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VAR ANALYSIS OF THE TRANSMISSION MECHANISM OF MONETARY POLICY IN ROMANIA

Empirical study

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Abstract

The purpose of this article is to evaluate the efficiency of the monetary policy impulses transmission on inflation and unemployment in Romania, through the interest rate channel and to show the role played by interest rate in the transmission mechanism of monetary policy impulses. I have also revised a variable's response to the shocks of another variable VAR analysis. VAR analysis on Romania during 2005 - 2013 shows that an interest rate shock can explain the movement in inflation and unemployment rates. We find that there are significant changes in the interest rate based on the inflation rate, and vice versa, due to the relationship of co-integration between variables.

Introduction

The monetary policy is an active field in the research dedicated to macro economy. In the last decade, the interest in knowing the transmission mechanism of monetary policy has increased considerably. Various empirical studies confirm the importance of knowing the transmission mechanism of monetary policy and the existing literature in the field recognizes it. Knowing the dynamics of inflation and a thorough monetary analysis provides important information for consumers and investors and other decision factors.

In the last few years, the empirical results obtained for the countries of Central and Eastern Europe (CEE) regarding the study of the transmission mechanism of monetary policy, are less conclusive, sometimes even contradictory. If for the US, the UK or the eurozone, we find various studies, on the example of countries in Central and Eastern Europe, we will find less, of which we can mention: Ganev et al. (2002), Elbourne and de Haan (2006), Coricelli, Egbert and MacDonald (2006), Anzuini and Levy (2007), Minea and Rault (2008), Gavin and Kemma (2009), Jarocinska (2010), Minea and Rault (2011), Pirovano (2011), Spulbăr et al. (2012). The differences between monetary policy in the emerging economies and the one in the developed countries are caused by different economic contexts. If in developed economies, monetary policy rates have been reduced almost to zero since the beginning of the crisis to avoid the risk of deflation, in the emerging economies, the supply shocks have prevented a higher reduction in the monetary policy interest rate.

An example of a country where empirical studies have identified an important function of the interest rate channel is Germany, a change in interest rates leading to significant change in investment decisions (Sigfried, 2000). Also, Columbia is a case of operation of the interest rate channel, states Carrasquilla (BIS). Another assessment on the functioning of the credit channel belongs to Nemenyi Judith (ONB, 1996) regarding Hungary. The above mentioned author also claims the importance of the real interest rate and not of the nominal one. However the operation of one or another transmission channels of monetary policy are quite controversial in Hungary, because it is quite difficult to reveal the role of each in a changing economy, with inflows of foreign capital and a strong capital market development. In Poland, Rzszard Kokoszcznski (ONB, 1996), mentions the existence of an interest rate channel, at least in the first part of the transition, when economic agents were based on external financing, taking the form of a bank credit.

The transmission mechanism of the monetary policy in Romania

Over the past few years, many central banks in emerging countries or in countries in transition have developed or are developing structural models for the monetary policy transmission mechanism.

Starting from the definition of the NBR, according to which the monetary policy transmission mechanism is the totality of the channels through which the central bank, using a varied set of monetary policy instruments can influence aggregate demand and price dynamics in the economy, we will try to evaluate the effectiveness of transmission for these impulses on inflation and employment.

Many researchers (Cecchetti, 2001; Angeloni et al, 2003) showed that there are differences in the monetary policy transmission channels from one country to another, although important steps have been taken to integrate market goods and services, to implement integrated financial and monetary policies and synchronization of economic cycles. In the Romanian economy, the issue of monetary policy transmission mechanism was approached by Antohi, Udrea and Braun (2003) who have attempted to identify the main features of this mechanism in Romania.

In this chapter we will evaluate the effectiveness of monetary policy impulse transmission on inflation and unemployment in Romania, through the interest rate channel and we will show the role played by the interest rate transmission mechanism of monetary policy impulses, that is, we will try to show that a shock interest rate can explain a movement in the inflation rate and in the unemployment rate by default. Using the AutoCorrect model vector (Vector Error Correction Model) and the shock response function, we study the response of macroeconomic variables to a monetary policy shock through the interest rate, during 2005M01-2013M12.

For the Central Bank, the information on the period in which inflation manages to reach an equilibrium state after a shock, is vital. This information helps the Central Bank to take decisions on interest rate adjustment in order to achieve the objective of inflation targeting. One of the problems the Central Bank faces, refers to imperfect control that it has on inflation because of the lags in monetary policy transmission mechanism, of uncertainties related to this mechanism, the current state of the economy and the future shocks related to it, as well as of the factors that are unrelated to monetary policy.

The methodology and the data used in the empirical analysis

The transmission of monetary policy impulses through the interest rate, on inflation and unemployment is analyzed using the auto-regression vector model (VAR), to capture the dynamic interactions between variables. The analysis is based on data series with monthly frequency range between 2005M01-2013M12. This model provides a simplified and formalized description of the monetary policy transmission mechanism towards inflation and other macro variables of interest. Here we present a VAR analysis model for the estimation of the effects caused by the monetary policy shocks, using Romania as a case study.

To achieve the target (analysis of the relationship between inflation rate and the chosen macroeconomic variables) we analyze a dataset at the level of Romania. The analyzed variables are shown in Appendix A, Table 1.

In order to estimate a model among the studied variables we must follow these steps:
- Verify the stationarity of time series;
- Verify the co-integration relationship between the studied variables.

This model's role is to integrate all relevant information in a consistent way, to generate an inflation projection of a trajectory of monetary policy interest rate that serve as benchmarks for the NBR Administration Board decisions.

- **Testing the time series stationarity**

To verify if the time series are stationary, unit root tests can be applied, such as the Augmented Dickey-Fuller (ADF) test.

The hypotheses of the stationarity testing using the ADF test are:
H0: $y_t \sim I(1)$ (the series is not stationary)
H0: $y_t \sim I(0)$ (the series is stationary)

A time series is stationarized through the *d* order difference filter. An y_t time series containing d real roots of unit is called *d* order integrated series and it is noted *I(d)*. If the tests show the presence of a single unit root, then the time series is called order one integrated and it is noted I(1) (Gage 2009).

a) Checking the data series stationarity in regards to the *Interest rate*

For the *Interest rate* series, ADF's statistic value is equal to 0.087 and has as correspondent a probability equal to 0.963 (see Appendix A, Table 2). The critical values are presented in the table for risk values of 0.01, 0.05 and 0.1. It is noted that the calculated absolute value is less than the theoretical value, so the null hypothesis is accepted, the series is stationary.

The stationarity for the differentiated series of order 1 is verified and we obtain a calculated value equal to 6804 correspondent to a probability of 0.000 (see see Appendix A, Table 3). So, the differentiated series of order 1 is stationary and is therefore integrated I (1)

b) Checking the data series stationarity in regards to the inflation rate

For the inflation rate series, the value of the ADF statistics equals – 1.776 and corresponds to a probability equal to 0.390 (see Appendix A, Table 4). It is noted that the calculated absolute value is less than the theoretical value, so it accepts the null hypothesis, the series is stationary.

The stationarity for the differentiated series of order 1 is verified and we obtain a calculated value equal to -4.09 correspondent to a probability of 0.00159 (see Appendix A, Table 5). So, the differentiated series of order 1 is stationary.

c) Checking the data series stationarity in regards to the *Unemployment rate*

For the *Unemployment rate* series, the value of the ADF statistics equals – 2.164 and corresponds to a probability equal to 0.2206 (see Appendix A, Table 6). It is noted that the calculated absolute value is less than the theoretical value, so it accepts the null hypothesis, the series is not stationary.

The stationarity for the differentiated series of order 1 is verified and we obtain a calculated value equal to -5.480 correspondent to a probability of 0.000 (see Appendix A, Table 7). So, the differentiated series of order 1 is stationary.

In conclusion, the differentiated series of order 1 are stationary, so the 3 initial data series are integrated series I (1).

- **The analysis of the cointegration relationship between the studied variables**

Given that our empirical analysis focuses on three variables, we suspect the existence of some equilibrium relationship between them. I tested the number of the cointegration relations using the Johansen Cointegration test. The Cointegration analysis involves the following steps:

A) Verification of a long-term equilibrium relationship. If two data series are cointegrated, then there is a stationary linear combination between them. Two cointegrated series cannot vary too much from one another, because deviations between their values have finite variance. The presence of cointegration also implies a causality relationship between the series' variation. If one series varies then the other series varies as well. This type of statistical causality is called Granger causality.

B) Estimation of a dynamic correlation model, called *error correction model.* This model explains the manner in which the short-term deviations are corrected from the equilibrium relationship.

A) The estimation the relationship between the considered variables is based on a system of regression models called autoregressive vector model (VAR). Each endogenous variable in the system is analyzed as a function of the lag values of all other endogenous variables in the system.

We consider Y_t a VAR model of p order. A VAR(p) process is a multivariate model used to represent a set of chronologic stationary series, dependent in time. The cointegrated series depend on one another in the long term. On short term, they may deviate from each other, but after a period of time, they have the same deviation.

The first step in building the VAR model is to establish the size corresponding to the lag (the delay operator). The values of an y_t series can be expressed based on the previous y_{t-1} value using a delay operator (Turturean, 2006). To determine the lag size different information criteria in E-Views are used. It is obtained based on the Schwartz (SC) and Hannan - Quinn (HQ) criteria, the identification of an optimal lag equals 2. Thus, the model that we want to estimate is a VAR (2) model. It is a model that includes the series of order 2 differences of the original series.

The VAR model estimation results are presented in Appendix A, Table 8. Each column in the table corresponds to an equation from the VAR model. The presented results correspond to the estimated coefficients, to the corresponding standard errors (in brackets) and to the *t*-test value.

For each equation statistical indicators are presented which allow assessing the quality of the estimated model. The values of the adjusted determination report (R^2_{adj}) are large, allowing the acceptance of the considered models.

For the model in which the inflation rate is the dependent variable, the estimated equation is

$$RI_t = \hat{\beta}_1 RI_{t-1} + \hat{\beta}_2 RD_{t-1} + \hat{\gamma}_1 RI_{t-2} + \hat{\gamma}_2 RD_{t-2} + e_t$$

$$RI_t = 1{,}656 RI_{t-1} - 0{,}096 RD_{t-1} - 0{,}702 RI_{t-2} + 0{,}122 RD_{t-2} + e_t$$

The model includes only variables with significant influence, that is, variables whose regression coefficients are statistically significant (coefficients for which $|t_{calc}| > t_{critic} = 1{,}96$).

For the model in which the *Interest rate* is the dependent variable, the estimated equation is

$$RD_t = \hat{\alpha} + \hat{\beta}_1 RD_{t-1} + \hat{\beta}_2 RI_{t-1} + \hat{\gamma}_1 RD_{t-2} + e_t$$

$$RI_t = 0{,}975 + 1{,}295 RD_{t-1} + 0{,}319 RI_{t-1} - 0{,}449 RD_{t-2} + e_t$$

Between the two models, the best model is the model in which the *Inflation rate* is the dependent variable (according to the information criteria, it is the model with the lower AIC value).

The causal relationship requires a relationship of sequence of the variation of a variable depending on variation of another variable. The causality in this context is that the turning points for a series precede the turning points of the other series. This does not mean that if we change the structure of a series, the other series is also changed. The causality analyzed statistically is called Granger causality. When the series are cointegrated, there must be at least a causal flow in the system.

The causality analysis results are significant for the following variables:

- there is a significant causality between the inflation and the interest rate risk considered by 1% and there is a significant causality and, vice-versa, between the interest rate and the inflation rate for the same risk of 1%.
- there is a significant causality for a risk of 10% between the unemployment rate and the interest rate, but the causality in reverse is not significant.

We can consider that the changes of the inflation and interest rate precede the unemployment changes. Also, it can be said that a change in the interest rate changes precede a change in the inflation rate.

Impulse responses

The response of a variable to another variable's shocks is represented in Appendix G. According to the estimates of the model parameters and the Granger causality test results, the links between the analyzed data series are shown through the graphs of the impulse-response function. A shock transmitted to an *i* variable directly affects not only that *i* variable but it is also sent to all endogenous variables through a dynamic structure (with lags) of the VAR model. The impulse response function traces the effects of a variable shock on the present and future values of the endogenous variables.

According to the study of Spulbar et al. (2012), we can say that we are witnessing the consolidation of the interest rate as an instrument of monetary policy transmission in Romania, which represents a support for the inflation targeting strategy(see Appendix B, Fig. 1).

Through the amplitude of the curves we measure the responses of a variable to the shocks of the variable itself or to the shocks of another variable (different values of 0 of the response function to impulse). In the example we got concerning the answer of the inflation and unemployment rate to an interest rate shock, we observe strong changes of the evolution of inflation to interest rate shocks and the other way around, as well as moderate response of the unemployment rate to the interest rate shocks. The changes in interest rates gradually act on inflation.

B) In order to study the mechanisms that connect the cointegrated series, we study a model that analyzes the short-term dynamics, called *error correction model*.

Because the three data sets are I integrates (1) it is necessary to check whether the series are cointegrated or not (linear combination of these series is still I (1). That is why the Johansen test is applied in Eviews. The presence of cointegration implies the existence of a long-term link between variables.

Based on the results of the Trace test statistics, we can accept the existence of a long-term link between the studied variables, given a 5% risk.

The second step in the analysis is to estimate the cointegrating error correction model (ECM) also called the equilibrium correction model. This model allows the short-term analysis of dynamic correlations and correcting the short term deviations from the long-term equilibrium. The ECM is a dynamic model of the 1 order differences of the variables used in the cointegration analysis.

The ECM estimated model, in which the *inflation rate* is the dependent variable, can be written in two equivalent forms:

1) $$\Delta RI_t = \hat{\beta}_1(RI - RD)_{t-1} + \hat{\beta}_2 RI_{t-1} + \hat{\beta}_3 RI_{t-2} + \hat{\beta}_4 RD_{t-1} + \hat{\beta}_5 RD_{t-2} + e_t$$

Deci,

$$\Delta RI_t = 0{,}031(RI - RD)_{t-1} + 0{,}694 RI_{t-1} + 0{,}162 RI_{t-2} - 0{,}262 RD_{t-1} + 0{,}221 RD_{t-2} + e_t$$

2) $$RI_t = (1 - \hat{\beta}_1 - \hat{\beta}_2) RI_{t-1} + (\hat{\beta}_3 - \hat{\beta}_2) RI_{t-1} - \hat{\beta}_3 RI_{t-3} + (\hat{\beta}_1 + \hat{\beta}_4)\, RD_{t-1} + (\hat{\beta}_1 + \hat{\beta}_5)\, RD_{t-2} - \hat{\beta}_5 RD_{t-3} + e_t$$

Deci,

$$RI_t = 0{,}275 RI_{t-1} - 0{,}532 RI_{t-1} - 0{,}162 RI_{t-3} - 0{,}321\, RD_{t-1} + 0{,}252\, RD_{t-2} - 0{,}221 RD_{t-3} + e_t$$

where e_t is the residual variable estimated by the method of the smallest squares.

The estimated equations only include variables that have significant influence on the dependent variable.

The ECM model is a mechanism that adjusts automatically so that deviations from the long-term equilibrium relationship are corrected automatically. This model is useful for the analysis regarding the response of one or more cointegrated variables to shock. It allows obtaining the response function to impulse, showing each variable's change to shock for a period of time.

Our empirical results show that, under the impact of a positive shock of the central bank monetary policy through interest rate, the macroeconomic variables move in the expected direction: inflation has a slightly downward trend and the unemployment has a moderate response to interest rate shocks (see Appendix B, Fig.2).

From a monetary policy perspective, our empirical results show the following aspects:

- Significant changes in the interest rate are observed based on the inflation rate, and vice versa, as a consequence of the relationship of cointegration between variables.
- It may also be noted that the inflation rate responds positively to its own shocks and to interest rate shocks.
- In case of a shock in the unemployment rate, the inflation rate decreases, and after a period, its trajectory is going upward again.

Conclusions:

To capture the influence of the monetary policy rate and the unemployment rate on inflation, I used the autoregression vector methodology (VAR). We know that macroeconomic phenomena manifest as complex dynamic systems with feedback and mutual causality. Following a system type analysis, I tried to capture the connections between macroeconomic variables. The VAR model analysis materialized on the shock analysis in interest and unemployment rate on inflation. The cointegration relationship can be seen as a long-term relationship, a relationship of balance between variables. It was observed that on short-term, there are deviations from this equilibrium due to unforeseen shocks, but, if the analysis would be conducted on a longer term, the cointegration relationship between variables would tend towards equilibrium.

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Appendices

Appendix A

Table 1.
The statistical variables considered in the analysis

Name	Description	Period	Frequence
Inflation_rate	Monetary policy interest rate	2005-2013	monthly
Inflation_rate	Inflation_rate	2005-2013	monthly
Unemployment_rate	Unemployment_rate	2005-2013	monthly

The source is NRB, the Romanian National Institute of Statistics and Eurostat

Table 2.
Results of the ADF test for the series of data concerning the interest rate

Null Hypothesis: Interest_rate has a unit root
Exogenous: Constant
Lag Length: 3 (Automatic - based on SIC, maxlag=12)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		0.087145	0.9634
Test critical values:	1% level	-3.492523	
	5% level	-2.888669	
	10% level	-2.581313	

*MacKinnon (1996) one-sided p-values.

Table 3.
Results of the ADF test for the series of data concerning the differentiated Interest rate

Null Hypothesis: D(Interest_rate) has a unit root
Exogenous: Constant

Lag Length: 3 (Automatic - based on SIC, maxlag=12)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-6.804489	0.0000
Test critical values:	1% level	-3.493129	
	5% level	-2.888932	
	10% level	-2.581453	

*MacKinnon (1996) one-sided p-values.

Table 4.
Results of the ADF test for the series of data concerning the Inflation rate

Null Hypothesis: INFLATION_RATE has a unit root
Exogenous: Constant
Lag Length: 1 (Automatic - based on SIC, maxlag=12)

		t-Statistic	Prob.*

Augmented Dickey-Fuller test statistic		-1.776586	0.3903
Test critical values:	1% level	-3.491345	
	5% level	-2.888157	
	10% level	-2.581041	
*MacKinnon (1996) one-sided p-values.			

Table 5.

Results of the ADF test for the series of data concerning the differentiated Inflation rate

Null Hypothesis: D(INFLATION_RATE) has a unit root
Exogenous: Constant
Lag Length: 2 (Automatic - based on SIC, maxlag=12)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-4.090023	0.0015
Test critical values:	1% level	-3.492523	
	5% level	-2.888669	
	10% level	-2.581313	

Table 6.

Results of the ADF test for the series of data concerning the Unemployment rate

Null Hypothesis: UNEMPLOYMENT_RATE has a unit root
Exogenous: Constant
Lag Length: 1 (Automatic - based on SIC, maxlag=12)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-2.164049	0.2206
Test critical values:	1% level	-3.491345	
	5% level	-2.888157	
	10% level	-2.581041	

*MacKinnon (1996) one-sided p-values.

Table 7.

Results of the ADF test for the series of data concerning the differential Unemployment rate

Null Hypothesis: D(UNEMPLOYMENT_RATE) has a unit root
Exogenous: Constant
Lag Length: 0 (Automatic - based on SIC, maxlag=12)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-5.480603	0.0000
Test critical values:	1% level	-3.491345	
	5% level	-2.888157	
	10% level	-2.581041	

*MacKinnon (1996) one-sided p-values.

Table 8.
The estimated coefficients of the VAR model

Vector Autoregression Estimates
Date: 09/06/14 Time: 14:29
Sample (adjusted): 2005M03 2014M03
Included observations: 109 after adjustments
Standard errors in ( ) & t-statistics in [ ]

	INTEREST_RATE	INFLATION_RATE	UNMPLOYMENT_RATE
INTEREST_RATE (-1)	1.295016	-0.096907	0.030615
	(0.08385)	(0.03928)	(0.03752)
	[15.4443]	[-2.46681]	[0.81599]
INTEREST_RATE (-2)	-0.449792	0.122092	-0.027768
	(0.07370)	(0.03453)	(0.03298)
	[-6.10266]	[3.53575]	[-0.84199]
INFLATION_RATE (-1)	0.319212	1.656481	-0.055459
	(0.14386)	(0.06740)	(0.06437)
	[2.21894]	[24.5774]	[-0.86157]
INFLATION_RATE (-2)	-0.228207	-0.701550	0.058379
	(0.14237)	(0.06670)	(0.06370)
	[-1.60290]	[-10.5177]	[0.91640]
UNEMPLOYMENT_RATE (-1)	0.176712	-0.091137	1.517806
	(0.18761)	(0.08790)	(0.08395)
	[0.94190]	[-1.03686]	[18.0805]
UNEMPLOZMENT_RATE (-2)	-0.257730	0.086830	-0.551046
	(0.18885)	(0.08848)	(0.08450)
	[-1.36471]	[0.98135]	[-6.52100]
C	0.975225	0.080610	0.138876
	(0.28415)	(0.13313)	(0.12714)
	[3.43208]	[0.60552]	[1.09228]
R-squared	0.945132	0.988298	0.971422
Adj. R-squared	0.941905	0.987610	0.969741
Sum sq. resids	19.41964	4.262582	3.888080
S.E. equation	0.436335	0.204426	0.195239
F-statistic	292.8355	1435.727	577.8666
Log likelihood	-60.64836	21.99597	27.00777
Akaike AIC	1.241254	-0.275155	-0.367115
Schwarz SC	1.414093	-0.102317	-0.194276
Mean dependent	7.203028	6.072844	5.451376
S.D. dependent	1.810297	1.836504	1.122383

Determinant resid covariance (dof adj.)	0.000290
Determinant resid covariance	0.000238
Log likelihood	-9.227938
Akaike information criterion	0.554641
Schwarz criterion	1.073158

Appendix B

Figure 1.
Impulse response function of a variable on other variables

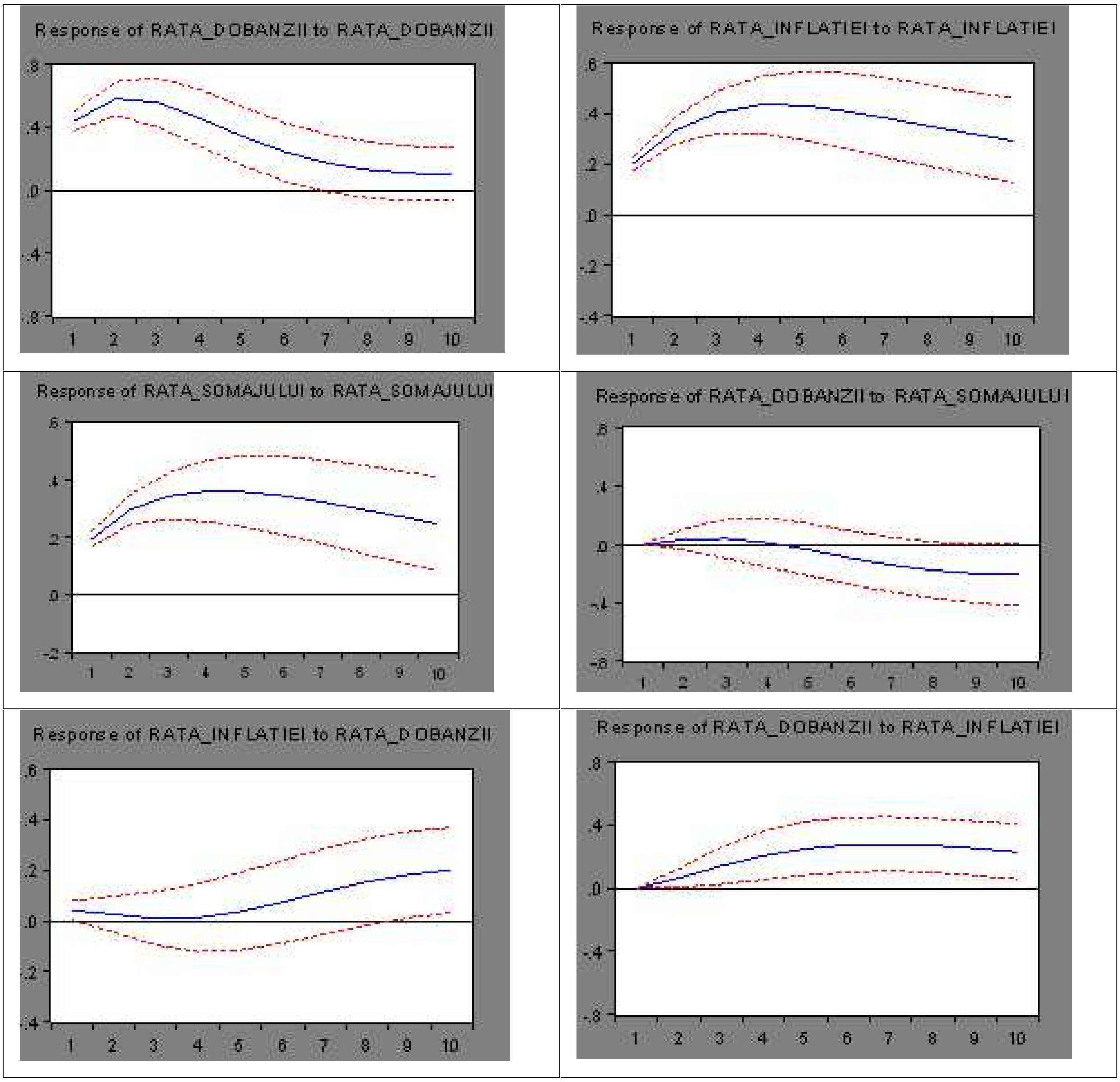

Figure 2
Impulse response function of a variable on the other variable