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Abstract

In this paper I use a medium scale open economy DSGE model developed by Baksa, Benk and Jakab (2010) for the Hungarian economy. This model provides a notable degree of disaggregation both on the government revenue and expenditure side, being able to capture the shocks that come from fiscal policy decisions.

My contributions can be summed up in the following three actions. First of all, I estimated the model for the Romanian economy, using Bayesian techniques. Secondly, I determined the parameters of fiscal feedback rules in order to establish if the automatic stabilizers work properly. And thirdly, I tried to analyze the impulse response functions in order to assess the effects of different fiscal policy measures on the most important macroeconomic variables.

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The views expressed in this paper are those of the author

Contents

1. Introduction

The fiscal authorities of many countries were coerced by the actual financial crisis to implement fiscal consolidation or a fiscal stimulating plan in order to ensure fiscal stability. Thus, to reduce the budgetary disequilibrium, fiscal authorities have the possibility of reducing public spending or/and to increase taxes; but having these possibilities, one can ask himself "which spending items should be reduced?" or/and "which taxes should be increased?", but most importantly one must find the answer to the question "what implications will these changes have on the economy?"

Many countries have already implemented fiscal policy measures, such as cuts in public wages and investments, cuts in public employment, rise of taxation rates etc., which have a major impact on economy. In this context it is interesting and also necessary to study how the fiscal policy shocks are transmitted in economy, as well as their impact on the macroeconomic framework. Moreover, this topic has generated intense debates among economists and there are various approaches to this problem.

One of the most popular methods used to evaluate the impact of fiscal policy measures on the economy is that of Blanchard and Perotti (1999). In their study, they use structural VAR models and argue that government spending increases have a positive effect on the output, while tax increases have a negative effect. This article was a starting point for many studies, such as Giuliodori and Beetsma (2004), Romer and Romer (2007), Caldara and Camps (2008), but the method is also subject to many criticisms.

Also, in the last years, the DSGE models have become a reliable tool for evaluating economic policy measures and most recently a series of articles analyze the fiscal policy issues. An important advantage of this approach is that the DSGE models are not subject to Lucas critique, these being able to model the behavior of economic agents and to incorporate their expectations.

Given the economic development of Romania during recent years, I consider that is necessary and relevant to implement a DSGE model in order to quantify the effects of different fiscal policy shocks on the most important macroeconomic variables. Thus, I would like to adjust the model created by Baksa, Benk and Jakab (2010) for the Hungarian economy according to the specific features of our economy.

The aim of this paper is to provide evidence on the effects of fiscal policy actions using a model with a notable degree of disaggregation, both on the government revenue and expenditure side. Also, using fiscal feedback rules that share similar characteristics with the Taylor rule in monetary economics, I would like to estimate the feedback parameters that capture the automatic stabilizing effects. Thus, this paper should be a step towards estimating the government behavior based on quarterly fiscal data.

The present paper is organized as follows: section two gives a brief of relevant literature, section three describes the DSGE model used by Baksa, Benk and Jakab (2010), section four gives details on data used, calibration and estimation procedures, as well as the estimation results. In section five, I present an analysis of impulse response functions, while in section six I state my conclusions, taking into account the results from the previous section.

2. Literature Review

Among economists there is a lack of consensus on the stabilizing effects of fiscal policy measures in the form of spending decrease or tax increase. In more recent years, DSGE models have become a reliable tool for evaluating fiscal policy measures, and that's because, now, these models include a more developed fiscal policy block.

Such a case is the one of Baksa, Benk and and Jakab (2010) who estimated a DSGE model for the Hungarian economy (being an extended version of the model proposed by Smets and Wouters (2003)) with a disaggregated fiscal policy block. If, in other models, the fiscal block appears only implicitly (the fiscal authority collect lump sum taxes and give transfers), here the fiscal policy is modeled explicitly by introducing three types of tax rates (personal income tax rates, social contribution rate paid by employers and VAT) and two types of expenditures (social transfers and goods and services expenditure). For each item of revenue and expenditure a fiscal rule was implemented (a fiscal reaction function).

Thomassi Stahler (2011) presents in his paper a model, jointly developed by Banco de España and Deutsche Bundesbank staff, used for fiscal policy simulations. This model provide a better disaggregation on the fiscal expenditure side, including some components like public investment, public purchases of goods and services, public sector wage bill, and transfers.

Forni, Gerali and Pisani (2010) created a model for Italian economy (based on Global Economy Model developed by IMF) used to simulate the macroeconomic and welfare implications of different fiscal consolidation scenarios. This model considers that Italy is a member of euro area and takes into account the role of the common monetary policy and the spillovers from the rest of the area.

Stork (2011) developed Hubert, a simple DSGE model for the Czech Republic used to simulate different macroeconomic scenarios at the Ministry of Finance; this model has a good representation of fiscal policy block.

Other relevant studies are the following: Kliem and Kriwoluzky (2010), who presents a procedure to determine fiscal policy feedback rules for tax instruments, Iwata (2009), who studies the impact of fiscal policy measures on Japan economy, Zubairy (2009), who estimates a

DSGE model that features a rich fiscal policy block and a transmission mechanism for government spending shocks and calculates the multiplier for spending shock.

3. The Model

In this section I present the model used by Baksa, Benk and Jakab (2010), which is an extended version of the DSGE model presented in Smets and Wouters (2003).

This model includes a series of specific features as in the model developed by Smets and Wouters (2003), but some notable differences can be found. Thus, it incorporates rigidities like: habit formation, investment adjustment cost, capital utilization rate, price and wage settings as in Calvo (1983), indexation mechanisms in prices and wages.

Baksa, Benk and Jakab extended the model of Smets and Wouters (2003) mainly by introducing a more developed fiscal policy block, designed to capture the shocks coming from fiscal policy decisions. If in other models the fiscal block appears only implicitly (the fiscal authority collect lump sum taxes and give transfers), here the fiscal policy is modeled explicitly by introducing three types of tax rates (personal income tax rates, social contribution rate paid by employers and VAT) and two types of expenditures (social transfers and Government expenditure). For each item of revenue and expenditure a fiscal rule was implemented (a fiscal reaction function).

In this model, the imports are treated as intermediate products as in McCallum and Nelson (2001). In their paper they argue that in the standard set-up (in most models, imports are treated as final consumer goods) only a subset of the consumer price index is sticky, while in this approach the import prices influence the overall inflation via their impact on potential output. So, in this approach, the consumer price index is the relevant price index for produced goods.

Another feature of this model is that the agents can learn the inflation trend gradually by applying an adaptive algorithm. The perceived trend of inflation depends on the current deviation of inflation from its trend and on the previous period inflation trend.

As was pointed in IMF Country Report No. 08/314 “Hungary: selected issues (2008)” a disadvantage of the model is that it does not include a block with partner-country dynamics.

The model describes the behavior of four categories of players: households, firms, government (represented by central bank and fiscal authority) and external market. The loglinearized equations around their steady state are in ***Annex I.***

3.1 Households

The economy is populated by a continuum of households of measure one indexed by $t \in [0,1]$.. We assume that a part 1-ω of households is Ricardian (approximately 75%) and they have access to financial markets. The remaining households are liquidity-constrained and they spend their entire current disposable income on consumption.

We suppose that Ricardian households have an identical preference toward consumption and leisure. They decide on labor supply and on consumption of goods, by maximizing the following utility function:

$$\sum_{t=0}^{\infty} \beta^t E_0\left((1+\eta_t^c)\left[\frac{\left(C_t^o(j)-hC_{t-1}^o(j)\right)^{1-\sigma}}{1-\sigma}\right]-\left(1+\eta_t^l\right)\left[\frac{L_t^{1+\varphi}(j)}{1+\varphi}\right]\right) \qquad (3.01)$$

where β is the discount factor, $c_t^o(j)$ represents the real consumption of consumer j, h measures the habit formation in consumption, $L_t(j)$ is the labor supplied by household j, σ is the inter-temporal elasticity of consumption and φ denotes the inter-temporal elasticity of labor.

In this expression, η_t^c is the preference shock to consumption, while η_t^l is the preference shock to labour supply and these are modeled as a first order autoregressive process. The preference shock of consumption (the shock to consumer's impatience level) affects the marginal disutility of labor and the marginal utility of consumption. These preference shocks imply that households' consumption and employment valuation may vary over time.

The Ricardian household faces with the following budget constraint:

$$(1+\tau_t^c)P_t c_t^o(j) + P_t I_t(j) + \frac{B_t(j)}{1+i_t} + \frac{B_t^s(j)}{1+i_t^*} = B_{t-1}(j) + B_{t-1}^s(j) + \left(1-\tau_t^l\right)W_t(j)L_t(j)$$

$$+ P_t r_t^k u_t(j)k_{t-1}(j) - \Psi\left(u_t(j)\right)P_t k_{t-1}(j) + Div_t - OT_t \quad (3.02)$$

where τ_t^c, τ_t^l denotes consumption respectively labor income tax rates, P_t is the aggregate price level, $I_t(j)$ is the investment level, $B_t(j)$ is the nominal bond, $B_t^s(j)$ is the home country's nominal net foreign asset position, i_t is the nominal interest rate, i_t^* is the foreign interest rate,

r_t^k is the rental rate of capital, $\Psi(u_t(j))$ [2]is the cost of the capital utilization rate $u_t(j)$, k_t is the stock of capital, Div_t denotes the dividends and OT_t denotes a lump-sum tax.

So, the individual households receive wages for their work, dividends, capital income and interest income and they pay an income and a consumption tax (VAT) to the government.

Ricardian households have access to financial markets and they can to maximize their lifetime utilities deciding on consumption, labor supply, domestic and foreign bond holding, investment, capital stock and capital utilization rate.

In this model, the households act as investors, lending out the capital to the firm and earning rental rate from this. The physical capital accumulation law is given by the following dynamic equation:

$$K_t = (1-\delta)K_{t-1} + \left[1 - \mathrm{S}\left(\frac{(1+\eta^{\mathrm{I}}{}_t)\mathrm{I}_t(\mathrm{j})}{\mathrm{I}_{t-1}(\mathrm{j})}\right)\right]\mathrm{I}_t(j) \tag{3.03}$$

where δ is the depreciation rate and S represents the investment adjustment cost function[3] that have the following form:

$$\mathrm{S}\left(\frac{(1+\eta^{\mathrm{I}}{}_t)\mathrm{I}_t}{\mathrm{I}_{t-1}}\right) = \frac{\phi}{2}\left(\frac{(1+\eta^{\mathrm{I}}{}_t)\mathrm{I}_t(\mathrm{j})}{\mathrm{I}_{t-1}(\mathrm{j})} - 1\right)^2$$

and η_t^{I} is a shock to the adjustment function.

Households maximize the utility function subject to the budget constraint and to capital motion. Solving the maximization problem of consumers and taking derivatives with respect to decision variables yields the following first order conditions:

Derivative with respect to b_t: we obtain the Euler equation

$$\lambda_t = \beta(1+i_t)E_t\left[\frac{\lambda_{t+1}}{1+\pi_{t+1}}\right] \tag{3.04}$$

where λ_t is the marginal utility of consumption in period t.

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[2] $\Psi(u_t(j)) = r_t^k\psi\left[\exp\left(\frac{u_t-1}{\psi}\right) - 1\right], \psi = \Psi'(1)/\Psi''(1)$

[3] $\mathrm{S}\left(\frac{(1+\eta^{\mathrm{I}}{}_t)\mathrm{I}_t}{\mathrm{I}_{t-1}}\right)$ is a function that transforms investment into capital. The investment adjustment cost function is assumed to satisfy S (1) = S' (1) = 0.

Derivate with respect to b_t^s :

$$\lambda_t e_t \frac{1}{1+i_t^*} = \lambda_{t+1}\beta e_{t+1} \left[\frac{1}{1+\pi_{t+1}}\right] \tag{3.05}$$

Combining this relation with the derivative with respect to b_t^s yields the UIP condition:

$$\frac{1+i_t}{1+i_t^*} = \frac{e_{t+1}}{e_t} \tag{3.06}$$

Derivative with respect to c_t^o:

$$C_t^o(j)(A+h) = C_{t+1}^o(j) + hAC_{t-1}^o(j) \text{ , where} A = \left\{\frac{[1-\lambda_t(1+\tau_t^c)](1+\eta^c{}_t)}{h\beta(1+\eta^c{}_{t+1})}\right\}^{-\frac{1}{\sigma}} \tag{3.07}$$

Derivative with respect to I_t: (3.08)

$$\frac{\lambda_t}{(1+\tau_t^c)} Q_t \left[1 - \Phi_I\left(\frac{(1+\eta^I{}_t)I_t}{I_{t-1}}\right) - \Phi'_I\left(\frac{(1+\eta^I{}_t)I_t}{I_{t-1}}\right)\frac{(1+\eta^I{}_t)I_t}{I_{t-1}}\right]$$
$$= \frac{\lambda_t}{(1+\tau_t^c)} - \beta E_t \frac{\lambda_{t+1}}{(1+\tau_{t+1}^c)}\left[Q_{t+1}\Phi'_I\left(\frac{(1+\eta^I{}_{t+1})I_{t+1}}{I_t}\right)\left(\frac{(1+\eta^I{}_{t+1})I^2{}_{t+1}}{I^2{}_t}\right)\right]$$

Derivative with respect to k_t: we obtain the shadow price of capital

$$Q_t = \beta E_t \frac{\lambda_{t+1}}{\lambda_t}\left[Q_{t+1}(1-\delta) + r_{t+1}^k u_{t+1} - \Psi\big(u_{t+1}(j)\big)\right] \tag{3.09}$$

Derivative with respect to $u_t(j)$: we obtain the capital utilization level (the marginal cost of capital utilization is equal to the rental rate)

$$r_t^k = \Psi'\big(u_t(j)\big) \tag{3.10}$$

A part of households (ω) are liquidity-constrained and they spend their entire current disposable income (wages and transfers) on consumption. This kind of agents is modeled as non-optimizing and their budget constraint is given by:

$$(1+\tau_t^c)P_t C_t^{no}(j) = \left(1-\tau_t^l\right)W_t(j)L_t(j) + \frac{TR_t}{1-\varpi} \tag{3.11}$$

Wage setting

Each household supplies a differentiated labor service to domestic firms. These different types of labor are sold to an employment agency (labor aggregator) that transforms them into a composite labor good using the following CES function (Dixit-Stiglitz aggregator function):

$$L_t = \left(\int_0^1 L(j)_t^{\frac{\theta_w - 1}{\theta_w}} dj\right)^{\frac{\theta_w}{\theta_w - 1}} \qquad (3.12)$$

where θ_w denotes the elasticity of substitution between different types of labor.

The employment agency solves a cost minimization problem (it minimizes the labor cost (wage) to obtain a unit of labor) and obtains the individual demand for each labor service supplied by household j:

$$L_t(j) = \left(\frac{W_t}{W_t(j)}\right)^{\theta_w} L_t \qquad (3.13)$$

where W_t is the aggregate wage index expressed as:

$$W_t = \left(\int_0^1 W_t(j)^{1-\theta_w} dj\right)^{\frac{1}{1-\theta_w}} \qquad (3.14)$$

Following Calvo (1983), households can re-optimize their wage at a given date with probability $1 - \gamma_w$ when they receive a random signal to change their wage. If a household cannot re-optimize its wage then it will adjust its wage according to the following rule of thumb that supposes an indexation with the perceived trend of inflation:

$$W_T(i) = W_t(i)\Pi_{T,t}^{Iw} = P_t(i)\Pi_T^{Iw}\Pi_{T-1}^{Iw} \ldots \Pi_t^{Iw} \qquad (3.15)$$

where $\Pi_T^{Iw} = \left(\frac{\Pi_t^w}{\overline{\Pi}_t}\right)^{\vartheta_w} \overline{\Pi}_{t+1}$, $\Pi_t^w = W_t/W_{t-1}$, ϑ_w represents the degree of indexation according to past inflation, and $\overline{\Pi}_t$ s the perceived trend of inflation.

The agents learn inflation trend gradually, by applying an adaptive algorithm. The perceived trend of inflation depends on the current deviation of inflation from trend and on the previous period inflation trend:

$$(1+\overline{\pi_t}) = (1+\overline{\pi_{t-1}})^{\rho_\pi}\left(\frac{(1+\pi_t)}{(1+\overline{\pi_{t-1}})}\right)^g \quad (3.16)$$

where $\overline{\pi_t}$ is the trend inflation, ρ_π is the persistence of trend inflation, g denotes the learning speed parameter.

If the household can to re-optimize its wage, then it will maximize its lifetime utility function taking as given the nominal wage and the labor:

$$\max \sum_{t=0}^{\infty} (\gamma_w \beta)^{T-t} E_t\left((1+\eta_t^c)\left[\frac{\omega^o U(H_T^o)+\omega^{no} U(H_T^{no})}{\omega^o+\omega^{no}}\right] - (1-\eta_t^l)\left[\frac{L_t^{1+\phi}(j)}{1+\phi}\right]\right) \quad (3.17)$$

subject to the budget constraint, capital accumulation law and to the labor demand equation.

The wage chosen by household in this period will remain unchanged T-t periods in the future, with a probability of γ_w.

From the first order conditions of the problem, we obtain that the re-optimized aggregate wage can be described by the following recursive form:

$$\mathcal{W}_t = \left(\frac{\theta^w}{\theta^w - 1}\frac{\mathcal{L}_t^{w1}}{\mathcal{L}_t^{w2}}\right)^{1+\theta^w \varphi} \quad (3.18)$$

where $$\mathcal{L}_t^{w1} = (1+\eta_t^c)(1-\eta_t^l)\,\mathcal{L}_t^{\varphi+1} + \gamma_w\ \beta E_t\left[\left(\frac{\Pi_{t+1}^w}{\Pi_t^{Iw}}\right)^{\theta^w(1+\varphi)-1} \mathcal{L}_{t+1}^{w1}\right] \quad (3.19)$$

$$\mathcal{L}_t^{w2} = (1-\tau_t^l)\Lambda_t^L\,\mathcal{L}_t + \gamma_w\ \beta E_t\left[\left(\frac{\Pi_{t+1}^w}{\Pi_t^{Iw}}\right)^{\theta^w-1} \mathcal{L}_{t+1}^{w2}\right] \quad (3.20)$$

From the definition of the aggregate wage index, the law of motion for the aggregate wage index is:

$$\mathcal{W}_t^{1-\theta^w} = \frac{1-\gamma_w\left(\frac{\Pi_{t+1}^w}{\Pi_t^{Iw}}\right)^{\theta^w-1}}{1-\gamma_w} \quad (3.21)$$

Finally, the log-linear wage Phillips curve is given by: (3.22)

$$\widehat{\pi_t^w} = \frac{(1-\gamma_w)(1-\beta\gamma_w)}{\gamma_w(1+\theta_w\varphi)(1+\beta\vartheta_w)}\left\{\varphi L_t - w_t + \eta_t^l + \frac{\sigma}{1-h}\left(\tilde{c}_t^l - h\tilde{c}_{t-1}^l\right) + \frac{\tau^c}{1+\tau^c}\tau_t^c + \frac{\tau^l}{1+\tau^l}\tau_t^l + \xi_t^w\right\}$$
$$+ \frac{\beta}{(1+\beta\vartheta_w)}E_t\widehat{\pi_{t+1}^w} + \frac{\vartheta_w}{(1+\beta\vartheta_w)}\widehat{\pi_{t-1}^w}$$

where $\tilde{c}_t^l = \frac{\varpi^o (c^o)^{-\sigma}\widetilde{c_t^o} + \varpi^{no}(c^{no})^{-\sigma}\widetilde{c_t^{no}}}{\varpi^o (c^o)^{-\sigma} + \varpi^{no}(c^{no})^{-\sigma}}$ represent the weighted marginal utility of consumption

and $\hat{\pi}_t^w = \frac{w_t}{w_{t-1}}\widehat{\pi_t}$ denotes the wage inflation while ξ_t^w denotes the mark-up shock.

3.2 Firms

In this model, production takes place in two stages. In the first stage, a homogenous intermediate good is created in a perfectly competitive industry using labor and imports as inputs. In the second phase, the intermediate good is sold to the final good producers who combine it with the capital supplied by households and produce differentiated goods in a monopolistically competitive industry.

There is a continuum of intermediate good producing firm that uses labor and imports as inputs. Labor is supplied by an employment agency that hires differentiated labor from households and aggregates it into homogeneous labor good.

Imports are offered by the importing firms that buy differentiated external goods and services and aggregate it into homogeneous import good. The final imported good is a Dixit-Stiglitz aggregate:

$$m_t = \left(\int_0^1 m_t(i)^{\frac{\theta-1}{\theta}} di\right)^{\frac{\theta}{\theta-1}} \tag{3.23}$$

From the cost minimization problem result the demand for individual imported consumption good: $m_t(i) = \left(\frac{P_t^{ms}}{P_t^{ms}(i)}\right)^{\theta} m_t$, where P_t^{ms} is the aggregate foreign-currency price expressed as:

$$P_t^{ms} = \left(\int_0^1 P_t^{ms}(i) di\right)^{\frac{1}{1-\theta}} \tag{3.24}$$

There, the foreign-currency price of imported inputs is expressed as a first order autoregressive process.

The composite intermediate input is produced in a competitive industry by the following CES technology: (3.25)

$$z_t = \left\{ a^{\frac{1}{\rho_z}} [(1+\phi_1)^{-1} L_t]^{\frac{\rho_z - 1}{\rho_z}} + (1-a)^{\frac{1}{\rho_z}} [(1+\phi_2)^{-1} m_t]^{\frac{\rho_z - 1}{\rho_z}} \right\}^{\frac{\rho_z}{\rho_z - 1}}$$

where a denotes the share of labor used in production, ρ_z is the substitution elasticity between the factors and ϕ_1, ϕ_2 are the adjustment costs.

Solving the cost minimization problem yields the marginal cost of the intermediate product and the demand for each production factor:

The marginal cost of the intermediate product is: (3.26)

$$w_z = \left[a \overline{w}_t^{1-\rho_z} + (1-a) q_t \overline{P_t^{ms}}^{1-\rho_z} \right]^{\frac{1}{1-\rho_z}}$$

where: $\overline{w_t} = \frac{(1+\tau_t^s) w_t}{(1+\phi_1)^{-1} - L_t (1+\phi_1)^{-2} \phi'_1}$ denotes the effective wage, and

$\overline{q_t P_t^{ms}} = \frac{q_t P_t^{ms}}{(1+\phi_2)^{-1} - m_t (1+\phi_2)^{-2} \phi'_2}$ is the effective import price.

Labor demand has the form of: (3.27)

$$L_t = a \left(\frac{w_t^z}{\overline{w}_t} \right)_z^{\rho_z} z_t (1+\phi_1)$$

And import demand equation is: (3.28)

$$m_t = (1-a) \left(\frac{w_t^z}{\overline{\overline{q_t P_t^{ms}}}} \right)_z^{\rho_z} z_t (1+\phi_2)$$

The continuum of differentiated final goods $y_t(i)$ is produced in a monopolistically competitive market and each $y_t(i)$ is made by an individual firm. The composite good is bought by the final goods producers and combined through a CES production function with the accumulated capital supplied by households: (3.29)

$$y_t(i) = (1+\eta_t^A)\left\{\alpha^{\frac{1}{\rho}}\overline{[K_t(i)]}^{\frac{\rho-1}{\rho}} + (1-\alpha)^{\frac{1}{\rho}}[z_t]^{\frac{\rho-1}{\rho}}\right\}^{\frac{\rho}{\rho-1}} - \mathrm{y}\overline{\mathrm{f}}$$

where η_t^A is a productivity shock, α denotes the share of capital used in production, ρ denotes the substitution elasticity and $\overline{\mathrm{f}}$ is the fixed cost of production.

Solving the cost minimization problem yields the marginal cost of the final product and the demand for each production factor:

The real marginal cost of final goods is: (3.30)

$$mc_t = \left(\frac{1}{1+\eta_t^A}\right)(\alpha\left(r_t^k\right)^{1-\rho} + (1-\alpha)\,(w_t^z)^{1-\rho}\,)\,)^{\frac{1}{\rho-1}}$$

where r_t^k is the rental fee.

Capital demand is: (3.31)

$$u_t k_t = \frac{\alpha\left(\frac{mc_t}{r_t^k}\right)^{\rho}(DP_t y_t + yf)}{(1+\eta_t^A)^{1-\rho}}$$

where $DP_t = \int_0^1 \left(\frac{P_t}{P_t(i)}\right)^{\theta} di$ is the prices' dispersion.

The intermediate product demand is: (3.32)

$$z_t = \frac{(1-\alpha)\left(\frac{mc_t}{w_t^z}\right)^{\rho}(DP_t y_t + yf)}{(1+\eta_t^A)^{1-\rho}}$$

The aggregate final good y_t is produced in a competitive market from a continuum of differentiated final goods $y_t(i)$, $i \in [0,1]$.Retailers buy differentiated final goods from producers, aggregate and sell them to households, government or exporters:

$$y_t = \left(\int_0^1 y_t(i)^{\frac{\theta-1}{\theta}} di\right)^{\frac{\theta}{\theta-1}} \qquad (3.33)$$

where θ>1 denotes the substitution elasticity between different kind of goods.

The demand for each individual final good is obtained from a cost minimization problem:

$$y_t(i) = \left(\frac{P_t}{P_{t(i)}}\right)^{\theta} y_t \tag{3.34}$$

where $P_t = \left(\int_0^1 P_t(i)^{1-\theta} di\right)^{\frac{1}{1-\theta}}$ is the (composite) price index and $P_t(i)$ represents the price of differentiated good i.

Price setting

As in the model of Calvo (1983), we assume that prices are sticky. Each producer of differentiated final good changes its price at a given date in a rational way with a constant probability of $1-\gamma_d$. The price chosen by firm i in this period remain unchanged T-t periods in the future, with a probability γ_d.If a firm cannot re-optimize its price at the given date, it will follow a rule of thumb. Rule of thumb price setters' increase their prices by the expected underlying rate of inflation, as in Yun (1996), and to some extent by the difference between the past actual and perceived underlying inflation rates, similarly to Christiano et al. (2005). If the firm is not allowed to change its price for t periods ahead the updated price will be:

$$P_T(i) = P_t(i)\Pi_{T,t}^I = P_t(i)\Pi_T^I \Pi_{T-1}^I \dots \Pi_t^I \tag{3.35}$$

where $\Pi_T^I = \left(\frac{\Pi_t}{\overline{\Pi}_t}\right)^{\vartheta_d} \overline{\Pi}_{t+1}$, $\Pi_t = \frac{P_t}{P_{t-1}}$, ϑ_d represents the degree of indexation according to past inflation, and $\overline{\Pi}_t$is the perceived inflation trend.

If the firm i can to re-optimize its price, then it does so by solving the following maximization problem: (3.36)

$$max \sum_{T=t}^{\infty} (\beta\gamma_d)^{T-t} \left(\frac{(\Lambda_T^o)/P_T}{(\Lambda_t^o)/P_t}\right) V_T(P_t(i))$$

where $V_T(P_t(i))$ is the firm profit, Λ_T^o is the marginal utility of consumption of optimizing consumers.

From the first order conditions of the problem, we obtain that the re-optimized aggregate price can be described by the following recursive form:

$$\mathcal{P}_t = \left(\frac{\theta}{\theta-1}\frac{\mathcal{L}_t^1}{\mathcal{L}_t^2}\right) \tag{3.37}$$

where $$\mathcal{L}_t^1 = \Lambda_t^o y_t mc_t + \gamma_d\ \beta E_t\left[\left(\frac{\Pi_{t+1}}{\Pi_t^I}\right)^{\theta}\mathcal{L}_{t+1}^1\right] \tag{3.38}$$

$$\mathcal{L}_t^2 = \Lambda_t^o y_t + \gamma_d\ \beta E_t\left[\left(\frac{\Pi_{t+1}}{\Pi_t^I}\right)^{\theta-1}\mathcal{L}_{t+1}^2\right] \tag{3.39}$$

From the definition of the aggregate price index, the law of motion of the aggregate price index can be shown to be as: (3.40)

$$\mathcal{P}_t^{1-\theta} = \frac{1-\gamma_d\left(\frac{\Pi_{t+1}}{\Pi_t^I}\right)^{\theta-1}}{1-\gamma_d}$$

Finally, the log-linear inflation Phillips curve is given by: (3.41)

$$\widehat{\pi_t} = \frac{(1-\gamma_d)(1-\beta\gamma_d)}{\gamma_d(1+\beta\vartheta_d)}\{mc_t + \xi_t^d\} + \frac{\beta}{(1+\beta\vartheta_d)}E_t\widehat{\pi_{t+1}} + \frac{\vartheta_d}{(1+\beta\vartheta_d)}\widehat{\pi_{t-1}}$$

The exporting firms buy a domestic good and transform it into a differentiated export good which is sold on foreign market, which leads to the exporting firms being the sole supplier of differentiated goods. The marginal cost of an exporting firm is the price paid for domestic good (P_t). The external sector is represented in an ad hoc manner and the demand for export goods is given by: (3.42)

$$x_t = \left(x_{t-1}^{h_x}\right)(1+\eta_t^x)P_t^{xs^{-\theta_{xs}}}$$

where h_x is the export smooth parameter, η_t^x is a shock, θ_{xs} denotes the export price elasticity, P_t^{xs} is the price index of exported goods denominated in foreign currency

The exporters set their prices in a similar way as the producers of final goods do and the Phillips curve for export price inflation takes the following form: (3.42)

$$\widehat{\pi_t^{xs}} = \frac{(1-\gamma_x)(1-\beta\gamma_x)}{\gamma_x(1+\beta\vartheta_x)}\{-P_t^{xs} - q_t + \xi_t^x\} + \frac{\beta}{(1+\beta\vartheta_x)}E_t\widehat{\pi_{t+1}^{xs}} + \frac{\vartheta_x}{(1+\beta\vartheta_x)}\widehat{\pi_{t-1}^{xs}}$$

and $\widehat{\pi_t^{xs}} = \frac{P_t^{xs}}{P_{t-1}^{xs}}$.

3.4 Monetary policy

The central bank sets nominal interest rates following a Taylor type rule. This simple feedback rule assumes that monetary policy responds to inflation, output gap and nominal exchange rate: (3.43)

$$1 + i_t = (1 + i_{t-1})^{\zeta_i}(1 + \pi_t)^{\zeta_\pi} e_t^{\zeta_e} {gdp_t}^{\zeta_{gdp}}$$

where ζ_i denotes the degree of interest rate smoothing, ζ_π is the weight on inflation, ζ_e is the weight of the nominal exchange rate, ζ_{gdp} denotes the weight of the GDP and e represent the nominal exchange rate.

$$rev_t = exp_t + t_t - \left(\frac{1 + i_t}{1 + \pi_t} - 1\right) b_{t-1}$$

3.5 Fiscal policy

In the model of Baksa, Benk and Jakab (2010), the government budget constraint is given by: (3.44)

$$\tau_t^c c_t + \left(\tau_t^l + \tau_t^s\right) w_t L_t + ot_t = tr_t + g_t + b_t - \left(\frac{1 + i_t}{1 + \pi_t}\right) b_{t-1}$$

In order to match the data series to model I defined some extra variables as follows. I considered that the budget revenues are obtained collecting VAT, income tax and social contributions paid by employees and employers but also by collecting a lump sum tax:

$$rev_t = pit_t + sc_t + vat_t + ot_t \quad (3.45)$$

where $vat_t = \tau_t^c c_t$, $pit_t = \tau_t^l w_t L_t$, $sc_t = \tau_t^s w_t L_t$ and ot_t is a first order autoregressive process: $ot_t = \rho_{ot} ot_{t-1} + \varepsilon_{ot_t}$

The government has two types of discretionary expenditures: it provides financial transfers to the non-ricardian consumers and purchases goods and services from the private sector: (3.45)

$$exp_t = g_t + tr_t + oe_t$$

where oe_t (other expenditure) is a first order autoregressive process: $oe_t = \rho_{oe} oe_{t-1} + \varepsilon_{oe_t}$

The primary balance of the budget is the difference between revenues and expenditure:

$$ps_t = rev_t - exp_t \tag{3.46}$$

The fiscal deficit and the real flow budget constraint for the fiscal authority are defined as:

$$t_t = ps_t + \left(\frac{1+i_t}{1+\pi_t} - 1\right) b_{t-1} \tag{3.47}$$

where b_t represent the government debt (government bonds in real term) calculated as accumulated deficits: (3.48)

$$b_t = b_{t-1} + t_t$$

Although there are many studies on the subject, these don't yield a consensus regarding the formulation of fiscal rules. The budget constraint itself represents a fiscal rule. There are five fiscal policy instruments and for each one, we need to define a fiscal rule designed to ensure the fiscal solvency in the model, such that government deficit to be covered by future taxes in order to satisfy the government budget constraint.

According to these rules, fiscal authority reacts to past deficits and to current output in order to fulfill its stabilizing role (or simply letting the automatic stabilizers work). Thus, fiscal policy tries to stabilize the deficits and consequently the debt level.

Tax rates[4] are modeled to allow a positive response to an increase in deficit to output ratio (the circumflexes above variables denote log-deviations from steady state): (3.49)

$$\hat{\tau}_t^i = \rho^{\tau^i} \hat{\tau}_{t-1}^i + \left(1 - \rho^{\tau^i}\right)\left(f_{\tau^i}^g \widehat{gdp_t} - f_{\tau^i}^t \hat{t}_{t-1}\right) + \varepsilon_i$$

where i={c, s, l}, ρ^{τ^i} denotes the degree of tax rate smoothing, $f_{\tau^i}^g$, $f_{\tau^i}^t$ are reaction parameters.

The government expenditure and financial transfers are assumed to follow a rule that negatively respond to an increase in deficit to output ratio: (3.50)

[4] These tax rates can be considered as effective tax rates

$$\hat{\chi}_t^i = \rho^{\chi^i}\hat{\chi}_{t-1}^i + \left(1-\rho^{\chi^i}\right)\left(-f_{\chi^i}^g\widehat{gdp_t} + f_{\chi^i}^t\hat{t}_{t-1}\right) + \varepsilon_i$$

where χ={G, TR}, ρ^{χ^i} denotes the degree of expenditure item smoothing, $f_{\chi^i}^g$,$f_{\chi^i}^t$ are reaction parameters.

3.6 Equilibrium conditions

At equilibrium, all markets clear, the demand of goods is equal with the supply. The goods market equilibrium condition follows from aggregating the individual budget constraints:

$$y_t = c_t + I_t + g_t + DP_t^x x_t + \Psi\big(u_t(j)\big)k_{t-1}(j) \tag{3.51}$$

where $c_t$is the aggregated consumption of the two types of consumers, $\Psi\big(u_t(j)\big)k_{t-1}(j)$ is the volume of capital not used in production and $DP_t^x$is the dispersion of export prices.

In order to determine the total GDP of the economy, it still needs to be adjusted by the export revenues, import expenses (calculated in domestic currency) and the expenses used for export production: (3.52)

$$gdp_t = y_t + q_t P_t^{xs} x_t - q_t P_t^{ms} m_t - x_t$$

Economic agents may accumulate debts against foreign partners, so net foreign assets' market clears when the net position of export/import firms equals domestic investment in foreign bonds. The evolution of net foreign assets (measured in foreign currency) is given by:

$$b_t^s = (1 + i_{t-1}^*)b_{t-1}^s + P_t^{xs} x_t - P_t^{ms} m_t \tag{3.53}$$

In order to ensure stationary equilibrium we assume that foreign interest rate depends on the financial premium shock η_{pr} and on the NFA position that increases with the country's net foreign asset position as in Schmitt-Grohé-Uribe (2002):

$$(1 + i_t^*) = e^{-\upsilon(b_t - b)}\big(1 + \eta_{pr}\big) \tag{3.54}$$

Nominal exchange rate is determined by the uncovered interest rate parity:

$$\frac{1+i_t}{1+i_t^*} = \frac{e_{t+1}}{e_t} \tag{3.55}$$

Unfortunately there are no data available for worked hours in Romania. Adolfson et al. (2005) does not have an observable series of worked hours for the Euro area, so he models the employment using Calvo rigidity. He assumes that only a fraction of the firms can adjust the level of employment to the preferred amount of total labor input while the rest of the firms keep employment from the last period. The following equation links the employment to labor supplied by households: (3.56)

$$\Delta\tilde{n}_t = \beta E_t[\Delta\tilde{n}_{t+1}] + \frac{(1-\gamma_n)(1-\beta\gamma_n)}{\gamma_n}\left(\tilde{L}_t - \tilde{n}_t\right) + \tilde{\varepsilon}_t^n$$

4. Estimation

4.1 Estimation procedure

In this section I introduce some basic information about Bayesian estimation. This method can be defined as a bridge between calibration and maximum likelihood. The priors are weights on the likelihood function in order to give more importance to certain areas of the parameter subspace.

The posterior distribution is linked with the prior and likelihood function by Bayes' rule (see ***Annex II***) as follows:

$$Posterior\ information = prior\ information * sample\ information$$

The model estimation was performed using DYNARE toolbox with MATLAB R2010a. Dynare put the model in a state-space form and use the Kalmann filter to find the log-likelihood function $ln\, L(\theta|Y_T^*)$, where θ is a vector of parameters and Y_T^* is the set of observable variables. Then, using the specified priors and the likelihood function, Dynare compute the log posterior kernel (the posterior density function of parameters):

$$ln\, K(\theta|Y_T^*) = ln\, L(\theta|Y_T^*) + ln\, p(\theta)$$

In the next step, the log posterior kernel is maximized using a numerical optimization routine and is calculated the mode of the posterior density function; then, the posterior kernel is simulated using a sampling-like or Monte Carlo method such as the Metropolis-Hastings, a "rejection sampling algorithm" which generates a sequence of samples (Markov Chains) from a distribution that is unknown.

The posterior distribution was simulated using two MH chains with 100,000 draws each and scale parameter of 0.35 that imply an acceptation rate of 23%. The convergence of MH algorithm was checked using the method of Brooks & Gelman (1998).

4.2. Data

The model parameters were estimated using quarterly data of the Romanian economy which cover the period of 2000:Q1 - 2011:Q4. Unfortunately, Baksa, Benk and Jakab (2010) does not specify in their article what data series used in estimation, so I followed Iwata (2009) and Kliem (2011) to match the data to model. Iwata (2009) considered that the tax rates “can be appropriately approximated by the aggregate effective tax rates, which are computed using macroeconomic data, such as national accounts and revenue statistics”. For Romanian economy it is difficult to calculate these effective tax rates, so I chose to use as observable series the amounts collected under these taxes.

The set of eighteen variables, considered as observables, includes:

- Ordinary series used in literature: GDP, households’ consumption, investment, export, import, wage. These data are real, seasonally adjusted, logged and detrended with HP filter.

- Fiscal data as: public debt, budget revenues, budget expenditure, VAT, personal income tax, Social contributions paid by employees and employers, transfers and government consumption. Also, these data are real, seasonally adjusted, logged and de-trend with HP filter.

- Employment, nominal interest rate and CPI. These data are seasonally adjusted, logged and de-trend with HP filter.

The data sources and other explanations can be found in ***Annex III***.

4.3. Calibrated parameters

Some parameters were difficult to identify due to weak identification and small sample, so those were kept fixed in the estimation procedure; these coefficients can be considered as a very strict prior. Also, some parameters are directly related to the steady state values of endogenous variables.

Unfortunately, there is a lack of relevant studies for Romanian economy on this field, so the parameters were calibrated using values common to the business cycle literature.

The discount factor β was set at 0.97 (that implies a quarterly interest steady state nominal interest rate of 3%) and the depreciation rate δ was set to be 3% per quarter. Following the paper of Stork (2011) (this model was created for Czech Republic economy), the inter-temporal elasticity of consumption σ was set at 2 and the inter-temporal elasticity of labor ϕ was set to 5. The substitution elasticity between labor and imports, ρ_z is assumed to be 0.8 according to Jakab (2010), while substitution elasticity between capital and composite input ρ is set equal to 1.05. Also, the fix cost of production was set equal to 0.25 and the debt elasticity of financial premium is equal to 0.01, as in Schmitt-Grohé-Uribe (2002). The remaining parameters from Table1 were set matching values used by Baksa, Benk and Jakab (2010):

Table 1:	Calibrated parameters	value
β	discount factor	0.97
δ	depreciation rate	0.03
σ	Intertemporal elasticity of consumption	2
φ	intertemporal elasticity of labor	5
ϖ	share of ricardian households	0.75
ρ	elasticity of substitution between capital and composite input	1.05
ρ_z	elasticity of substitution between labor and imports	0.8
fix	fix cost	0.25
θ	home price elasticity	6
θ_w	elasticity of labor	3
Φ_I	investment adjustment cost	13
ψ	parameter of capital utilization	0.2
Φ_l	labor input adjustment cost	3
Φ_m	import input adjustment cost	3
$\boldsymbol{\upsilon}$	debt elasticity of financial premium	0.01

The steady state variables (the steady state shares) are calibrated using averages over the sample period 2000q1-2011q4, while the steady state values of taxation rates were set at their current levels:

Table 2.	Steady state:	values
τ_t^c	VAT	0.24
τ_t^l	Labor tax rate+social contribution tax rate (paid by employees)	0.325
τ_t^s	Social contribution tax rate (paid by employers)	0.315
D/GDP	Ratio of debt to GDP	-0.2686
T/GDP	Ratio of deficit to GDP	-0.0358
G/GDP	Share of gov. consum. to GDP	0.171
C/GDP	Share of households consumption to GDP	0.67
m/GDP	Share of imports to GDP	0.4292
x/GDP	Share of exports to GDP	0.3457
tr/GDP	Ratio of transfers to GDP	0.13
rev/gdp	Ratio of budgetary revenues to GDP	0.341
expn/gdp	Ratio of budgetary expenditure to GDP	0.3768
pit/gdp	Ratio of Pit to GDP	0.066
vat/gdp	Ratio of vat to GDP	0.075
sc/gdp	Ratio of social contributions to GDP	0.068
oe/gdp	Ratio of other expenditure to GDP	0.0758
i_ss	Nominal interest rate	0.0309
rk_ss	Rental fee	0.0609
a	Share of labor used in production	0.2987
α	Share of capital used in production	0.3929

Source: author's own calculation

The steady state values of those parameters implies a share of labor used in production of 0.2987 and a share of capital of 0.3929.

4.4. Prior distributions

The remaining parameters were estimated, and for each one there was a prior distribution defined. The prior distributions were selected in line with the four common distributions used in literature: Normal distribution for sign unrestricted parameters, Beta distribution for parameters between 0 and 1, Gamma and Inverse-Gamma distribution for parameters restricted to be always positive.

For habit consumption h_c, I selected a beta distribution with mean 0.7 and a standard error of 0.05, while for export smooth parameter h_x, I chose a Beta distribution with mean 0.8 (in by Baksa, Benk and Jakab (2010) it was 0.75) and a standard error of 0.01.

For Calvo parameters in domestic and export price setting equations (γ_d and γ_x), I selected a Beta distribution with mean of 0.5 and standard deviation of 0.03, while for Calvo parameter in wage price setting equation (γ_w), I chose a mean of 0.7. Thus, I assumed that prices adjust every 2 quarters, while the length of work contract is about one year.

Following Zubairy (2009), for autoregressive parameters in shock processes, I selected Beta distributions with mean of 0.7 and standard deviation of 0.05.

For parameters of the monetary policy rule, I chose the standard values proposed by Taylor: 1.5 for the inflation coefficient ζ_π, 0.5 for GDP coefficient ζ_{gdp} and the standard deviation were set at 0.05. For interest rate smoothing ζ_i, I chose a Beta distribution with mean 0.7 and standard deviation of 0.5.

There were defined fiscal rules for labor tax rate, VAT, social contribution tax rate, transfers and government spending. According to these rules, fiscal authority reacts to past deficits and to current output in order to fulfill its stabilizing role (or simply letting the automatic stabilizers work).

Regarding the fiscal rule parameters, there is a lack of consensus in choosing the prior means. I considered that the coeficients (which can be interpreted as elasticities) that capture the response to government deficit are Inverse-Gamma distributed with mean 0.05 and standard deviation of 0.1, just as in Baksa, Benk and Jakab. This is because the Inverse-Gamma distribution allows a positive respond to an increase in deficit to output ratio in order to ensure fiscal solvency.

Kliem and Kriwoluzky (2010) argue in their paper that "the choice of the Inverse-Gamma distribution is motivated by the estimation results of Blanchard and Perotti (2002) which suggest a positive elasticity between tax revenues and output implying also a positive elasticity of the total households' average tax rate with output. But, this does not imply that each tax instrument faces a positive elasticity with output." Following this approach, I deviated from the standard prior choice and selected a normal distribution for these parameters with mean 0 and standard deviation of 0.2.

4.5. Estimation results

The model estimation was performed using DYNARE toolbox with MATLAB R2010a. I used two parallel MH chains of 100000 replications each and I kept 20000 draws to build the posterior distributions. The graphs of prior distributions, posterior distributions and mode are reported in the ***Annex IV***. These graphs indicate that the posterior distributions are well approximated around the posterior mode. The prior and posterior density graphs differ and the data series used in estimation are informative. The following table summarizes prior distributions, posterior means, and 90% credible intervals (or Bayesian confidence intervals) of the parameters:

Table 3:

Simbol	**Description**	**Prior distribution**	**Mean**	**Standard error**	**Posterior mean**	**Conf. Interval**	
Utility function parameters							
h_c	habit formation	beta	0.7	0.05	0.8803	0.849	0.9118
Prices and wage settings parameters							
γ_x	Calvo export prices	beta	0.5	0.03	0.4935	0.4439	0.5462
γ_w	Calvo wages	beta	0.7	0.01	0.6763	0.6608	0.6924
γ_d	Calvo domestic prices	beta	0.5	0.03	0.5112	0.4961	0.5289
γ_n	Calvo employment	beta	0.5	0.03	0.4211	0.3735	0.4705
ϑ_w	indexation rate wages	beta	0.5	0.1	0.1173	0.0714	0.1666
ϑx	indexation rate export prices	beta	0.5	0.1	0.4965	0.4086	0.5894
ϑ_d	indexation rate domestic prices	beta	0.5	0.1	0.5775	0.5016	0.6626
Interest rate coefficients							
ζ_i	interest smooth	norm	0.7	0.05	0.4944	0.4342	0.5531
ζ_π	inflation policy rule	norm	1.5	0.05	1.3795	1.2974	1.4561
ζ_e	exchange rate	norm	0.01	0.01	0.0017	0	0.0035
ζ_{gdp}	GDP	norm	0.5	0.05	0.6092	0.5348	0.6854
Inflation learning							
ρ_π	trend inflation persistence	beta	0.9	0.05	0.7994	0.6936	0.9064
g	Gain	beta	0.2	0.05	0.0596	0.0312	0.0868

Export							
h_x	export smoothing	beta	0.8	0.01	0.8074	0.7903	0.8231
θ_{xs}	Elasticity	beta	0.3	0.05	0.3627	0.3159	0.4098
Autoregressive parameters							
$\rho_{P_{ms}}$	inport prices	beta	0.7	0.05	0.7235	0.6229	0.8107
ρ_{xs}	export demand	beta	0.7	0.05	0.7317	0.6438	0.815
ρ_a	productivity	beta	0.7	0.05	0.691	0.6036	0.7733
ρ_{pr}	financial premium	beta	0.7	0.05	0.5097	0.4453	0.5772
ρ_r	Interest	beta	0.7	0.05	0.5528	0.4776	0.632
ρ_{Tob}	Tobin factor	beta	0.7	0.05	0.5741	0.5133	0.6341
ρ_c	consumption preference	beta	0.7	0.05	0.68	0.5983	0.7591
ρ_{v_w}	Wage	beta	0.7	0.05	0.7099	0.626	0.7925
ρ_{v_x}	export	beta	0.7	0.05	0.6934	0.6119	0.7741
ρ_{v_d}	domestic price	beta	0.7	0.05	0.656	0.5784	0.7383
ρ_{Inv}	investments	beta	0.7	0.05	0.9041	0.877	0.9327
Autoregressive parameters of fiscal elements							
ρ_{τ_c}	VAT	beta	0.7	0.05	0.6975	0.6161	0.78
ρ_{τ_l}	PIT	beta	0.7	0.05	0.6946	0.6157	0.7776
ρ_{τ_s}	SC	beta	0.7	0.05	0.6965	0.6194	0.7805
ρ_g	government expenditure	beta	0.7	0.05	0.6965	0.6073	0.7804
ρ_{tr}	Transfers	beta	0.7	0.05	0.7008	0.6272	0.7819
ρ_{ot}	Lump sum tax	beta	0.7	0.05	0.6942	0.6049	0.7753
ρ_{oe}	other expenditures	beta	0.7	0.05	0.692	0.6062	0.7695
Reaction function parameters							
$f^t_{\tau^c}$	VAT to deficit	invg	0.05	0.1	0.0526	0.0143	0.0996
$f^g_{\tau^c}$	VAT to GDP	norm	0	0.2	0.0302	-0.2877	0.3518
$f^t_{\tau^l}$	PIT to deficit	invg	0.05	0.1	0.0402	0.012	0.0721
$f^g_{\tau^l}$	PIT to GDP	norm	0	0.2	-0.0053	-0.3171	0.3039
$f^t_{\tau^s}$	SC to deficit	invg	0.05	0.1	0.0364	0.0143	0.058
$f^g_{\tau^s}$	SC to GDP	norm	0	0.2	-0.0132	-0.3535	0.3386
f^t_{rt}	TR to deficit	invg	0.05	0.1	0.036	0.0131	0.0572

f_{tr}^{g}	TR to GDP	norm	0	0.2	-0.0015	-0.3262	0.3234
f_{g}^{t}	G to deficit	invg	0.05	0.1	0.0328	0.0139	0.0508
f_{g}^{g}	G to GDP	norm	0	0.2	-0.0998	-0.4052	0.2199

Source: author's own calculation

The estimated posterior mean for habit consumption h_c is 0.8884 even if the mean of the prior was set to 0.7. This result indicates that the degree of deep habit in private consumption is high, the current level of consumption being influenced by the previous consumption level. Thus, for households their standard of living is very important.

The Calvo parameter for sticky wages γ_w is estimated at 0.6752 and this implies that wages can be negotiated in an optimal way once every three quarters.

According with estimated value for price stickiness, domestic prices are set in an optimal way once every three quarters and export prices adjustment takes place every two ones. Thus, the export prices seem to be more flexible than domestic prices.

The domestic price indexation parameter is estimated at 0.794, indicating that the weight on lagged inflation from Phillips price curve $\frac{\vartheta_d}{(1+\beta\vartheta_d)}$ is 0.44, while the export price indexation parameter implies a weight $\frac{\vartheta_x}{(1+\beta\vartheta_x)}$ approximated at only 0.33. The posterior mean of wage indexation parameter is 0.1737, implying that the weight on lagged wage inflation from wage setting equation, $\frac{\vartheta_w}{(1+\beta\vartheta_w)}$ is only 0.1486. Baksa, Benk and Jakab (2010) argue that the indexation parameters should be interpreted with caution because the indexation formulas imply that "both prices and wages are fully indexed to the perceived long-run component of inflation". Parameters ϑ_d and ϑ_w represent "the degree of additional indexation to the cyclical components of past price and wage inflation rates".

The estimated parameters for monetary policy rule have the expected signs and almost satisfy the Taylor principle: the response to inflation ζ_π is 1.39 while the response to output ζ_{gdp} is 0.61 but the degree of interest rate smoothing is relatively low, 0.49. Thus, the model shows that interest rate responds stronger to inflation than to output gap. Also the exchange rate parameter ζ_e has the expected sign, but statistically it seems not to be significantly different from zero.

In this model, the agents are able to learn inflation trend gradually applying an adaptive algorithm. The perceived trend of inflation depends on the current deviation of inflation trend and on the previous period inflation trend. The estimated value for learning speed parameter g is much lower than prior mean (0.06) and the trend inflation persistence ρ_π is estimated to be 0.8.

Almost all the autoregressive parameters of shocks range from 0.6 to 0.75 and are relatively close to specified prior means, indicating a high persistence of shocks in economy over time.

The estimated fiscal response coefficients to deficit level are significant. According to estimated parameters, the most responsive one to budget deficit seems to be the VAT rate ($f^t_{\tau^c}$=0.0526), followed by personal income tax rate ($f^g_{\tau^l}$=0.04); both government spending and transfers respond almost equal to deficit level.

These results are somewhat reliable, given recent measures taken by Romanian authorities in order to adjust the budgetary deficit accumulated until the end of 2009 (9% according to ESA95 methodology, 7.4% in cash basis). The Government decided in 2010 to implement a fiscal consolidation plan, mainly based on increase of VAT rate by 5 percentage points (from 19 per cent to 24 per cent) and on the temporary cut of public sector wages by 25%. Also, the level of social assistance expenditure was decreased, as well as the level of goods and services expenditure. Compared to previous year, the level of deficit decreased at 7.1% according to ESA95 standard (6.5% following cash methodology). The consolidation process was continued in 2011, and as a result the budget deficit decreased at 4.12% in cash basis.

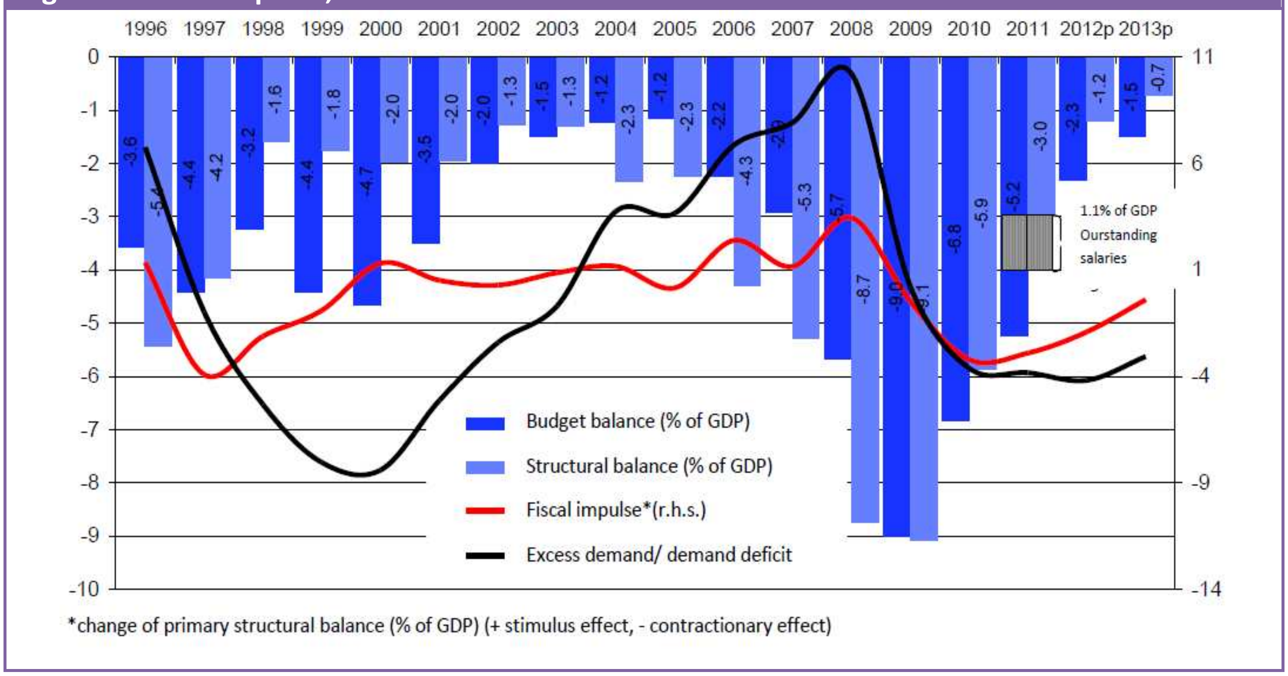
In conclusion, our results suggest that taxation of consumption and labor played an important role in stabilizing the fiscal deficit during the sample period.

The estimated fiscal response parameters to output gap seem to indicate a pro-cyclical fiscal policy, the automatic stabilizers being too weak or insufficient to stabilize the economy. On the expenditure side, the government spending reacts negatively to a change in output gap with a high degree of persistence (-0.1), while the transfers coefficient is not reliably different from zero. These results are similar with those obtained by Baksa, Benk and Jakab (2010) for Hungarian economy.

On the revenue side, the response of social contributions rate paid by employers is also negative, reflecting the high correlation between firms' activity and macroeconomic framework. The estimated coefficient of personal income tax rate seems to be not reliably different from zero; this result is somewhat explained through the lack of progressivity of wage taxes. The VAT rate is the only parameter relevant for fiscal policy stabilization.

Again, these results are not surprising because in the pre-crisis period the Romanian fiscal policy was pro-cyclical with badly consequences for the sustainability of public finances. The following graph show that the fiscal impulse was positive before 2008-2009 and contributed to overheating of the economy:

Figure 1: Fiscal impulse, structural deficit and excess demand.



Source: The Fiscal Council of Romania, Annual report 2011.

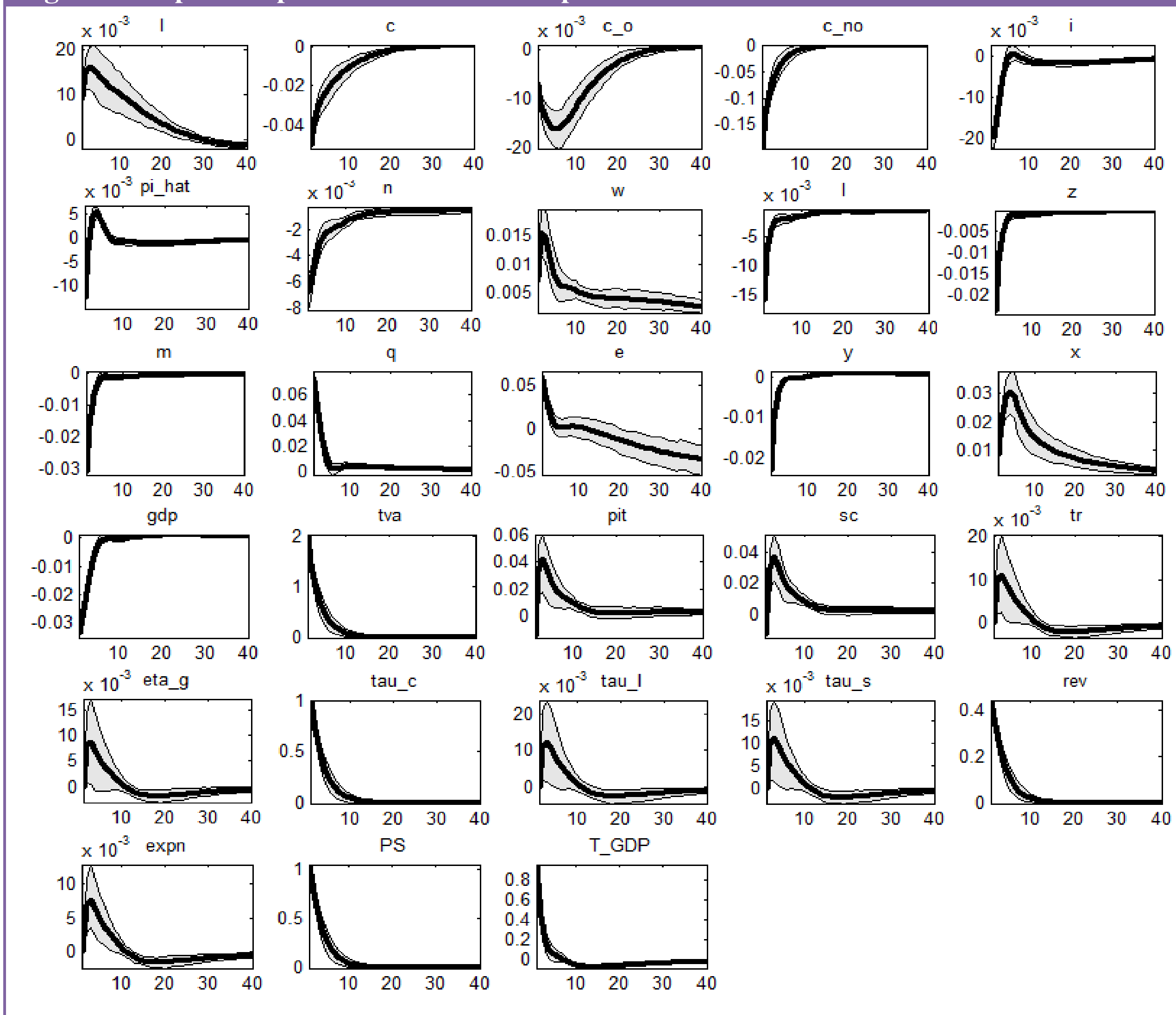
The pro-cyclicality of fiscal policy was maintained during the crisis due to the lack of fiscal space needed to stimulate the economy.

5. Irf interpretation

Using the estimated model, I tried to present in this section the macroeconomic variables' reactions to fiscal policy shocks. Impulse response functions are calculated as reactions of the endogenous variable to 1 percent increase in innovation in the initial period. The x-axis indicates quarters after the shock hits the economy and the y axis shows the variables' percentage deviation from their steady state.

The following figure shows the impulse response functions to a shock in VAT rate.

Figure 2: Impulse response functions to a one percent increase in the VAT rate.



Source: author's own calculation

Note: I – investments; c – total consumption; c_o – the consumption of ricardian type households; c_no – the consumption of liquidity constrained households; i – nominal interest rate; pi_hat – inflation; n – employment; w – wage; l – labor; z – intermediate good; m – import; q, e – real/nominal interest rate; y – final good; x – export, tva – VAT revenue; pit – PIT revenue; sc – social contribution revenue; tr – transfers; eta_g – government spending; rev – budgetary revenues; expn – budgetary expenditures; PS – primary balance; T_GDP – the deficit ratio to GDP;

For an increase in VAT rate, the consumption declines mainly due to a sharply fall in consumption of liquidity constrained households. The degree of habit formation is high, so the consumption of Ricardian type households remains almost unchanged.

As a result of consumption decline, the demand for goods decreases, as well as GDP, while the responses of interest, inflation, labor and investments are insignificant.

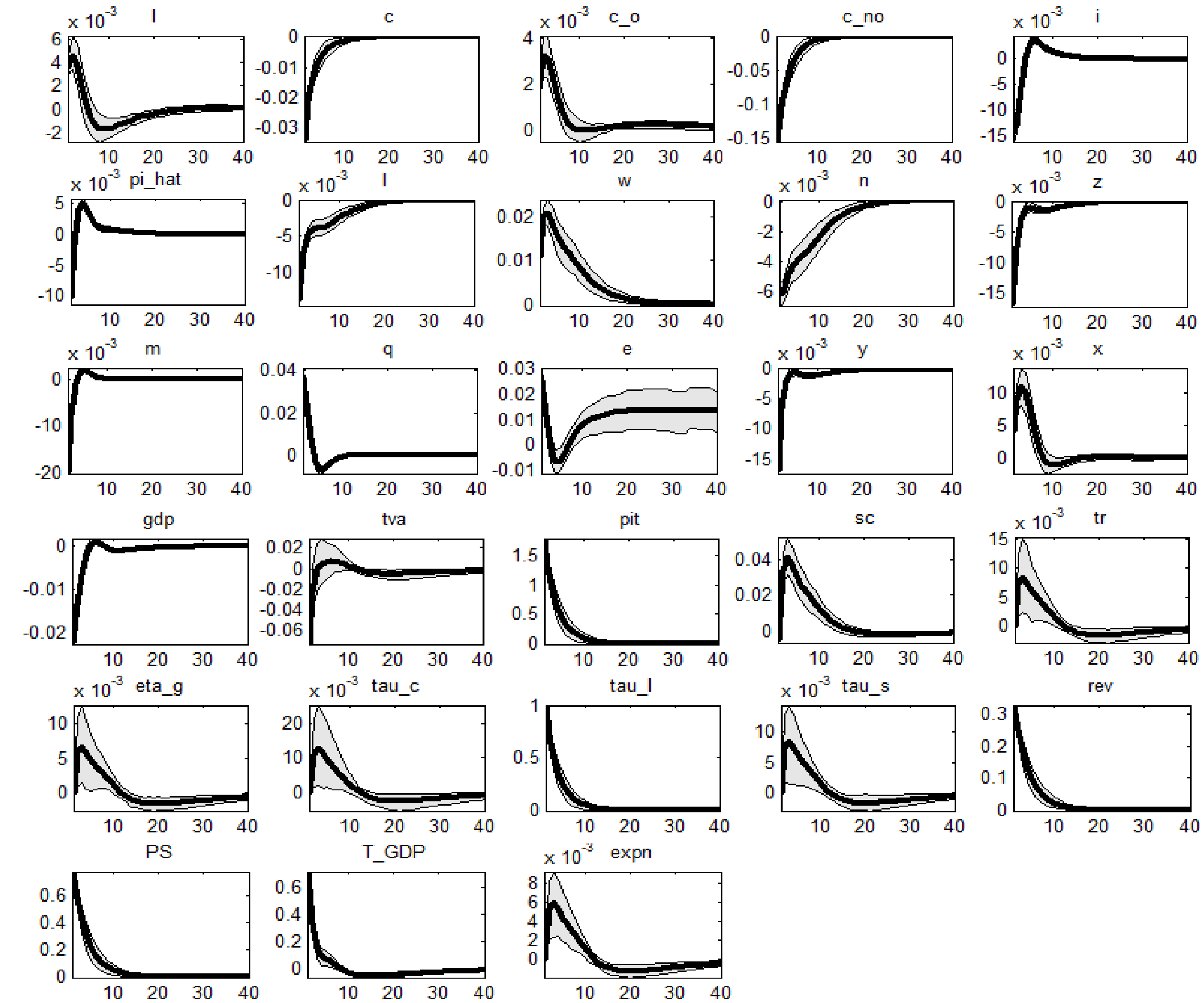
Figure 3 shows that as a response to a shock in the PIT rate (including social contribution paid by employees and personal income tax rate), consumption and output decrease on the short-run. The consumption of non-optimizers households decreases sharply while the consumption of ricardian type households remains almost unchanged, indicating a high degree of habit formation. One can observe a small shift of demand from consumption to investment goods, but this is also insignificant.

Surprisingly, an increase in labor tax rate also causes an increase in wages and this can be explained due to efforts to renegotiate work contracts.

The responses of interest, inflation, labor and investments are insignificant. At the same time, the production of intermediate and final goods appears to be unaffected by this shock.

The VAT revenue decreases due to consumption fall; also the revenue from personal income tax increases, contributing to a budget surplus accumulation.

Figure 3: Impulse response functions to a one percent increase in the PIT rate.



Source: author's own calculation

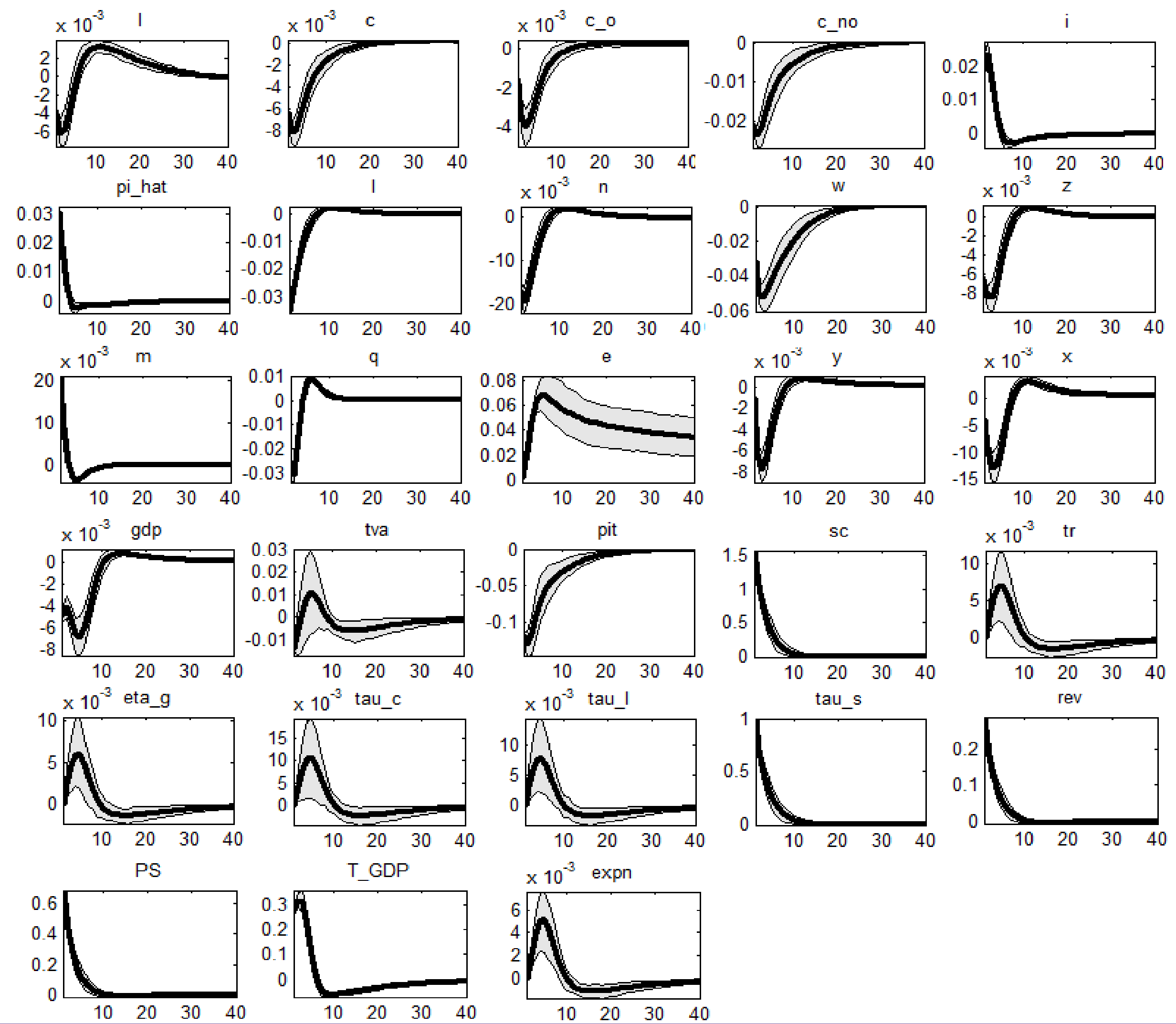
Note: I – investments; c – total consumption; c_o – the consumption of ricardian type households; c_no – the consumption of liquidity constrained households; i – nominal interest rate; pi_hat – inflation; n – employment; w – wage; l – labor; z – intermediate good; m – import; q, e – real/nominal interest rate; y – final good; x – export, tva – VAT revenue; pit – PIT revenue; sc – social contribution revenue; tr – transfers; eta_g – government spending; rev – budgetary revenues; expn – budgetary expenditures; PS – primary balance; T_GDP – the deficit ratio to GDP;

The impulse response functions to a one percent increase of social contribution rate (paid by employer) can be seen in **Figure 4**. This shock has some implications in firms' economic activity. First of all, firms try to minimize their costs, so wages fall on impact and then slowly rise at steady-state value; secondly, labor demand decreases as well as employment. Thirdly, producers will try to maintain the same profit rate, so they will increase prices and, as a result, the interest rate will increase.

Again, the consumption of ricardian type households remains almost unchanged and the total consumption is insignificantly influenced even if the consumption of non-optimizers agents decreases. Thus, the demand for goods and services remains approximately the same. Compared to a shock in PIT rate, the response of GDP is not statistically significant from zero.

The revenue from social contribution increases, but the revenue from VAT decreases (due to non-optimizers households' consumption decrease) as well as PIT revenue (due to wages decrease).

Figure 4: Impulse response functions to a one percent increase in the Social Contrib. rate.



Source: author's own calculation

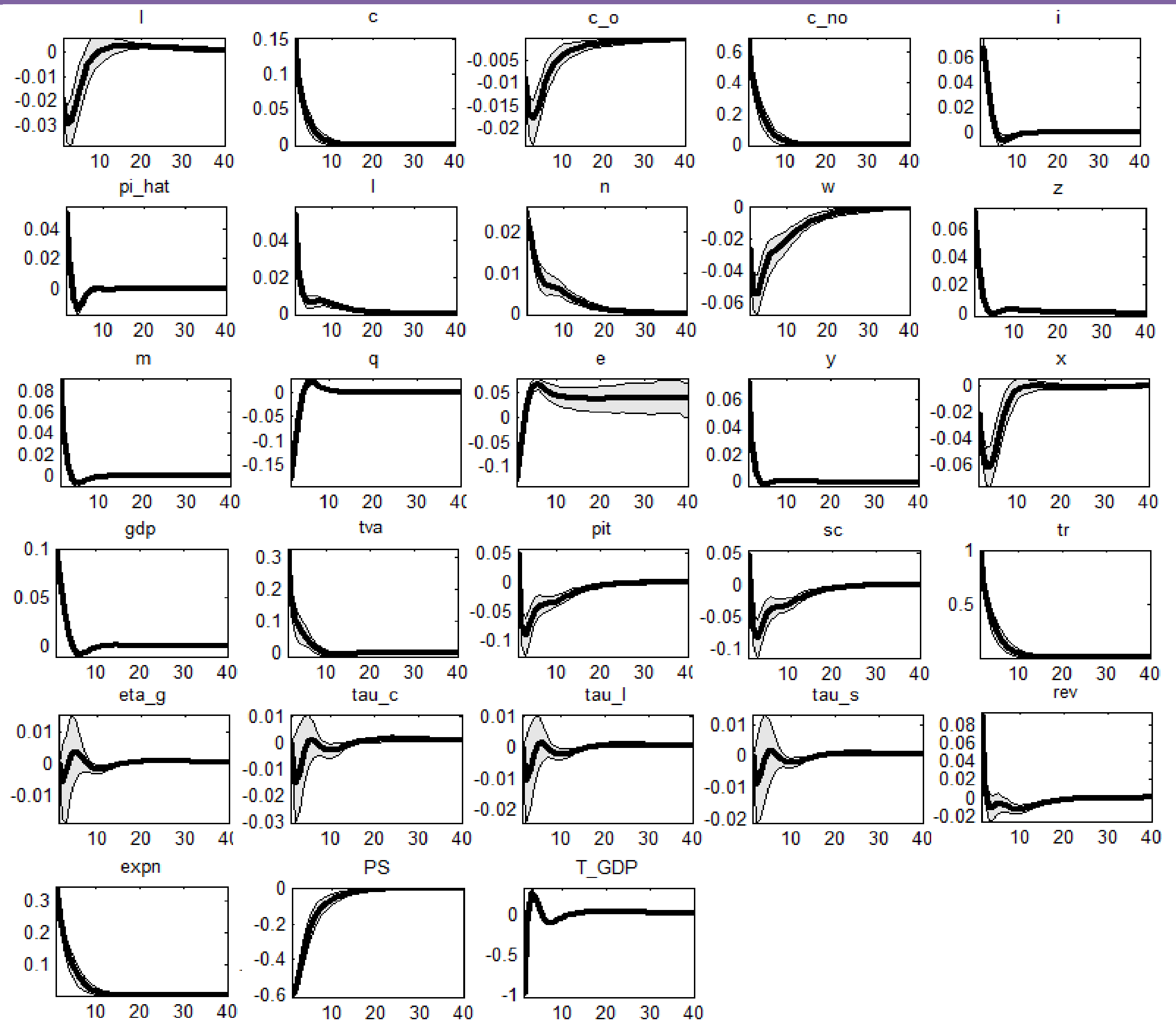
Note: I – investments; c – total consumption; c_o – the consumption of ricardian type households; c_no – the consumption of liquidity constrained households; i – nominal interest rate; pi_hat – inflation; n – employment; w – wage; l – labor; z – intermediate good; m – import; q, e – real/nominal interest rate; y – final good; x – export, tva – VAT revenue; pit – PIT revenue; sc – social contribution revenue; tr – transfers; eta_g – government spending; rev – budgetary revenues; expn – budgetary expenditures; PS – primary balance; T_GDP – the deficit ratio to GDP;

In **Figure 5** we present the responses to an increase in transfers. Increasing transfers has a strongly positive effect on non-optimizers households' consumption. The consumption of ricardian type consumers declines, but the total consumption rise.

Regarding the wages' dynamics, Iwata (2009) argues that their path is a sum of two effects: "both price stickiness and inclusion of non-Ricardian households induce a real wage increase after a government spending shock, whereas wage stickiness and distortionary taxation reduce the wage increase". Also, he argues that "real wages decline after a government spending shock, in order to meet labor supply increase in basic neoclassical models." In conclusion, the increase of wages can be explained by wage stickiness and distortionary taxation.

After an increase in transfers, one can see strong crowding out effects on investments. Also, the supply of final and intermediate goods increases as well as output.

Figure 5: Impulse response functions to a one percent increase in transfers.

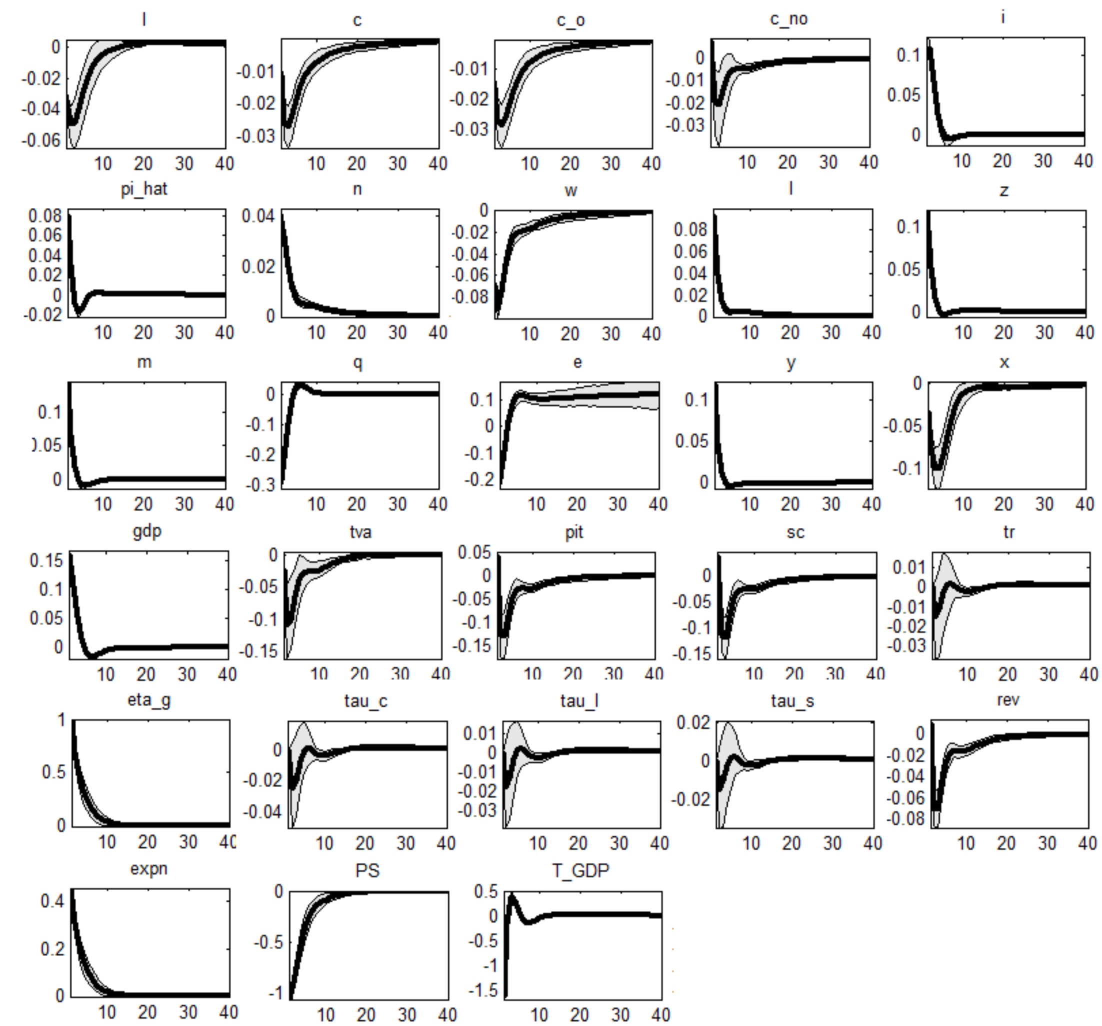


Source: author's own calculation

Note: I – investments; c – total consumption; c_o – the consumption of ricardian type households; c_no – the consumption of liquidity constrained households; i – nominal interest rate; pi_hat – inflation; n – employment; w – wage; l – labor; z – intermediate good; m – import; q, e – real/nominal interest rate; y – final good; x – export, tva – VAT revenue; pit – PIT revenue; sc – social contribution revenue; tr – transfers; eta_g – government spending; rev – budgetary revenues; expn – budgetary expenditures; PS – primary balance; T_GDP – the deficit ratio to GDP;

Figure 6 shows the impulse response functions to a shock in government spending. The model is not in agreement with specific literature (for example, Blanchard and Perotti (2002)) which argues a positive effect on consumption and wages at an increase in government expenditures. Even so, one can identify a weakly Keynesian multiplier effect on non-optimizers' consumption.

Figure 6: Impulse response functions to a one percent increase in government spending.



Source: author's own calculation

Note: I – investments; c – total consumption; c_o – the consumption of ricardian type households; c_no – the consumption of liquidity constrained households; i – nominal interest rate; pi_hat – inflation; n – employment; w – wage; l – labor; z – intermediate good; m – import; q, e – real/nominal interest rate; y – final good; x – export, tva – VAT revenue; pit – PIT revenue; sc – social contribution revenue; tr – transfers; eta_g – government spending; rev – budgetary revenues; expn – budgetary expenditures; PS – primary balance; T_GDP – the deficit ratio to GDP;

But, in the short run the decrease in optimizers' consumption offsets the increase in non-optimizers' consumption. Thus, after an increase in government spending, we can see strong crowding out effects on private consumption and investment. The government's spending is financed by a rise in taxes and this affects the marginal return on labor causing a decrease of after tax wages. Thus, according with Iwata (2009), these kinds of shocks "generate a negative wealth effect, which induces households to increase the labor supply and to decrease consumption".

Government demand offsets the decline of private demand and, as a result, the supply of final and intermediate goods increases, as well as output, inflation rate and interest rise and also the level of budgetary deficit grow sharply.

6. Conclusions

In this paper,I used and adjusted the model created by Baksa, Benk and Jakab (2010) for the Hungarian economy according to the specific features of the Romanian economy. This model is an extended version of the DSGE model presented by Smets and Wouters (2003) and it incorporates rigidities like: habit formation, investment adjustment cost, capital utilization rate, price and wage settings as in Calvo (1983), indexation mechanisms in prices and wages. Baksa, Benk and Jakab extended the model of Smets and Wouters (2003) mainly by introducing a more developed fiscal policy block, designed to capture the shocks coming from fiscal policy decisions. Also, for each item of revenue and expenditure, a fiscal rule was implemented (a fiscal reaction function).

My contributions towards developing Baksa, Benk and Jakab's model even further can be summed up in the following three actions. First of all, I estimated the model for the Romanian economy, using Bayesian techniques. Secondly, I determined the parameters of fiscal feedback rules in order to establish if the automatic stabilizers work properly. And thirdly, I tried to analyze the impulse response functions in order to assess the effects of different fiscal policy measures on the most important macroeconomic variables.

My main findings can be summarized as follow:

The degree of deep habit in private consumption is high, the current level of consumption being influenced by the previous consumption level. Thus, for households, their standard of living is very important.

The Calvo parameter for sticky wages implies that wages can be negotiated in an optimal way once every three quarters. Also, according with the estimated value for price stickiness, domestic prices are set in an optimal way once every three quarters and export prices adjustment takes place every two ones. These results are consistent with the empirical findings from other studies.

The estimated parameters for monetary policy rule have the expected signs and almost satisfy the Taylor principle.

My results suggest that taxation of consumption and labor played an important role in stabilizing the fiscal deficit during the sample period. According to estimated parameters, the most responsive one to budget deficit seems to be the VAT rate, followed by personal income tax rate. These results are somewhat reliable, given recent measures taken by Romanian authorities in order to adjust the budgetary deficit accumulated until the end of 2009.

The estimated fiscal response parameters to output gap seem to indicate a pro-cyclical fiscal policy, the automatic stabilizers being too weak or insufficient to stabilize the economy. On the expenditure side, the government spending reacts negatively to a change in output gap with a high degree of persistence (-0.1), while the transfers coefficient is not reliably different from zero. These results are similar with those obtained by Baksa, Benk and Jakab (2010) for Hungarian economy. On the revenue side, the response of social contributions rate paid by employers is also negative, reflecting the high correlation between firms' activity and macroeconomic framework. Again, these results are not surprising because in the pre-crisis period, the Romanian fiscal policy was pro-cyclical with bad consequences for the sustainability of public finances.

Regarding the analyses of IRF, some important conclusions can be formulated. First of all, a shock in VAT rate has negative effects on total consumption, mainly due to a sharply fall in consumption of liquidity constrained households. Secondly, the degree of habit formation is high, so the consumption of Ricardian type households remains almost unchanged. Surprisingly, an increase in labor tax rate also causes an increase in wages and this can be explained due to efforts to renegotiate work contracts.

Also, the shocks in social contribution rate (paid by employer) have some implications in firms' economic activity. First of all, firms try to minimize their costs, so wages fall on impact and then slowly rise at steady-state value; secondly, labor demand decreases as well as employment. Thirdly, producers will try to maintain the same profit rate, so they will increase prices and, as a result, the interest rate will increase.

Increasing transfers has a strongly positive effect on non-optimizers households' consumption. After an increase in transfers, one can see strong crowding out effects on investments. Also, the model is not in agreement with specific literature (for example, Blanchard and Perotti (2002)) which argues a positive effect on consumption and wages as a result of an increase in government expenditures. Even so, one can identify a weakly Keynesian multiplier effect on non-optimizers' consumption.

This paper is a small step toward estimating the fiscal policy behavior based on a DSGE model that uses quarterly fiscal data. But some issues remain that should be pursued. The fiscal policy block should provide a better disaggregation on the fiscal expenditure side (including some components like public investment, public purchases of goods and services or public sector wage bill). As further work, my estimated model could serve in variance decomposition analysis and also, the model can be used in forecasting observable variables.

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Annexes

Annex I: The loglinearized equations around their steady state.

Source: author's own calculation

1. Accumulation of capital

$$k_t = (1-\delta)k_{t-1} + \delta I;$$

2. Euler equation

$$c_t^o = \left(\frac{1-h_c}{\sigma(1+h_c)}\right) * \left(\eta^c - \eta^{c(t+1)}\right) + \left(\frac{h_c}{1+h_c}\right) c_{t+1}^o + \left(\frac{1}{1+h_c}\right) c_{t+1}^o + \left(\frac{1-h_c}{\sigma(1+h_c)}\right) * (\pi_{t+1} - i_t) + \left(\frac{1-h_c}{\sigma(1+h_c)}\right)\left(\frac{\tau_{c_{ss}}}{1+\tau_{c_{ss}}}\right)(\tau_{t+1}^c - \tau_t^c);$$

3. Tobin-Q

$$Q_t = -\phi_I I_{t-1} + \phi_I(1+\beta)I_t - \beta\phi_I I_{t+1} + \phi_I(\eta_t^I - \eta_{t+1}^I);$$

4. No-arbitrage condition

$$i_t - \pi_{t+1} + Q_t = \left(\frac{1}{1-\delta+rk_{ss}}\right)\left((1-\delta)Q_{t+1} + rk_{ss}r_{t+1}^k + \eta_{Tob}\right);$$

5. Definition of rental fee

$$r_t^k = \left(\frac{1}{\psi}\right)u_t;$$

6. Constraint of non-optimizers

$$\frac{\tau_{ss}^c}{1+\tau_{ss}^c}\tau_t^c + c_t^{no} = \left(\frac{1}{(1+\tau_{ss}^c)c_{ss}^{no}}\right)\left((1-\tau_{ss}^l)l_{ss}w_{ss}(w_t + l_t) - \tau_{ss}^l w_{ss} l_{ss}\tau_t^l + \left(\frac{tr_{ss}}{1-\varpi}\right)tr_t\right);$$

7. Aggregate labour supply, New Keynesian Phillips Curve by nominal wage rigidity

$$\widehat{\pi_t^w} = \frac{(1-\gamma_w)(1-\beta\gamma_w)}{\gamma_w(1+\theta_w\varphi)(1+\beta\vartheta_w)}\left\{\varphi L_t - w_t + \eta_t^l + \frac{\sigma}{1-h}\left(\tilde{c}_t^l - h\tilde{c}_{t-1}^l\right) + \frac{\tau^c}{1+\tau^c}\tau_t^c + \frac{\tau^l}{1+\tau^l}\tau_t^l + \xi_t^w\right\} + \frac{\beta}{(1+\beta\vartheta_w)}E_t\widehat{\pi_{t+1}^w} + \frac{\vartheta_w}{(1+\beta\vartheta_w)}\widehat{\pi_{t-1}^w}$$

8. Definition of wage inflation

$$\pi_t^w = w_t - w_{t-1} + \widehat{\pi_t};$$

9. Definition of c_l

$$\tilde{c}_t^l = \frac{\varpi^o (c^o)^{-\sigma} \widetilde{c_t^o} + \varpi^{no} (c^{no})^{-\sigma} \widetilde{c_t^{no}}}{\varpi^o (c^o)^{-\sigma} + \varpi^{no} (c^{no})^{-\sigma}}$$

10. Labour demand

$$l_t = \rho_z \left(w_t^z - \left(\frac{\tau_{ss}^s}{1 + \tau_{ss}^s} \right) \tau_t^s - w_t - \phi_l l_t \right) + z_t;$$

11. Import demand

$$m_t = \rho_z (w_t^z - q_t - P_t^{ms} - \phi_m m_t) + z_t;$$

12. Marginal cost of composite input

$$w_t^z = a \left(\left(\frac{\overline{w}_{ss}}{w_{ss}^z} \right)^{1-\rho_z} \right) \left(\left(\frac{\tau_{ss}^s}{1 + \tau_{ss}^s} \right) \tau_t^s + w_t + \phi_l l_t \right) + (1 - a) \left(\left(\frac{qpms_{ss}}{w_{ss}^z} \right)^{1-\rho_z} \right) (q_t + P_t^{ms} + \phi_m m_t);$$

13. Import price

$$P_t^{ms} = \eta_t^{Pms};$$

14. Marginal cost of production (composite and capital)

$$mc_t = \alpha \left(\left(\frac{rk_{ss}}{mc_{ss}} \right)^{1-\rho} \right) rk_t + (1 - \alpha) \left(\left(\frac{w_{ss}^z}{mc_{ss}} \right)^{1-\rho} \right) w_t^z - \eta_t^a;$$

15. Capital demand

$$u_t + k_{t-1} = \rho mc_t - \rho rk_t + \left(\frac{1}{DP + fix} \right) (y) - (1 - \rho) \eta_t^a;$$

16. Composite demand

$$z_t = \rho mc_t - \rho w_t^z + \left(\frac{1}{DP + fix} \right) (y) - (1 - \rho) \eta_t^a;$$

17. Aggregate supply of domestic product, New Keynesian Phillips Curve by domestic nominal price rigidity

$$\widehat{\pi_t} = \frac{(1 - \gamma_d)(1 - \beta\gamma_d)}{\gamma_d (1 + \beta\vartheta_d)} \{mc_t + \xi_t^d\} + \frac{\beta}{(1 + \beta\vartheta_d)} E_t \widehat{\pi_{t+1}} + \frac{\vartheta_d}{(1 + \beta\vartheta_d)} \widehat{\pi_{t-1}}$$

18. Aggregate supply of export, New Keynesian Phillips Curve by nominal export price rigidity

$$\widehat{\pi_t^{xs}} = \frac{(1-\gamma_x)(1-\beta\gamma_x)}{\gamma_x(1+\beta\vartheta_x)}\{-P_t^{xs} - q_t + \xi_t^x\} + \frac{\beta}{(1+\beta\vartheta_x)}E_t\widehat{\pi_{t+1}^{xs}} + \frac{\vartheta_x}{(1+\beta\vartheta_x)}\widehat{\pi_{t-1}^{xs}}$$

19. Definition of export price

$\widehat{\pi_t^{xs}} = P_t^{xs} - P_{t-1}^{xs};$

20. Export demand

$$x_t - h_x x_{t-1} = -\theta_{xs} P_t^{xs} + s_t;$$

21. NFA

$$b_t = (1 + i_{t-1}^*)b_{t-1} + \frac{P_t^{xs} x_t}{gdp_{ss}} + \frac{P_t^{ms} m_t}{gdp_{ss}}$$

$$ca_t = b_t - b_{t-1};$$

22. Real exchange rate

$$q_t - q_{t-1} = e_t - e_{t-1} - \pi_t;$$

23. Credit supply curve

$$i_t^s = -\upsilon b_t + \eta_t^{pr};$$

24. Uncovered interest rate parity

$$i_t - i_t^s = e_{t+1} - e_t;$$

25. External demand

$$s = \eta_t^x;$$

26. Taylor rule, Monetary authority

$$i_t = \zeta_i i_{t-1} + (1-\zeta_i)\zeta_\pi \pi + (1-\zeta_i)\zeta_e e_t + (1-\zeta_i)\zeta_{gdp}\, gdp_t + \eta_t^r;$$

27. Inflation: trend and cyclical parts

$$\pi_t = \overline{\pi_t} + \widehat{\pi_t};$$

28. Inflation learning

$$\overline{\pi_t} = \left(\frac{\rho_\pi}{1+g}\right)\overline{\pi_{t-1}} + \left(\frac{g}{1+g}\right) * \pi_t;$$

29. Revenues

$$rev_{ss}rev_t = vat_{ss}vat_t + pit_{ss} * pit_t + sc_{ss}sc_t + ot_{ss}ot_t$$

$$vat_{ss}vat_t = (\tau^c_{ss}c_{ss})(\tau^c_t + c_t)$$

$$pit_{ss} * pit_t = (\tau^l_{ss}w_{ss}l_{ss}\ )(\tau^l_t + w_t + l_t)$$

$$sc_{ss}sc_t = (\tau^s_{ss}w_{ss}l_{ss})(\tau^s_t + w_t + l_t)$$

$$ot_{ss}ot_t = \rho_{ot}ot_{t-1} + \varepsilon^{ot}_t$$

30. Expenditures

$$expn_{ss}expn_t = G_{ss}G_t + tr_{ss}tr_t + oe_{ss}oe_t;$$

$$oe_{ss}oe_t = \rho_{oe}oe_{t-1} + \varepsilon^{oe}_t$$

31.Primary surplus

$$PS_{ss}PS_t = expn_{ss}expn_t - rev_{ss}rev_t;$$

32. T=Total surplus, positive - Deficit

$$T_{ss}T_t = PS_{ss}PS_t + (1 + ir_{ss})(i_{t-1} - \pi_t)D_{ss} + ir_{ss}D_{t-1};$$

33. Debt accumulation

$$D_t - D_{t-1} = T_t;$$

34. Deficit definition

$$T^{GDP}_t = T_t - gdp_t;$$

35. Fiscal reaction functions:

$$\tau^i_t = \rho^{\tau^i}\tau^i_{t-1} + \left(1 - \rho^{\tau^i}\right)\left(f^g_{\tau^i}\ gdp_t - f^t_{\tau^i}T_{t-1}\right) + \varepsilon_i$$

$$\chi^i_t = \rho^{\chi^i}\chi^i_{t-1} + \left(1 - \rho^{\chi^i}\right)\left(-f^g_{\chi^i}\ gdp_t + f^t_{\chi^i}T_{t-1}\right) + \varepsilon_i$$

36. Equilibrium in goods market

$$y_t = \left(\frac{c_{ss}}{y_{ss}}\right) c_t + \left(\frac{I_{ss}}{y_{ss}}\right) I_t + \left(\frac{G_{ss}}{y_{ss}}\right) G_t + \left(DP \frac{x_{ss}}{y_{ss}}\right) x_t + \left(\frac{rk_{ss} k_{ss}}{y_{ss}}\right) u_t;$$

37. Aggregate consumption

$$c_t = \varpi \left(\frac{c_{ss}^o}{c_{ss}}\right) c_t^o \; + (1-\varpi) \left(\frac{c_{ss}^{no}}{c_{ss}}\right) c_t^{no};$$

38. GDP definition

$$gdp_t = \left(\frac{y_{ss}}{gdp_{ss}}\right) y_t + \left(q_{ss} \frac{x_{ss}}{gdp_{ss}}\right) (q_t + P_t^{xs} + x_t) - \left(q_{ss} \frac{m_{ss}}{gdp_{ss}}\right) (q_t + P_t^{ms} + m_t) - \left(\frac{x_{ss}}{gdp_{ss}}\right) x_t + \eta_t^{gdp_{meas}} \; ;$$

39. Measurement equation of employment

$$\Delta \tilde{n}_t = \beta E_t[\Delta \tilde{n}_{t+1}] + \frac{(1-\gamma_n)(1-\beta\gamma_n)}{\gamma_n} \left(\tilde{L}_t - \tilde{n}_t\right) + \tilde{\varepsilon}_t^n$$

40. Shocks equations:

$$\eta_t^i = \rho_i \eta_{t-1} + \varepsilon_t^i;$$

Annex II.

Bayes theorem is used twice and yields the posterior density (the density of parameters knowing the data):

$$p(\theta | Y_T) = \frac{p(\theta; Y_T)}{p(Y_T)}$$

And $p(Y_T|\theta) = \frac{p(\theta; Y_T)}{p(\theta)} \Leftrightarrow p(\theta|Y_T) = p(Y_T|\theta) * p(\theta)$

Combining these identities, we can get the posterior density:

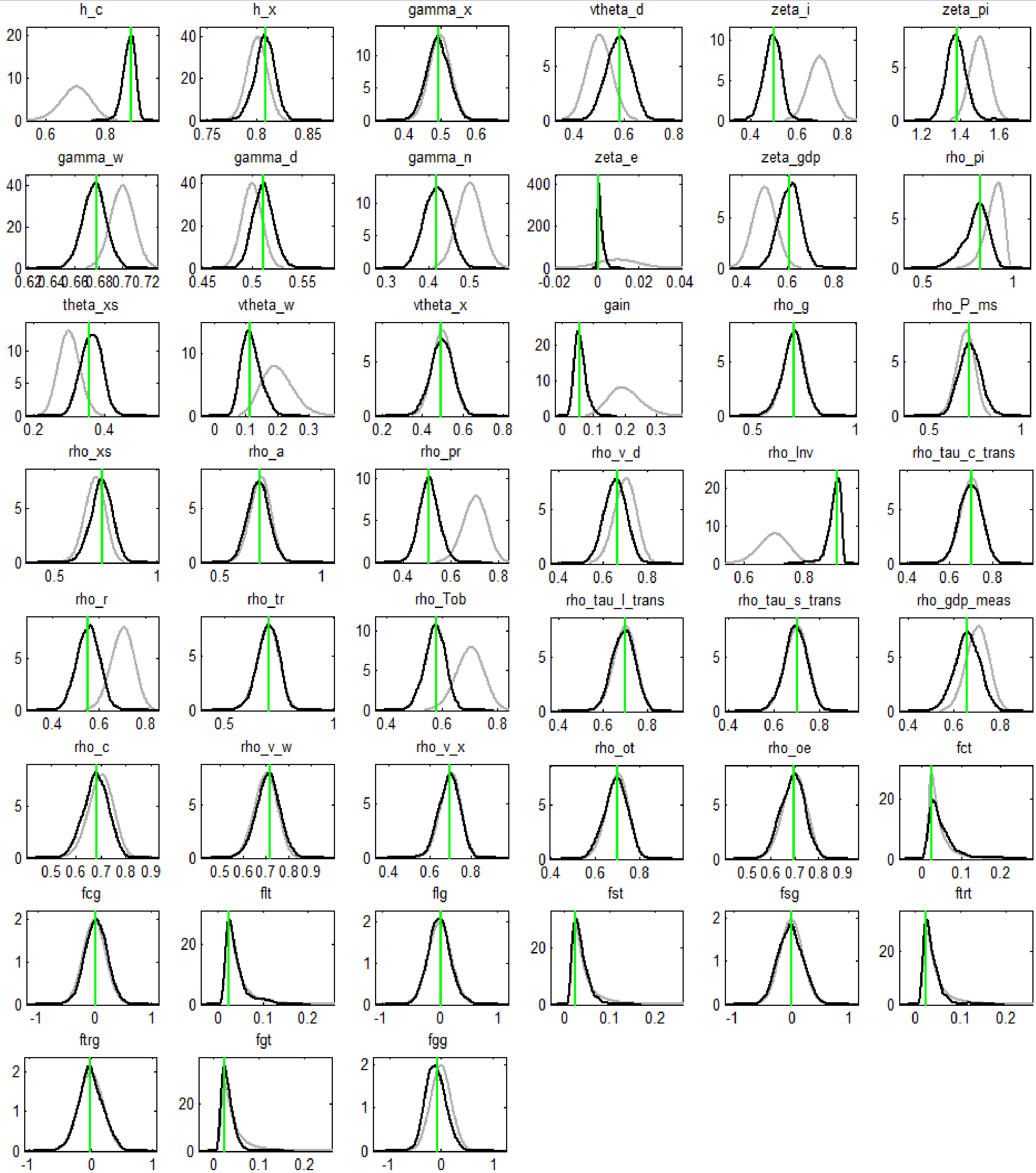
$$p(\theta_M | Y_T, M) = \frac{p(Y_T | \theta_M, M) * p(\theta_M | M)}{p(Y_T | M)}$$

Where $p(Y_T|M)$ is the marginal density conditioned by the model M, $p(\theta_M|M)$ is the prior, $p(Y_T|\theta_M, M)$ is the likelihood function that describes the density of the observed data and $p(\theta_M|Y_T, M)$ is the posterior.

Annex III: Data.

Series:	**Source:**	**Details**	**Deflated with**
GDP	Eurostat		**GDP deflator**
Investment	Eurostat	Gross fixed capital formation	**GDP deflator**
Consumption	Eurostat	Household and NPISH final consumption expenditure	**CPI**
Export	Eurostat		**CPI**
Import	Eurostat		**CPI**
Wages	INSSE	calculated as averge from montly data	**CPI**
Public debt	Eurostat		
Budget revenues	Eurostat, MFP		**GDP deflator**
Budget expenditure	Eurostat, MFP		**GDP deflator**
VAT	Eurostat, MFP		**CPI**
PIT	Eurostat, MFP	Calculated as sum between personal income tax and employees' social contributions	**GDP deflator**
Social contribution	Eurostat, MFP	Employers' actual social contributions	**GDP deflator**
Transfers	Eurostat, MFP	Social benefits	**GDP deflator**
Government spending	Eurostat	Final consumption expenditure of general government	**GDP deflator**
Employment	NBR, monthly reports	calculated as averge from montly data	
Nominal interest rate	NBR, monthly reports	Reference interest rate	
Nominal exchange rate	NBR	calculated as averge from montly data	
GDP deflator	Eurostat	Price index - percentage change on previous period, based on 2000=100 and national currency	
CPI	BNR, INSSE		
Note: all data series are seasonally adjusted, logged and detrended with HP filter			

Annex IV: prior distributions, posterior distributions and mode.



Source: author's own calculation