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STRUCTURAL ECONOMIC MODEL FOR ECUADOR: A DOLLAR-IZED AND OIL-IZED ECONOMY

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RESUMEN

El trabajo desarrolla un Modelo Estructural con las principales características macroeconómicas de la economía ecuatoriana. Modela los principales canales de transmisión de una economía pequeña, abierta y dolarizada, altamente dependiente de la producción de petróleo y las remesas del exterior. Se estima por métodos bayesianos para el período 2001-2010. El modelo permite analizar los principales riesgos que afectan el desempeño macroeconómico, incluyendo los shocks externos. También se subraya el efecto de la política fiscal así como el papel independiente y significativo del valor agregado petrolero en la economía doméstica.

Clasificación JEL: E02, O11, Q43

Palabras clave: Nuevo modelo keynesiano, Métodos bayesianos, Valor agregado petrolero, Política Fiscal.

ABSTRACT

The paper develops a Structural Model with the main macroeconomic features of the Ecuadorian economy. It models the main transmission channels of a small open and dollarized economy, highly dependent on oil production and foreign remittances. It is estimated by Bayesian methodsfor the period 2001-2010. The framework highlights the main risks affecting the macroeconomic performance, including the importance of international shocks. It also underscores the importance of the fiscal policies and the independent and significant role of the oil value added in the domestic economy.

JEL Classification: E02, O11, Q43

Keywords: New Keynesian model, Bayesian methods, Oil Value Added, Fiscal policy

STRUCTURAL ECONOMIC MODEL FOR ECUADOR: A DOLLAR-IZED AND OIL-IZED ECONOMY

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I. Introduction

Ecuador is a small and open economy with exports plus imports above 70% of the GDP. Since 2000 is a dollarized economy. In this economy, Petroleum is an important economic sector with a value added representing approximately 15% of the non-oil GDP. Also, the crude oil exports account for more than 50% of total exports and refined oil imports are approximately 20% of total imports. The country receives an important remittances inflow from developed countries (mainly Spain and US) accounting for 5.2% of the GDP[1]. In this dollarized economy, oil exports and remittances generate a supply of foreign currency that helps enhancing domestic liquidity.

The international crisis of 2007 generated several challenges for Ecuador. In fact, international financial and economic variables that are key for a small open and dollarized economy suffered major changes. The international inflation rose at the same time that oil prices and the remittances inflows dropped. During 2007, international inflation experienced a significant acceleration. In developed countries, inflation almost doubled in less than one year. Between 2006 and 2007, inflation rate rose from 2.5% to 4.1% in the US and from 1.9 % to 3.1% in Europe. The most significant changes in inflation rates were observed at developing countries. However, the increase in inflation rates at those economies was below the levels characterizing the 80 or 90s.

The dollarized Ecuador, with no monetary and/or exchange rate policy instruments faced difficulties to accommodate the shocks. The domestic inflation rate rose from 3.3% in 2007 to 8.83% in 2008. In this context the

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[±]LiD & McKinsey.
[1] Source: World Bank Databank. Average 2001-2010.

government applied both price and income policies, as well as foreign trade policies to reduce the inflationary impact. In addition, crude oil exports were affected as oil prices fell by nearly 80% in mid-2008, only recovering in 2009. In the case of remittances, the crisis in the US and Europe, led to an inflow reduction of around 11% between 2007-2009.

As emphasized by Weisbrot et al. (2013), the combined effect of an increased commodity inflation, falling oil prices together with the reduction of remittances received meant for Ecuador a shock similar to the one suffered by US during the 2007 financial crisis. However, the economy registered only a mild recession and after seven quarters regained the pre-crisis GDP levels. The combination of price, income and commercial policies in conjuction with fiscal impulse and financial policy measures, were essential to restore growth, reduce inflation and continue the social indicators improvement in the economy.[2]

This document develops a simple structural economic model[3] describing in a *New Keynesian* environment the main macroeconomic dynamic features of the Ecuadorian economy. As stated by Berg, A., et al. (2003) the model "*is structural because each of its equations has an economic interpretation*."[4] At the same time is stochastic and incorporates rational expectations into a general equilibrium framework. Indeed, the main objective of the model is to provide a coherent framework of the risks and transmission mechanisms that characterize the economy, Cho, S. et al. (2003). The proposed model includes the *non-oil value added gap*[5] and the *oil value added gap*[6] as separate variables to analyze the relationship between these two components of the total *GDP gap*.[7] The model also considers the role of remittances inflows, the *fiscal*

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[2] Weisbrot et.al.(2013), Nehring, R. (2012), Correa, R. (2011) and CEPAL (2010).

[3] These types of models are in use in a number of central banks. See Berg, A., Karam, P. and Douglas Laxton (2006) and Elosegui, P. et al (2008).

[4] These models are general and not partial equilibrium models. The model structure includes links between the endogenous variables. It is possible to have an economic interpretation for each of the equations in the model, to analyze causality and to consider the effect of changes in policy variables. Berg, et al. (2006).

[5] Usually, the GDP (total value added) gap is included as endogenous variable in these type of models.

[6] As another key feature, the energy sector (crude oil production) plays an important and independent role in the model.

[7] In a close, but not similar venue, Agnani, B. and Iza Padilla, A. (2011) consider a growth accounting model for Venezuela, showing the importance of the non oil value added for the long run economic growth rate in Venezuela.

surplus (*deficit*) and the *terms of trade* as relevant variables explaining the main economic variables evolution. With the purpose of making economic policy analysis the model was designed and estimated in the context of the recent international financial crisis of 2007-2008.[8]

It should be noted that the core model arises from a *Real Business Cycle* tradition. These models require long time series data and may also present difficulties in modeling breaks in such series. These two obstacles are overcome by using the Bayesian estimation technique. Indeed, this technique requires less data and allows us to estimate the model using post dollarization economic series. Also, the Bayesian methodology can incorporate prior information to deal with possible breaks or sudden changes in the evolution of the economy [Canova (2005)].[9] In fact, we use quarterly information from 2001 to 2010.

The structure of the paper includes four sections. The second section introduces the main structure of the economic model with the explanation for each of its equations. The third section analyzes the data and the model estimation. The final section analyzes the main results.

II. Main characteristics of the Model

II. 1. The model

The model is "*a simple dynamic general equilibrium New Keynesian model for forecasting and policy analysis*" [Berg, A. et. al. (2006)] including the main features of the equadorian economy. It includes three main endogenous variable, the domestic inflation rate, the *non oil value added gap*, and the nominal interest rate. Therefore, the model includes an equation describing the domestic inflation dynamics or "*Phillips equation*", an equation for the *non oil*

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[8] See Berg, A. et al (2006), page 4.

[9] "Bayesian techniques are preferable to standard likelihood methods or to indirect inference (impulse response matching) exercises, because the model we consider is clearly false and possibly misspecified. We show that the method delivers reasonable posterior distributions for the structural parameters when priors are broadly non-informative and the policy reaction function schrewdly chosen." Canova, F. (2005)

value added gap, or "*IS equation*", and an equation for the *uncovered interest rate parity* or "*UIP equation*". The endogenous variables and the corresponding equation are listed in the table below.

Endogenous Variable	**Equation**
Inflation rate in domestic prices	*Phillips equation*
Non oil value added Gap	*IS equation*
Nominal Interest Rate	*UIP equation*

The model introduces variables that are particularly relevant for the economy under analysis, such us the *oil value added gap*, the remittances, the terms of trade among others. In this sense, it provides a simple framework for assessing the risks and analyzing different possible economic policy scenarios.

Technically, the model is a system of stochastic difference equations. As usual in this literature, the model variables are expressed as deviations from a long run value.[10] Note thata circumflex (caret) character over a $\widehat{x_t}$ variable means that the variable is measured as a log deviation with respect to its long-term steady-state value, x.[11]

$$E_t[f(\hat{s}_{t+1}, \hat{s}_t)] = 0 \tag{1}$$

As a log linearized system centered around a long run equilibrium it can be expressed as follows:

$$AE_t\hat{s}_{t+1} = B\hat{s}_t \tag{2}$$

[10] A calibrated non-stochastic steady state or equilibrium level. Berg, A. et al (2006) page 9.

[11] Then $\widehat{x_t} = \log\left(\frac{x_t}{x}\right) = \log(x_t) - \log(x)$. This is aproximately equivalent to percentage deviation. Recall that for a small x, $\log(1+x) \cong x$. Then, $\log\left(\frac{x_t}{x}\right) = \log\left(1 + \frac{x_t - x}{x}\right) \cong \frac{x_t - x}{x}$

These type of models can arise from a completely microfounded model, as in a *LDRE (linear dynamic rational expectation model).* In such cases the formal equation system includes (i) optimality conditions (or first-order conditions of the model, such as the intertemporal utility maximization for the representative agent and/or profit maximization firms, etc.); (*ii*) resource constraints and market equilibriums; (*iii*) intertemporal equations for the exogenous variables.Four types of variables are usually included in the general structure of LDRE models. First, the *predetermined* or *backward looking* variables that generally correspond to the endogenous variables such as capital stock, foreign assets or those exogenous shock such as productivity shocks s_{1t}. Second, *non predetermined, forward-looking* variables (or *jump* variables). Thelatter usually correspond to policy variables such as consumption or in our case, the *non-oilvalue added gap*, s_{2t}. Third, additional flow variables, s_{3t}. And finally, innovations on the predetermined variables, ε_t.

The general specification of the model can be written as:

$$A\hat{s}_{t+1} = B\hat{s}_t + \varepsilon_{t+1} \tag{3}$$

and it can be generalized as,

$$A\begin{pmatrix}\hat{s}_{1t+1}\\ \hat{s}_{2t+1}\end{pmatrix} = B\begin{pmatrix}\hat{s}_{1t}\\ \hat{s}_{2t}\end{pmatrix} + \begin{pmatrix}\varepsilon_{t+1}\\ 0\end{pmatrix} \tag{4}$$

with an additional equation given by,

$$\hat{s}_{3t} = C\hat{s}_{t+1} + D\hat{s}_t \tag{5}$$

Taking into account that the model usually includes backward as well as forward- looking endogenous variables, the solution of the equations system requires numerical methods. Tosolve the system we use *Dynare*,[12] a free software platform for handling this class of economic models under *MATLAB*.

II. 2. The Equadorian Model

This section introduces the main equations of the proposed model. As mentioned before, the model includes the usual equations in this type of models and related to the output gap, the inflation rate and the nominal interest rate taking into account the dollarization of the economy.In addition, the model includes modifications designed to take into account the main features of the economy under analysis. In fact, the model introduces the *non oil value added gap* evolution and emphasizes the role of the oil sector production, the remittances inflows and the terms of trade. As usual in this type of models variables are measured as deviations fromits long run trend, or in "*gap*" terms. For such purposes dynamic equations, which would be non-linear in an explicitly microfounded model, are expressed as linear in the logs of variables. The model does not attempt to model the output, inflation rate or interest rate equilibrium level.

Therefore, the main endogenous variables are: $\hat{\pi}_t$, $\hat{y}_t$ and $\hat{\imath}_t$, representing *domestic inflation rate*, *non oil value added gap* and *nominal interest rate*. The formal equations for each of the variables are described below.

II. 2. 1. Phillips equation

In this type of models, the inflation rate dynamic is analyzed through a "*Phillips equation*". The equation modeling the dynamics of inflation includes adaptive and forward looking expectations. The postulated setting is commonly used in inflation rate econometric estimation,

$$\hat{\pi}_t = \alpha_1 E_t \hat{\pi}_{t+1} + (1-\alpha_1)\hat{\pi}_{t-1} + \alpha_3 \hat{y}_{t-1} + \alpha_4 \hat{\pi}_t^* + \alpha_5 \Delta \widehat{tot}_t + \alpha_6 \hat{y}_t^p + \varepsilon_t^\pi \qquad (6)$$

[12] For more information, visit http://www.dynare.org/.

II. 2. 2. Output gap equation

As usual in this literature the output gap equation reflecting good market equilibrium is also called the "*IS equation*". The equation includes both the expected (*forward looking*) and the past value of the endogenous variable.

As a characteristic feature of the model, we consider the *non oil value added gap* as the modeled variable $\hat{y}_t$.

$$\hat{y}_t = \beta_1 E_t \hat{y}_{t+1} + \beta_2 \hat{y}_{t-1} - \beta_3 \hat{r}_{t-1} + \beta_4 \widehat{sf}_t^{np} + \beta_5 \hat{y}_t^p + \beta_6 \Delta \widehat{tot}_t + \beta_7 \widehat{re}_t + \epsilon_t^y \quad (7)$$

In addition to consider past and future values of *non oil value added gap*, the "*IS equation*" includes variables having an independent effect on the aggregate demand. The model includes the real interest rate, r_t.[13] The model incorporates the *non oil fiscal surplus* (*as a percentage of the GDP*) $\widehat{sf}_t^{np}$, as a measure of the *fiscal stance* in the economy. Also, $\widehat{re}$ corresponds to the remittances received from the rest of the world, a very relevant variable for the domestic economy and a proxy for the domestic liquidity in the economy.

The direct effect arising from the oil production is incorporated through the *oil value added gap*, $\hat{y}_t^p$. The latest variable captures the independent effect generated by the fluctuation in the *oil value added gap*. The interaction between *non-oil value added gap* and oil production has marked the development of the Ecuadorian economy since the discovery of this mineral.[14] For this reason the model distinguishes the behavior of these two variables separately. Actually, the different evolution of these two variables ($\hat{y}_t$ and $\hat{y}_t^p$) can be observed in Figure 1 below together with the rest of the variables included in the model. It can be noted that the *oil value added gap* ($\hat{y}_t^p$) presents more volatility than the *non-oil value added gap* ($\hat{y}_t$). As we will show, such variability is relevant for the evolution of the *non-oil value added gap* ($\hat{y}_t$). During the period under consideration, the government pursued legal

[13]The real interest rate is given by $r_t = i_t - E_t \pi_{t+1}$, and it is included with one lag. See Elosegui, P. et. al (2007).

[14] See Correa, R. (2011) and Mateo et. al (2014).

and tax reforms aimed at obtaining a greater share of oil revenues.[15] Besides the fiscal impact, the investment and production in this sector is relevant to the sustained growth of the *non-oil value added gap* ($\tilde{y}_t$). Another important variable reflects the changes in the terms of trade, $\widehat{tot}_t$, capturing the wealth effect due to changes in the external price of the main exported and imported goods and services. Finally, the random shock corresponding to this equation is given by ϵ_t^y.

II. 2. 3. Interest rate equation

In the case of a small open and dollarized economy[16], the equation for the interest rate adjustment relates the domestic interest rate with the international one through a risk premium. The risk premium considers all possible rigidities for free capital mobility such as capital controls and taxes.

$$\hat{\imath}_t = \hat{\imath}_t^* + risk_t \quad (8)$$

with $i_t = \log(1 + I_t)$, $i_t^* = \log(1 + I_t^*)$, where I_t is the short run domestic nominal interestrate and I_t^* is the international short run interest rate. In some models, [See Escudé, G. (2014)], the risk premium can be explained by the total indebtedness level. In our case, $risk_t$ is an exogenous risk premium.

II. 2. 4. Fiscal sector equations

The fiscal sector is modeled in various equations. It should be noted that in a dollarized economy the government financial constraint does not include monetary financing, $B_t^g + SF_t = B_{t-1}^g(1 - I_{t-1})$. Therefore, the log linearized equation for the total government fiscal surplus (or deficit) is given by,

[15] In fact, Mateo, J. et al (2014), shows that the oil related fiscal revenues averaged 6.2 % of the GDP in 2000-2006 and 12.0% of the GDP for the period 2007-2012.
[16] There is no role for the foreign exchange rate.

$$\hat{b}_t^g + \widehat{sf}_t = \hat{b}_{t-1}^g \exp(\hat{\imath}_{t-1} - \hat{\pi}_t - \tilde{y}_t) \tag{9}$$

with $sf_t = log\frac{SF_t/P_t}{Y_t}$, and $\hat{b}_t^g = log\frac{B_t^G/P_t}{Y_t}$, where the growth rate of *non oil value added gap* is given by, $\tilde{y}_t = \hat{y}_t - \hat{y}_{t-1} + \bar{\bar{y}}_t$. In the case of the oil value added gap (y_t^P), the growth rate equation becomes $\tilde{y}_t^p = \hat{y}_t^p - \hat{y}_{t-1}^p + \bar{\bar{y}}_t^p$.

The total fiscal result surplus $\widehat{sf}_t = \widehat{sf}_t^p + \widehat{sf}_t^{np}$ is divided into the fiscal result with ($\widehat{sf}_t^p$) and without oil revenues ($\widehat{sf}_t^{np}$). This distinction allows us to emphasize the role of non oilrevenue´ s fiscal surplus (which is actually a deficit) as a potential fiscal impulse variable.

The *non oil fiscal surplus* dynamics is determined by its persistence (ρ_1) and procyclical (ρ_2) components.

$$\widehat{sf}_t^{np} = \rho_1 \widehat{sf}_{t-1}^{np} + \lambda \hat{y}_t + \varepsilon_t^{sf^{np}} \tag{10}$$

On the other hand, the oil based *fiscal surplus* is explained by its persistence (ϕ_1), the oilprice (p_t^p) and the *oil value added gap* ($\hat{y}_t{}^p$).

$$\widehat{sf}_t^p = \rho_{12} \widehat{sf}_{t-1}^{np} + \theta \hat{p}_t{}^P + \tau \hat{y}_t{}^P + +\varepsilon_t^{sf^P} \tag{11}$$

II. 2. 5. The oil value added and oil price

In the model the oil value added and oil price are assumed to be determined by the followingequations:

$$\hat{y}_t{}^p = \rho_3 \hat{y}_{t-1}{}^p + \varepsilon_t^{y^p} \tag{12}$$

$$\hat{p}_t{}^p = \rho_2 \hat{p}_{t-1}{}^p + \varepsilon_t^{\pi^p} \tag{13}$$

II. 2.5. Remittances and Terms of Trade

In the case of these two variables the model assumes them to be exogenously determined. An autoregressive movement law is assumed for both gaps. In the case of the terms of trade, the international oil price is also included,

$$\widehat{tot}_t = \rho_{13}\widehat{tot}_{t-1} + \iota\widehat{p}_t^{\,p} + \varepsilon_t^{tot} \tag{14}$$

$$\widehat{re}_t = \rho_{14}\widehat{re}_{t-1} + \varepsilon_t^{re} \tag{15}$$

II. 3. Additional behavior equations

We need to postulate a dynamic behavior of the equations corresponding to the exogenous variables in the model.

In the case of the foreign interest rate we assume $\hat{\imath}_t^*$ follows an stochastic process given by,

$$\hat{\imath}_t^* = \rho_5\hat{\imath}_{t-1}^* + \epsilon_t^{i^*} \tag{16}$$

We assume foreign inflation follows a behavior given by,

$$\hat{\pi}_t^* = \rho_6\hat{\pi}_{t-1}^* + \epsilon_t^{i^*} \tag{17}$$

It should also be added that we assume the growth rate[17] of non oil value added gap and oil value added gap dynamic are given by,

$$\tilde{y}_t = \rho_7 \hat{y}_{t-1} + \varepsilon_t^{\bar{\tilde{y}}} \tag{18}$$

$$\tilde{y}_t^p = \rho_8 \hat{y}_{t-1}^p + \varepsilon_t^{\bar{\tilde{y}}^p} \tag{19}$$

Finally, the exogenous risk premium behavior is given by,

$$\widehat{risk}_t = \rho_9 \widehat{risk}_{t-1} + \varepsilon_t^r \tag{20}$$

II. 4. The Equation System

All variables in the system can be compressed in the following vector s_t,

$$s_t = \{\hat{y}_t, \hat{\pi}_t, \hat{\imath}_t, \hat{y}_t^p, \widehat{sf}_t, \widehat{sf}_t^p, \widehat{sf}_t^{np}, \hat{b}_t^g, \tilde{y}_t, \tilde{y}_t^p, \hat{p}_t^p, \widehat{tot}_t, \widehat{re}_t, \hat{\pi}_t^*, \hat{\imath}_t^*, \widehat{risk}_t\} \tag{21}$$

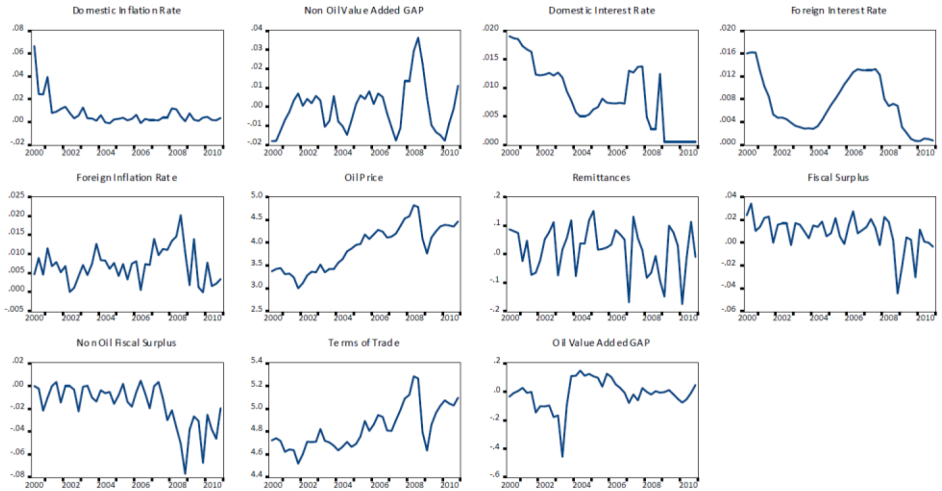
the system of equations is then given by,

$$E_t[f(s_{t+1}, s_t)] = 0 \tag{22}$$

As mentioned before, this is a nonlinear difference and stochastic equation system. A numerical solution for this type of model can be approximated by a lineal solution to the steady state deterministic equilibrium. Next section shows model estimation and main results, including the impulse response and variance decomposition analysis.

[17]Where the ~ character indicates growth rate.

Figure 1.
Main Economic Variables



All variables are expressed as a deviation with respect to the long run value, except for both domestic and foreign interest rates.

III. Model Estimation

The model is estimated by using a Bayesian methodology.[18] This methodology allows the parameter to be estimated even with a small sample data. The Bayesian density version of the Bayes Theorem is given by,

$$P(\theta/Y_T) = \frac{p(Y_T/\theta)p(\theta)}{p(Y_T)} \tag{23}$$

where, Y_T represent the observable variables up to the time T and θ is the parameter's vector. This formula shows how the prior density, $p(\theta)$ is updated by the data and transformed in aposterior density $P(\theta/Y_T)$. Therefore,

$$P(\theta/Y_T) \propto p(Y_T/\theta)\ \mathrm{p}(\theta)\ = \mathcal{L}(\theta; Y_T)\ p(\theta) \tag{24}$$

the mode of the posterior distribution can be calculated by solving,

$$max_\theta\ ln\ K(\theta/Y_T) = ln\ \mathcal{L}(\theta/Y_T) + ln\ p(\theta) \tag{25}$$

In this case is possible to use the Kalman Filter to evaluate the maximum likelihood function. In addition, subsequent distributions are computed using the *Metropolis-Hastings* algorithm (MCMC). The *Metropolis-Hastings* (MH) algorithm is a method used to simulate the Bayesian posterior distribution. It is a "rejection sampling algorithm' that generates a sequence of samples ("*Markov Chains*") from a normal distribution. The algorithm constructs a normal approximation around the posterior mode allowing an efficient exploration of the posterior distribution at the neighborhood of the mode.

In the case under analysis, the observable variables are the following,

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[18]See Escude, G. (2010).

$$\hat{y}_t, \hat{\pi}_t, \hat{\imath}_t, \hat{y}_t^p, \widehat{sf}_t, \widehat{sf}_t^p, \widehat{sf}_t^{np}, \hat{b}_t^g, \tilde{y}_t, \tilde{y}_t^p, \hat{p}_t^p, \widehat{tot}_t, \widehat{re}_t, \hat{\pi}_t^*, \hat{\imath}_t^*, \widehat{risk}_t \quad (26)$$

For the estimation, we use quarterly information for the period 2000:1-2010:1. The series are *non-oil value added gap*, *oil value added gap, consumer price inflation rate, nominal interestrate (3 month), fiscal surplus over GDP (oil and non oil based), international inflation rate (US inflation), 3 month TB interest rate (international interest rate benchmark).* As mentioned before, the Bayesian estimation procedure is performed by using Dynare platform in MATLAB.

III. 1. Estimation Results

III. 1. 1. Main Parameters

The following table shows the results arising from the *MH simulation*. It includes the estimated posterior mean of the parameters and the confidence interval. It should be noted that for each parameter it is postulated not only a prior value, which can be validated or not according to information obtained from the sample, but also a probability distribution. The latter provides the random support for the mean value of the parameter. Both, the mean and the distribution support of the parameter emerge from the literature[19] and are shown in Table 1.

[19]An, S., and F. Schorfheide (2007).

Table 1.

Estimation Results.

Parameters	Prior mean	Posterior mean	Conf. interval		Prior	Pstdev
α_1	0.5	0.6710	0.5476	0.7849	beta	0.2
α_3	0.2	0.0288	0.0101	0.0437	beta	0.1
α_4	0.2	0.1805	0.0433	0.2944	beta	0.1
α_5	0.2	0.0245	0.0115	0.0388	beta	0.1
α_6	0.2	0.0127	0.0026	0.0238	beta	0.1
β_1	0.5	0.1253	0.0230	0.2243	beta	0.2
β_2	0.5	0.6129	0.4776	0.7457	beta	0.2
β_3	0.3	0.0722	0.0014	0.1417	norm	0.2
β_4	0.5	0.1256	0.0263	0.2072	beta	0.2
β_5	0.5	0.0184	0.0049	0.0304	beta	0.2
β_6	0.5	0.0148	0.0055	0.0240	beta	0.2
β_7	0.5	0.0275	0.0075	0.0462	beta	0.2
ρ_1	0.5	0.6624	0.4754	0.8844	beta	0.2
ρ_2	0.5	0.9449	0.9106	0.9828	beta	0.2
ρ_3	0.5	0.5913	0.4322	0.7330	beta	0.2
ρ_5	0.5	0.9256	0.8734	0.9867	beta	0.2
ρ_6	0.5	0.4412	0.2418	0.6311	beta	0.2
ρ_7	0.5	0.5584	0.3761	0.7586	beta	0.2
ρ_8	0.5	0.1836	0.0352	0.3200	beta	0.2
ρ_9	0.5	0.8449	0.7483	0.9453	beta	0.2
ρ_{12}	0.5	0.6426	0.4854	0.7928	beta	0.2
ρ_{13}	0.5	0.6988	0.5749	0.8383	beta	0.2
ρ_{14}	0.5	0.2110	0.0512	0.3683	beta	0.2
λ	0.5	0.2415	0.0356	0.4455	beta	0.2
τ	0.2	0.0160	0.0044	0.0280	beta	0.1
θ	0.2	0.0027	0.0011	0.0039	beta	0.1
ι	0.5	0.0415	0.0133	0.0670	beta	0.2

III. 1. 2. Random shocks

Table 2 below shows the prior and posterior mean of the standard deviation of shocks in each of the equations. In general, they assume relatively low values. It should also be noted that the deviations of the shocks corresponding both to the inflation (ϵ_t^{π}) and *non oil value added gap* (ϵ_t^{y}) show levels according to the methodology's standards.

Table 2.

Standard deviation of shocks

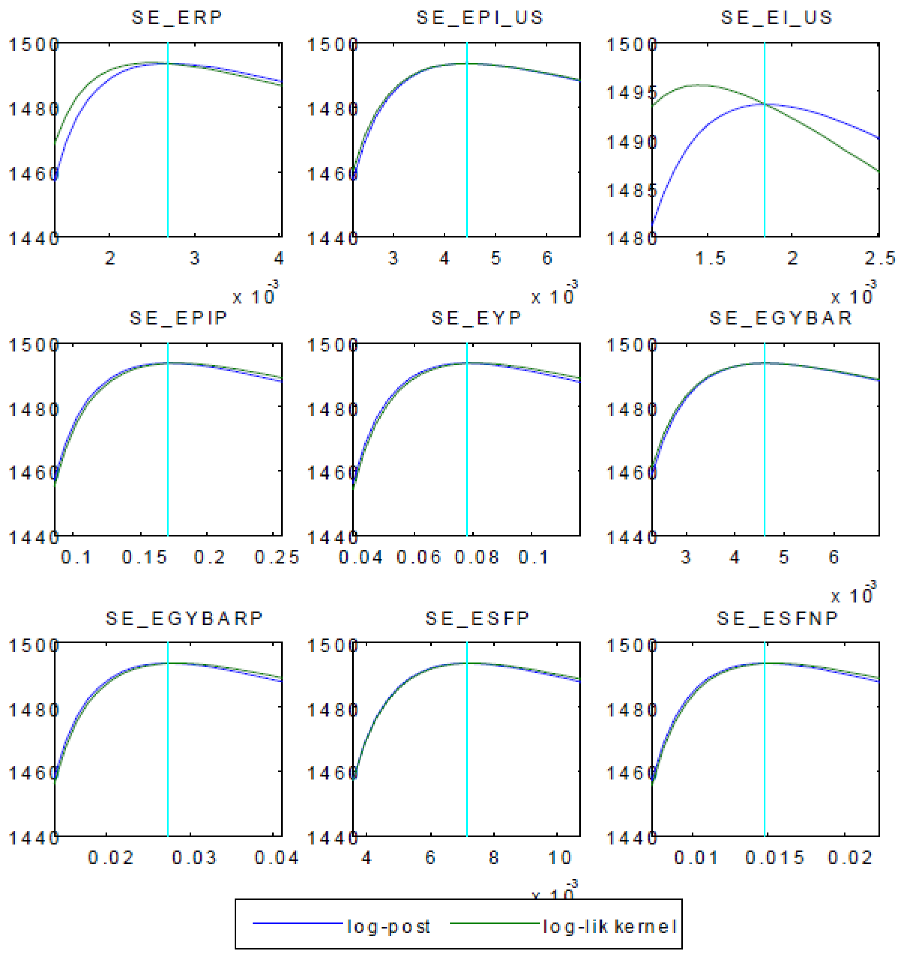
	prior mean	post. mean	conf. interval		prior	pstdev
ε_t^{risk}	0.01	0.0028	0.0023	0.0034	invg	Inf
$\varepsilon_t^{\pi^{us}}$	0.01	0.0046	0.0038	0.0053	invg	Inf
$\varepsilon_t^{i^{u}}$	0.01	0.0019	0.0015	0.0022	invg	Inf
$\varepsilon_t^{\pi^{P}}$	0.01	0.1767	0.1432	0.2064	invg	Inf
$\varepsilon_t^{y^{p}}$	0.01	0.0797	0.0660	0.0920	invg	Inf
$\varepsilon_t^{\overline{\tilde{y}}}$	0.01	0.0048	0.0039	0.0056	invg	Inf
$\varepsilon_t^{\overline{\widetilde{y^{p}}}}$	0.01	0.0283	0.0236	0.0329	invg	Inf
$\varepsilon_t^{sf^{p}}$	0.01	0.0076	0.0063	0.0089	invg	Inf
$\varepsilon_t^{sf^{np}}$	0.01	0.0161	0.0131	0.0190	invg	Inf
ε_t^{tot}	0.01	0.1135	0.0903	0.1399	invg	Inf
ε_t^{re}	0.01	0.0815	0.0665	0.0951	invg	Inf
ϵ_t^{π}	0.01	0.0073	0.0051	0.0095	invg	Inf
ϵ_t^{y}	0.01	0.0079	0.0061	0.0097	invg	Inf

Figure 2 shows the mode check plots[20]. The estimated mode should be at the maximum of the posterior likelihood as showed in the figure.

[20] The figure only presents some of the estimated parameters to save space.

Figure 2.

Check Plots

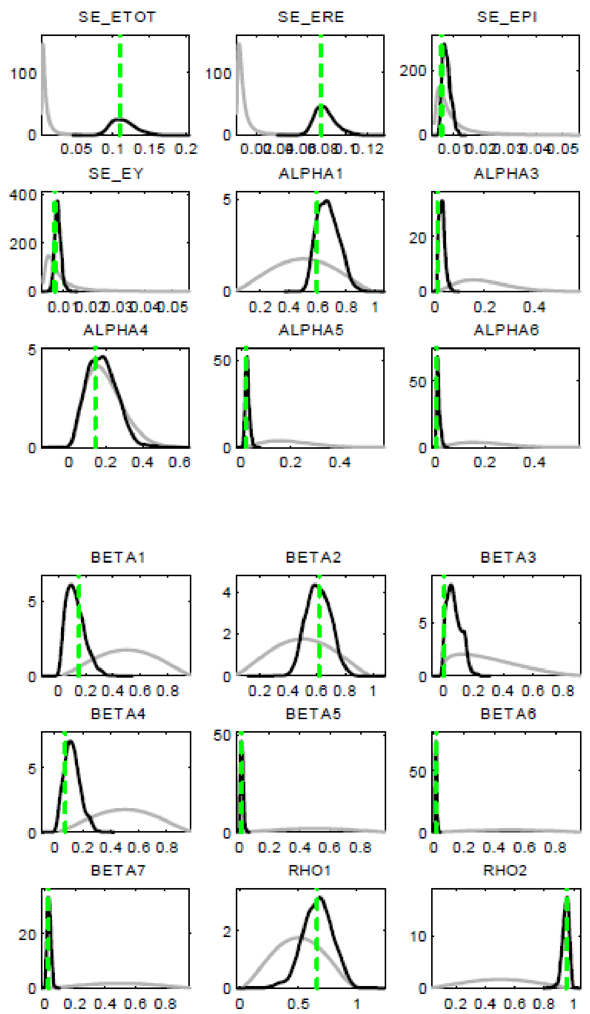


On the other hand, Figure 3 shows *the Prior-Posterior Plots*. The x axis shows the support of the prior and posterior distribution. The y-axis displays the corresponding density. The greyline shows the prior distribution and the black line indicates the posterior distribution. Finally, the vertical segmented line corresponds to the posterior mode of the distribution.

It should be noted that prior and posterior distributions should not be similar, but they should not be very different. A similarity between the prior and posterior may indicate that data add nothing to the estimation. It may be the case that either the prior was a very accurate reflection of the information in the data or the data provides no information to update the prior. In general, the plots are very informative; both distributions should be compared to analyze the result of the estimation. Differences in the mode and the standard deviation must also be considered. Finally, we can check whether the posterior distribution looks like a normal onesince the MH procedure performs a normal approximation to the posterior distribution.

Figure 3.

Prior- Posterior Check Plots

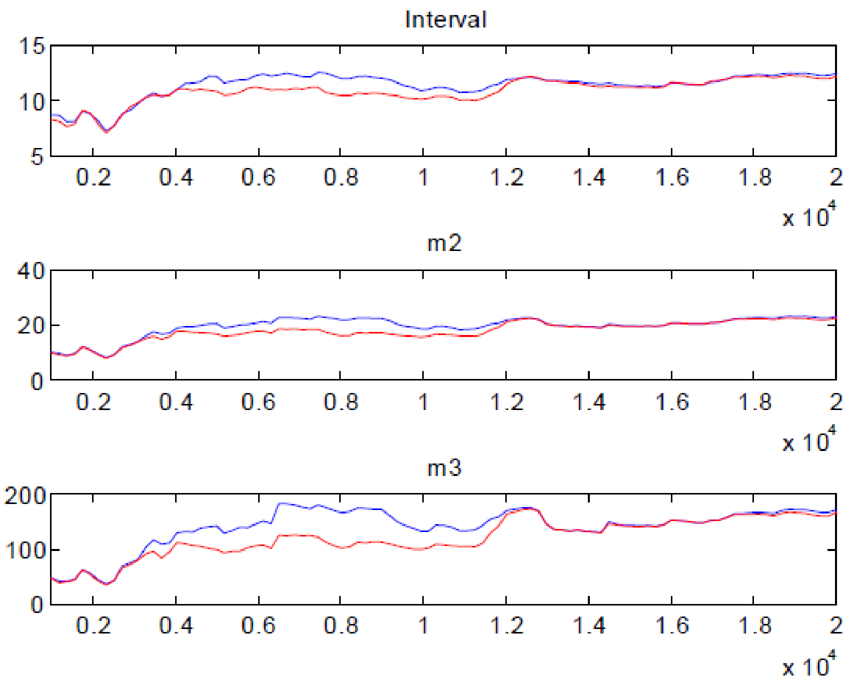


Note: The plots indicate the prior (gray line) and the posterior distribution (black line) together with the mode (green dotted vertical line) previous to the estimation.

In Figure 4 below, the *Multivariate Convergence Diagnostic* can be observed. This diagnostic is a useful tool for checking model convergence. The x-axis indicates the MH iterations. It compares the within variance from each markov chain with the variances of all chains (within and between) mixed together. At convergence, the chains should have mixed and we should not observe any difference among the variances. Therefore, convergence is indicated by the twolines in Figure 4 stabilizing and being close to each other. The figure shows the convergence results for all the variables (it can also be performed for individual variables) and includes the 80% confidence interval around the mean (top graph), the variance (second graph) and the third moment at the bottom graph.

Figure 4.

Multivariate Convergence Diagnostic



III. 1. 3. The estimated parameters of the model

III. 1. 3. 1. Preliminary Analysis

The equations for the endogenous variables $\hat{\pi}_t$ and $\hat{y}_t$ using the modes estimated for the 2001 - 2010 period by using the Bayesian methodology are showed in the system below.

$$\hat{\pi}_t = 0.671\, E_t\hat{\pi}_{t+1} + 0.329\hat{\pi}_{t-1} + 0.087\hat{y}_{t-1} + 0.180\hat{\pi}_t^* + 0.024\Delta\widehat{tot}_t + 0.012\, \hat{y}_t^p$$

$$\hat{y}_t = 0.125\, E_t\hat{y}_{t+1} + 0.612\hat{y}_{t-1} + 0.072\hat{r}_{t-1} + 0.125\widehat{sf}_t^{np} + 0.018\hat{y}_t^p + 0.0148\,\Delta\widehat{tot}_t + 0.027\widehat{re}_t$$

The equations show the direct effect arising from a possible change in any of the variables. However, the real value of the model lies in the fact that all the equations and variables are inter-related in a general equilibrium framework. Therefore, the final effect of any shock depends on the interaction of the different transmission mechanisms in the general equilibrium of this model. Indeed, the analysis of the parameters only indicates the sign and the order of magnitude but not final effect of any impact on the variable of interest. The latter must be evaluated using the impulse response (*IR*) analysis that is developed in the next sub section.

However, the parameter magnitude and signs in the previous equations indicate an important role for the real interest rate and the fiscal impulse *non oil based fiscal surplus* on the *non-oil value added gap*. Also, the *oil value added gap* parameter shows a positive and relevant (in magnitude) impact on the *non-oil value added gap*. However, the order of magnitude seems to be smaller than the one corresponding to other variables, for instance the *terms of trade* and *remittances*.

Finally, it is interesting to note, that the domestic inflation shows low persistence and a relatively small lagged parameter. The *non-oil value added gap* captures the potential demand pressures and shows a positive and significant impact. That impact is lower than the one captured by the *foreign inflation*. Indeed, the estimated parameter for *foreign inflation* may be reflecting the importance of this variable for the *domestic inflation rate*. Actually, the impact arising from *international inflation* seems to be captured both by US inflation (*foreign inflation*) and by the change in the *terms of trade*. Finally, the *oil based value added gap* seems to have no effect on domestic inflation. Any possible effect on this side seems to be operating only through its effect on the *non-oil value added gap*.

III. 1. 3. 2. Impulse Response

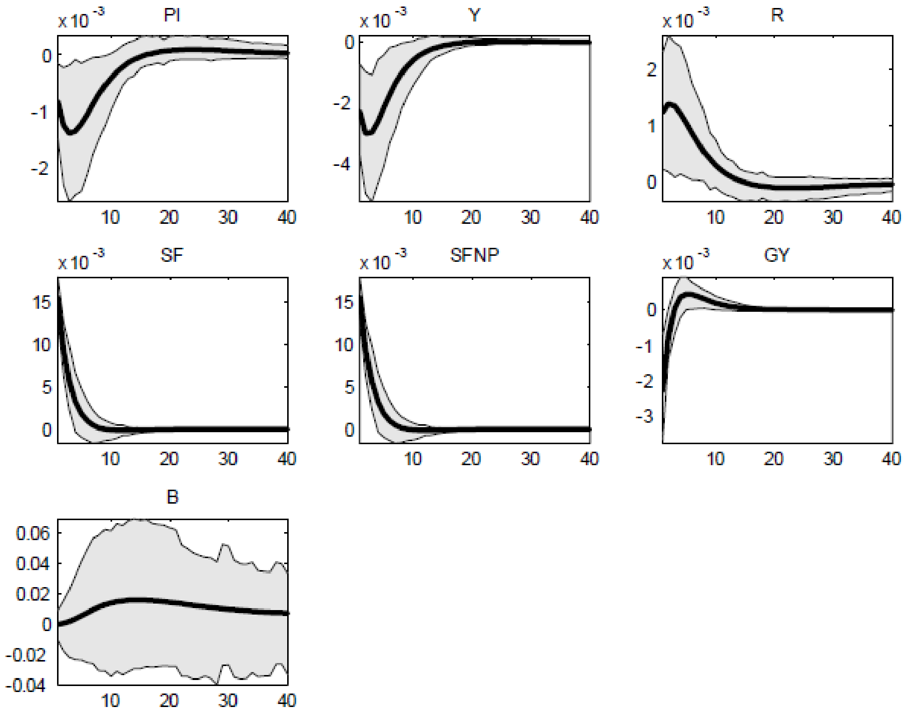
The impulse response (*IR*) analysis is a useful tool for analyzing the model performance. The *IR* analysis, considers the system response to a shock in a selected equation. In this sense, it indicates both the systemic impact arising from a shock and the convergence path followed by the system after the initial disturbance. It can be used to check the internal consistency and to detect undesired convergence paths of the model variables. These features make *IR* an interesting analysis tool to reviewing policy options under different scenarios. In addition, the information analyzed from the impact *IR* can be easily summarized. The *IR* analysis adds valuable information by allowing a better understanding of the relationship and interactions between model variables. For instance, Figure 5 shows the effect of a positive disturbance (an expenditure reduction) of a *non-oil fiscal surplus exogenous* shock. The shock has an effect on the *non oil value added* growth rate $\tilde{y}_t$. Also, there is an effect on *inflation rate* $\hat{\pi}_t$ but it is revealed only a few quarters later and does not seem to be persistent. The results indicate a positive effect of the *fiscal impulse* (a decrease in the *non-oil fiscal surplus*), over the *non oil value added gap*, together with a minor impact on *domestic inflation rate*.

It should be noted that we use the *Bayesian IRFs*, where the mean of the distribution of the *IRFs* are generated when parameters are drawn from the posterior distribution. The traditional *IRFs* are computed at the calibrated parameter combination, while the *Bayesian IRFs* are the mean impulse responses. The gray shaded areas provide highest posterior density intervals (HPDI) and give an idea of the uncertainty surrounding the IRFs.[21]

[21] See Adjemian, Stéphane et al (2011).

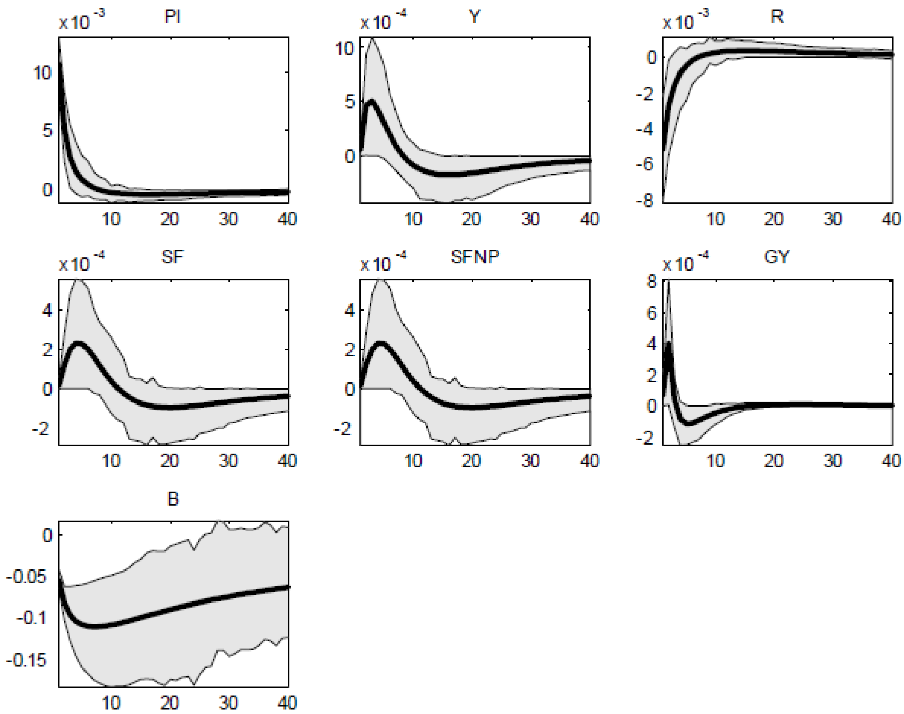
Figure 5.

Non-oil fiscal surplus shock



The impact of a domestic inflation rate shock on the other relevant variables is depicted on Figure 6.

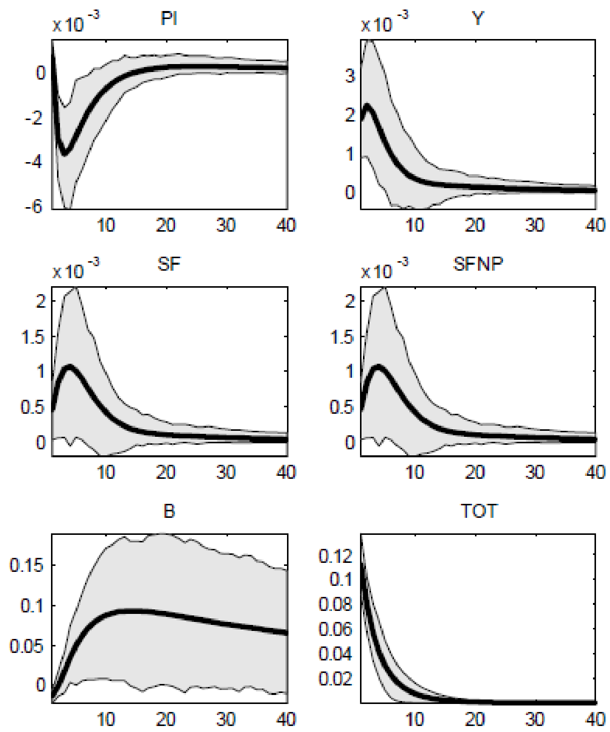
Figure 6.
Domestic inflation rate shock



Finally, Figure 7 shows the effect of a shock in *terms of trade* over the other relevant variables. Albeit with low persistence, an initially positive effect on domestic inflation rate can be noted. The result shows the relevance of foreign shocks on domestic inflation. This is an expected result in an open and dollarized economy. In fact, as we shall see in the next section, the result is also underscored by the variance decomposition analysis.

Figure 7.

TOT shock



III. 1. 3. 3.Variance Decomposition

The endogenous variable *variance decomposition* is another useful tool for understanding the shocks transmission mechanisms affecting the modelled economy. As can be seen in the Table 3 below, the variance of d*omestic inflation rate* is mainly explained by shocks in the *terms of trade* and, to a lesser extent by shocks to the *oil* and *non-oil value added gap*. The impact of the *fiscal stance* shocks[22] over *domestic inflation rate* variance is low. The *remittances* also have a small effect on *domestic inflation rate* variance.

In the case of the *non-oil value added gap* variance, the results indicate that the main determinants are *oil price shocks* and the *terms of trade* together with the *fiscal stance* shocks. In fact, shocks to the *oil price and production*, *terms of trade* and *remittances* along with shocks in *oil value added gap* account for almost 50% of the variance.

Table 3.

Variance Decomposition

	ε_t^{risk}	$\varepsilon_t^{\pi^{us}}$	$\varepsilon_t^{i^u}$	$\varepsilon_t^{\pi^P}$	$\varepsilon_t^{y^p}$	$\varepsilon_t^{\overline{y}}$	$\varepsilon_t^{\overline{\widetilde{y^p}}}$	$\varepsilon_t^{sf^p}$	$\varepsilon_t^{sf^{np}}$	ε_t^{tot}	ε_t^{re}	ϵ_t^{π}	ϵ_t^{y}
$\widehat{\pi}_t$	0.54	5.9	1.33	2.12	0.39	0.19	0	0.03	0.52	34.99	1.62	51.54	0.83
$\widehat{y}_t$	0	0	0.01	9.13	7.91	0	0	0	8.51	18.54	5.13	0.01	50.76
$\widehat{i}_t$	48.92	0	51.08	0	0	0	0	0	0	0	0	0	0
$\widehat{sf}_t$	0	0	0	4.84	2.74	0	0	17.94	72.29	0.72	0.15	0	1.33
$\widehat{sf}_t^{np}$	0	0	0	0.58	0.38	0	0	0	96.12	0.96	0.2	0	1.77
$\widehat{sf}_t^{p}$	0	0	0	11.35	6.17	0	0	82.48	0	0	0	0	0
$\widetilde{y}_t$	0	0	0	0.14	2.56	27.67	0	0	2.37	4	4.31	0	58.95
$\widetilde{y}_t^p$	0	0	0	0	90.77	0	9.23	0	0	0	0	0	0
$\widehat{risk}$	100	0	0	0	0	0	0	0	0	0	0	0	0
$\widehat{p}_t^p$	0	0	0	100	0	0	0	0	0	0	0	0	0
$\widehat{y}_t^p$	0	0	0	0	100	0	0	0	0	0	0	0	0
$\widehat{\pi}_t^*$	0	100	0	0	0	0	0	0	0	0	0	0	0
$\widehat{i}_t^*$	0	0	100	0	0	0	0	0	0	0	0	0	0
$\widehat{b}_t^g$	8.92	4.02	21.44	0.98	1.03	3.19	0	0.49	0.37	32.12	1.26	24.94	1.24
$\widehat{tot}_t$	0	0	0	21.52	0	0	0	0	0	78.48	0	0	0
$\widehat{re}_t$	0	0	0	0	0	0	0	0	0	0	100	0	0

IV. Conclusions

The paper presents a small structural macroeconomic model with New Keynesian features for the Ecuadorian economy. It allows identifying the main macroeconomic risks and transmission mechanism of this dollarized economy. The main endogenous variables in the model are the *non-oil value added gap*

[22] As measured by the non oil based fiscal surplus.

and the *domestic inflation rate*. The *oil value added gap*, the *non oil fiscal surplus*, the *foreign inflation rate*, the *terms of trade* and the *remittances inflows* are among the variables included in the model. The model is solved and estimated by using a Bayesian methodology.

The results show that the evolution of the *non-oil value added gap* is positively correlated with the *fiscal stance* as measured by the *non oil fiscal deficit* and negatively correlated with the *real interest rate* .The *oil value added gap* has a positive, significant and independent impact on the *non-oil value added gap*. However, the order of magnitude is lower than the one corresponding to the variation of the *terms of trade* and *remittances*. The increase in the *domestic inflation rate* was an issue in this dollarized economy during 2008. The analysis of the *domestic inflation rate* equation indicated its low persistence. In fact, the most important and direct effect over *domestic inflation rate* comes from the *foreign inflation rate*. This finding is consistent with the reversal in the inflationary phenomenon observed immediately after the decline in *foreign inflation rate*. Also, *inflation expectation* emerges as another important determinant of *domestic inflation rate*. Whereas, the *non-oil value added gap* shows a positive sign, but with an order of magnitude below the one corresponding to the *foreign inflation rate*. In the case of the *oil value added gap*, it seems to have no economic significant effect on *domestic inflation rate*. The main effect of this variable over *domestic inflation rate* is indirect, through its effect on the *non-oil value added gap*. Finally, the *fiscal stance* does not seem to have a significant direct role in explaining *domestic inflation rate*.

The variance decomposition analysis reveals the importance of the *terms of trade shocks* and *oil* and *non-oil value added gap* on dom*estic inflation rate variance*. The *fiscal stance* has a low explanatory power with respect to the *domestic inflation rate* variance. However, the fiscal demand pressure shows an effect over the *non-oil value added gap* variance. The shocks to the *terms of trade* and *remittances* along with shocks in *oil value added gap* account for about 50% of the *non-oil value added gap* variance. It should be emphasized the fact that the *non oil based fiscal gap* has an effect on the *non-oil value added gap* and (a lower one) on *domestic inflation rate*.

Also noteworthy is the role of resources flowing from the oil sector to the rest of the economy. The impact of the *non oil based fiscal gap* over the *non-oil value added gap* may be an argument supporting its use as a countercyclical economic policy instrument[23]. The next step would be to advance in a microfounded model with an explicit and independent oil producer sector in a dollarized economy.

[23]Weisbrot, M. (2013)

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