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IMPULSE-RESPONSE FUNCTION ANALYSIS AND FORECASTS WITH A DYNAMIC STOCHASTIC GENERAL EQUILIBRIUM MODEL

Abstract. *The present paper is dedicated to the analysis of the Romanian economy from a double perspective: on one hand, our intention is to capture the reaction of the model variables to the structural shocks considered, so as to be able to take all necessary steps in order to accelerate their return to the initial equilibrium state and, on the other hand, to make long-run forecasts, the final objective being related to the proposal of macroeconomic policies generating sustainable economic growth. The study results reveal the fact that all variables, analysed quarterly, for a 12-year period, emerging from a dynamic stochastic general equilibrium model previously developed and briefly rendered herein, begin their way back to equilibrium, subsequent to the impact of the structural shocks, in about 20 periods, therefore standing for the model stability. At the same time, the anticipation of the economic evolution, based on the model outcomes, make us propose both expansionary fiscal-budgetary and monetary policies able to contribute to a grounded future economic development.*

Keywords: *dynamic stochastic general equilibrium model, impulse-response functions, forecasts, economic growth, macroeconomic policies.*

JEL Classification: C22, C53, C61, D12, D22, D58, E12, E17, E27

1. Introduction

By this paper, entitled *Impulse-Response Function Analysis and Forecasts with a Dynamic Stochastic General Equilibrium Model*, we undertake to outline, empirically, the effects generated, at various levels, by the shocks occurred all along the analysed period, capturing at the same time the evolution of the Romanian economy in the long run and intuiting the measures to be taken so as to provide a healthy economic development.

The study is based on a Dynamic Stochastic General Equilibrium (DSGE), model having its roots in the new Keynesian theory, approached in the vision of Adolfson, Laséen, Lindé and Villani (2005), on the premises established by Christiano, Eichenbaum and Evans (2005) and Altig, Christiano Eichenbaum and Lindé (2005),

but enriched with elements specific to open economies, however adjusted, from a multiple perspective, in the manner of Almeida (2009). This modelling process starts with the construction the basic economic blocks, as elements of the modular structure, namely: households, firms, more exactly the firm producing intermediate goods, the firm producing final goods, the firm creating composite goods and the importing firm, the Government, as fiscal and budgetary organism, and the foreign sector and continues with the rendering of markets at equilibrium: the input market, the intermediate good market, the final good market and the foreign bond market. The functions of the economic agents in relation to the main influence factors are also revealed, this being subsequently followed by the specific optimisations, more precisely, the maximisation of the utility of households and of the profit of firms, from a dynamic and stochastic perspective. This phase ends by the log-linearisation of the model equations, by Taylor series expansion around the steady state, issues which, due to the lack of space, are not provided in the present paper.

The model, developed during a previous research stage and generally presented in this paper, starts from the idea of both price and wage stickiness, resorting in this respect to a specific approach in the manner of Calvo (1983).

The data relating to the model variables are taken over both from domestic sources, such as the National Institute of Statistics and the National Bank of Romania, and from databases of international bodies, like Eurostat, the International Monetary Fund and the statistics of the National Bank of France, considering the foreign variables used as result of the introduction in the model of the foreign trade.

Herein are also specified the initial transformations to which certain deseasonalised data are subject, namely their put into logarithm and their differentiation, but also the use of the Hodrick Prescott filter in order to extract the common trend and to create in this way new data series, became representative for the steady state.

The implementation of the model involved the development of a specific code, within the software package Dynare 4.3.0 of Matlab 7.11.0 (R2010b), being generated, beside the estimation, based on the Bayesian analysis, of the a-posteriori probabilities, having made the object of a previous paper, also the impulse-response functions, rendered in order to capture the impact of various shocks on the model variables, as well as the long-run forecasts, favouring the identification of the main directions in order to provide a sustainable economic growth.

2. Literature Review

The class of dynamic stochastic general equilibrium models, having mainly emerged from the papers of Kydland & Prescott (1982), subsequently developed by Rotemberg & Woodford (1997), Clarida et al. (2000), Christiano et al. (2005) and so on, has been largely disputed lately, as, while a significant number of economic

specialists are increasingly interested in dealing with them, there are others contesting their capacity of accurately estimating and forecasting the economic evolution of a nation, based on their failure to anticipate the nowadays world economic crisis.

Yet, the former prevailed, such last hour equilibrium models continuing to be used, to a large extent, either for pure estimation, as in the work of Smets & Wouters (2003), or for forecasting purposes, as in Christiano et al. (2005) or Adolfson et al. (2005). These models are meant to render the causes and effects of various aggregate economic phenomena, like economic growth or business cycles, or to reveal the impact of fiscal or monetary policies on real economic life.

Therefore, their estimation and forecasting power succeeded, despite the above mentioned controversy, in convincing both academic researchers and economists acting on behalf of several central banks of the world developed countries, in focussing on such models.

Ratto and Roeger (2009), for instance, provide a Bayesian based modelling of the Euro Zone economy. After the specific adaptation of the DSGE type model and the rendering of the estimations previous and subsequent to the analysis moment, the authors present the decomposition of the model variance and the impulse-response functions of the macroeconomic variables to the structural shocks. The model outlines the real and nominal frictions, as well as the financial frictions, under the form of the liquidity constraints of households. The rules of the monetary and fiscal policies regarding the governmental consumption, investments, transfers and taxes on wages are used in order to reveal the efficacy of the stabilisation policies. The estimation of a Keynesian model is also encountered in the paper of Leu şi Sheen (2011), focussing their attention on the Australian economy. By resorting to a small macroeconomic model and by applying various econometric methods: maximum likelihood type estimation, Kalman filters etc., the authors analyse the potential GDP and its growth rate, NAIRU, the real interest rate and the subjective discount factor, making forecasts on short term. The simulation of scenarios from the crisis perspective seems quite interesting; by combining the estimated model with a monetary policy rule, they examine the impulse-response functions of inflation and output to the shocks associated with the current world crisis. Stahler şi Thomas (2012), representatives of the Bank of Germany, respectively Spain, developed, in collaboration, a medium-scaled DSGE model, where the fiscal policies are simulated, considering a structure of the monetary union made exclusively of the two important countries of the Euro Zone. They analyse a series of fiscal consolidation scenarios at the level of the Spanish economy, allowing for the exceeding of the economic crisis, the most efficient measures proving to be the ones relating to the diminishing of the budgetary wage-

related expenses, the cutting of the resources allotted to the public investments generating serious economic damages both in the short and in the long run.

On the other hand, we could also mention the models developed for various central banks, such as the ones constructed by Harrison et al. (2005), for the Bank of England, Adolfson et al. (2005), for the Bank of Sweden, Kilponen & Ripatti (2006), for the Bank of Finland, Murchison & Rennison (2006), for the Bank of Canada or Andrés et al. (2006), for the Bank of Spain, these ones being just several examples in this direction.

3. Model and Data

3.1. Model

The model on which this paper is based, emerging from the new Keynesian thinking, is approached in the vision of Adofson et al. (2005), on the fundamentals established by Christiano et al. (2005), but adjusted in the manner of Almeida (2009) mainly as for the grouping of the companies acting on the Romanian territory and for the markets analysed at equilibrium[1].

The model starts by rendering the basic economic blocks, elements of the modular structure, that is: households, firms, divided into the intermediate domestic good firm, the final good firm, the composite good firm and the import good firm, the Government, a fiscal-budgetary organism, and the foreign sector, and goes on with the presentation at equilibrium of the analysed markets: the input market, the intermediate good market, the final good market and the foreign bond market.

***Households*.**

The households maximise their inter-temporal utility considering the level of consumption and spare time:

$$\mathrm{E}_0 \sum_{t=0}^{\infty} \beta^t \times \left[\zeta_t^c \times \ln\left(C_{j,t} - \theta \times C_{j,t-1}\right) - \zeta_t^h \times \frac{(H_{j,t})^{1+\sigma_L}}{1+\sigma_L} \right] \qquad (1)$$

where E_0 is the current value expected by household j, β^t, the subjective discount factor, ζ_t^c, the consumption preferences, $C_{j,t}$ the consumption of household j, θ, the consumption habit persistence, ζ_t^h, the labour time-related preferences, $H_{j,t}$, the quantity of labour provided by household j and σ_L the reverse of the labour elasticity in relation to its marginal disutility, subject to the budget constraint:

[1] The model is rendered in more detail in the paper entitled *The Behaviour of the Romanian Economy Seen from the Perspective of a Dynamic Stochastic General Equilibrium Model*, drawn up and presented by myself at the Workshop on Empirical Methods in Macroeconomic Policy Analysis (EMMPA2013), Bucharest, Romania, the present study being a development of the above-mentioned paper.

$$B_{j,t+1} + S_t \times B^*_{j,t+1} + P^c_t \times C_{j,t} \times \left(1+\tau^c_t\right) + P^i_t \times I_{j,t} = R_{t-1} \times B_{j,t} + \\ + R^*_{t-1} \times \Phi\left(\frac{A_{t-1}}{z_{t-1}}, \tilde{\phi}_{t-1}\right) \times S_t \times B^*_{j,t} + W_{j,t} \times H_{j,t} \times \left(1-\tau^y_t\right) + R^k_t \times \overline{K}_{j,t} + D_{j,t} + Tr_t + Div_t \quad (2)$$

where $B_{j,t}$ represents the zero-coupon domestic bonds held by household j, $B^*_{j,t}$, the zero-coupon foreign bonds held by household j, S_t is the nominal exchange rate, P^c_t, the consumption price index, τ^c_t, the value added tax, P^i_t, the investment price index, R_t, the domestic gross interest rate (determined as $1+ r_t$), r_t, the domestic net interest rate, R^*_t, the foreign gross interest rate, (determined as $1+ r^*_t$), r^*_t, the foreign net interest rate, $\Phi(\bullet)$, the foreign bond risk premium, A_t, the foreign assets net position, $\tilde{\phi}_t$, the time-varying risk premium shock, $W_{j,t}$, the nominal wage of household j, τ^y_t, the income tax, R^k_t, the capital rental rate, $\bar{K}_{j,t}$, the physical capital of household j, $D_{j,t}$, the income from state contingent securities held by household j, Tr_t, the governmental transfers, Div_t, the dividends of households, this equation rendering in fact the equality between the resources being at the disposal of households and used by the latter and the sources of such resources,

and given the equation of the capital stock accumulation, which depends on the capital depreciation level and on the function turning investments into physical capital:

$$\overline{K}_{t+1} = (1-\delta) \times \overline{K}_t + \chi_t \times F(I_t, I_{t-1}) \quad (3)$$

where δ represents the physical capital depreciation rate, χ_t, the investment shock and $F(\bullet)$, the function mentioned above, this one being rendered by the equation:

$$F(I_t, I_{t-1}) = \left(1 - S\left(\frac{I_t}{I_{t-1}}\right)\right) \times I_t \quad (4)$$

where $S(\bullet)$ is the function of the investment adjustment cost

The next step is related to the first order conditions as for consumption, domestic and foreign bonds held at time t and kept for time $t+1$, capital and investments, being rendered below:

- First order condition relating to $C_{j,t}$:

$$\beta^t \times \left(\frac{\zeta^c_t}{C_{j,t} - \theta \times C_{j,t-1}} - \psi_{z,t}\right) - \theta \times \mathrm{E}_t\left[\beta^{t+1} \times \frac{\zeta^c_{t+1}}{C_{j,t+1} - \theta \times C_{j,t}}\right] = 0 \quad (5)$$

- First order condition relating to $B_{j,t+1}$:

$$-\psi_{z,t} + \beta^t \times \frac{1}{P_t} + R_t \times \mathrm{E}_t\left[\beta^{t+1} \times \psi_{z,t+1} \times \frac{1}{P_{t+1}}\right] = 0 \quad (6)$$

where $\eth_t$ represents the Lagrange multiplier associated with the budget constraint (the marginal utility of an additional unit of resources destined for consumption, bond acquisition or investments), and ω_t, the Lagrange multiplier associated with the capital stock accumulation equation (the marginal utility of an additional unit of resources destined for obtaining physical capital).

The model nominal variables are turned into real variables by dividing them to the consumption price index and are rendered stationary by relating the same to the technological trend z_t. Therefore, the Lagrange multiplier associated with the budget constraint becomes:

$$\psi_{z,t} = z_t \times \psi_t = \vartheta_t \times P_t \times z_t \tag{7}$$

Equation (6) gives us the consumption Euler equation, given the equality between the Lagrange multiplier associated with the budget constraint and the consumption lifetime marginal utility:

$$\frac{1}{U_{j,t}^{c,life}} \times \mathrm{E}_t\left[U_{j,t+1}^{c,life}\right] = \frac{1}{\beta \times R_t} \times \mathrm{E}_t\left[\pi_{t+1}\right] \tag{8}$$

where π_t is the inflation rate.

- First order condition relating to $B^*_{j,t+1}$:

$$-\psi_{z,t} \times S_t \times \beta^t \times \frac{1}{P_t} + R_t^* \times \Phi\left(a_t, \tilde{\phi}_t\right) \times \mathrm{E}_t\left[\beta^{t+1} \times \psi_{z,t+1} \times S_{t+1} \times \frac{1}{P_{t+1}}\right] = 0 \tag{9}$$

- First order condition relating to $I_{j,t}$:

$$\begin{aligned} &\beta^t \times \left\{-\psi_{z,t} \times \frac{P_t^i}{P_t} + \omega_t \times \chi_t \times \left(-S'\left(\frac{I_t}{I_{t-1}}\right) \times \frac{1}{I_{t-1}} \times I_t + 1 - S\left(\frac{I_t}{I_{t-1}}\right)\right)\right\} + \\ &+ \mathrm{E}_t\left[\beta^{t+1} \times \omega_{t+1} \times \chi_{t+1} \times I_{t+1} \times S'\left(\frac{I_{t+1}}{I_{t1}}\right) \times \frac{1}{I_t^2} \times I_{t+1}\right] = 0 \end{aligned} \tag{10}$$

- First order condition relating to $\bar{K}_{j,t+1}$:

$$-\beta^t \times \omega_t + \mathrm{E}_t\left[\beta^{t+1} \times \left(\psi_{z,t+1} \times r_{t+1}^k + \omega_{t+1} \times (1-\delta)\right)\right] = 0 \tag{11}$$

Firms.

The firms are divided into two main categories: intermediate good firms, producing either differentiated goods or homogenous goods, and final good firms, acquiring intermediate goods and transforming them into end products, directed to domestic households, domestic Government or export.

The intermediate good firms are then divided into: the domestic good firm, combining differentiated inputs in order to create a differentiated good, acting on the

national market; the import good firm, transforming the homogenous goods acquired from the foreign market into differentiated import goods, destined to the domestic market; and the composite good firm, acquiring both domestic and import homogenous goods and making, by their combination, homogenous composite goods directed towards the firms producing end goods.

The model also considers the existence of several aggregation firms transforming the differentiated goods of the domestic good and import good firm into homogenous products used thereafter by the composite good firm, on one hand, and the ones turning the differentiated products supplied by the final good firm into a homogenous good, which are subsequently sold to the final users.

The Cobb-Douglas type production function of the representative domestic intermediate good firm *i* is:

$$Y_{i,t} = z_t^{1-\alpha} \times \Omega_t \times K_{i,t}^{\alpha} \times H_{i,t}^{1-\alpha} - z_t \times \phi \tag{12}$$

where $Y_{i,t}$ represents the domestic intermediate production obtained by firm *i*, α, the production elasticity in relation to the capital factor, *1-* α, the production elasticity in relation to the labour factor, Ω_t, the technological shock relating to the domestic production, $K_{i,t}$, the capital used by firm *i*, $H_{i,t}$, the labour used by firm *i*, ϕ, the fixed cost level of the domestic intermediate good firm.

The domestic intermediate firm intends to minimise its costs, this resulting in the following first order conditions:

- First order condition relating $H_{i,t}$:

$$W_t - (1-\alpha) \times \varsigma_t \times P_{i,t} \times z_t^{1-\alpha} \times \Omega_t \times K_{i,t}^{\alpha} \times H_{i,t}^{-\alpha} = 0 \tag{13}$$

- First order condition relating to $K_{i,t}$:

$$R_t^k - \alpha \times \varsigma_t \times P_{i,t} \times z_t^{1-\alpha} \times \Omega_t \times K_{i,t}^{\alpha-1} \times H_{i,t}^{1-\alpha} = 0 \tag{14}$$

By combining equation (13) and (14), we obtain the capital-labour relation:

$$\frac{K_{i,t}}{H_{i,t}} = \frac{\alpha}{1-\alpha} \times \frac{W_t}{R_t^k} \tag{15}$$

The differentiated goods, provided by the domestic intermediate good firms, are aggregated by specific firms, turning into homogenous products:

$$Y_t = \left[\int_0^1 \left(Y_{i,t} \right)^{1/\lambda_{d,t}} di \right]^{\lambda_{d,t}} \tag{16}$$

where $\lambda_{d,t}$ represents a stochastic process that determines the time-varying domestic good mark-up as average between the equilibrium mark-up and the previously period mark-up:

$$\lambda_{d,t} = \left(1-\rho_{\lambda_d}\right)\times \lambda_d + \rho_{\lambda_d} \times \lambda_{d,t-1} + \varepsilon_{\lambda_d,t} \tag{17}$$

The firm which aggregates differentiated domestic intermediate goods pursues to minimise its costs, therefore having the optimum condition:

$$P_{i,t} - \eta_t^d \times \left[\lambda_{d,t} \times \left(\int_0^1 \left(Y_{i,t}\right)^{1/\lambda_{d,t}} di \right)^{\lambda_{d,t}-1} \times \frac{1}{\lambda_{d,t}} \times \left(P_{i,t}^{\,1/\lambda_{d,t}-1}\right) \right] = 0 \tag{18}$$

where η_t^d represents the multiplier associated with the cost minimising function of the aggregation firm above.

Similarly, for the aggregation firms relating to the import and final good firm, we get:

$$P_{r,t}^m - \eta_t^m \times \left[\lambda_{m,t} \times \left(\int_0^1 \left(Y_{r,t}^m\right)^{1/\lambda_{m,t}} dr \right)^{\lambda_{m,t}-1} \times \frac{1}{\lambda_{m,t}} \times \left(P_{r,t}^m\right)^{1/\lambda_{m,t}-1} \right] = 0 \tag{19}$$

or, considering that the acquisition price of the differentiated import goods is in fact the marginal cost of the firm which aggregates such products:

$$Y_{r,t}^m = \left(\frac{P_t^m}{P_{r,t}^m} \right)^{\lambda_{m,t}/\left(\lambda_{m,t}-1\right)} \times Y_t^m \tag{20}$$

respectively

$$P_{n,t}^f - \eta_t^f \times \left[\lambda_{f,t} \times \left(\int_0^1 \left(Y_{n,t}^f\right)^{1/\lambda_{f,t}} dn \right)^{\lambda_{f,t}-1} \times \frac{1}{\lambda_{f,t}} \times \left(P_{n,t}^f\right)^{1/\lambda_{f,t}-1} \right] = 0 \tag{21}$$

or, given that the acquisition price of the differentiated final goods represents in fact the marginal cost of the firm which aggregates the said products:

$$Y_{n,t}^f = \left(\frac{P_t^f}{P_{n,t}^f} \right)^{\lambda_{f,t}/\left(\lambda_{f,t}-1\right)} \times Y_t^f \tag{22}$$

There is also, on domestic market, a domestic company which acquires domestic and import aggregated products and creates, from their combination, by a CES production function, a composite homogenous good destined to the final good firms:

$$Y_t^h = \left[\left(1-w_h\right)^{1/(\eta_h+1)} \times \left(Y_t\right)^{\eta_h/(\eta_h+1)} + w_h^{\,1/(\eta_h+1)} \times \left(Y_t^m\right)^{\eta_h/(\eta_h+1)} \right]^{(\eta_h+1)/\eta_h} \tag{23}$$

where w_h is the weight of import goods in the total production of composite good, 1-w_h, the weight of domestic goods in the total production of composite good and η_h, the elasticity of substitution between the domestic and the import goods

Trying to minimise its costs, the composite good firm gets the following optimum conditions:

- First order condition relating to Y_t :

$$Y_t = (1 - w_h) \times \left(\frac{P_t^h}{P_t^d} \right)^{\eta_h + 1} \times Y_t^h \tag{24}$$

- First order condition relating to Y_t^m :

$$Y_t^m = w_h \times \left(\frac{P_t^h}{P_t^m} \right)^{\eta_h + 1} \times Y_t^h \tag{25}$$

There is a continuous series of final good firms divided into four categories: those oriented towards the private domestic environment, with consumption or investment goods; the ones interested in the public domestic environment; and the remainder oriented towards the foreign sector. Each of them acquires homogenous composite goods and differentiates them by brand, selling the same thereafter, via the aggregation companies, to the end users.

The prices are reset in the manner of Calvo (1983), a part of the firms (*1-ξ*) being able to re-optimise their prices at a given time, the others (*ξ*) updating such prices given the current and target inflation level.

If a domestic intermediate good firm which optimises its price in *t* cannot change it for *s* periods, at *t+s* it becomes:

$$\ddot{P}_{t+s}^d = \left(\pi_t^d \times \pi_{t+1}^d \times \pi_{t+2}^d \times ... \times \pi_{t+s-1}^d \right)^{k_d} \times \left(\bar{\pi}_{t+1} \times \bar{\pi}_{t+2} \times \bar{\pi}_{t+3} \times ... \times \bar{\pi}_{t+s} \right)^{(1-k_d)} \times P_t^{new,d} \tag{26}$$

where $P^{\cdot\cdot d}_{t+s}$ represents the level at time *t+s* of the price optimised by the domestic intermediate good firm exclusively at time *t*, π_t^d, the inflation specific to the domestic intermediate good price, $\bar{\pi}_t$, the target CPI inflation, k_d, the indexation parameter and $P_t^{new,d}$, the price optimised by the domestic intermediate good firms at *t*.

The above-mentioned companies intend to maximise their profit as follows:

$$\max_{P_t^{new,d}} \mathrm{E}_t \sum_{s=0}^{\infty} (\beta \times \xi_d)^s \times \varsigma_{t+s}^u \times \left[\ddot{P}_{t+s}^d \times \ddot{Y}_{i,t+s} - C_{i,t+s} \right] \tag{27}$$

where $\ddot{Y}_{i,t+s}$ is the production obtained at time *t+ s* by the domestic intermediate good firms having optimised their prices exclusively at *t* and ς_t^u is the marginal utility of households, given by an additional unit of nominal income, as the firms are actually owned by households

Therefore, for those domestic intermediate good firms we get the following first order condition:

$$\mathrm{E}_t\sum_{s=0}^{\infty}\left(\beta\times\xi_d\right)^s\times\varsigma_{t+s}^u\times\left\{\begin{array}{c}\left(1-\dfrac{\lambda_{d,t+s}}{\lambda_{d,t+s}-1}\right)\times\ddot{P}_{t+s}^{d\ -\lambda_{d,t+s}/\left(\lambda_{d,t+s}-1\right)}\times\dfrac{\ddot{P}_{t+s}^d}{P_t^{new,d}}\times\\ \times\left(P_{t+s}^d\right)^{\lambda_{d,t+s}/\left(\lambda_{d,t+s}-1\right)}\times Y_{t+s}+\lambda_{t+s}\times\left(\dfrac{\lambda_{d,t+s}}{\lambda_{d,t+s}-1}\right)\times\\ \times\left(\dfrac{P_{t+s}^d}{\ddot{P}_{t+s}^d}\right)^{\left[\lambda_{d,t+s}/\left(\lambda_{d,t+s}-1\right)\right]-1}\times\dfrac{P_{t+s}^d\times P_t^{new,d}}{\ddot{P}_{t+s}^d}\times\left(\dfrac{1}{P_t^{new,d}}\right)^2\times Y_{t+s}\end{array}\right\}=0\quad(28)$$

The rest of the said firms update their prices based on the following rule:

$$P_{i,t+1}^d=\left(\pi_t^d\right)^{k_d}\times\left(\overline{\pi}_{t+1}\right)^{(1-k_d)}\times P_{i,t}^d\qquad(29)$$

The import and final good firms behave analogously as for the price inflexibility issue.

The idea of stickiness has been also considered in case of wages, this time in the manner of Erceg (2000).

If a household which optimises its nominal wage at *t* cannot re-optimise it for *s* periods, it becomes, at time *t+s*:

$$\ddot{W}_{j,t+s}=\left(\pi_t\times\pi_{t+1}\times\pi_{t+2}\times...\times\pi_{t+s-1}\right)^{k_w}\times\left(\overline{\pi}_{t+1}\times\overline{\pi}_{t+2}\times\overline{\pi}_{t+3}\times...\times\overline{\pi}_{t+s}\right)^{(1-k_w)}\times\left(\mu_{z,t+1}\times...\times\mu_{z,t+s}\right)\times W_{j,t}^{new}\quad(30)$$

where $W^{\cdot\cdot}_{j,t+s}$ represents the nominal wage at *t+s*, optimised by household *j* exclusively at *t*, π_t, the CPI inflation, $\mu_{z,t}$, the technological growth rate and $W_{j,t}^{new}$, the nominal wage optimised by household *j*

The households optimising their wage at *t*, without being able to re-optimise it for *s* periods, has in view to maximise their satisfaction, this leading to the optimum condition presented below:

$$\mathrm{E}_t\sum_{s=0}^{\infty}\left(\beta\times\xi_w\right)^s\times\left\{\begin{array}{c}\zeta_{t+s}^h\times\ddot{H}_{j,t+s}^{\ \sigma_L+1}\times\dfrac{\lambda_w}{1-\lambda_w}\times\dfrac{1}{W_{j,t}^{new}}-\\ -\psi_{z,t+s}\times\left(1-\tau_{t+s}^y\right)\times\dfrac{\ddot{W}_{j,t+s}}{W_{j,t}^{new}}\times\dfrac{1}{1-\lambda_w}\times\ddot{H}_{j,t+s}\times\dfrac{1}{P_{t+s}}\end{array}\right\}=0\quad(31)$$

The remainder of households update their wages based on the rule:

$$W_{j,t+1}=\left(\pi_t\right)^{k_w}\times\left(\overline{\pi}_{t+1}\right)^{(1-k_w)}\times\mu_{z,t+1}\times W_{j,t}\qquad(32)$$

Government.

In the governmental constraint, the expenses on public consumption, transfers and payment of debt-related interest rates are covered from state budget revenues, obtained from taxes and fees, as well as from the state contingent securities, as follows:

$$P_t^g \times G_t + Tr_t + R_{t-1} \times B_t = \tau_t^c \times P_t^c \times \int_0^1 C_{j,t} dj + \tau_t^y \times \int_0^1 W_{j,t} \times H_{j,t} dj + B_{t+1} \quad (33)$$

where P_t^g represents the price of the final goods destined for public consumption and G_t, the public consumption level

Foreign sector.

Considering that the external trade of our country is especially related to the countries members of the Euro Area, for simplification purposes, the foreign sector is identified with the latter.

The external firms are deemed to have a similar behaviour as the domestic ones, combining the homogenous goods exported by our national economy with their domestic goods so as to produce a composite homogenous good at external level, according to the equation:

$$Y_t^* = \left(\frac{P_t}{P_t^*} \right)^{\eta_* + 1} \times Y_t^x \quad (34)$$

where Y_t^* is the external production of homogenous composite good, Y_t^x, the quantity of exported domestic homogenous good, η_*, the elasticity of substitution, at external level, between the goods exported by our national economy and those produced by the foreign sector on their territory and P_t, the price of the domestic final consumption good after having applied the value added tax.

As concerns the markets analysed at equilibrium, we distinguish: the input market, the intermediate good market, the final good market and the foreign bond market, rendered hereinafter:

♦ **The input market**

The domestic input market reaches equilibrium when the aggregate demand for inputs equals the related aggregate supply.

The domestic intermediate good firms require the capital and labour production factors so as to obtain the targeted level of output. On this market, the equilibrium is reached when the total demand, made by owner of such inputs, meets the total supply, came from the firms which aggregate the labour force, as for the labour factor, respectively from households, as for the capital:

$$\int_0^1 H_{i,t} di = H_t \quad (35)$$

respectively

$$\int_0^1 K_{i,t} di = K_t \quad (36)$$

♦ **The intermediate good market**

The intermediate good market could be seen either from the perspective of the aggregate production of the domestic intermediate good firms, on one hand, and of the import good firms, on the other hand, or by considering the homogenous production of the composite good firm.

Thus, the demand for homogenous intermediate goods, made by the homogenous composite good firm equals, at equilibrium, the total supply of such goods, resulting from the process of aggregation of the production obtained by the domestic intermediate good firms, respectively by the import good firms, as per the previously rendered equations (24) and (25).

Regarding the homogenous composite good market, the demand for such intermediate goods, manifested by the final product firm, equals, at equilibrium, the related supply coming from the homogenous composite good firms:

$$\sum_f Y_t^f = Y_t^h \tag{37}$$

or, considering the differentiated demand, depending on the destination of the final goods produced by the final good firms, that is private consumption and investments, public consumption and export:

$$Y_t^c + Y_t^i + Y_t^g + Y_t^x = Y_t^h \tag{38}$$

♦ **The final good market**

On the final good market the equilibrium is reached when the demand for private consumption and investment goods, expressed by households, for public consumption goods, manifested by the Government, and for export goods, coming from the foreign sector, equals the supply of the firms which produce the related goods, as rendered below:

$$C_t = Y_t^c \tag{39}$$

$$I_t = Y_t^i \tag{40}$$

$$G_t = Y_t^g \tag{41}$$

$$X_t = Y_t^x \tag{42}$$

♦ **The foreign bond market**

The equilibrium on the foreign bond market is obtained when the supply of foreign bonds, revealed by the net position of the import and export firms, equals the demand of household for the same.

$$S_t \times B_{t+1}^* - R_{t-1}^* \times \Phi\left(a_{t-1}, \tilde{\phi}_{t-1}\right) \times S_t \times B_t^* = P_t^x \times S_t \times X_t - P_t^* \times S_t \times M_t \tag{43}$$

The present model deals with twenty structural shocks: the shock on investments, on consumption and spare time preferences, on risk premium, the

domestic technological shock, the shock on the mark-up of the intermediate domestic, import and final good market, the latter being directed, as before-mentioned to four destinations, the shock on the target inflation, on the technological growth rate, on the technological asymmetry between the domestic and the foreign economy, the shock on the foreign inflation, foreign production and foreign interest rate, on income tax and consumption tax, as well as the shock on governmental expenses, each of them representing average between their steady state value and their previous period value:

$$\xi_t = (1-\rho_\xi)\times\overline{\xi} + \rho_\xi \times \xi_{t-1} + \eta_{\xi,t} \quad (44)$$

where $\xi=\{\chi,\ \zeta^c,\ \zeta^h,\ \varnothing^{\sim},\ \Omega,\ \lambda_d,\ \lambda_m,\ \lambda_c,\ \lambda_i,\ \lambda_g,\ \lambda_x,\ \pi^{-},\ \mu_z,\ \mu^*_z,\ \pi^*,\ y^*,\ r^*,\ \tau^y,\ \tau^c,\ G\}$, with normally distributed $\eta_{\xi\,t}$ of zero mean and σ_{ξ^2} variance.

The model selected equations are then subject to log-linearisation, by using the logarithm and by subsequently developing them in Taylor series around the steady-state, thus obtaining simplified equations which, due to the limited space, are not rendered in this paper.

3.2. Data

For the empirical analysis, we resorted to data relating to 14 variables, captured quarterly, for a 12-year period, between the first quarter of 2000 and the last quarter of year 2011, representing 48 observations, reduced subsequently to 40 due to the second order differentiation performed in order to render stationary the model data.

The model variables considered are: gross domestic product, consumption, investments, imports and exports, all of them analysed at the level of Romania, and gross domestic product for the foreign sector, rendered in this paper as the Euro Area, number of employees, real wage, the latter expressed as labour cost index, GDP deflator, consumption deflator, investment deflator, exchange rate, domestic interest rate and foreign interest rate, the last two being analysed as ROBOR 3M, respectively EURIBOR 3M. Such variables are used in logarithm and are either left in level or first or second order differentiated, for stationarity purposes.

As for the sources of the related data: the national gross domestic product and its components, as well as the related deflators and the number of employees, were obtained from the databases of the Romanian National Institute of Statistics; the real wage, expressed as the labour cost index, was taken over from Eurostat; the exchange rate and the domestic interest rate were supplied by the statistics of the National Bank of Romania; the external GDP was provided by the International Monetary Funds; and the foreign interest rate was downloaded from the databases of the National Bank of France.

The deseasonalised series, in logarithm, have been subject to the Hodrick Prescott filter, therefore resulting in new data series, become pattern of the steady state.

All initial transformations, to which the time series data have been subject, were performed by resorting to the econometric software Eviews 7.0.

4. Empirical results

4.1. IRFs Analysis

The model implementation supposed the development of a specific code, in Dynare 4.3.0 of Matlab 7.11.0 (R2010b), therefore generating the impulse-response functions of the said model variables under the impact of the above-mentioned structural shocks. The fact that, subsequent to such impact, the variables return, generally, in about 20-40 periods, to equilibrium, sustains the idea of stability of this model.

Hereinafter are rendered and analysed selectively, for exemplification purposes only, the reaction of the model variables to the occurrence of specific shocks, such as the shock on the mark-up of the domestic intermediate goods, the shock on the income tax and on the consumption tax, the shock on the technological growth rate, on the technological asymmetry between the domestic and the foreign economy, and on the external interest rate, rendered by the *Figures 4.1*, *4.2*, *4.3*, *4.4*, *4.5* and *4.6* below:

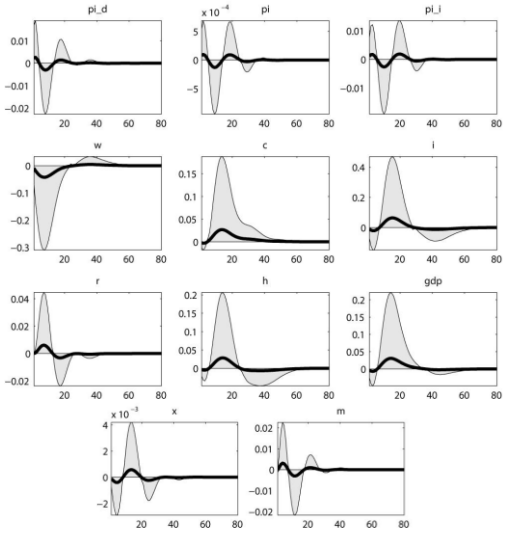

Figure 4.1. Reaction of variables to the shock on the mark-up of the domestic intermediate goods

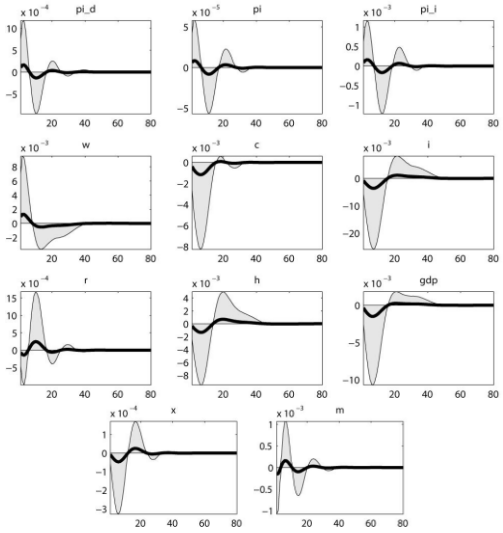

Figure 4.2. Reaction of variables to the shock on the income tax

The shock on the mark-up of the domestic intermediate goods causes the generalised increase in the prices of the final goods and, therefore, the decrease of consumption, investments, exports and, in consequence, of the gross domestic product, labour force and wages.

Yet, little by little, after about 5 periods, the inflation moderates, and the level of GDP and of its components starts increasing, determining the return of the wage level towards its initial position, with effect on the diminish of the interest rate, from the perspective of a slowdown of the crediting-related needs.

At the same time, we assist to an augmentation of the net export which, as a component of GDP, also contributes to the latter increase, up to its steady state return.

The positive shock on the income tax inhibits not just the consumption, but also the investments, with adverse effect both on the gross domestic product, and implicitly on the net export, and on the labour force supply, with positive impact on wages.

The drop of investments generates also a temporary diminish of the interest rate which, under the inflation pressure generated by the increase in wages, and given the return to equilibrium of the gross domestic product, begins its ascendant trend.

Once the gross domestic product beings its slow increase, after the first 20 periods, we ascertain the recovery tendency of consumption and investments, but also the ascendance of the labour force which determines, as expected, a wage adjustment in a descendent direction.

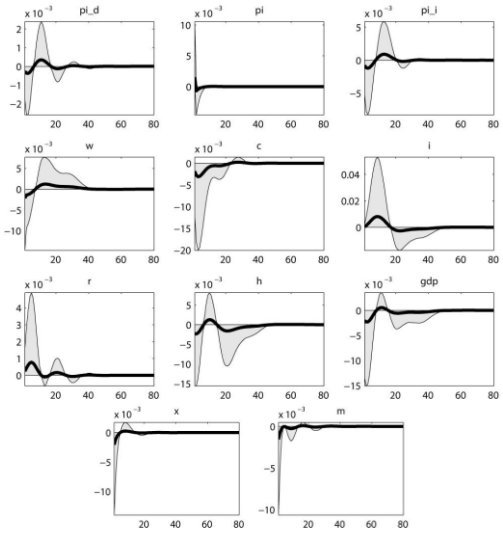

Figure 4.3. Reaction of variables to the shock on the consumption tax

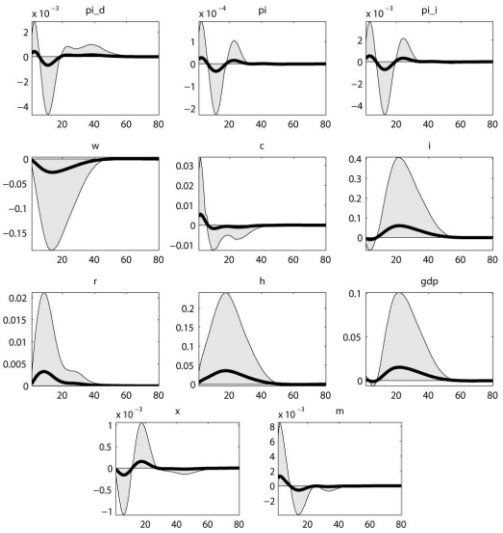

Figure 4.4. Reaction of variables to the shock on the technological growth rate

The positive shock on the consumption tax, represented by the increase of the value-added tax, causes the immediate reaction of consumers, who direct their financial resources towards investments.

As the severe diminish of consumption is not compensated by an equal-sized increase of investments, the gross domestic product manifests a decline, also encountered at the level of imports and exports.

The drop of the demand for goods generates the slowdown, in consequence, of the supply of goods, the former diminishing the inflation and the latter the number of employees, and subsequently the related wages, as result of the tendency of producers to minimise the losses caused by the lowered production level.

The positive shock on the technological growth rate is the result of previous consistent investments, this justifying a slow decrease of such level in the period to come, compensated by a small increase in consumption and, implicitly, an overall diminish of the gross domestic product and exports.

This is just a short-term reaction, the technological development implying a significant augmentation, in the medium and long run, of the GDP level and a re-stimulation of investments. The increase of the supply of goods generates the increase of the labour force demand which, doubled by a modification of the labour force supply in the same direction, determines the lowering of wages.

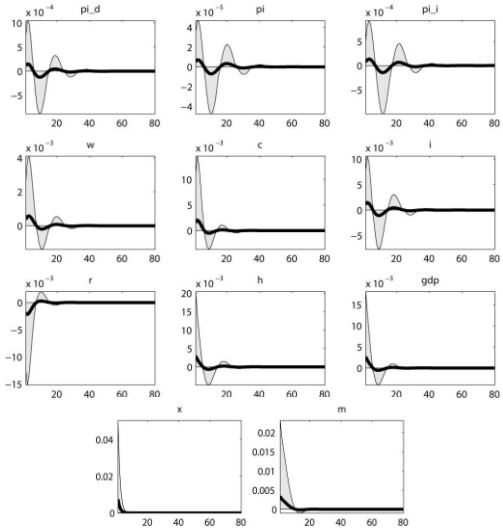

Figure 4.5. Reaction of variables to the shock on the technological asymmetry between the domestic and the foreign economy

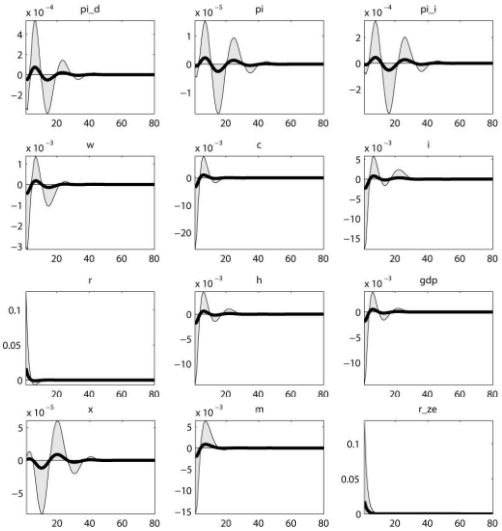

Figure 4.6. Reaction of variables to the shock on the external interest rate

The positive shock on the technological asymmetry between the domestic and the foreign economy reflects in fact a more alert increase of the technological level abroad than within our national economy.

Consequently, it causes both a quantitative and a qualitative increase of imports and an augmentation of the consumption of the import goods, with impact on the level of the gross domestic product.

The higher level of the demand for consumption and investment goods, associated with the imported inflation, determines an increase in prices domestically, but also, according to the well-known Phillips curve, a drop of unemployment.

Although *the shock on the external interest rate* should normally cause a domestic increase in investments, the latter registers in fact the contrary, due to the tendency to align the domestic interest rate, considering our affiliation to the EU, which involves the minimisation of the interest rate differential.

Obviously, this phenomenon lowers the investments and also the gross domestic product, this resulting in the decrease of the number of employees.

Also, the desire of producers to maintain their profit margin, under the circumstances of the drop of sales, as result of the diminish of the demand and of the prices of goods, makes them decreasingly adjust the related wages, up to the return of the gross domestic product to the ascendant line.

4. 4. Lon-run Forecasts

The following step consisted in the use of the forecasting instrument provided by the Dynare software, especially developed by specialists in the matter for this category of models.

Hereinafter is rendered and construed *Figure 4.7*, which reflects the forecast made in relation to the evolution of the variables analysed within this model.

Although the Dynamic Stochastic General Equilibrium models are mainly used to determine the trajectory of variables on short or medium term, we hereby undertook to capture their behaviour in the long run, more exactly all along 80 periods, representing a 20-years term, comprised between the first quarter of 2012 and the last quarter of 2031.

Before interpreting the results revealed by the said figure, it is to be mentioned that the variables, analysed in perspective, have as reference point the steady state reflected by the zero value.

Beside the average value of the variable, the graph also renders the confidence interval which, in our example, is of 90%.

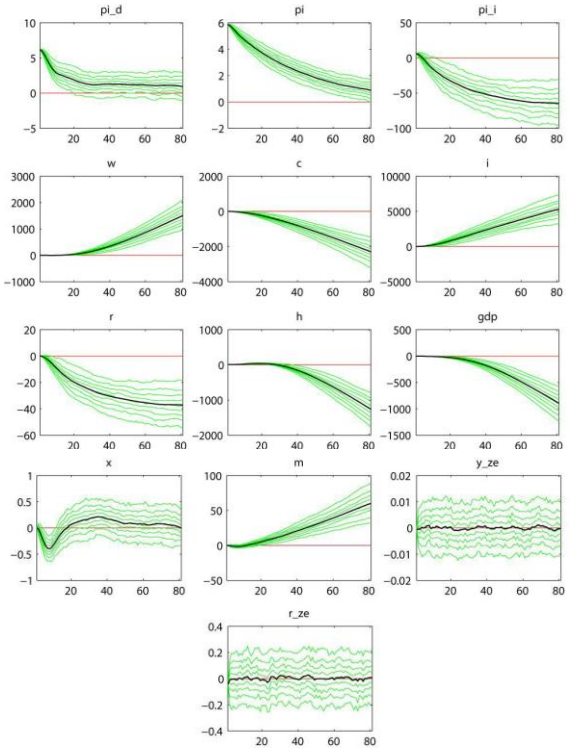

Figure 4.7. Forecasts regarding the long-run evolution of variables

As ascertained, for about 6 periods, representing 1 year and a half, the consumption and investments maintain their steady state position, subsequently followed by a clear tendency of the population to change its consumption habits, by diminishing the consumed quantity, its financial resources being therefore oriented towards investments.

Since that moment, the evolution of consumption and investments is constantly decreasing, respectively increasing, during the entire period subject to analysis. This fact is mainly due to the evolution of the related deflators. While the consumption deflator goes towards the steady state, coming from an upper level of it, however without succeeding in reaching the same, the investment deflator progressively decreases under that level, therefore underlining the antithesis between the relatively low purchasing power and the expansionary investment one.

The augmentation of the investment power, from the very first quarter of forecast, generates the lowering of the level of crediting destined for investments, which determines a simultaneous decrease of the interest rate level.

The gross domestic product has a period of 5 years of relative stability, registering afterwards a long-run decline, caused, the most probably, by the inadequate stimulation of the population consumption and by an imperfectly sustainable investment increase.

Besides, the GDP drop is also "encouraged" by the trade balance deficit. While the exports have a fluctuating trajectory, with an obvious decrease during the first 2 years, followed by an increase for about 8 years, then by a slow return to the steady state, the imports progressively increase from the first periods of forecast.

The lowering of the demand for goods causes an adjustment in the same direction of the supply for the same, this involving, as expected, a drop of the number of employees, which manifests a serious descendent trend, following a period of 2 years and a half, between the 16^{th} and the 26^{th} quarter when, under the impact of the increasing investments, has known a slightly favourable impulse.

Considering the high unemployment level, clearly increased after the first 6 years of forecast, the level of wages begins to augment, especially due to the effort of the domestic producers to stimulate the productivity of their employees.

Externally, both the production and the interest rate have consistently stable values for the analysed period, their oscillations around the steady state being, although quite frequent, insignificant in size, thus unable to cause serious economic changes.

Concerning the fiscal-budgetary measures necessary to adopt, considering the forecasted evolution of the model variables, we suggest, given the deficit of the demand for consumption, an expansionary fiscal-budgetary policy, consisting in the reduction of both direct and indirect taxes, doubled by a grounded increase of the governmental expenses, with long-run effects, the arising budgetary deficit providing a favourable adjustment of the aggregate demand level.

As for the monetary measures to take, although the interest rate looks like decreasing during the period to come, an expansionary monetary policy consisting in a slow augment of the money supply, accompanied by an extended drop of the interest rate, inhibiting savings and stimulating consumption, is also recommendable.

Under such circumstances, by encouraging the demand for goods we would also stimulate the supply of the same, with positive effects both on consumption and employment, which might return to their steady state level, stabilising, at least for the moment, the national economy, in the absence of any unpredictable, unfavourable conjuncture, economic or otherwise in nature.

5. Conclusions

This paper is meant to capture both the reaction of the variables of the model developed at the level of the Romanian economy, under the impact of the structural shocks considered, and the evolution of such variables in the long run, so as to reveal a coherent image of the fiscal-budgetary and monetary policies necessary to adopt in order to create the premises of a sustainable economic growth.

The shock on the mark-up of the domestic intermediate goods, the shock on the income tax and on the consumption tax, the shock on the technological growth rate, on the technological asymmetry between the domestic and the foreign economy, and on the external interest rate are analysed from the perspective of the response of the model variables in their trial to return to the steady state, the economic interpretations being made accordingly. It is ascertained the fact that, subsequent to the impact of the said shocks, the variables return, generally, after about 20 periods, to equilibrium, piece of information allowing for the assuming of pertinent measures, able either to rush the reaching of that state, or to fix more quickly the affected variables in the steady state point, diminishing, to a possible extent, the amplitude of any subsequent oscillations.

The long-run forecasts on the analysed model variables have been also approached within the present paper. The study of the results provided in this regard by the software Dynare of Matlab, opens the possibility to express our opinion relating to the fiscal-budgetary and monetary measures necessary to undertake so as to lay the grounds of a real economic growth. Thus, the increasing deficit of consumption imposes the promotion of an expansionary fiscal-budgetary policy, mainly based on the drop of the value-added tax, but also on the diminish of other taxes and on the increase of the level of budgetary expenses, and of a monetary policy, also expansionary, able to strengthen the support necessary for the consolidation of the demand for consumption, and to provide, in this way, the re-establishment of the equilibrium value of the gross domestic product, with all the beneficial effects generated by it.

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REFERENCES

[1] **Adolfson, M., Laséen, S., Lindé, J. and Villani, M. (2005),** ***Bayesian Estimation of an Open Economy DSGE Model with Incomplete Pass-through***. *Working Paper Series 179,* Sveriges Riksbank;

[2] **Almeida, V. (2009),** ***Bayesian Estimation of a DSGE Model for the Portuguese Economy***. *Economics and Research Department, Working Paper Series w200914*, Banco de Portugal;

[3] **Almeida, V., Castro, G. and Felix, R. (2008),** ***Improving Competition in the Non-tradable Goods and Labour Markets: The Portuguese Case***. *Working Papers Series No.16,* Banco de Portugal;

[4] **Altig, D., Christiano, L., Eichenbaum, M. and Lindé, J. (2005),** ***Firm-Specific Capital, Nominal Rigidities and the Business Cycle***. *NBER Working Paper 11034*;

[5] **Andrés, J., Burriel, P. and Estrada, A. (2006),** ***BEMOD: a DSGE Model for the Spanish Economy and the Rest of the Euro Area***. *Working Papers 0631*, Bank of Spain;

[6] **Calvo, G. A. (1983),** ***Staggered Prices in a Utility-maximizing Framework***. *Journal of Monetary Economics*, 12 (3), pp.383–398;

[7] **Christiano, L., Eichenbaum, M. and Evans, C. (2005),** ***Nominal Rigidities and the Dynamic Effects of a Shock to Monetary Policy***. *Journal of Political Economy*, 113(1), pp.1-45;

[8] **Erceg, C. J., Henderson, D. W. and Levin, A. T. (2000),** ***Optimal Monetary Policy with Staggered Wage and Price Contracts***. *Journal of Monetary Economics* 46(2), pp.281–313;

[9] **Griffoli, T. M. (2010),** ***DYNARE v4 - User Guide***, beta version;

[10] **Hudea (Caraman), O.S. (2012),** ***Dynamic and Stochastic Estimation of the Romanian Economy, based on the New Keynesian Model***. *SCCECE*, 1-2, pp.1-14;

[11] **Hudea (Caraman), O.S. (2012),** ***An Estimated Dynamic Stochastic General Equilibrium Model for the Romanian Economy, Considering Nominal and Real Rigidities***. *Emerging Market Queries in Finance and Business*, Procedia Economics and Finance, pp.105-110;

[12] **Hudea (Caraman), O.S. (2013),** ***The Behaviour of the Romanian Economy Seen from the Perspective of a Dynamic Stochastic General Equilibrium Model***. *Workshop on Empirical Methods in Macroeconomic Policy Analysis (EMMPA2013), Bucharest, Romania*;

[13] **Hudea (Caraman), O.S. (2013),** ***DSGE Modelling Architecture. Exemplification of the Romania Case***. *IECS, Sibiu*;

[14] **Kydland, F. E. and Prescott, E. C. (1982),** ***Time to Build and Aggregate Fluctuations***. *Econometrica 50 (6),* pp.1345–1370;

[15] **Leu, C.Y. and Sheen, J. (2011),** ***A Small New Keynesian State Space Model of the Australian Economy***. *Economic Modelling*, 28 (1-2): 672-684;

[16] **Ratto, M. and Roeger, W. (2009),** ***An Estimated Open-economy DSGE Model of the Euro Area with Fiscal and Monetary policy***. *Elsevier: Economic Modelling*, 26 (1): 222-233;

[17] **Rotemberg J. and Woodford, M. (1997),** ***An Optimization-Based Econometric Framework for the Evaluation of Monetary Policy***. *NBER Chapters, in: NBER Macroeconomics Annual* 1997, 12, pp.297-361, National Bureau of Economic Research, Inc.;

[18] **Smets, F. and Wouters, R. (2003),** ***An Estimated Dynamic Stochastic General Equilibrium Model of the Euro Area***. *Journal of the European Economics Association*, 1(5), pp.1123-1175;

[19] **Stahler, N. and Thomas, C. (2012),** ***FiMod – A DSGE Model for Fiscal Policy Simulations***. *Economic Modelling*, 29 (2): 239-261.