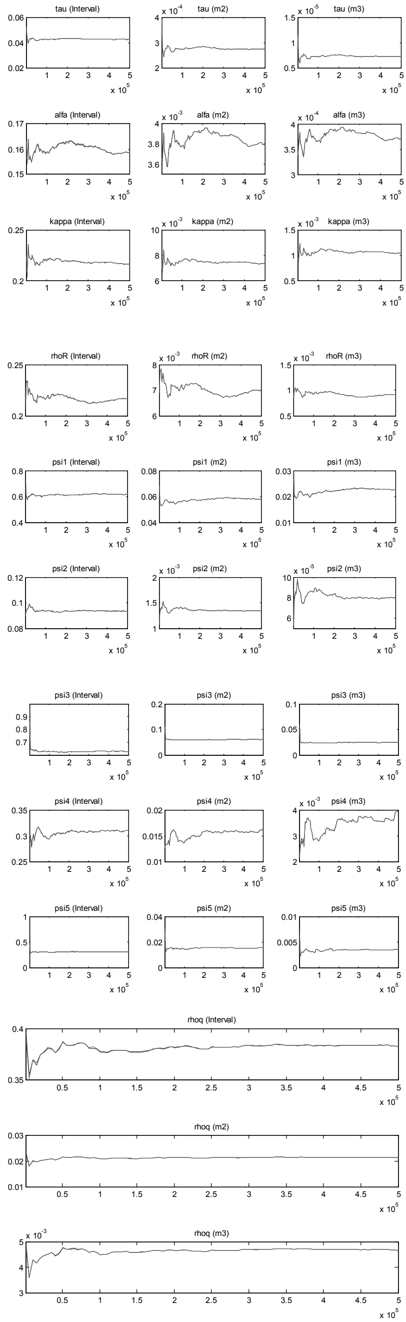
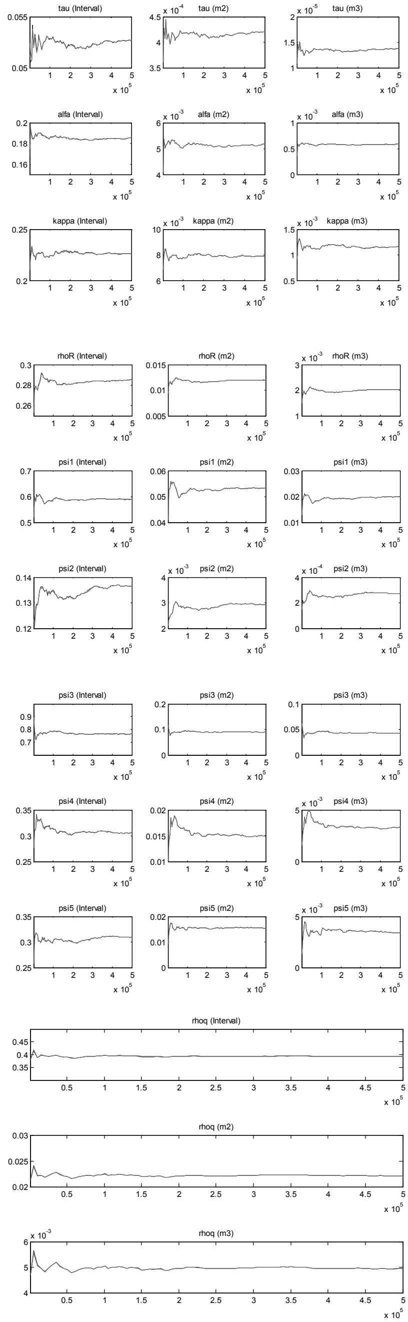
Annex 1

A. Brooks-Gelman (1998) univariate convergence statistics

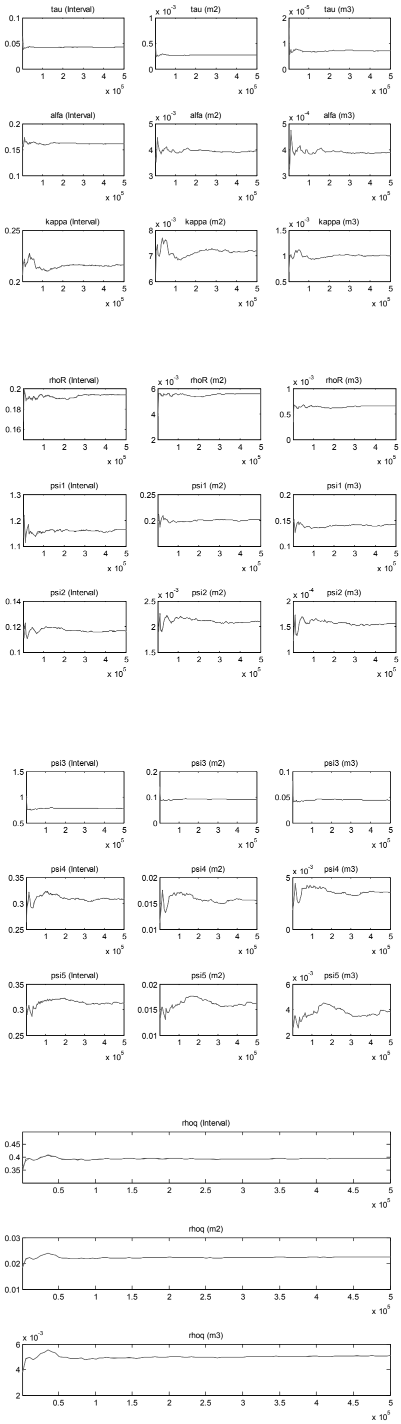
the Czech Republic case (2004q1:2013q1)



the Czech Republic case (2008q4:2013q1)



the case of Poland (2002q4:2013q1)



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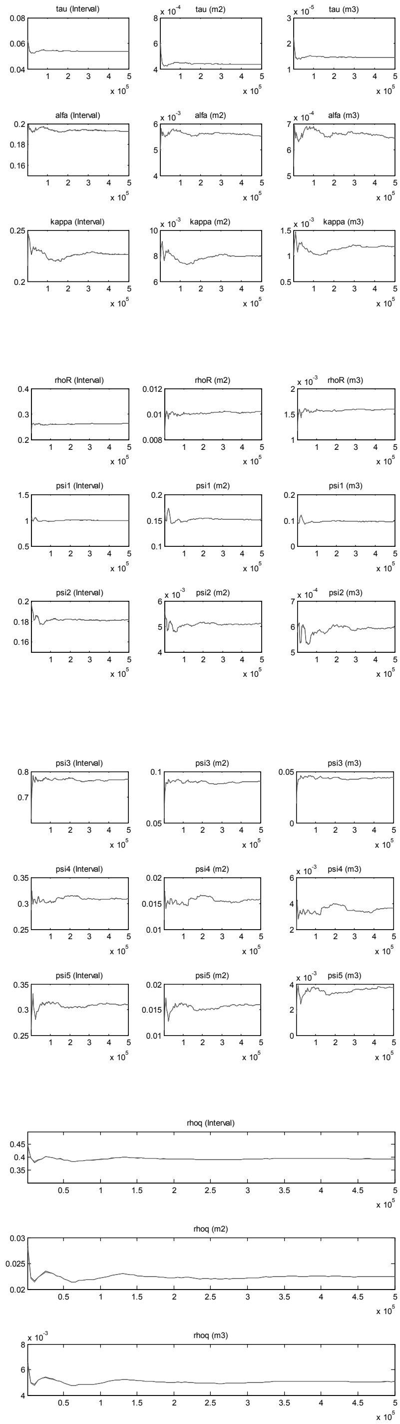
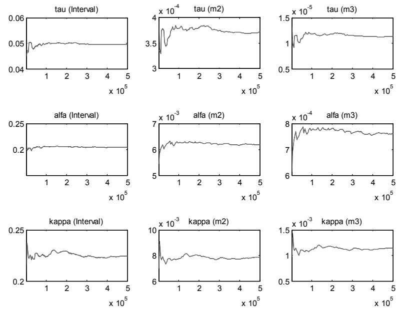
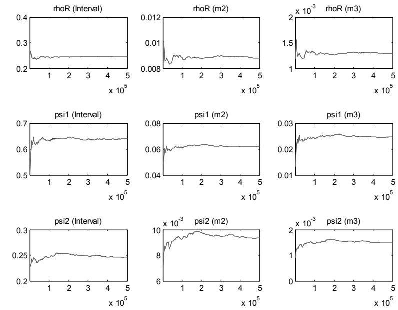
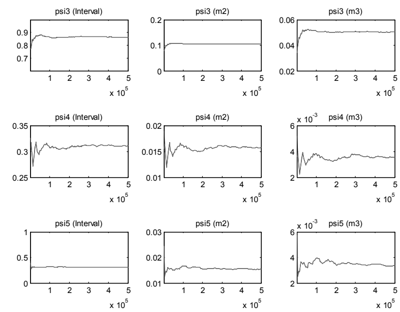
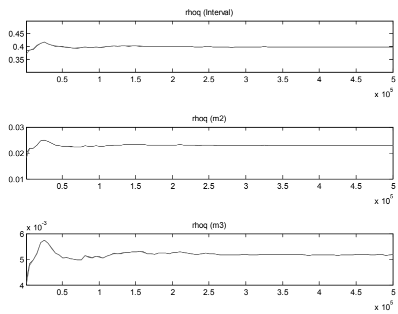


the case of Romania (2005q3:2013q1)

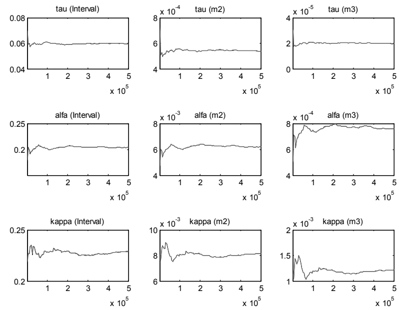


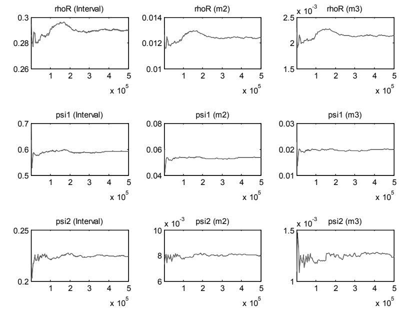


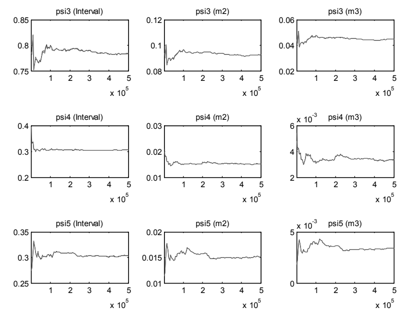


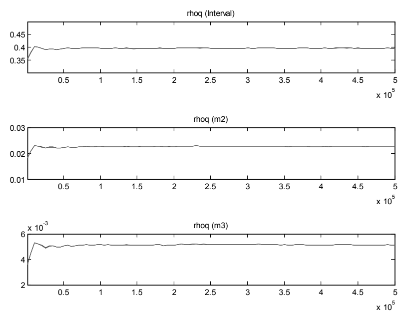


the case of Romania (2008q4:2013q1)

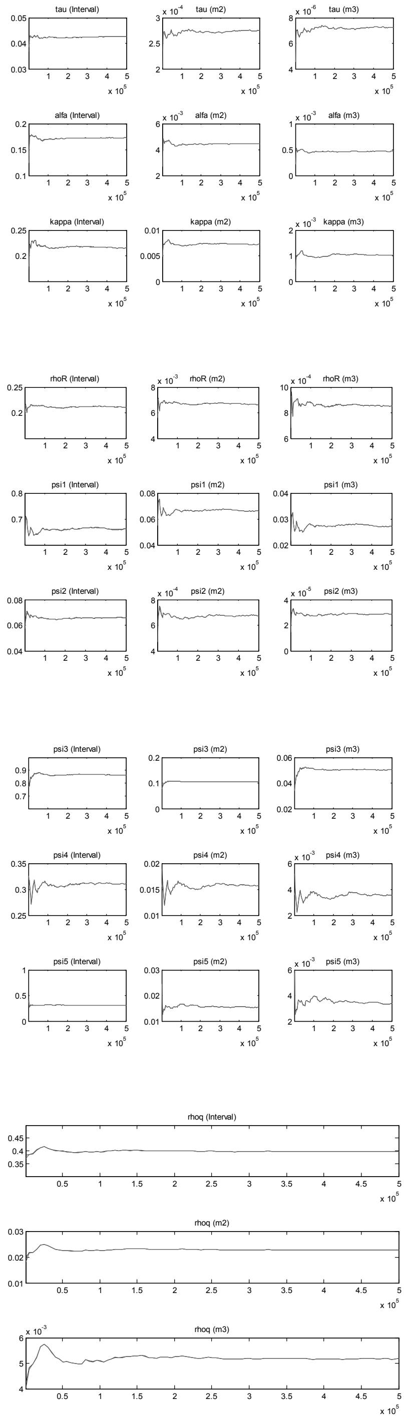




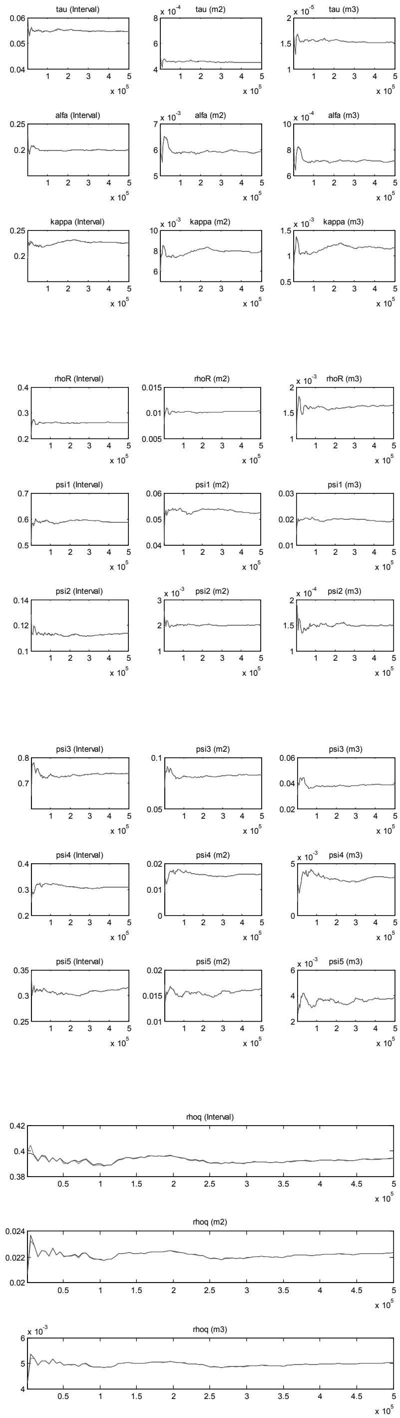




the case of Hungary (2001q4:2013q1)

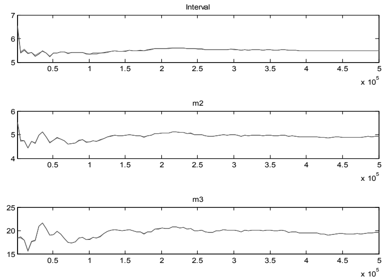


the case of Hungary (2008q4:2013q1)

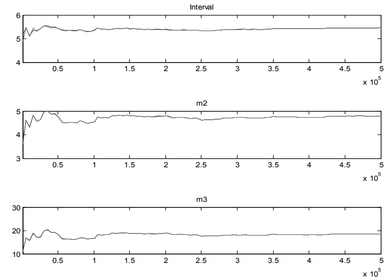


B. Multivatiate convergence statistics

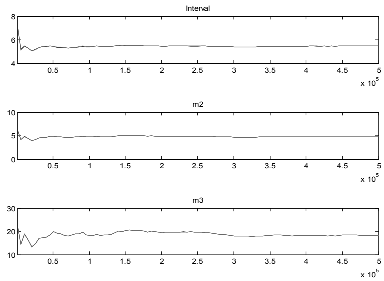
the Czech Republic case (2004q1:2013q1)



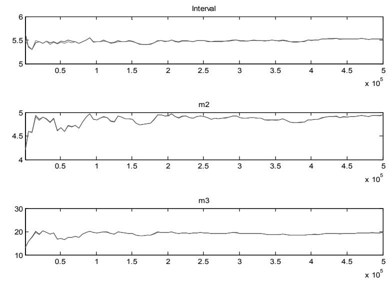
the Czech Republic case (2008q4:2013q1)



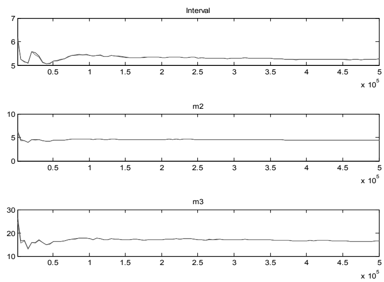
the case of Poland (2002q4:2013q1)



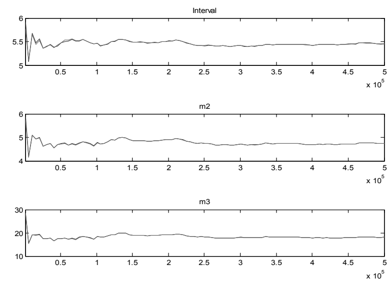
the case of Poland (2008q4:2013q1)



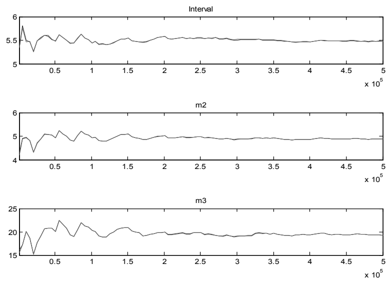
the case of Romania (2005q3:2013q1)



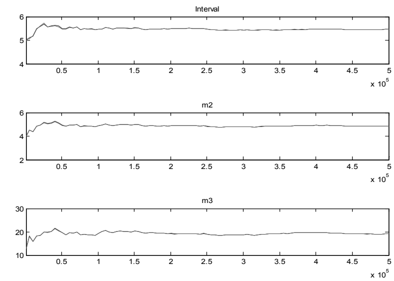
the case of Romania (2008q4:2013q1)



the case of Hungary (2001q4:2013q1)



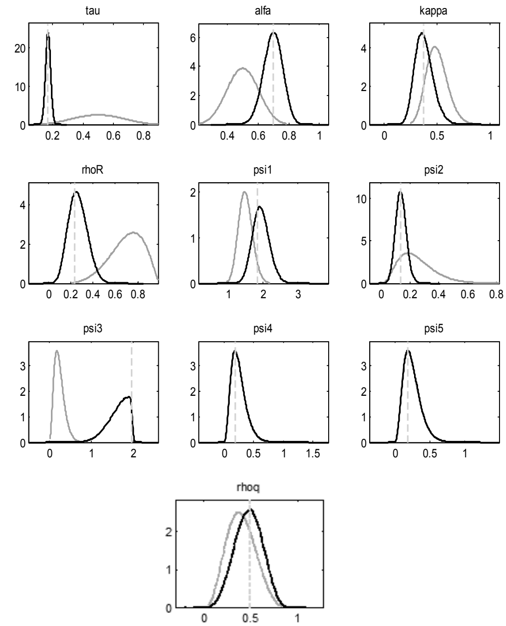
the case of Hungary (2008q4:2013q1)



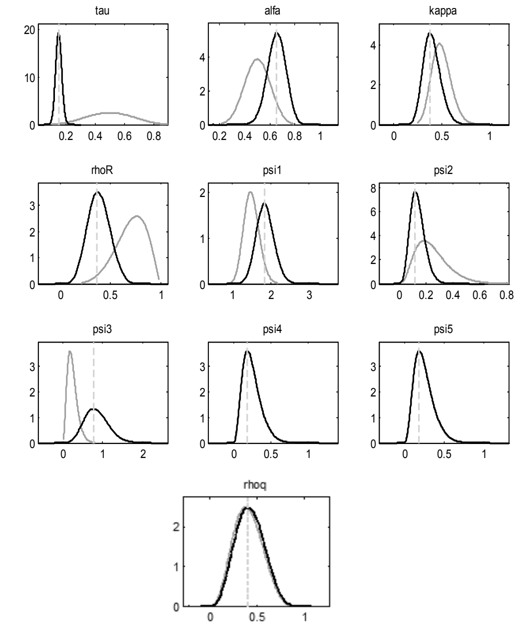
Annex 2

Prior and posterior distributions

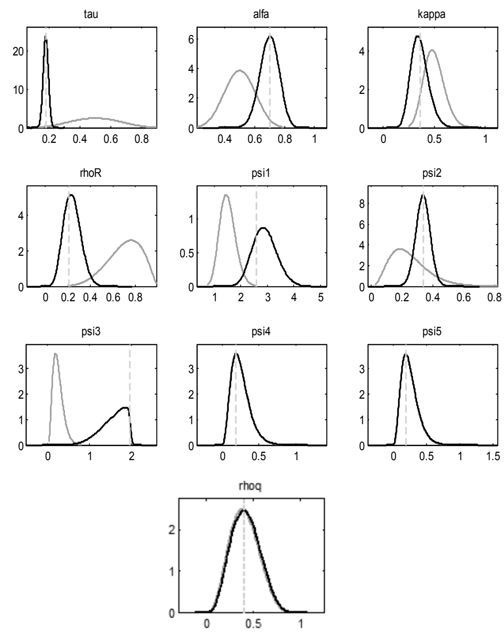
the Czech Republic case (2004q1:2013q1)



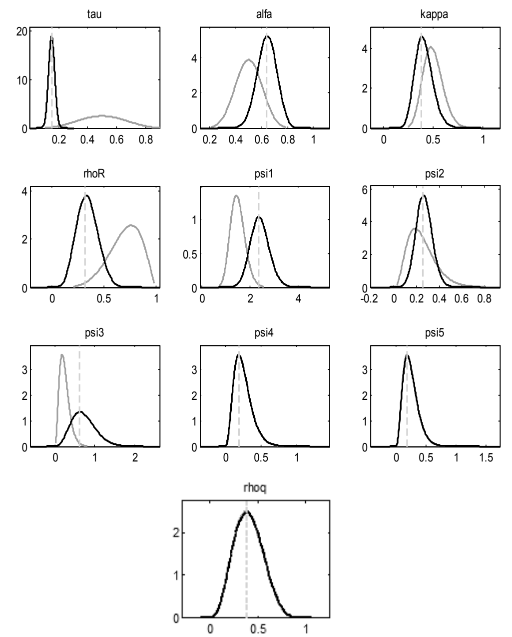
the Czech Republic case (2008q4:2013q1)



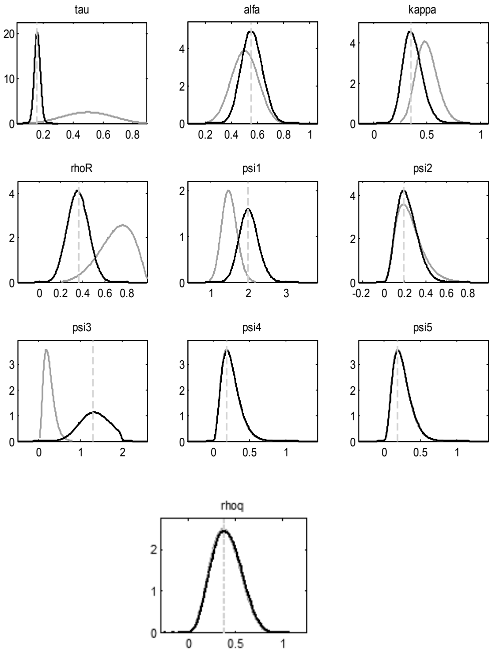
the case of Poland (2002q4:2013q1)



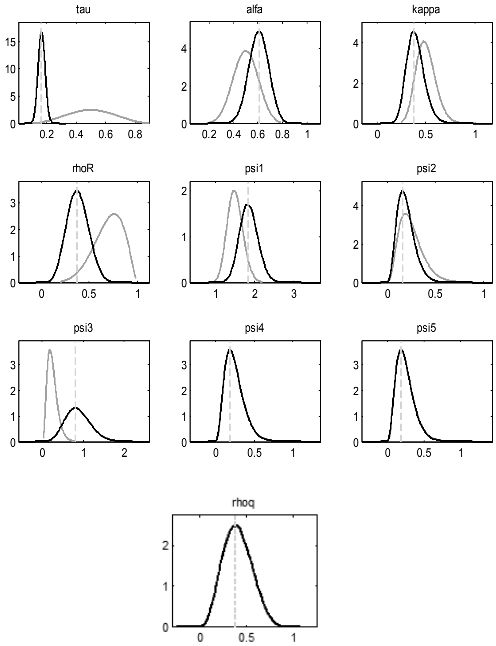
the case of Poland (2008q4:2013q1)



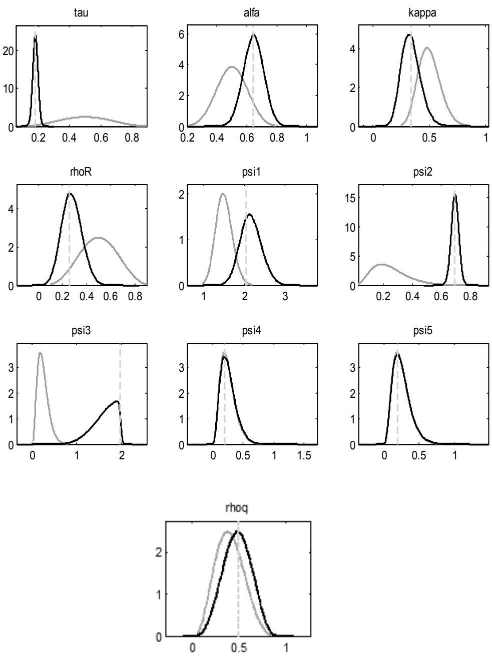
the case of Romania (2005q3:2013q1)



the case of Romania (2008q4:2013q1)



the case of Hungary (2001q4:2013q1)



the case of Hungary (2008q4:2013q1)