A Bayesian Approach for the Analysis of Macroeconomic Dynamic in Case of Emerging Countries-Monetary and Fiscal Policy Model

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Abstract: The paper proposes the analysis of the main drivers of the economic growth in Central and Eastern Europe, in three emerging countries: Czech Republic, Hungary and Poland, with a development stage similar with that of Romania. Given the vulnerabilities of the Central and Eastern Europe region at the beginning and during the recent global economic and financial crisis, there is an increased interest to identify the models that can describe the principalcharacteristics of the Central and Eastern Europe macroeconomic variables: gross domestic product, investment, wages and salaries, inflation, hours worked, consumption and themonetary variable- interest rate. Moreover, another scope is to analyze the frictions that describe the evolution of the seven data series, as the stochastic dynamic of the macroeconomic model is driven by orthogonal structural shocks.

Keywords:monetary; policy; frictions; shocks

JEL Classification: C01; D50; B22; C4.

1. Introduction

I have proposed to analyze in the current thesis the degree in which the model responses to the requests of the Central and Eastern Europe economies, based on a study completed for the following countries: Poland, Hungary and Czech Republic. In this purpose I have used a Bayesian approach for the estimation of this forward-looking model, in a general equilibrium framework.

The current model is not a simple monetary policy model, involving also the fiscal policy, so it can be analyzed taking into account the policy shocks involved: price and interest rate shocks (as monetary policy shocks) and also the exogenous spending shock (which includes together with net exports also the government spending, instrument of the fiscal policy).

So, the model which is an improvement and a simplified version of the one proposed by the authors Frank Smets and RafWouters in 2003 in the article "An Estimated Stochastic Dynamic General Equilibrium Model for the Euro Area has

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the purpose to analyze the main drivers of the economic growth, putting an eye on the frictions of these four economies (seven frictions- reduced to the number of the seven observed variables).

As a result, the research proposes an overview of the dynamic of monetary policy that should be conducted in the face of multiple sources of uncertainty, including model and parameter uncertainty as well as uncertainty about future shocks.

2. The Non-Linear Model

2.1. Producers

The product with destination of final consumption, Y_t, is composed of good for intermediate consumption, $Y_t(i)$ that are bought by final good producers, grouped into Y_t and sold in a perfectly competitive market.

They maximize the profit obtained, as per maximization function:

Max $P_t Y_t - \int_0^1 P_t(i) Y_t(i) di$, s.t. $[\int_0^1 G(\frac{Y_t(i)}{Y_t}; \lambda_{p,t}) di] = 1$ $(\mu_{f,t})$,

$Y_t, Y_{t(i)}$

$P_t, P_t(i)$ are the prices of goods for final consumption and for intermediate consumption and G is a function having the characteristic of being strictly concave on one hand and being an increasing function on the other hand, with the property: G(1)=1.

ε_t^p istheprice mark-up shock, $\varepsilon_t^p \in (0;\infty)$ and follows and exogenous ARMA processln $\varepsilon_t^p = (1-\rho_p)\ln \varepsilon^p + \rho_p \ln \varepsilon_{t-1}^p - \theta_p \eta_{t-1}^p + \eta_t^p, \eta_t^p \approx N(0, \sigma_P)$.

2.2. Intermediate Goods Producers

The producers of goods with the destination of intermediate consumption follow the technology equation:

$Y_t(i) = \varepsilon_t^a K_t^s(i)^\alpha \gamma^t L_t(i)]^{1-\alpha} - \gamma^t \Phi$, $K_t^s(i)$ represents capital in services form, $L_t(i)$ represents the input of labor, while Φ is a fixed cost.

γ^t represents the labor growth rate and ε_t^a represents the shock of the productivity factor and is defined as:

$\ln \varepsilon_t^a = (1-\rho_z)\ln \varepsilon^a + \rho_a \ln \varepsilon_{t-1}^a + \eta_t^a, \eta_t^a \approx N(0,\sigma_a)$.

The profit of any firm from the economy follows the following equation: $P_t(i)Y_t(i)$- $W_t L_t(i) - R_t^k K_t^s(i)$, W_t represents nominal wage or salary rate and R_t^k represents the capital rental rate.

The model assumes that firms are able to adjust prices used with probability 1-ξ_p in each period.

The resulting price that is optimal is obtained from the following maximization function:

$$\text{Max } E_t \sum_{s=0}^{\infty} \xi_p^s \frac{\beta^s \Xi_{t+s} P_t}{\Xi_t P_{t+s}} [\ P_t^{\approx}(i)\,(\prod_{l=1}^{s} \pi_{t+l-1}^{l_p} \pi_*^{1-l_p}) - MC_{t+s}]Y_{t+s}(i)$$

$$P_t^{\approx}(i)$$

$$\text{s.t.}\ Y_{t+s}(i) = Y_{t+s} G'^{-1}(\frac{P_t(i) X_{t,s}}{P_{t+s}} \tau_{t+s}) .$$

ξ_p^s represents firms probability of price adjustment, π_t is inflation defined as π_t = $P_t / P_{t-1},$ $\frac{\beta^s \Xi_{t+s} P_t}{\Xi_t P_{t+s}}$ is the discount factor for firms,

$\tau_t = \int_0^1 G'(\frac{Y_t(i)}{Y_t}) \frac{Y_t(i)}{Y_t} di$ and

Theindex of prices obtained has the following equation form:

$$P_t = (1-\zeta_p) P_t(i) G'^{-1}[\frac{P_t(i)\tau_t}{P_t}] + \zeta_p \pi_{t-1}^{l_p} \pi_*^{1-l_p} P_{t-1} G'^{-1}[\frac{\pi_{t-1}^{l_p} \pi_*^{1-l_p} P_{t-1} \tau_t}{P_t}].$$

2.3. Households

Households in order to maximize utility function are able to choose final consumption$C_t(j)$, the number of working hours $L_t(j)$, acquisition of bonds $B_t(j)$

capital investment $I_t(j)$ and capital utilization $Z_t(j)$. The utility function is as follows: $E_t\sum_{s=0}^{\infty}\beta^s[\frac{1}{1-\sigma_c}(C_{t+s}(j)-\lambda C_{t+s-1})^{1-\sigma_c}]\exp(\frac{\sigma_c-1}{1+\sigma_l}L_{t+s}(j)^{1+\sigma_l})$, related to the following equation of the budget:

$$C_{t+s}(j)+I_{t+s}(j)+\frac{B_{t+s}(j)}{\varepsilon_t^b R_{t+s}P_{t+s}}-T_{t+s}$$
$$\leq\frac{B_{t+s-1}(j)}{P_{t+s}}+\frac{W_{t+s}^h(j)L_{t+s}(j)}{P_{t+s}}+\frac{R_{t+s}^k Z_{t+s}(j)K_{t+s-1}(j)}{P_{t+s}}-a(Z_{t+s}(j))K_{t+s-1}(j)+\frac{Div_{t+s}}{P_{t+s}}$$

Capital at moment "t" has the following form: $K_t(j)=(1-\delta)_{t-1}(j)+\varepsilon_t^i[1-S(\frac{I_t(j)}{I_{t-1}(j)})]I_t(j)$,

ε_t^b represents the stochastic premiumresulted frominvestment in bonds, ε_t^b follows the stochastic process: $\ln\varepsilon_t^b=\rho_b\ln\varepsilon_{t-1}^b+\eta_t^b,\eta_t^b\approx N(0,\sigma_b)$,

where, δ has the significance ofrate of depreciation, S(.) is a function for quantifying the cost adjusting, with S(γ)=0, S'(γ)=0, S''(.)>0. ε_t^i illustrates the shock of investment component and is described by the equation: $\ln\varepsilon_t^i=\rho_i\ln\varepsilon_{t-1}^i+\eta_t^i,\eta_t^i\approx N(0,\sigma_i)$. T_{t+s} represents taxes, while Div_t represents the dividends for distribution.

2.4. Intermediate labor and labor packers

Households provide their labor forthe intermediate labor union, the labor provided having the following form: $L_t=[\int_0^1 L_t(l)^{\frac{1}{1+\lambda_{w,t}}}dl]^{1+\lambda_{w,t}}$. (16)

Labor packers are those who acquire labor from unions and distribute the labor to producers of intermediary goods. Their maximization profit function has the following form:

Max $W_tL_t-\int_0^1 W_t(i)L_t(i)di$, s.t.$[\int_0^1 H(\frac{L_t(i)}{L_t};\varepsilon_t^w)di]=1$ ($\mu_{l,t}$)

$L_t, L_t(i)$,where W_t and $W_t(i)$ represent the price of total and for intermediary labor services , while H is a function strictly concave , which follows H(1)=1 and is increasing.

ε_t^w is an exogenous shocks of wages mark-up, $\varepsilon_t^w \in (0,\infty)$ and has the form of an ARMA process: $\ln\varepsilon_t^w = (1-\rho_w)\ln\varepsilon^w + \rho_w \ln\varepsilon_{t-1}^w - \theta_w\eta_t^w, \eta_t^w \sim N(0,\sigma_w)$.

From the first order conditions of the labor packers, we obtain:

$$L_t(l) = \left(\frac{W_t(l)}{W_t}\right)^{-\frac{1+\lambda_{w,t}}{\lambda_{w,t}}} L_t \,.$$

Combining this condition with the zero profit condition we obtain an expression for the wage cost for the intermediate goods producers:

$W_t = \left[\int_0^1 W_t(l)^{\frac{1}{\lambda_{w,t}}} dl\right]^{\lambda_{w,t}}$, where $\lambda_{w,t}$ is defined as an ARMA process:

$$\ln\lambda_{w,t} = (1-\rho_w)\ln\lambda_w + \rho_w \ln\lambda_{w,t-1} - \theta_w\varepsilon_{w,t-1} + \varepsilon_{t,w}, \varepsilon_{t,w} \sim N(0,\sigma_w)\,.$$

The dividends that are received by households from labor unions are included in the constraint of budget for households:

$$C_{t+s}(j) + I_{t+s}(j) + \frac{B_{t+s}(j)}{b_t^2 R_{t+s} P_{t+s}} + A_{t+s}(j) - T_{t+s} \le \frac{B_{t+s-1}(j)}{P_{t+s}} + \frac{W_{t+s}^h(j) L_{t+s}(j)}{P_{t+s}} + \frac{Div_{t+s}}{P_{t+s}} + \frac{R_{t+s}^k u_{t+s}(j)\bar{K}_{t+s-1}(j)}{P_{t+s}} - a(\mu_{t+s}(j))\bar{K}_{t+s-1}(j)$$

In case of unions there are also nominal rigidities as proposed by Calvo (1983), more precisely wages being adjusted with the probability of 1-ζ_w.

In case of unions who readjust wages, the optimization rule consists of choosing a wage $\breve{W}_t(l)$ in order to maximize subsequent wage income in case when unions keep this fixed wage.

The expression of aggregate wageobtained is:

$$W_t = [(1-\zeta_w)\tilde{W}_t^{\frac{1}{\lambda_{w,t}}} + \zeta_w(\gamma\pi_{t-1}^{l_w}\pi_*^{1-l_w}W_{t-1})^{\frac{1}{\lambda_{w,t}}}]^{\lambda_{w,t}}\,.$$

2.5. Monetary policy and government budget constraint

The interest rate established by central bank by taking into account the deviation of output and inflation from the targeted levels is as follows:

$$\frac{R_t}{R^*} = \left(\frac{R_{t-1}}{R^*}\right)^{\rho_R}\left[\left(\frac{\pi_t}{\pi_*}\right)^{\psi_1}\left(\frac{Y_t}{Y_t^*}\right)^{\psi_2}\right]^{1-\rho_R}\left(\frac{Y_t/Y_{t-1}}{Y_t^*/Y_{t-1}^*}\right)^{\psi_3} r_t\,.$$

R^* is the value of nominal interest rate at steady-state and Y_t^* is the natural gross domestic product.

The parameter ρ_R represents the interest ratesmoothness, while the definition of the shock of monetary policy, r_t , is: $\ln r_t = \rho_r \ln r_{t-1} + \varepsilon_{r,t}$.

The constraint of government budget is described as follow : $P_t G_t + B_{t-1} = T_t + \frac{B_t}{R_t}$.

T_t represents the nominal lump-sum taxes and the government spending in relation with the steady-state output $g_t = G_t /(Y\gamma^t)$ follows the process:

$\ln g_t = (1-\rho_g)\ln g_t + \rho_g \ln g_{t-1} + \rho_{ga} \ln Z_{t-1} + \varepsilon_{g,t}, \varepsilon_{g,t} \sim N(0,\sigma_g)$.

3. The Linearized Model

The aggregate constraint for the linearized model is described as follows: (1) $y_t = c_y c_t + i_y i_t + z_y z_t + \varepsilon_t^g$,

The interpretation of the resource constraint is that gross domestic product (y_t) is absorbed by investment (i_t), consumption (c_t), capital utilization costs (expressed in relation to the capital utilization rate (z_t) and the exogenous spending shock (ε_t^g)). In addition, c_y is the state-state share of consumption in output and is equal to $1 - g_y - i_y$, where g_y and i_y are the steady-state exogenous spending-output ratio and investment-output ratio.

In addition, $z_y = R_*^k k_y$, where R_*^k is the steady-state rental rate of capital and k_y is the steady-state capital-output ratio.

The dynamics of consumption function is described as follows:

(2) $c_t = c_1 c_{t-1} + (1-c_1) E_t c_{t+1} + c_2 (l_t - E_t l_{t+1}) - c_3 (r_t - E_t \pi_{t+1} + \varepsilon_t^b)$, where $c_1 = \frac{\lambda/\gamma}{1+\lambda/\gamma}$,

$c_2 = \frac{(\sigma_c - 1)(W_*^h L_* / C_*)}{\sigma_c (1+\lambda/\gamma)}$ and $c_3 = \frac{1-\lambda/\gamma}{(1+\lambda/\gamma)\sigma_c}$.

Consumption (c_t) is defined in a direct relation with the past and expected consumption, with workinghours expected increase $(l_t - E_t l_{t+1})$, with ex-ante real interest-rate ($r_t - E_t \pi_{t+1}$) and theshock factor- ε_t^b .

The investment dynamic is described by the function below:

(3) $i_t = i_1 i_{t-1} + (1-i_1)E_t i_{t+1} + i_2 q_t + \varepsilon_t^i$,where $i_1 = \dfrac{1}{1+\beta\gamma^{(1-\sigma_c)}}$,

$i_2 = \dfrac{1}{(1+\beta\gamma^{(1-\sigma_c)})\gamma^2\varphi}$, φ represents represent the steady state elasticity of the cost function for capital adjustment, while β represents the factor of discount.

The corresponding arbitrage equation for the capital is given by:

(4): $q_t = q_1 E_t q_{t+1} + (1-q_1)E_t r_{t+1}^k - (r_t - \pi_{t+1} + \varepsilon_t^b)$, in direct relation with expected value and expectedcapital rental rate ($E_t r_{t+1}^k$) and inverse relation with therisk premium shock and ex-ante real interest rate.

$$q_1 = \beta\gamma^{-\sigma_c}(1-\delta) = \frac{1-\delta}{R_*^k + (1-\delta)}.$$

The production function is described by the following equation: (5) $y_t = \phi_p(\alpha k_t^s + (1-\alpha)l_t + \varepsilon_t^a)$.

The production of output by firms is based on two components: capital (k_t^s) and labor (l_t).

Current capital services used (k_t^s) depends onpreviously capital (k_{t-1}) and capital utilization rate (z_t): (6) $k_t^s = k_{t-1} + z_t$.

Theaccumulated capital (k_t) is depends on investment and its technology disturbance:

(8) $k_t = k_1 k_{t-1} + (1-k_1)i_t + k_2 \varepsilon_t^i$, where $k_1 = (1-\delta)/\gamma$ and $k_2 = (1-(1-\delta)/\gamma)(1+\beta\gamma^{(1-\sigma_c)})\gamma^2\varphi$.

In case of goods market, price mark-up, (μ_t^p), is defined by differentiating the marginal product of labor (mpl_t) and the real wage (w_t):

(9) $\mu_t^p = mpl_t - w_t = \alpha(k_t^s - l_t) + \varepsilon_t^a - w_t$

As firms that are price adjusters have the objective of profit maximization, this leads to the New-Keynesian Philips curve described below: (10) $\pi_t = \pi_1\pi_{t-1} + \pi_2 E_t\pi_{t+1} - \pi_3\mu_t^p + \varepsilon_t^p$, where $\pi_1 = \frac{l_p}{1+\beta\gamma^{1-\sigma_c} l_p}$, $\pi_2 = \frac{\beta\gamma^{1-\sigma_c}}{1+\beta\gamma^{1-\sigma_c} l_p}$ and $\pi_3 = \frac{1}{1+\beta\gamma^{1-\sigma_c} l_p}\frac{(1-\beta\gamma^{1-\sigma_c}\xi_p)(1-\xi_p)}{\xi_p((\phi_p - 1)\varepsilon_p + 1)}$.

Rental rate of capital is in an inverse relation with the ratio capital-labor and in a direct relation with the real wages: (11) $r_t^k = -(k_t - l_t) + w_t$.

In case oflabor market the wage mark-up is described by the difference between real salaries and marginal substitution rate working-consumption (mrs_t): (12) $\mu_t^w = w_t - mrs_t = w_t - (\sigma_l l_t + \frac{1}{1-\lambda}(c_t - \lambda c_{t-1}))$, where σ_l represents elasticity of labor supply in relation with real salaries and λ illustrates the habit in consumption of households.

In terms of real wages it is assumed that are adjusted progressive in order to reach the target level of wage mark-up, as follows:

(13) $w_t = w_1 w_{t-1} + (1-w_1)(E_t w_{t+1} + E_t\pi_{t+1}) - w_2\pi_t + w_3\pi_{t-1} - w_4\mu_t^w + \varepsilon_t^w$, where

$w_1 = \frac{1}{1+\beta\gamma^{1-\sigma_c}}$, $w_2 = \frac{1+\beta\gamma^{1-\sigma_c} l_w}{1+\beta\gamma^{1-\sigma_c}}$, $w_3 = \frac{l_w}{1+\beta\gamma^{1-\sigma_c}}$ and $w_4 = \frac{1}{1+\beta\gamma^{1-\sigma_c}}\frac{(1-\beta\gamma^{1-\sigma_c}\xi_w)(1-\xi_w)}{\xi_w((\phi_w - 1)\varepsilon_w + 1)}$.

The monetary policy equation is described as follows:

(14): $r_t = \rho r_{t-1} + (1-\rho)\{r_\pi \pi_t + r_Y(y_t - y_t^p)\} + r_{\Delta y}[(y_t - y_t^p) - (y_{t-1} - y_{t-1}^p)]]) + \varepsilon_t^r$.

The authorities responsible with the monetary describe a generalized Taylor rule and adjust the interest rate (r_t) based on information regarding inflation and output gap. The parameter ρ captures interest rate smoothing degree.

The linearized system is composed of 14 equations and 14 endogenous variables: y_t, i_t, q_t, c_t, i_t, k_t^s, k_t, z_t, r_t^k, μ_t^p, π_t, μ_t^w, w_t, l_t, r_t.

The stochastic behavior of the system of linear rational expectations equations is driven by seven exogenous disturbances which follow a first-order autoregressive dynamic: productivityfactor (ε_t^a), risk premium (ε_t^b), investment technology (ε_t^i) ,wage mark-up (ε_t^w), price mark-up(ε_t^p), exogenous spending (ε_t^g) and monetary policy (ε_t^r).

4. Solution and Analysis of the Model

4.1. Econometric Estimation Methodology

In the current research I have proposed to analyze the way in which the proposed DSGE model responses to the economic matters of the three analyzed countries: Poland, Hungary and Czech Republic.

I have chosen to estimate the DSGE model through a Bayesian approach, using Matlab and Dynare tool as this approach is able to give estimates based on the a-priori distributions assumed of the parameters and the information brought by the seven observed variables (extracted with the Kalman filter maximization of the likelihood function), in line with F.Canova, 2007, pp. 26-45, inthe article *"Methods for Applied Macroeconomic Research"*, and Johannes Pfeifer, 2014, pp. 1-150 in the article*A Guide to Specifying Observation Equations for the Estimation of DSGE Models*.

Moreover, using the Bayesian approach I was able to include in the estimation the seven shocks of the model (each one for each observed variable) and to estimate their standard deviation.

I have used for the estimation of the model 350,000 Metropolis-Hastings draws, with a scale of 0.3, in case of each of the three countries, in line with Geweke, J. (1998), *"Using simulation methods for Bayesian econometric models: inference, development and communication"*, pp. 1-75 and with Kimball, M. (1995), *"The quantitative analytics of the basic neo-monetarist model"*, pp. 1241-1277.

4.2. Calibration and prior distribution of the parameters and parameter estimates

One important step of estimation of a DSGE model consists of calibration of the model's parameters.

Regarding the choice of the prior distribution, a number of parameters were kept fixed from the start of the exercise.

The standard errors of shocks are defined as inverse-gamma distributions, having the characteristics described in the table below.

Table 1. Parameters calibrated -shock factors

Symbol	Description	Value
ρ_a	the t-1 term coeficient, in the AR process ε_t^a	0.968
ρ_b	the t-1 term coefficient of the AR process ε_t^b	0.27
ρ_g	the t-1 term coefficient of the AR process ε_t^g	0.9928
ρ_i	the t-1 term coefficient of the AR process ε_t^i	0.7165
ρ_R	the t-1 term coefficient of the AR process ε_t^r	0
ρ_p	the t-1 term coefficient of the process ε_t^p	0
ρ_w	the t-1 term coefficient of the process ε_t^w	0
μ_t^p	the coefficient of the η_t^p IID-Normal price mark-up shock (error term)	0
μ_w	the coefficient of the η_{t-1}^w IID-Normal wage mark-up shock (error term)	0
ε_t^p	price mark-up disturbance	10
ε_t^w	wage-markup disturbance	10

Other parameters, such as the discount factor, β, is calibrated to be 0.9994, which is the mean of the sample of the quarterly real interest rate, while the exogenous spending-GDP ratio is set at 18%. The demand elasticity for labor, λ_w, is equal with 1.5, the degree of wage stickiness, ξ_w, is 0.7937, the degree of price stickiness, ξ_p, is 0.75, which is in accordance with the assumptions with the calibrations proposed by the author Mihai Copaciu (2012), in the article "*Estimation of an open economy DSGE model with financial and employment frictions for Romania".*

Table 2. Parameters calibrated

Symbol	Description	Value
α	share of capital in production	0.4
β	is the discount factor applied by households.	0.999
σ_c	elasticity of intertemporal substitution between consumption and leisure	1.5
ϕ_p	reflects the presence of fixed costs in production (one plus the share of fixed costs in production)	1.5
ρ_{ga}	the degree in which the productivity shock impacts the exogenous spending	0.51
φ	the steady-state elasticity of the capital adjustment cost function	6.014
λ	the habit parameter in consumption (external consumption habit)	0.636
ξ_w	the degree of wages stickiness	0.794
σ_l	the elasticity of labour supply with respect to the real wage	1.942
ξ_p	the degree of price stickiness	0.75
l_w	wages indexation to past inflation indicator	0.324
l_p	the degree of price indexation to past inflation	0.329
z_t	the degree of capital utilization	0.27
δ	depreciation rate of capital	0.0246
λ_w	demand elasticity for labor	1.5
g_y	steady-state exogenous spending-output ratio	0.18

Finally, parameters used for the quantification of monetary policy rule follow a standard Taylor rule and are calibrated as described in the table below:

Table 3. Parameters calibrated-Taylor rule

Symbol	**Description**	**Value**
r_π	the coeficient of inflation in the interest rate Taylor rule	1.488
ρ	the degree of interest rate smoothing	0.826
r_Y	the coeficient of the output-gap in the interest rate Taylor rule	0.059
$r_{\Delta y}$	the coeficient of the output gap variation (t, t-1)	0.224

I have also analyzed the posterior distribution of parameters and standard deviation of shocks, before and after the optimization using Metropolis-Hastings algorithm. The results of the posterior distribution of the parameters obtained through the Metropolis- Hastings sampling algorithm was based on 350,000 draws and 2 Markov Chains.

4.3. Data Set

The dataset used in this paper were collected from Eurostat Database, Federal Reserve Economic Data -FRED –St. Louis Fed and European Central Bank-ECB, National Bank of Czech Republic, Hungary and Poland for the period: 2001q1 and 2015q4, for a quarterly frequency.

The seven observed quarterly macroeconomic variables are the following: real GDP, consumption, investment and wages, hours worked, GDP deflator and short-term nominal interest rate.

The GDP, investment (gross fixed capital formation-namq_gdp_c) and consumption series (final consumption expenditure in current prices (namq_fcs_c) were collected from Eurostat site, being expressed in Eur millions, in current prices. Regarding the real wages, I have collected from Eurostat the quarterly wages series ([namq_nace10_c]), representing the gross wages and salaries in Eur millions. All these four variables: investment, consumption, wages and gross domestic product are deflated by gross domestic product deflator for the use of real variables and expressed per capita, being divided by the number of employees (16 years to 64 years, part-time and full-time employment-Eurostat series: [lfsq_epgais]).

All the real variables (real gross domestic product, investment, consumption andsalaries) have been expressed in 100 times log, in order to get an evidence of the real growth rates.

In terms of monetary policy, given the high volatility of ON interest rate, I have collected the daily rates for PRIBOR 3M, BUBOR 3M and, WIBOR 3M, from 2001q1 and I have computed an average interest rate for each quarter during 2001 q1 to 2015 q4.

The series used in Dynare soft for the observable variables were: the log difference of real GDP, the log difference of real consumption, the log difference of real investment, the log difference of real wages, the log of the index of hours worked, the log difference of GDP deflator and the quarterly interest rate.

Once all the observed variables are seasonally adjusted and tested for stationarity in Eviews 7, imported in Matlab for a further processing with Dynare 4.4.0 tool.

5. Econometric Analysis of the Model

5.1. Interpretation of Apriori and Aposteriori Distribution Graphs

For each parameter the graphs illustrates the prior and the posterior distribution in one figure (the grey line representing the prior, the black line the posterior). The distributions are different from each other, so the parameters are identified.

The dotted green line represents the value at the posterior mode, which in case of all parameters is approximately the center of the posterior distribution.

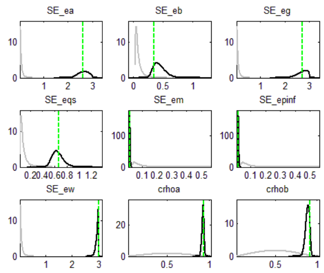
The posterior distribution is also distributed around the mode. Moreover, in almost all cases the posterior distribution has the form of a normal distribution and is close, but still different from the a-priori distributions.

This means that the observable variables bring new information than the assumptions made regarding the a-priori distribution.

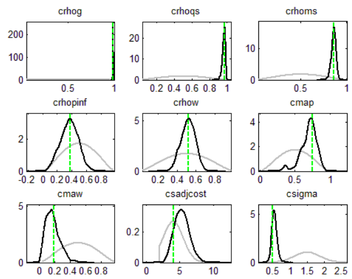
Each graph contains the a-priori assumptions that were made regarding each parameter's mean and, respectively, the a-posteriori results with the mode estimated by numerical methods, posterior approximations of the standard deviations, all obtained after the maximization algorithm, the posterior mean obtained from MH algorithm for the 350,000 draws on the 2 chain that I chose.

Overall, according with the a-priori and a-posteriori distribution graphs and t-statistics, all estimated parameters are significantly different from zero. This is true for all the standard errors of all the shocks.

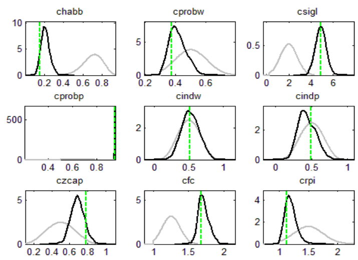
Poland



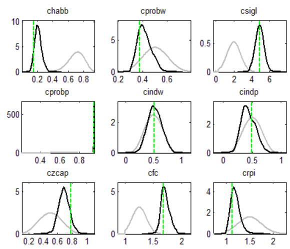
Graph 9. A-priori and a-posteriori distribution



Graph 10. A-priori and a-posteriori distribution

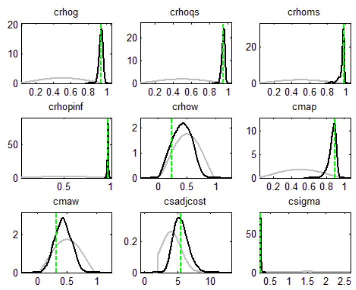


Graph 1. A-priori and a-posteriori distribution

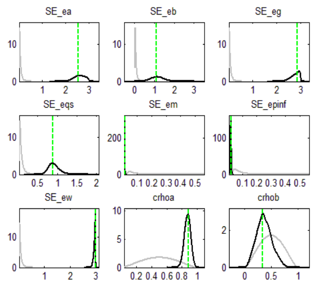


Graph 2. A-priori and a-posteriori distribution

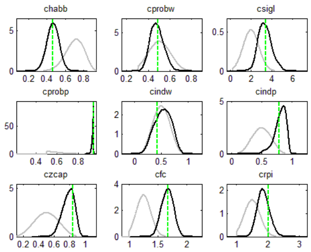
Hungary



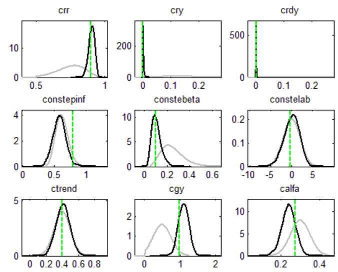
Graph 3. A-priori and a-posteriori distribution



Graph 4. A-priori and a-posteriori distribution



Graph 5. A-priori and a-posteriori distribution



Graph 6. A-priori and a-posteriori distribution

The tables described above contains in the first part the a-priori assumptions for the mean of each parameter and in the second part the a-posteriori results, estimated by numerical methods, the posteriori estimation of the standard deviation (obtained after the maximization algorithm), the posterior mean, the 10% and 90% percentiles (confidence intervals) obtained from the MH algorithm, for the 350,000 draws on the 2 chains that I have chosen.

5.2. The Model's Stability Analysis –Blanchard-Kahn Condition

The system is stable according with the analysis of the eigenvalues of the system.

In order to meet the Blanchard-Kahn condition, there must be as many roots larger than one in modulus as there are forward-looking variables in the model.

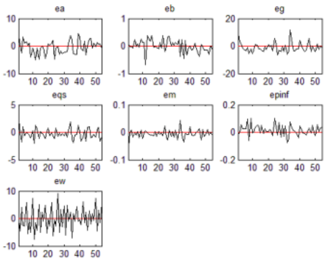
According with the output of Matlab, in the model there are 12 eigenvalue(s) larger than 1 in modulus for 12 forward-looking variable(s), which means that the Blanchard-Kahn condition is met. The rank condition is also verified.

5.3. Analysis of Smoothed Variables and Shocks

The posterior distribution of smoothed endogenous variables and shocks, i.e. infers about the unobserved state variables using all available information up to T: $x_{t/T} = E[x_t / I_T]$.

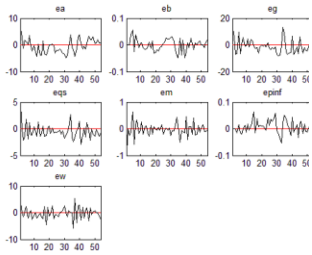
Using the smoothed shocks as a check for the model, the shock realizations are around zero (being white noises).

Hungary



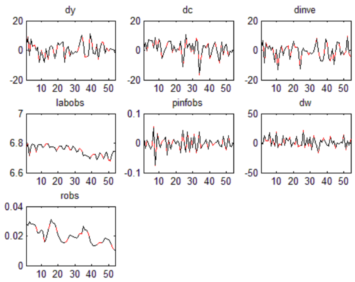
Graph 7. Smoothed shocks

Poland



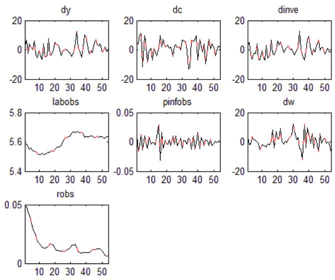
Graph 8-Smoothed shocks

Hungary



Graph 9. Smoothed Variables

Poland



Graph 10. Smoothed Variables

According with the estimates all the seven shocks are significant, taking into account the 90% HPD (highest probability density) confidence interval, that indicates the fact that with a 90% probability, the parameter is in the calculated interval.

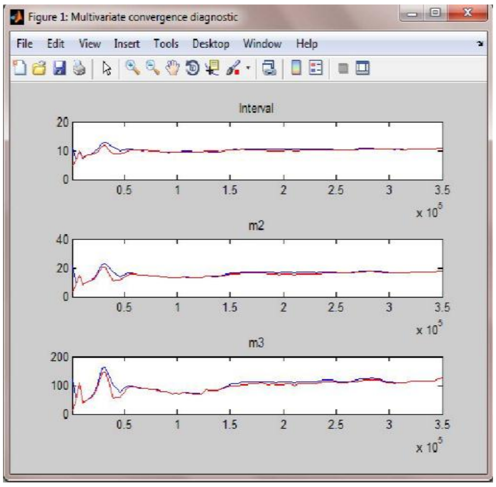
5.4. Brooks and Gelman's Markov Chain Monte Carlo (MCMC) Convergence

As resulted from the convergence graphs analysis for 2 Monte Carlo Chains, from the three economies analyzed, I concluded that in case of Czech Republic the convergence condition of the series is not respected, taking into consideration a number of 350,000 MCMC draws. The acceptance ratios of the MCMC are lower than the acceptance limit of 25% (chain 1: 9.452% and chain 2: 8.3891%). As a result, analysis of the steady-state does not lead to accurate result (the reason why this country was excluded from the further analysis).

The current acceptance ratio per chain were the following, at the level of each country: for Romania- chain 1: 26.5536% and chain 2: 23.9725%, for Poland-chain

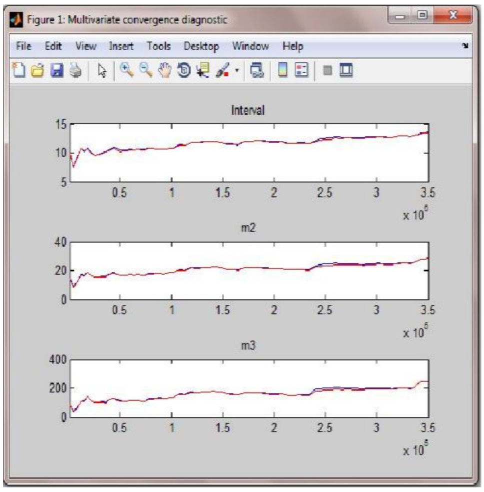
1:21.1708% and chain 2:24.6608% and for Hungary-chain 1:36.2359% and chain 2:37.0039%.

Poland



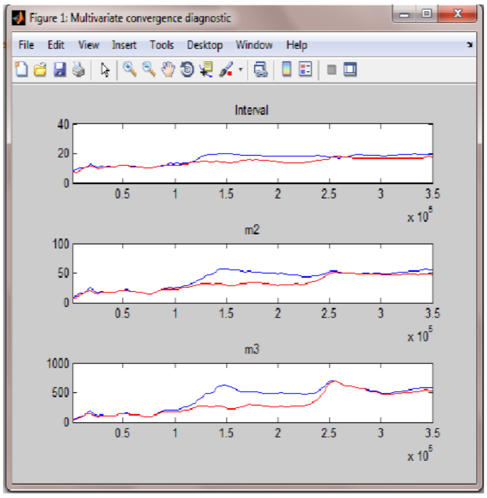
Graph 11

Hungary



Graph 12

Czech Republic



6. Conclusion

The proposal of this working paper is to analyze whether the model proposed for the economy of United Statesby Frank Smets and RafaelWouters in 2002, pp. 1-70 and 2003, pp. 1-57 and also in articles for the economy of Euro Area published in 2005, pp. 1-52 and pp. 2-36, and in 2003, pp. 1123-1175 and pp. 1-57 is suitable for the economies from Central and Eastern Europe.

Taking into consideration the tests performed I conclude through the current working paper that the results of the model are effective for the economy of Poland and Hungary. This is confirmed also by the analysis of the estimations performed: convergence analysis, Blanchard-Kahn stability of the model, the analysis of the a-priori and a-posteriori distributions and also by the analysis of parameters and variables identification. For the three economies analyzed, I concluded that in case of Czech Republic the convergence condition of the series is not respected, taking into consideration a number of 350,000 draws. As a result, analysis of the model for this country is not accurate, so it was excluded from the further analysis.

To conclude, the model has achieved the purpose of analyzing of the main drivers of the economic growth, putting an eye on the frictions of these three economies (seven shocks- reduced to the number of the seven observed variables).

The model can be analyzed also taking into account the policy shocks: exogenous spending shock (that includes government spending-fiscal policy instrument), price and interest rate shocks (monetary policy shocks).

Regarding the monetary policy, I can conclude that the Taylor rule proposed by the model approximates the behavior of the Central banks of the two Central and Eastern Europe countries: Poland and Hungary.

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