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## MEASURING THE OPTIMAL MACROECONOMIC UNCERTAINTY INDEX FOR TURKEY

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**ABSTRACT:** *The aim of this study is to calculate the optimal macroeconomic uncertainty index for the Turkish economy. The data used in the study are quarterly and cover the period 2002-2014. In this study the index is formed based on the small structural macroeconomic model. The study uses three important econometric processes. First, the model is estimated separately using generalized method of moments (GMM), seemingly unrelated regressions (SUR), and ordinary least squares (OLS). Secondly, the Broyden–Fletcher–*

*Goldfarb–Shanno (BFGS) algorithm is applied as an optimization algorithm. The BFGS algorithm calibrates the model using GMM, SUR, and OLS parameter estimations of the benchmark parameters. Next, the index variables are weighted under the estimated optimal coefficients and, finally, are aggregated to produce the optimal macroeconomic uncertainty index.*

**KEY WORDS:** *macroeconomic uncertainty, optimal macroeconomic uncertainty index, BFGS algorithm, GMM, SUR.*

**JEL CLASSIFICATION:** C10, D80.

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## **1. INTRODUCTION**

Macroeconomic uncertainty has been much studied in empirical literature. In the literature there are several different approaches to measuring macroeconomic uncertainty. A common approach is to produce proxies using the estimated conditional volatility of any variable. This approach only pays attention to the individual uncertainty of the macroeconomic variables, such as inflation uncertainty, exchange rate uncertainty, interest rate uncertainty, money growth uncertainty, and stock index uncertainty (Serven 1998, Goel and Ram 2001, Bredin and Fountas 2005, Kumo 2006, Cronin et al. 2011, Guglielminetti 2013).

In the empirical literature, besides the individual variable index there are studies that produce macroeconomic uncertainty as an aggregate index. Gan (2013) describes the macroeconomic uncertainty index as the combined effects of related endogenous variables. Macroeconomic policy variables can usually be used as endogenous variables. This index captures naturally the level of the stability index of economic activity. Atta-Mensah (2004), Baker et al. (2015), and Gan (2013) produce macroeconomic uncertainty indices from various aggregate variables under a given structural system. In his study, Atta-Mensah (2004) selects macroeconomic variables that contribute to an uncertain economic environment in Canada such as the stock market, the bond market commercial paper rate, the bilateral exchange rate between Canada and the United States, and economic activity. Atta-Mensah (2004) extracts the volatilities of these variables by using the GARCH technique and measures the macroeconomic uncertainty index as the volatility of these variables. Recently, Baker et al. (2015) developed a new index of economic policy uncertainty. In their approach the index is constructed according to three components: the frequency of newspaper references to economic policy uncertainty, the number of federal tax code provisions set to expire, and the extent of forecaster disagreement over future inflation and government purchases. In addition to the technique of Baker et al. (2015), Gan (2013) determines the optimal economic uncertainty index in a simple macroeconomic model. According to Gan (2013), the index can serve as a good information summary tool to characterize the uncertainty level under various macroeconomic conditions and as a guiding policy tool for improving the uncertainty level under various macroeconomic conditions.

The Central Bank of the Republic of Turkey and the Turkish Statistical Institute derive an economic confidence index for the Turkish economy. The economic confidence index is a composite index that encapsulates consumers' and producers' evaluations, expectations, and tendencies regarding the general economic situation. However, these indices are costly in terms of statistical method and data.

*Within this framework, the aim of this study is to produce an optimal macroeconomic uncertainty index for the Turkish economy by using a simpler and more effective approach. The data used in the study are quarterly and cover the period 2002-2014.*

There are several different measures of macroeconomic uncertainty series in the empirical literature. A common measure is to use the conditional volatility of any variable. Most approaches pay attention to time variation in the uncertainty variables implicitly, restrictedly, and indirectly. However, if there are specification errors such as omitted variables and linear approximation of nonlinear forms, these approaches will provide biased, inefficient, and inconsistent estimates. In addition, these approaches only pay attention to the individual uncertainty of the macroeconomic variables and not to the uncertainty of general macroeconomic conditions. Instead, we compute an optimal macroeconomic uncertainty index based on the small structural macroeconomic model, using an econometric estimation technique such as GMM and an optimization algorithm. Our approach does not substitute traditional econometric techniques but complements them. This technique is chosen as the analytical tool because it has many advantages. When the macroeconomic uncertainty index is computed the index can represent the uncertainty of general macroeconomic conditions, not just individual uncertainty. Our approach enables us to provide an uncertainty index that is the optimal estimate. Computing the optimal uncertainty index in this way is not a costly process in terms of statistical method and data and can therefore be easily utilized by policymakers, providing them with important information that indicates whether to apply restrictive or expansionary policies.

In this study the index is formed based on the small structural macroeconomic model. It is expected that this study will empirically contribute to Turkish

literature in terms of econometric process. This study uses three important econometric processes. First, a standard macroeconomic model is used to construct the optimal level of the economic uncertainty index. The model is estimated by using Ordinary Least Squares (OLS), Seemingly Unrelated Regressions (SUR), and Generalized Method of Moments (GMM). Secondly, the Broyden–Fletcher–Goldfarb–Shanno (BFGS) algorithm is applied as an optimization algorithm. Using the BFGS algorithm, the optimal parameters are found for the uncertainty index. Finally, the variables of the index are weighted under the estimated optimal coefficients and then aggregated to produce the optimal macroeconomic uncertainty index for the Turkish economy.

The study is organized as follows. Section 2 gives the theoretical model that describes the optimal economic uncertainty index. The data and methodology are described in Section 3. Empirical findings are given in Section 4 and the conclusion is presented in Section 5.

## 2. THEORETICAL MODEL

The optimal economic uncertainty index is analysed using the specifications of the standard macroeconomic model. The standard macroeconomic model is an extension of the small structural model described by Svensson (2000). The small structural model constructs the optimal level of the economic uncertainty index. The economic uncertainty index (*UI*) contains real output gap  $RGDP^g$ , inflation gap  $INF^g$ , real exchange rate gap  $E^g$ , and real interest rate gap  $R^g$ . The small structural model is shown by the following equations<sup>1</sup>:

$$RGDP_t^g = \alpha_1 RGDP_{t-1}^g - \lambda_1 R_{t-1}^g - \delta_1 E_{t-1}^g + \varepsilon_t \quad (1)$$

$$INF_t^g = \alpha_2 RGDP_{t-1}^g + \beta_1 INF_{t-1}^g - \delta_2 E_{t-1}^g + \eta_t \quad (2)$$

$$E_t^g = \lambda_2 R_t^g + v_t \quad (3)$$

$$UI_t = \alpha_3 RGDP_t^g + \beta_2 INF_t^g - \delta_3 E_t^g - \lambda_3 R_t^g + \bar{\omega}_t \quad (4)$$

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<sup>1</sup> “The general form used to identify the optimal economic uncertainty reaction function can be obtained through the construction of an entire macro model and a loss function for the central bank.” (Gan 2013: 162).

$$R_t^g = \alpha_4 R_{GDP_t}^g + \beta_3 INF_{t-1}^g - \delta_4 E_{t-1}^g + UI_{t-1} + \zeta_t \quad (5)$$

Equation 1 is an openeconomy IS curve, representing an economy's total output. Equation 2 is an open economy Phillips curve. Equation 3 shows a reduced form of the exchange rate. Equation 4 is a contemporaneous economic uncertainty function. Equation 5 is a monetary policy reaction function.

According to Gan (2013), the optimal economic uncertainty index captures the level of the stability index (non-zero uncertainty or zero uncertainty). The optimal economic uncertainty index can be constructed by explicitly considering the optimal combination of the real output gap, the inflation gap, the real exchange rate gap, and the real interest rate gap. In addition, Gan (2013) emphasizes that if the positive effects of the related variables outweigh the negative effects of the variables in the optimal economic uncertainty index function, the uncertainty value of the index will be positive. A positive uncertainty index implies that a tighter economic policy must be applied.

This index minimizes the central bank's loss function  $L$ . The central bank's loss function is modelled as

$$L_t = \mu_{RGDP_t} V_{RGDP_t} + \mu_{INF_t} V_{INF_t} + \mu_{R_t} V_{R_t} \quad (6)$$

where  $\mu_{RGDP_t}$ ,  $\mu_{INF_t}$  and  $\mu_{R_t}$  indicate the weights attached to the stabilization of the real output gap, the inflation gap, and the real interest rate gap, respectively.  $V_{RGDP_t}$ ,  $V_{INF_t}$ , and  $V_{R_t}$  denote the unconditional variance of the real output gap, the inflation gap, and the real interest rate, respectively.

### 3. DATA AND METHODOLOGY

This study produces an optimal macroeconomic uncertainty index for the Turkish economy. The data used in the study are quarterly and cover the period 2002-2014. The data include the gaps of inflation rate, real output, real exchange rate, and real interest rate variables. The variables are from the Electronic Data Delivery System of the Central Bank of the Republic of Turkey. The details of all variables are summarized in Table 1.

**Table 1.** Details of variables

<b><i>Inflation Rate</i></b>	First Difference of the Log of the Consumer Price Index (1987=100)
<b><i>Real Output</i></b>	Real Gross Domestic Product
<b><i>Real Exchange Rate</i></b>	Real Effective Exchange Rate Index (1995=100).
<b><i>Real Interest Rate</i></b>	The Difference Between the Nominal Interest Rate and the Inflation Rate

Note:  $\mu_{RGDP^g_i}:1.0, \mu_{INF^g_i}:1.0, \mu_{R^g_i}:0.25$  (Gan 2013: 169)

The gaps of all variables were computed as the difference between the current value and the potential value<sup>2</sup> (see Appendix, Figures 3-6). The small structural model presented in Section 2 provides the basis for formulating the optimal economic uncertainty index. In this study the model was estimated separately using the OLS, SUR, and GMM<sup>3</sup>. The BFGS algorithm optimization approach was applied to obtain the optimal parameters for the uncertainty index. The variables of the index were weighted under the estimated optimal coefficients and then aggregated to produce the optimal macroeconomic uncertainty index for the Turkish economy.

#### 4. EMPIRICAL FINDINGS

Before estimating the structural equations given in Section 2, unit root test procedures were used to determine the stationary characteristics of real output gap, inflation gap, real exchange rate gap, and real interest rate gap. ADF and PP approaches were separately applied to all variables.<sup>4</sup> All variables were found to be stationary in their levels (see Appendix Table 4). An optimal economic

<sup>2</sup> In this study the Hodrick–Prescott (HP) filter and trend specifications were used to get the best potential values of the variables (Yamak and Topbaş, 2008). Then the potential values of inflation rate, real output, and real interest rate were calculated by using the HP filter. The potential values of the real exchange rate were calculated by using the quadratic trend model.

<sup>3</sup> The GMM introduced by Hansen (1982) makes use of the orthogonality conditions to allow for efficient estimation in the presence of heteroscedasticity of unknown form. It provides a computationally convenient method of obtaining consistent and asymptotically normally distributed estimators of the parameters of statistical models. The GMM estimator is used to correct for bias caused by endogenous explanatory variables (Baum et al.2003).

<sup>4</sup> ADF: Augmented Dickey-Fuller developed by Dickey and Fuller (1979), PP: Phillips-Perron developed by Phillips and Perron (1988).

uncertainty index was formed based on the small structural macroeconomic model (see Section 2). OLS, SUR, and GMM methods were applied to estimate the small structural macroeconomic model. When the results of the three methods were compared the GMM was found to be the best method for estimating the small structural macroeconomic model (see Appendix, Tables 5 and 6). GMM estimations of the small structural macroeconomic model are reported in Table 2. As seen in Table 2, estimated parameters for all the explanatory variables have the expected signs from the theoretical model. The estimated coefficients are statistically significant at the 1% level for each equation, except for  $E^g_{t-1}$  in the first equation. In Table 2 the instrumental variables include the lagged values of the real output gap, the inflation gap, the real interest rate gap, and the real exchange rate gap. When Equations 1, 2, 3, and 4 are tested with HAC standard errors, various summary statistics are also made robust. In this case, the test of over-identifying restrictions, Hansen's J-test, <sup>(a)</sup> (p value of J- statistic in Table 2) indicates non-rejection of the null hypothesis that the over-identifying restrictions are orthogonal to the errors at the 1% level of significance. In all equations the J-statistics confirm that our instrument sets are appropriate.

In order to determine whether the instrument variables are weak, Cragg-Donald F-statistics were computed and are reported in Table 2. These statistics cannot be computed in equations 1, 2, and 4 because of the number of instrumental variables in the GMM. The Cragg-Donald F-statistic was computed only in Equation 3. According to the calculated F-statistic, this GMM equation suffers from weakness of the instrumental variables. However, the coefficient estimate, which is 0.0051, will be used only as the initial value of the BFGS optimization algorithm. Therefore, the probable bias that can be caused by the weakness of the instrumental variables is not a big problem and can be ignored.

**Table 2.** Results of the GMM estimation

$RGDP_t^g = 0.8238RGDP_{t-1}^g - 0.1277R_{t-1}^g + 1.8763E_{t-1}^g$			<i>Equation 1</i>
(0.0437)	(0.0685)	(2.6689)	
[18.8460]***	[-2.8646]***	[0.7030]	
<b>J-Statistic</b> = 7.1612 <b>p value of J-statistic</b> = 0.5193 <sup>a</sup>			
$INF_t^g = 0.0964RGDP_{t-1}^g + 0.1431INF_{t-1}^g - 3.9522E_{t-1}^g$			<i>Equation 2</i>
(0.0270)	(0.0816)	(1.3120)	
[3.5695]***	[1.7540]*	[-3.0123]***	
<b>J-Statistic</b> = 9.0815 <b>p value of J-statistic</b> = 0.5244 <sup>a</sup>			
$E_t^g = 0.0051R_t^g$			<i>Equation 3</i>
(0.0029)			
[0.0879]*			
<b>J-Statistic</b> = 6.5250 <b>p value of J-statistic</b> = 0.48 <sup>a</sup> <b>Cragg-Donald F-statistic</b> = 4.564838			
$R_t^g = 0.2966RGDP_{t-1}^g + 1.2090INF_{t-1}^g - 9.2993E_{t-1}^g$			<i>Equation 4</i>
(0.1377)	(0.4946)	(5.2811)	
[2.1536]**	[2.4445]**	[-1.7609]*	
<b>J-Statistic</b> = 9.1511 <b>p value of J-statistic</b> = 0.1032 <sup>a</sup>			

**Note:**\*\*\*, \*\* and \* denote statistical significance levels at 1%, 5%, and 10%, respectively. <sup>a</sup>indicates non-rejection of the null hypothesis that the over-identifying restrictions are orthogonal to the errors at the 1% level of significance.

The following scheme explains how an optimal uncertainty index can be calculated for the Turkish economy. The BFGS algorithm approach calibrates the small structural model using GMM parameter estimations of the benchmark parameters.

$$\begin{aligned}
 RGDP_t^g \alpha_3^{optimal} &= 0.8238RGDP_{t-1}^g - 0.1277R_{t-1}^g + 1.8763E_{t-1}^g \\
 INF_t^g \beta_2^{optimal} &= 0.0964RGDP_{t-1}^g + 0.1431INF_{t-1}^g - 2.9523E_{t-1}^g \\
 E_t^g \delta_3^{optimal} &= 0.0051R_t^g \\
 R_t^g \lambda_3^{optimal} &= 0.2966RGDP_{t-1}^g + 1.2090INF_{t-1}^g - 9.2993E_{t-1}^g \\
 UI_t &= \alpha_3^{optimal}RGDP_t^g + \beta_2^{optimal}INF_t^g - \delta_3^{optimal}E_t^g - \lambda_3^{optimal}R_t^g + \bar{\omega}_t
 \end{aligned}$$

The uncertainty index optimized by the coefficients and loss function of the Central Bank ( $L$ ) minimized by the unconditional variances of the variables are shown in Table 3. The loss function is not close to zero, as seen in Table 3.

**Table 3.** The results of BFGS optimization algorithm

Optimal Coefficient	Result
$\alpha_3^{optimal}$	0.7859
$\beta_2^{optimal}$	278.8280
$\delta_3^{optimal}$	71.2474
$\lambda_3^{optimal}$	0.5538
Unconditional Variance	
$V_{RGDP_t^g}$	11.2262
$V_{INF_t^g}$	14.0536
$V_{R_t^g}$	6.1870
$L$	26.8266

Thus, the uncertainty index was measured, using optimal coefficients, by the following specification.

$$UI_t = 0.7859RGDP_t^g + 278.8280INF_t^g - 71.2474E_t^g - 0.5538R_t^g$$

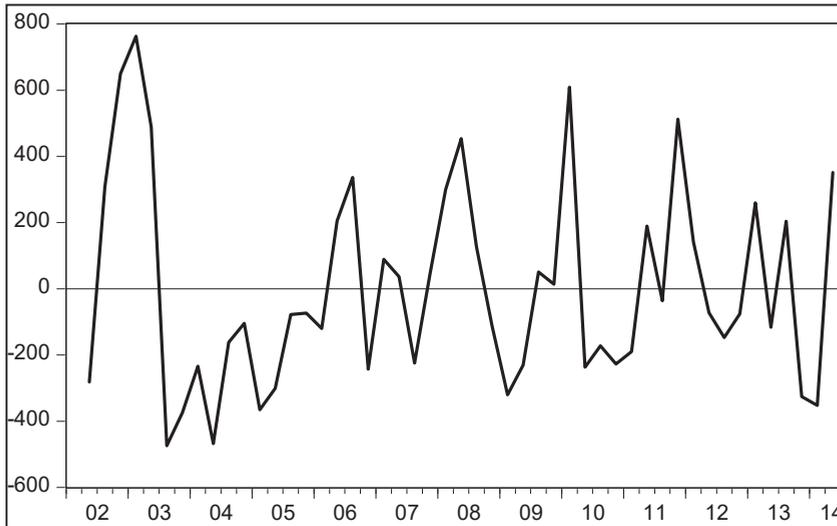
The variables in the  $UI_t$  regression were weighted under the estimated optimal coefficients and then aggregated to produce the optimal macroeconomic

uncertainty index. Figure 1 gives the optimal macroeconomic uncertainty index for Turkey. The periods of positive uncertainty are as follows:

1. 2002:03-2003:02,
2. 2006:02-2006:03,
3. 2007:01-2007:02,
4. 2007:04-2008:03,
5. 2009:03-2010:01,
6. 2011:02,
7. 2011:04-2012:01,
8. 2013:01,
9. 2013:03 and 2014:02

The rest of the periods have negative uncertainty.

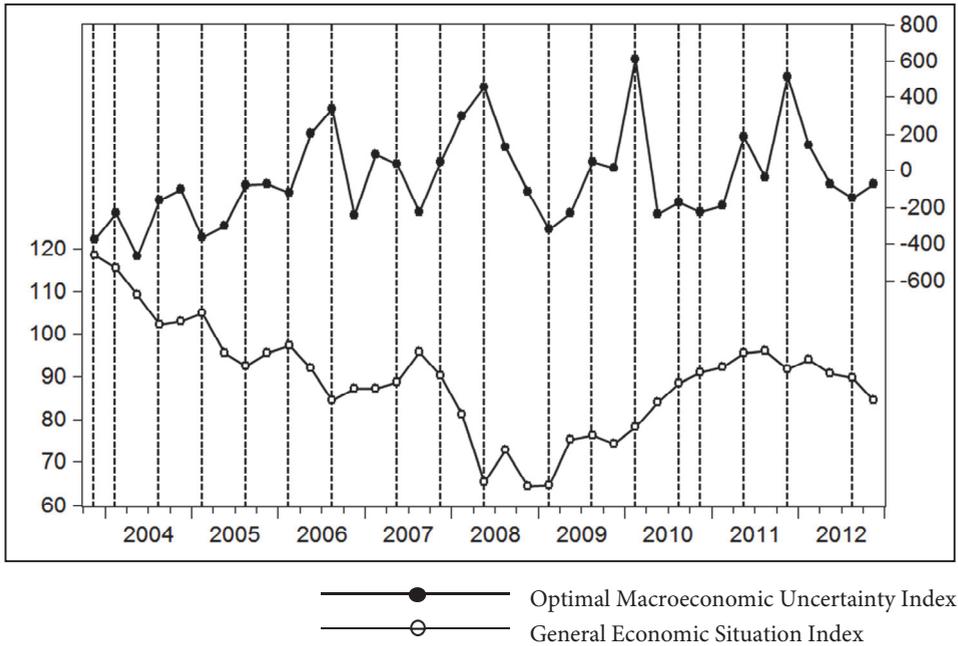
**Figure 1.** Optimal macroeconomic uncertainty index



The optimal macroeconomic uncertainty index was found to be negatively and significantly correlated with the general economic situation index, as expected. The Spearman Correlation coefficient is -0.368, which is statistically significant at the 5% level. In addition, the optimal macroeconomic uncertainty index measured in this study was compared to the general economic situation index

produced by the Central Bank of the Republic of Turkey, shown in Figure 2. As seen from Figure 2, the series move in opposite directions. Thus, the optimal macroeconomic uncertainty index produced in this study can be easily and effectively substituted for the general economic situation index for the Turkish economy.

**Figure 2.** Optimal macroeconomic uncertainty index and general economic situation



**5. CONCLUSIONS**

The aim of this study is to produce an optimal macroeconomic uncertainty index for the Turkish economy. The data used are quarterly and cover the period 2002-2014. In this study the index is formed based on the small structural macroeconomic model. The study includes three important econometric processes. First, the model is estimated separately using GMM, SUR, and OLS. Secondly, the BFGS algorithm approach is applied as an optimization algorithm. The BFGS algorithm approach calibrates the model using GMM, SUR, and OLS parameter estimations of the benchmark

parameters. The variables of the index are weighted under the estimated optimal coefficients and, finally, aggregated to produce the optimal macroeconomic uncertainty index.

*In this study it was found that the periods 2002:03-2003:02, 2006:02-2006:03, 2007:01-2007:02, 2007:04-2008:03, 2009:03-2010:01, 2011:02, 2011:04-2012:01, 2013:01, 2013:03, and 2014:02 had positive uncertainty and the remaining periods had negative uncertainty in the Turkish economy.* To mitigate the positive index value in the positive uncertainty periods a tighter economic policy could be applied. The optimal macroeconomic uncertainty index measured in this study was compared to the general economic situation index produced by the Central Bank of the Republic of Turkey and was found to be negatively and significantly correlated with the general economic situation index. Therefore the optimal macroeconomic uncertainty index could be easily and effectively substituted for the general economic situation index for the Turkish economy.

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**APPENDIX**

**Table 4.** Unit root test results

	ADF	PP
	No Constant-No trend	No Constant-No trend
$RGDP_t^g$	-2.8975*** (1)	-2.2012
$\Delta RGDP_t^g$	-5.5047*** (0)	-5.4816***
$INF_t^g$	-4.7753*** (0)	-4.8551***
$E_t^g$	-5.4075*** (5)	-5.0806***
$R_t^g$	-2.1648	-2.3894
$\Delta R_t^g$	-3.2277*** (1)	-6.3929***

**Note:** \*\*\*, \*\* and \* denote statistical significance levels at 1%, 5%, and 10%, respectively.  $\Delta$  is first difference of the variable. ( ) is optimal length.

**Table 5.** OLS analysis results

<b><math>RGDP_t^g = 1.0111RGDP_{t-1}^g + 0.2223RGDP_{t-2}^g - 0.1352R_{t-1}^g + 0.7070E_{t-1}^g</math></b>			
(0.1425)	(0.1486)	(0.0722)	(4.4467)
[7.0926]***	[-1.4963]	[-18740]*	[0.1590]
<b><math>R^2 = 0.73</math></b>			
<b><math>LM_{(1)}</math> and <math>LM_{(4)} = 0.2575</math> and <math>0.6549</math></b>			
<b><math>INF_t^g = 0.0996RGDP_{t-1}^g + 0.2386INF_{t-1}^g - 6.9617E_{t-1}^g</math></b>			
(0.0432)	(0.1290)	(0.2337)	
[2.3103]**	[1.8490]*	[-2.9831]***	
<b><math>R^2 = 0.30</math></b>			
<b><math>LM_{(1)}</math> and <math>LM_{(4)} = 2.9791^*</math> and <math>1.7874</math></b>			
<b><math>E_t^g = -0.0017R_t^g + 0.4879E_{t-1}^g - 0.1772E_{t-2}^g</math></b>			
(0.0020)	(0.1436)	(0.1362)	
[-0.8482]	[3.3979]****	[-1.3009]	
<b><math>R^2 = 0.23</math></b>			
<b><math>LM_{(1)}</math> and <math>LM_{(4)} = 1.3588</math> and <math>2.042</math></b>			
<b><math>R_t^g = -0.3080RGDP_{t-1}^g - 0.1608INF_{t-1}^g - 2.9004E_{t-1}^g + 0.8384R_{t-1}^g</math></b>			
(0.0826)	(0.2896)	(4.5238)	(0.0790)
[3.7306]***	[-0.5550]	[-0.6411]	[10.6097]***
<b><math>R^2 = 0.80</math></b>			
<b><math>LM_{(1)}</math> and <math>LM_{(4)} = 0.2918</math> and <math>1.5884</math></b>			

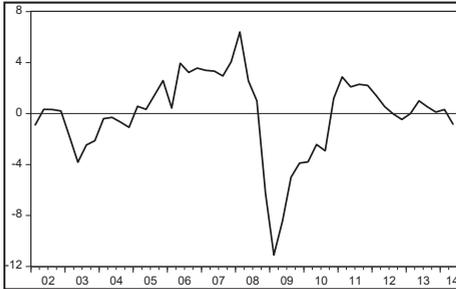
**Note:**\*\*\*, \*\* and \* denote statistical significance levels at 1%, 5%, and 10%, respectively. ( ): standard deviations and [ ]: t-statistics. In order to find out whether the residuals are serially correlated the Breush-Godfrey Serial Correlation Lagrange Multiplier (LM) test was used for first and fourth order serial correlation.

**Table 6.** SUR analysis results

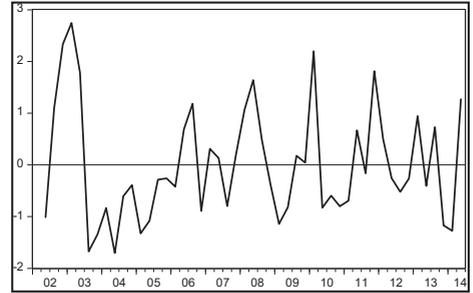
<b><math>RGDP_t^g = 0.8342RGDP_{t-1}^g - 0.1893R_{t-1}^g - 1.6616E_{t-1}^g</math></b>		
(0.0779)	(0.0645)	(4.3163)
[10.7091]***	[-2.9342]***	[-0.3850]
<b><math>R^2 = 0.72</math></b>		
<b><math>F_{TEST} (WALD) = 122.2445***</math></b>		
<b><math>INF_t^g = 0.0998RGDP_{t-1}^g + 0.2454INF_{t-1}^g - 6.5995E_{t-1}^g</math></b>		
(0.0418)	(0.1243)	(2.2568)
[2.3873]**	[1.9748]**	[-2.9243]***
<b><math>R^2 = 0.30</math></b>		
<b><math>F_{TEST} (WALD) = 20.0514***</math></b>		
<b><math>E_t^g = 0.0023R_t^g</math></b>		
(0.0021)		
[1.0938]		
<b><math>R^2 = -0.03</math></b>		
<b><math>F_{TEST} (WALD) = 1.1964</math></b>		
<b><math>R_t^g = 0.3232RGDP_{t-1}^g + 1.5430INF_{t-1}^g - 4.7537E_{t-1}^g</math></b>		
(0.1448)	(0.4350)	(7.8210)
[2.2328]**	[3.5475]***	[-0.6078]
<b><math>R^2 = 0.29</math></b>		
<b><math>F_{TEST} (WALD) = 21.9702***</math></b>		

**Note:**\*\*\*, \*\* and \* denote statistical significance levels at 1%, 5%, and 10%, respectively. ( ): standard deviations.

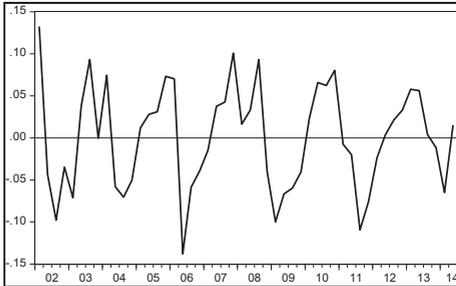
**Figure 3.**  $RGDP^g_t$



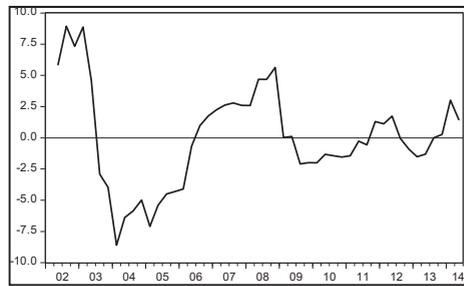
**Figure 4.**  $INF^g_t$



**Figure 5.**  $E^g_t$



**Figure 6.**  $R^g_t$



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