Irena Palić[a]

JEL classification: *C22, E52, F41*
Preliminary statement
https://doi.org/10.32910/ep.76.1.4

The Empirical Evaluation of Monetary Policy Rules in the Small Open Economy DSGE Model: Evidence from Croatia

Abstract

The aim of this article is to empirically evaluate the compliance of four different monetary policy rules in the DSGE model with empirical characteristics of a small open economy. The small open economy is represented by Croatia, while the large foreign sector is represented by the euro area without Croatia. The new Keynesian small open economy DSGE model with four monetary policy rules is calibrated. Since the essential characteristic of a small open economy is the exogeneity of foreign variables, to empirically test the effects of shocks in a small open economy, the structural vector autoregression (SVAR) model with block exogenous restrictions is estimated and euro area variables are treated as exogenous. The impulse response functions analysis points to the conclusion that fixed exchange rate suits the best to the empirical impacts of analysed shocks in Croatia. The results of the research are important in the context of recent accession of Croatia to the euro area and the monetary policy design in small open economies.

Keywords: *block exogeneity restrictions, Croatia, DSGE model; monetary policy evaluation; small open economy; SVAR model*

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[a] I. Palić, Ph.D., Associate Professor, University of Zagreb, Faculty of Economics & Business (e-mail: ipalic@efzg.hr). The paper was received on 19.12.2022. It was accepted for publication on 10.04.2024.

1. INTRODUCTION

Large part of the recent macroeconomic research addresses the way of conducting monetary policy, including the development and evaluation of monetary models that introduce imperfect competition and nominal rigidities in the dynamic stochastic general equilibrium (DSGE) models. The research of monetary policy design within the framework of DSGE models has been interesting to both scientists and policy makers for a long time. In the new Keynesian models, monetary policy is potentially a mean of stabilization, as well as an independent source of economic fluctuations. The analysis of the properties of alternative monetary policy rules and the way central banks change their policy instruments in response to changes in macroeconomic developments is interesting both for economic scientists and policy makers (Galì and Monacelli, 2005).

DSGE models are macroeconomic models with clear microeconomic foundations which include expectations of future decisions of economic policy what makes them resistant to the Lucas (1976) critique. Theoretical formulation of dynamic stochastic general equilibrium model can explain the impact of macroeconomic shocks on economic variables. However, the comprehensive empirical evidence is often obtained by the estimation of structural vector autoregression (SVAR) models. The VAR approach is frequently used for the evaluation of DSGE models in order to econometrically assess the nature and characteristics of economic variables.

Together with the rapid increase in world trade, policymakers are becoming more interested in the consequences of greater openness of countries on macroeconomic behavior. Considerable attention has been given to the increased role of foreign shocks in initiating domestic fluctuations due to the increase in world trade (Erceg et al., 2010). The optimal monetary policy in an open economy is analysed in Clarida et al. (2002) and Galì and Monacelli (2005). Galì and Monacelli (2005) formulate the small open economy DSGE model with sticky prices, which is used as a framework for analysis of the properties and the macroeconomic implications of alternative monetary policy regimes. Furthermore, Alba et al. (2012) suggest the need for review of monetary and exchange rate policy after the global financial crisis that originated in the summer of 2007, and investigate the role of monetary policy in mitigating the negative foreign shocks in East Asian countries.

This paper empirically evaluates the impact of domestic productivity shock and foreign demand shock in the DSGE model calibrated for Croatia, with four various assumptions of monetary policy regimes: the assumption of a fixed exchange rate regime, the regime in which the central bank reacts to inflation measured by the consumer price index, the regime in which the central bank reacts to domestic inflation and the optimal domestic inflation targeting regime. The aim of this paper is to identify which monetary policy regime within the small open economy DSGE model best fits the empirical characteristics of the Croatian economy using the SVAR model with block exogeneity restrictions.

This research offers the empirical evaluation of exchange rate regimes. Generally, a fixed exchange rate regime provides an environment for enhanced growth through a decline in uncertainty and limited variability in the interest rate, whereas a flexible regime is a source of macroeconomic uncertainty, as it allows the propagation of negative external shocks and therefore dampens growth (Lartey, 2017). The main research question is: "What is the adequate monetary policy rule for Croatia in the framework of macroeconomic models with microeconomic foundations?". This paper provides the answer through the lens of the DSGE model calibrated for Croatian economy and evaluated using the SVAR model. Euro adoption requires economic convergence and economic harmonisation with euro area countries. This paper offers empirical verification of euro adoption as the adequate monetary policy for Croatia in the framework of macroeconomic modelling with microeconomic foundations.

The issue of formulation and testing the validity of DSGE models is insufficiently explored in Croatian literature. A review of relevant literature revealed that Bokan et al. (2009) conducted a simulation of the impact of the financial crisis on the Croatian economy using the DSGE model. However, authors indicate that the mentioned model is not simulated and evaluated according to the standard norms of the academic literature on DSGE models. Palić (2015) offers the first comprehensive empirical evaluation of DSGE models in Croatia using vector autoregression models. Regarding the compliance of monetary policy regimes in DSGE models with empirical characteristics of the Croatian economy, Palić (2015) calibrated parameters of various DSGE models for Croatia using quarterly data. Arčabić et al. (2016a, 2016b) analysed the impact of productivity and foreign output shock in Croatia using the parameter calibration of Palić (2015). This paper provides the evaluation of the DSGE model using SVAR model with block exogeneity restrictions, which is an important modelling feature for Croatian small open economy. Moreover, the financial conditions index used in this research differs from values of financial conditions index used in Palić (2015) because of different variables included in the calculation as well as different temporal scope. Therefore, this paper extends on the analysis done by Palić (2015) mainly in data coverage and choice of variables, while it extends on Arčabić et al. (2016a, 2016b) in using block exogeneity restrictions to evaluate the DSGE model of Croatian economy.

In the next chapter, the new Keynesian DSGE model with four alternative monetary policy rules is exposed. Secondly, the exposed model is calibrated using data for the Croatian economy as a representative small open economy and the euro area (without Croatia) as a large foreign sector. After that the SVAR model with block exogeneity restrictions is estimated for the Croatian economy and Euro area using monthly data from March 2005 to June 2016. The comparative analysis of the impact of productivity shock and foreign shock in the DSGE and SVAR model is conducted using impulse response functions. Finally, main conclusions and policy implications are outlined, and the research limitations and the future research perspective are stated.

2. THE NEW KEYNESIAN SMALL OPEN ECONOMY MODEL

Galì and Monacelli (2005) developed a framework for modelling small open economies which became the starting point for the analysis of small open economies within the new Keynesian framework. Galì and Monacelli (2005) combine assumptions on preferences and technology with Calvo (1983) pricing and the assumption of complete financial markets and derive log-linearized equilibrium conditions. The coefficients of obtained equations in the framework of an open economy depend on specific parameters of an open economy, which is influenced by foreign sector variables, whereas the foreign sector is exogenous to a small open economy.

In this paper, Galì and Monacelli's (2005) model is calibrated for the Croatian economy and simulated using MATLAB R2014a and Dynare 4.4.2., which is a standard software platform for calibrating DSGE models (see Adjemian et al., 2011). To conduct simulation, ten key equations derived after the log-linearization of the model are used. Households maximise the following expected utility function:

$$E_0 \sum_{t=o}^{\infty} \beta^t U(C_t, L_t)\,, \tag{1}$$

where L_t is employment measured by hours of work, and C_t is the composite index of consumption defined by domestic and foreign goods. The composite index of consumption is defined as follows:

$$C_t \equiv \left[(1-\chi)^{\frac{1}{\varepsilon_H}} \left(C_{H,t}\right)^{\frac{\varepsilon_H - 1}{\varepsilon_H}} + \chi^{\frac{1}{\varepsilon_H}} \left(C_{F,t}\right)^{\frac{\varepsilon_H - 1}{\varepsilon_H}} \right]^{\frac{\varepsilon_H}{\varepsilon_H - 1}}, \tag{2}$$

where parameter $\chi \in [0,1]$ is the measure of openness, ε_H is the elasticity of substitution between domestic and foreign goods from the point of domestic consumers, $C_{H,t}$ is the index of consumption of domestic goods and $C_{F,t}$ is the index of consumption of foreign goods. The utility function given by (1) is maximised subject to the following budget constraint:

$$\int_0^1 P_{H,t}(i) C_{H,t}(i)\, di + \int_0^1 \int_0^1 P_{j,t}(i) C_{j,t}(i)\, di\, dj + \\ + E_t \left\{ Q_{t,t+1} D_{t+1} \right\} \le D_t + W_t L_t + T_t \tag{3}$$

for each *t= 0,1,2, …,* where $P_{(H,t)}(i)$ is the price of domestic good i, $P_{(j,t)}(i)$ is the price of good *i* imported from country *j*, D_{t+1} is the nominal payoff in period *t+1* on the portfolio held at the end of period t, $D_{t,t+1}$ is the stochastic discount factor for one-period ahead nominal payoffs relevant to the domestic household, W_t is the nominal wage, and T_t refers to total transfers/taxes. The typical firm in the observed small open economy model produces differentiated goods. Galì and Monacelli (2005) define the following production function:

$$Y_t(i) = A_t L_t(i)\ . \qquad (4)$$

The detailed exposition of the model, model solution and equilibrium conditions are given in Galì and Monacelli (2005). The log-linearized small open economy inflation π_t, effective terms of trade S_t, nominal interest rate i_t, technology a_t, output y_t, potential output y_t^n, output gap $\tilde{y}_t$, new Keynesian Phillips curve, dynamic IS curve, and natural interest rate r_t^n are given by equations (5)–(14), respectively:

$$\pi_t = \pi_{H,t} + \chi \Delta s_t \qquad (5)$$

$$s_t = s_{t-1} + e_t^{ef} - e_{t-1}^{ef} + \pi_t^* - \pi_{H,t} \qquad (6)$$

$$i_t = \left\{ \Delta e_{t+1}^{ef} \right\} \qquad (7)$$

$$a_t = \rho a_{t-1} + e_t \qquad (8)$$

$$y_t = y_t^* + \frac{1}{\sigma_\chi} s_t \qquad (9)$$

$$y_t^n = \Gamma_0 + \Gamma_a a_t + \Gamma_* y_t^* \qquad (10)$$

where $\Gamma_0 \equiv \frac{\nu - \mu}{\sigma_\chi + \phi}$, $\Gamma_a \equiv \frac{1-\phi}{\sigma_\chi + \phi} > 0$, $\nu \equiv \log(1-\tau)$

and $\Theta \equiv (\sigma\varepsilon_F - 1) + (1-\chi)(\sigma\varepsilon_H - 1)$

$$\tilde{y}_t \equiv y_t - y_t^n \qquad (11)$$

$$\pi_{H,t} = \beta \pi_{H,t+1} + \kappa_\chi \tilde{y}_t \qquad (12)$$

where $\kappa_\chi \equiv \frac{(1-\beta\theta)(1-\theta)}{\theta}(\sigma_\chi + \phi)$.

$$\tilde{y}_t = \left(\tilde{y}_{t+1}\right) - \frac{1}{\sigma_\chi}\left(i_t - \left(\pi_{H,t+1}\right) - r_t^n\right) \qquad (13)$$

$$r_t^n \equiv s - \sigma_\chi \Gamma_\chi (1-\rho) a_t + \frac{\chi(\Theta)\sigma_\chi \phi}{\sigma_\chi + \phi}\left\{\left(\Delta y_{t+1}^*\right)\right\} \qquad (14)$$

where $\pi_{H,t}$ is domestic inflation, e_t^{ef} is nominal effective exchange rate, p_t^* is world inflation, i_t is nominal interest rate, ρ is AR(1) parameter for technology, e_t is error term (innovations), y_t^* is world output, σ_x is the parameter which is a function of the degree of openness and the substitutability between domestic and foreign goods (see Galì, 2008), τ is employment subsidy, μ is the logarithm of price mark-up, φ is the elasticity of labour supply, ε_F is the elasticity of substitution between goods produced in different foreign countries, σ is relative risk aversion, β is the discount factor, and θ refers to price stickiness and σ is intertemporal discount rate.

Using the above model Galì and Monacelli (2005) analyse three alternative monetary policy rules. The first two rules are variations of Taylor's rule. The first rule is domestic inflation-based, hereinafter DIT rule, according to which domestic interest rate responds to domestic inflation:

$$i_t = s + \varphi_\pi \pi_{H,t}\ . \qquad (15)$$

The second rule is the CPI inflation-based Taylor rule, hereinafter CIT rule, which assumes that the central bank responds to inflation measured by the consumer price index in determining the interest rate:

$$i_t = s + \varphi_\pi \pi_t\ . \qquad (16)$$

The third analysed rule refers to the fixed exchange rate, i.e. the exchange rate peg:

$$e_t = 0. \qquad (17)$$

In this paper, in addition to three mentioned rules, the optimal monetary policy (OPTIDIT rule) is analysed. According to Galì and Monacelli (2005), the optimal monetary policy is stabilising the output gap, what implies that domestic prices are also stabilised under that optimal policy, namely:

$$\tilde{y}_t = 0 \qquad (18)$$

and

$$\pi_{H,t} = 0 \qquad (19).$$

3. THE CALIBRATION OF MODEL PARAMETERS

Calibration is the starting method in the empirical implementation of DSGE models, which serves as the basis for other empirical methods of implementation of DSGE models. When calibrating the model, numerical values are attributed to model parameters that characterise the stochastic disturbances, preferences and technology, in line with the empirical regularities that reflect the structure of the observed economy (Bokan *et al.,* 2009). The value of structural parameters is usually set on the basis of previous estimates from microeconomic studies or calculated using long-run averages of the aggregate data. The calibration of the model is done using the most recent data for the Croatian economy. However, for certain parameters that cannot be calibrated from the available data, their value is taken from the relevant empirical studies.

In order to calibrate the stochastic properties of exogenous shocks in the model, productivity and foreign income are described as autoregressive processes. The logarithmic value of productivity refers to the logarithmic value of productivity index A which is defined as the ratio of industrial production index Y (the proxy for output) and employment index. The approximation of output using industrial production indices is common for Croatia due to relatively short available time series for gross domestic product. Data are described in detail in Appendix A. Both industrial production and employment are seasonally adjusted using the X-13 ARIMA SEATS adjustment method (see U.S. Census Bureau, 2013). The following AR (1) process for labour productivity is estimated (with standard error in brackets):

$$\underset{}{a_t} = \underset{(0.015)}{4.577} + \underset{(0.037)}{0.827} a_{t-1} + e_t, \qquad (20)$$

with σ_{y^*} = 0.068. It is necessary that the parameter ρ is less than one to satisfy the condition of AR (1) process stationarity (Enders, 2015). In line with the domestic output approximation, the foreign output, which refers to the income of the euro area, is approximated using volume indices of industrial production, 2010=100 for the euro area (without Croatia). The following AR (1) process for foreign output (output of the euro area) is estimated (with standard error in brackets):

$$y_t^* = \underset{(0.021)}{4.627} + \underset{(0.018)}{0.957} y_{t-1}^* + e_t^*, \qquad (21)$$

with σ_{y^*} = 0.048. The calculated correlation of residuals from the AR (1) process for technology and AR (1) process for foreign output equals $corr(e_t, e_t^*)$ = 0.245.

Furthermore, it is necessary to calibrate the price stickiness parameter θ. The price stickiness is one of the key differences between the new Keynesian model and the real business cycle model. The average price duration equals $(1-\theta)^{-1}$. The only currently available research of price stickiness at companies' level in Croatia is conducted by Pufnik and Kunovac (2013). They conclude that a medial company in Croatia changes the price of its main product less frequently than once a year. The value θ = 0.90 is used for the calibration of the Croatian economy DSGE model, which points to the average price duration of 10 months and is consistent with Pufnik and Kunovac (2013).

The discount factor β is calibrated in line with equation for intertemporal discount rate given by:

$$r \equiv -\ln \beta \qquad (22).$$

The intertemporal discount rate is calculated as the equilibrium interest rate on the Croatian government bonds which represents the approximation of risk-free bond for Croatia (see Appendix). The discount factor equals $\beta = e^{-s} = e^{-0.01338} = 0.987$.

Given that the estimation elasticity of labour supply for the Croatian economy is insufficiently explored, the standard values in DSGE modelling are used for calibration of inverse elasticity of labour supply φ. In line with Galì and Monacelli (2005), Bokan *et al.* (2009) the calibrated inverse of the elasticity of labour supply is equal to 3. Regarding the risk aversion parameter σ, Gandelman and Hernandez-Murillo (2015) use the data on the satisfaction and personal well-being of individuals in 80 countries and classify Croatia as the developed country. The average risk aversion coefficient is 1.01, so they conclude that their result supports logarithmic utility function. Accordingly, the parameter σ equals 1, which is in line with the calibration of Galì and Monacelli (2005).

The elasticity of substitution between differentiated goods within the small open economy ε is calibrated in line with Bokan *et al.* (2010) and equals ε=4. The elasticity of substitution between domestic and foreign goods in terms of domestic consumers ε_H as well as that the elasticity of substitution between goods produced in different countries (including the domestic economy), equals one, what is in line with the condition $\sigma=\varepsilon_H=\varepsilon_F=1$ in Galì and Monacelli (2005).

The degree of openness of the Croatian economy χ is calibrated as the average share of imports to GDP for the period from the first quarter of 2000 to the second quarter of 2016, which equals 0.406. The values of imports and GDP refer to chain linked volumes (2010=100) in million euros (see Appendix A).

4. THE EMPIRICAL EVALUATION OF ALTERNATIVE MONETARY POLICY RULES IN DSGE MODEL OF CROATIAN ECONOMY USING SVAR APPROACH

In order to empirically assess whether the calibrated DSGE model fits the data well, the analysis of impulse response functions and their comparison with empirical impulse response functions from VAR models is used. VAR models are interpreted as stylized facts that DSGE model should reproduce. In the analysis of a small open economy it is necessary to consider that the small open economy is exposed to the influence of foreign sector, but has no impact on international economic fluctuations and the foreign variables are exogenous for a small open economy. Since the essential characteristic of a small open economy is the exogeneity of foreign variables, in order to empirically test the effects of shocks in a small open economy, the structural vector autoregression (SVAR) model with block exogenous restrictions is estimated and foreign variables are treated as exogenous. Cushman and Zha (1997) proposed the introduction of block exogeneity restrictions in the VAR model. Therefore, the SVAR model with block exogeneity restrictions is estimated for Croatia and the comparison of impulse response functions of DSGE model with four monetary policy regimes and estimated SVAR model is conducted.

Cushman and Zha (1997) use the following SVAR model for analysis of small open economy:

$$A^*(L)y(t)=\varepsilon_t, \qquad (23)$$

where y_t is a vector of variables, $A^*(L)$ is a $(k \times k)$ matrix of structural coefficients and ε_t is a k vector of structural innovations. The vector of variables y_t can be divided into two blocks, whereat:

$$y_t=\begin{pmatrix} y_{1t} \\ y_{2t} \end{pmatrix},\ A^*(L)=\begin{pmatrix} A^*_{11}(L) & A^*_{12}(L) \\ A^*_{21}(L) & A^*_{22}(L) \end{pmatrix},\ \varepsilon_t=\begin{pmatrix} \varepsilon_{1t} \\ \varepsilon_{2t} \end{pmatrix} \qquad (24).$$

The total number of variables $k=k_1+k_2$, where k_1 is the number of variables in the block y_{1t} and k_2 is the number of variables in the block y_{2t}. The restriction $A_{21}(L)=0$ is the block exogeneity restriction, which implies that the block y_{2t} is exogenous to the current and lagged values of variables of block y_{1t}.

The selection of variables for estimating SVAR model with block exogenous restrictions for Croatian economy is consistent with the calibrated new Keynesian model of a small open economy. The estimated SVAR model includes following variables: foreign output *YEA*, labour productivity *A*, output gap denoted by *GAP*, inflation rate denoted by *INF*, domestic inflation rate denoted by *DOMINF*, terms of trade denoted by *TOT*, financial conditions index denoted by *IFIS* and real effective exchange rate denoted by *E*. The variables and data sources are explained in detailed in Appendix A.

Regarding the referent interest rate, which is the standard variable in small open economy DSGE model, it is necessary to note that in Croatia the referent interest rate which might be used for econometric analysis of monetary policy is not available. Relevant empirical research of monetary policy transmission in Croatia has shown that monetary policy in Croatia affects the real sector primarily through direct money supply channel and the exchange rate channel. The existing studies show that the interest rate channel has the insignificant or very lowest impact on the real sector and the Croatian economy is not elastic to movements in interest rates (Palić, 2015). Taking the above characteristics of monetary policy into account, the interest rate is approximated by the index of financial conditions of the Croatian economy constructed by The Institute of Economics (2016).

Concerning the terms of trade, although Galì and Monacelli (2005) define terms of trade as the ratio of import and domestic prices, due to the inconsistency of import prices time series for Croatia, terms of trade for Croatia are calculated as the ratio of the deflator of exports and imports (see Appendix A). Since data on exports and imports are announced quarterly, terms of trade values are also calculated using quarterly values. Monthly values are interpolated using the cubic spline interpolation method in MATLAB R2014 software. In order to conduct cubic spline interpolation, every two consecutive points are connected by the part of the graph of the polynomial of the third degree. For the description of the method of cubic spline see Sastry (2012). In order to estimate output gap, the Hodrick and Prescott (1997) filter is used. It is the commonly used method for the removal of trend component of economic time series and is often used in macroeconomics to estimate output gap (Christiano *et al.*, 2010).

All variables except *INF, DOMINF* and *DIFIS* are transformed into logarithmic values for the SVAR estimation. All variables are seasonally adjusted using the X-13 ARIMA SEATS adjustment method (U.S. Census Bureau, 2013). The Augmented Dickey Fuller unit root tests indicate that all selected time series except output gap, inflation and domestic inflation are not stationary in levels and therefore they are included in the estimation of SVAR model in first differences. Therefore, the SVAR model is estimated using the following variables: *DYEA, DA, GAP, INF, DTOT, DOMINF, DIFIS* and *DE*. The SVAR model is estimated with 4 lags in order to eliminate the autocorrelation problem. The estimation period is therefore from August 2005 to April 2016, what is the longest available data period for variable *FCI*, considering that SVAR model is estimated with 4 lags and that the variable IFIS is transformed into first differences.

The White heteroskedasticity test is conducted and the chi-square value equals 2394.71, with corresponding empirical significance level equal to 0.092, indicating that the null hypothesis of homoscedasticity cannot be rejected at 5 percent significance level. The LM autocorrelation test indicates that the null hypothesis of no correlation of error terms cannot be rejected up to lag 12 at 1 percent significance, since all corresponding empirical significance levels are greater than 0.01. In addition, the stability of the model is checked by calculating the inverse roots of the characteristic AR polynomial using EViews8. Since no root lies outside the unit circle, the estimated model satisfies the stability condition.

The impulse response functions for productivity shock and foreign demand shock SVAR model and DSGE models are presented in Appendix B and Appendix C. The results of the impulse response function analysis for SVAR model and DSGE model with four monetary policy regimes are summarized in Table 1. Table 1 presents the summary of the impact of productivity and foreign demand shock on output gap, inflation, terms of trade, domestic inflation, financial conditions index (in case of SVAR model), interest rate (in case of DSGE model) and exchange rate.

Firstly, the compliance of the impact of estimated productivity shock in SVAR model with impacts in DSGE model with four various monetary policy rules is analysed using impulse response functions. The effect of the productivity shock on the output gap in the SVAR model is negative, which is in line with the impact of productivity shock in the DSGE model with CIT, DIT and PEG rule, but not with OPTIDIT rule. The estimated effect on inflation is significantly negative after 1 month from the shock, which is in line with all analysed monetary policy rules in the calibrated DSGE model. The effect of productivity shock on domestic inflation in the SVAR model is significantly negative after 1 month, what corresponds to the effect on domestic inflation in calibrated DSGE model with CIT, DIT and PEG rule, while in

DSGE model with OPTIDIT rule $\pi_{H,t} = 0$. Regarding the terms of trade, the estimated impact is positive and significant after 2 months, which is in line with all monetary policy rules in the calibrated DSGE model.

Regarding the impact of productivity shock on interest rate in DSGE model, it is negative for DIT and OPTIDIT rule, and where it is initially positive for CIT rule, while with PEG rule there is no impact of productivity shock on interest rate. The impact of productivity shock on the variable *DIFIS* is insignificant, which is in line with PEG rule.

After the analysis of the impact of productivity shock, the impulse response functions to foreign demand shock are analysed in SVAR model, as well as DSGE model with four various monetary rules. The impact of foreign demand shock on the output gap in the SVAR model is positive and significant. The positive impact is in line with the impact of foreign demand shock on output gap in DSGE model with PEG rule. In DSGE model with CIT and DIT rules, the impact of foreign demand shock on output gap is negative, while in DSGE model with OPTIDIT rule $\tilde{y}_t = 0$. Regarding the impact of foreign demand shock on inflation, it is positive and significant after 12 months in the SVAR model, which is also in line with PEG rule. If the monetary policy rule is CIT, DIT or OPTIDIT, the mentioned impact is negative. Concerning the impact of foreign demand shock on terms of trade in the SVAR model, it is insignificant. The impact of foreign demand shock on domestic inflation in the estimated SVAR model is significant and positive four months after the shock, which is in line with the DSGE model with PEG rule. When monetary policy is modelled using CIT and DIT rules, the impact on domestic inflation is positive, while with OPTIDIT rule $\pi_{H,t}=0$. The impact of foreign demand shock on *DIFIS* is insignificant, while all monetary policy rules in the calibrated DSGE model point to the negative impact. Regarding the impact of foreign demand shock on the exchange rate, it is also insignificant, which is in line with the PEG regime.

Altogether, on the basis of impulse response functions analysis, it can be concluded that fixed exchange rate regime in calibrated DSGE model best suits the estimated SVAR model with block exogeneity restrictions. It should be noted that, although Croatian National Bank claimed to conduct the policy of the managed floating exchange rate, 20 years ago the International Monetary Fund classified Croatia in the countries which allow exchange rate adjustment with a narrow margin of 2 percent compared to the statistically identified trend for six months or more, as indicated by Reinhart and Rogoff (2004). Reinhart and Rogoff (2004) conducted the classification of countries according to exchange rate regimes, and outlined that in Croatia, the exchange rate regime was de facto band around euro, with band width +/- 2 percent. The fixed exchange rate in DSGE model is therefore shown to be the most complied to the empirical estimation of the impact of productivity and foreign demand shocks in the Croatian small open economy. This finding is interesting in the context of recent accession to the euro area, as well as the international economic debate regarding the appropriateness of the exchange rate policy in small open economies. The recommendation of a fixed exchange rate in Croatia is also in line with the empirical research on the impact of depreciation on the Croatian economy conducted by Dumičić *et al.* (2011) and Palić *et al.* (2014). Dumičić *et al.* (2011) have shown the effect of the depreciation through competitiveness effect leads to a reduction in the current account deficit of the balance of payments on the one hand. On the other hand, it is shown that exchange rate depreciation also affects the increase in external debt through the wealth effect. Since the value of foreign debt in Croatia is much higher than the value of exports, authors conclude that the negative wealth effect outweighs the positive competition effects, which might have a negative impact on the economic growth of the country. Considering the characteristics of the Croatian economy, authors conclude that exchange rate depreciation is not the effective long-term solution to stimulate economic activity.

Moreover, Palić *et al.* (2014) analyze the misalignment of real exchange rate in Croatia using the permanent equilibrium exchange rate approach and cointegration analysis. Considering the empirical characteristics of the Croatian economy, authors also state that the depreciation of real exchange rate is not recommended

Table 1: The impact of productivity shock (first row) and foreign demand shock (second row) in SVAR model and new Keynesian small open economy DSGE model

Model	Variable / Shock	Output gap	Inflation	Terms of trade	Domestic inflation	DIFIS/ interest rate	Exchange rate
SVAR	A	Negative, significant ****	Negative, significant*	Positive, significant**	Negative, significant*	**Insignificant**	**Insignificant**
	Y*	**Positive, significant**	**Positive, significant after 12 months**	Insignificant	**Positive, significant******	**Insignificant**	**Insignificant**
DSGE (CIT rule)	A	Negative	Negative after one quarter	Positive	Negative	Negative after one quarter (firstly positive)	Positive, then negative after 5 quarters
	Y*	**Positive**	Negative	Negative	Negative	Negative	Negative
DSGE (DIT rule)	A	Negative	Negative after one quarter	Positive	Negative	Negative	Positive, then negative after 3 quarters
	Y*	Negative	Negative	Negative	Negative	Negative	Negative
DSGE (OPTIDIT rule)	A	Equals zero in the model	Negative after one quarter	Positive	Equals zero in the model	Negative	Positive
	Y*	Equals zero in the model	Negative	Negative	Equals zero in the model	Negative	Negative
DSGE (PEG rule)	A	Negative	Negative	Positive	Negative	**No impact**	**Fixed exchange rate**
	Y*	**Positive**	**Positive**	Negative	**Positive**	Negative	**Fixed exchange rate**

* one month after the shock, ** two months after the shock, *** three months after the shock, **** four months after the shock, ******six months after the shock

Source: Author's calculation

to economic policy makers and the current Croatian exchange rate policy is appropriate. This research supports the findings of mentioned research in the framework of macroeconomic models with microeconomic foundations by pointing to the fact that fixed exchange rate in the DSGE model suits the empirical characteristics of the Croatian economy. This is an important finding in the context of the recent accession of Croatia to the euro area. The results are also in line with the empirical evidence for developing countries using DSGE models in Ajevskis and Vitola (2011), which also suggests that small open developing economies can use fixed exchange rate as an instrument of stabilisation of prices.

5. CONCLUSION

This research explores the alternative monetary policy rules in the DSGE model of Croatian small open economy, with the emphasis on the empirical evaluation of four monetary policy rules using the structural vector autoregression approach. The Croatian economy has been characterised by high degree of openness, high external debt and highly euroised financial system for decades before official euro introduction, and therefore the question of adequate monetary policy regime within the framework of small open economy DSGE models has been very interesting both for macroeconomic analysts and policy makers.

In small open economies, it is often considered that exchange rate depreciation might increase competitiveness and, in that way, foster exports and economic growth. However, the Croatian economy has been highly indebted in foreign currency and highly euroized even before the official euro introduction. Fluctuations in exchange rate, namely depreciation, could have an overall negative effect through increasing foreign liabilities. Hence, the results of the conducted research are important in the context of the euro adoption in Croatia and the fact that Croatia opted for the fixed exchange rate regime vis-à-vis euro. This research empirically confirms the euro adoption as the most adequate monetary policy decision in Croatia, using the macroeconomic model with microeconomic foundations, namely DSGE model as a framework.

After the exposition of small open economy dynamic stochastic general equilibrium model with four possible monetary policy rules, namely the assumption of a fixed exchange rate regime, the regime in which the central bank reacts to inflation measured by the consumer price index, the regime in which the central bank reacts to domestic inflation and the optimal domestic inflation targeting regime, the calibration of parameters of DSGE model is conducted using data for Croatia and euro area (without Croatia). Furthermore, the structural vector autoregression model with block exogenous restrictions is estimated in order to examine the compliance of selected monetary policy rules in the DSGE model with empirical characteristics of the observed economies. The impulse response functions to domestic productivity shock and foreign demand shock in the DSGE model with four various monetary policy regimes and SVAR model are analysed. The results of the impulse response function analysis point to the conclusion that the empirical impacts of productivity shock and foreign demand shock in the DSGE model are better described when monetary policy rule is fixed exchange rate, in relation to alternative monetary policy rules in Croatia.

Finally, the limitations and the perspective for future research should be stated. When SVAR models are estimated with a large number of variables, the number of degrees of freedom is reduced. Hence, regarding the perspective for future research, it would be interesting to estimate calibrated models with Bayesian techniques. Moreover, robustness checking of other detrending methods to estimate output gap would be interesting, as well as using other proxies of interest rate.

It is important to outline that the analysis of DSGE models is considered to be a robust method for the analysis of monetary policy in central banks and research institutions around the world. Therefore, the further research and development of DSGE models at the level of institutions, such as central banks and economic research institutions is necessary in small open economies.

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Appendix A

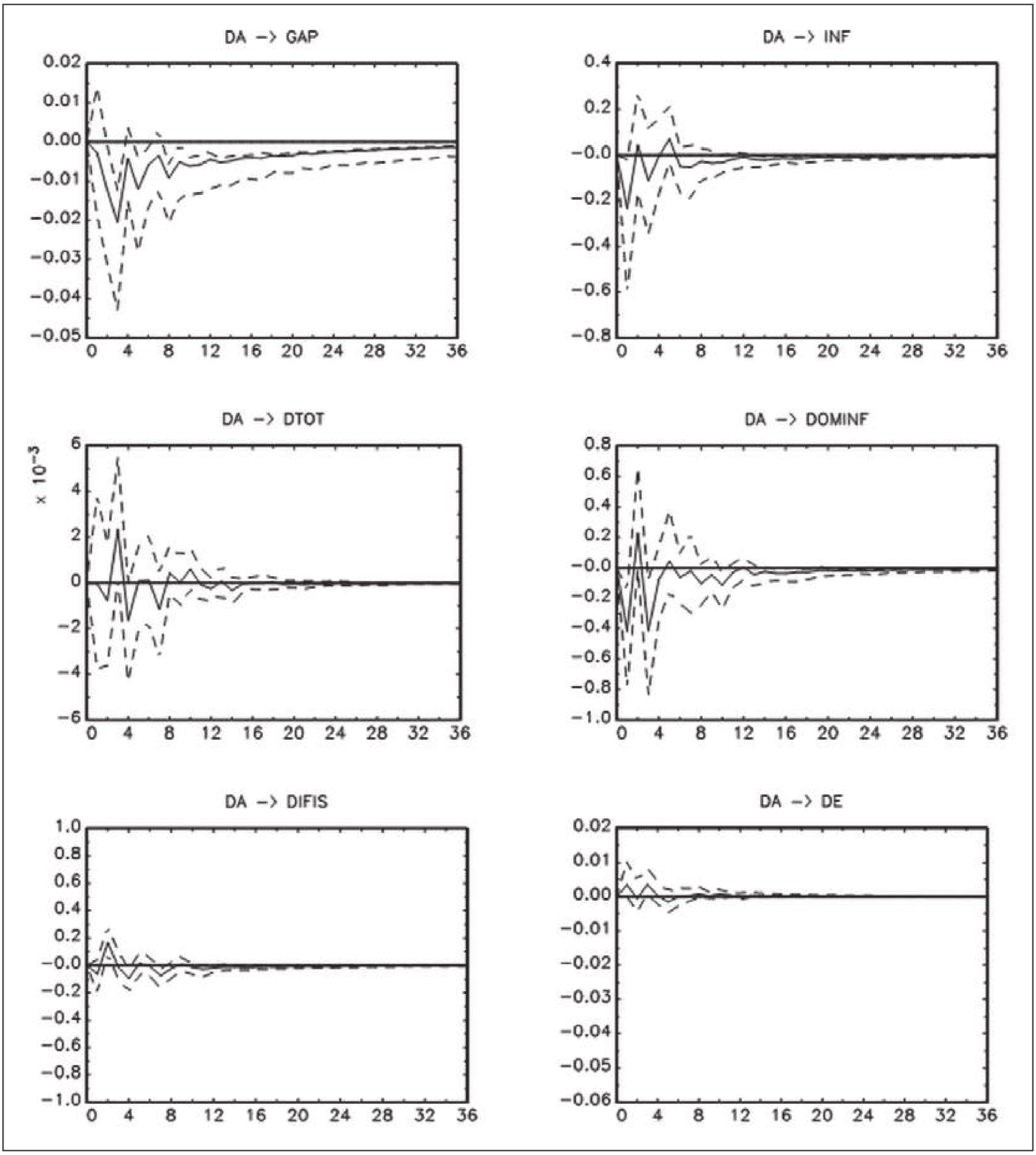
Table A.2: Description of variables used in empirical analysis

Variable	Notation	Description	Data source
Foreign output	Y*	Volume indices of industrial production, 2010=100 for euro area (19 countries, without Croatia), in logarithmic values	Eurostat, Short term business statistics, Industry
Employment	N	Indices of the monthly number of employed persons, 2010=100, given in logarithmic values	Croatian Bureau of Statistics, Employment and Wages
Labor productivity	A	The ratio of industrial production indices Y and employment indices denoted N, given in logarithmic values	Author's calculation
Domestic output	Y	Volume indices of industrial production, 2010=100 Croatia	Eurostat, Short term business statistics, Industry
Output gap	GAP	The cyclical component of the time series Y obtained using Hodrick and Prescott (1981, 1997) filter, in logarithmic values	Author's calculation
Inflation rate	INF	The inflation rate which is calculated using consumer price indices, 2010=100	Croatian National Bank, Author's calculation
Domestic inflation rate	DOMINF	The domestic inflation rate which is calculated using producer price indices, 2010=100	Croatian National Bank, Author's calculation
Terms of trade	TOT	The ratio of export and import deflators, given in logarithmic values	Author's calculation
Import deflator		The deflator of imports has been calculated as the ratio of the nominal value of imports (imports in current prices) and the value of exports in chain linked volumes, reference year 2010.	Eurostat, Quarterly national accounts, Author's calculation
Export deflator		The deflator of exports has been calculated as the ratio of the nominal value of exports (exports in current prices) and the value of exports in chain linked volumes, reference year 2010.	Eurostat, Quarterly national accounts, Author's calculation
Financial conditions index	FCI	Monthly financial conditions index calculated using 28 indicators, in logarithmic values	The Institute of Economics, Zagreb
Exchange rate	E	Real effective exchange rate indices, 2010=100, deflator; Consumer price index, in logarithmic values.	Croatian National Bank, Competitiveness, Table H11
Gross domestic product	GDP	Gross domestic products in chain linked volumes (2010=100), million euro	Eurostat, Quarterly national accounts
Intertemporal discount rate	r	The annual rate on Croatian government bonds refers to the interest rate on long-term government bonds in local currency according to Maastricht convergence criteria	Eurostat, Interest rates

Appendix B

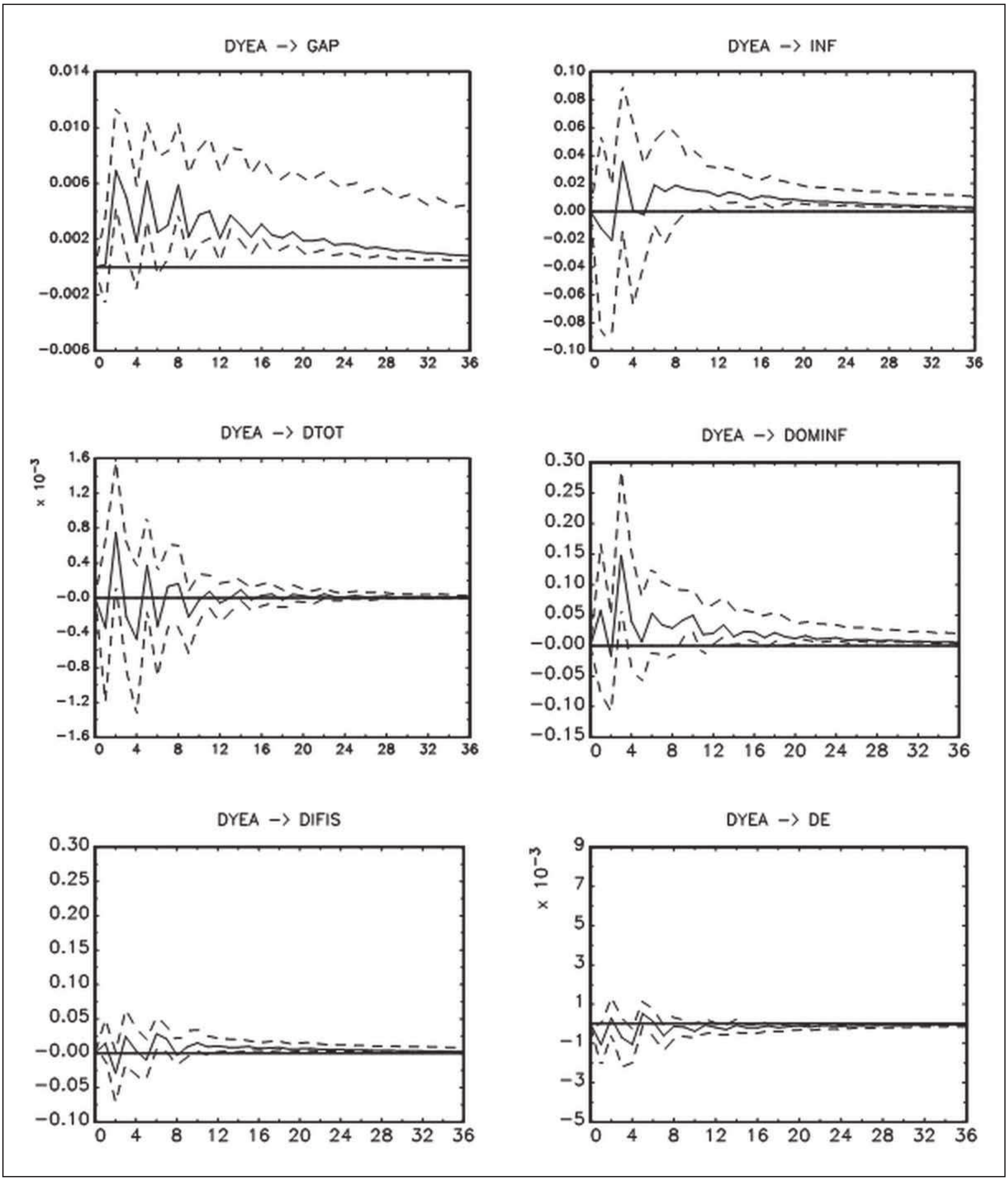
The impulse response functions of SVAR model with block exogeneity restrictions

Figure B.1: The impact of productivity shock in SVAR model



Source: Author's calculation, JMulTi

Figure B.2: The impact of foreign (euro area) demand shock in SVAR model

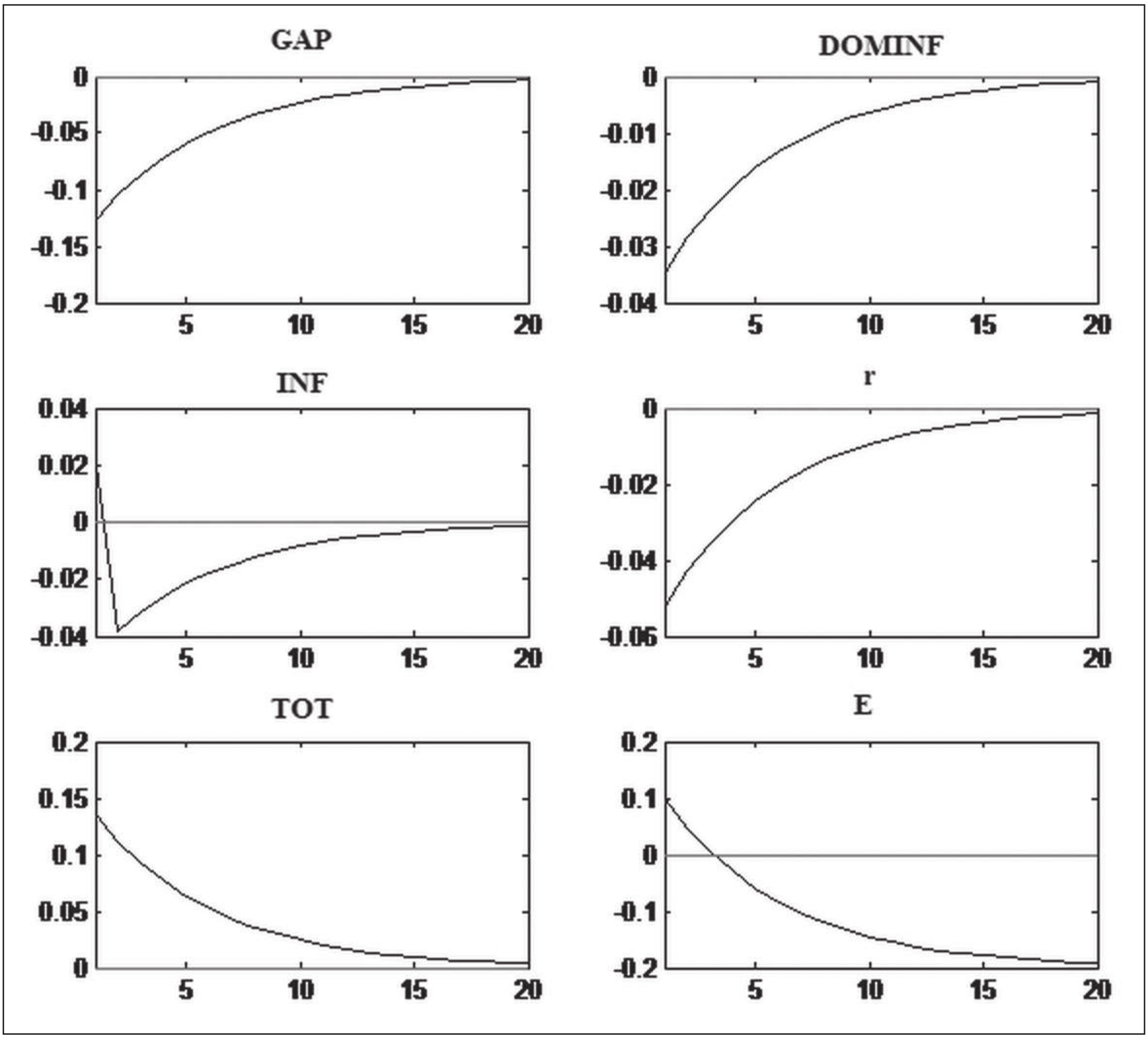


Source: Author's calculation, JMulTi

Appendix C

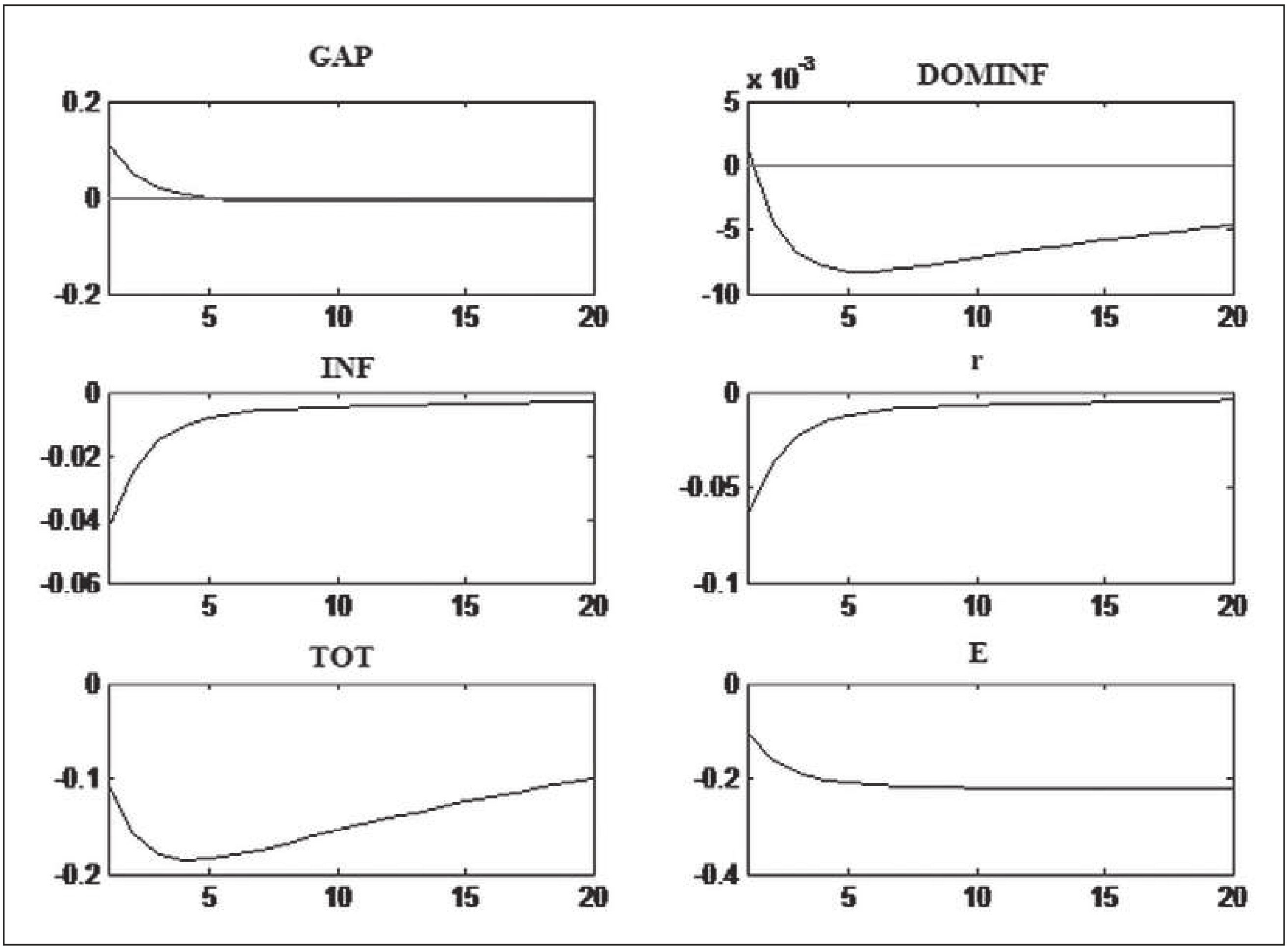
The impulse response functions of calibrated DSGE model

Figure C.1: The impact of productivity shock in DSGE model, CIT rule



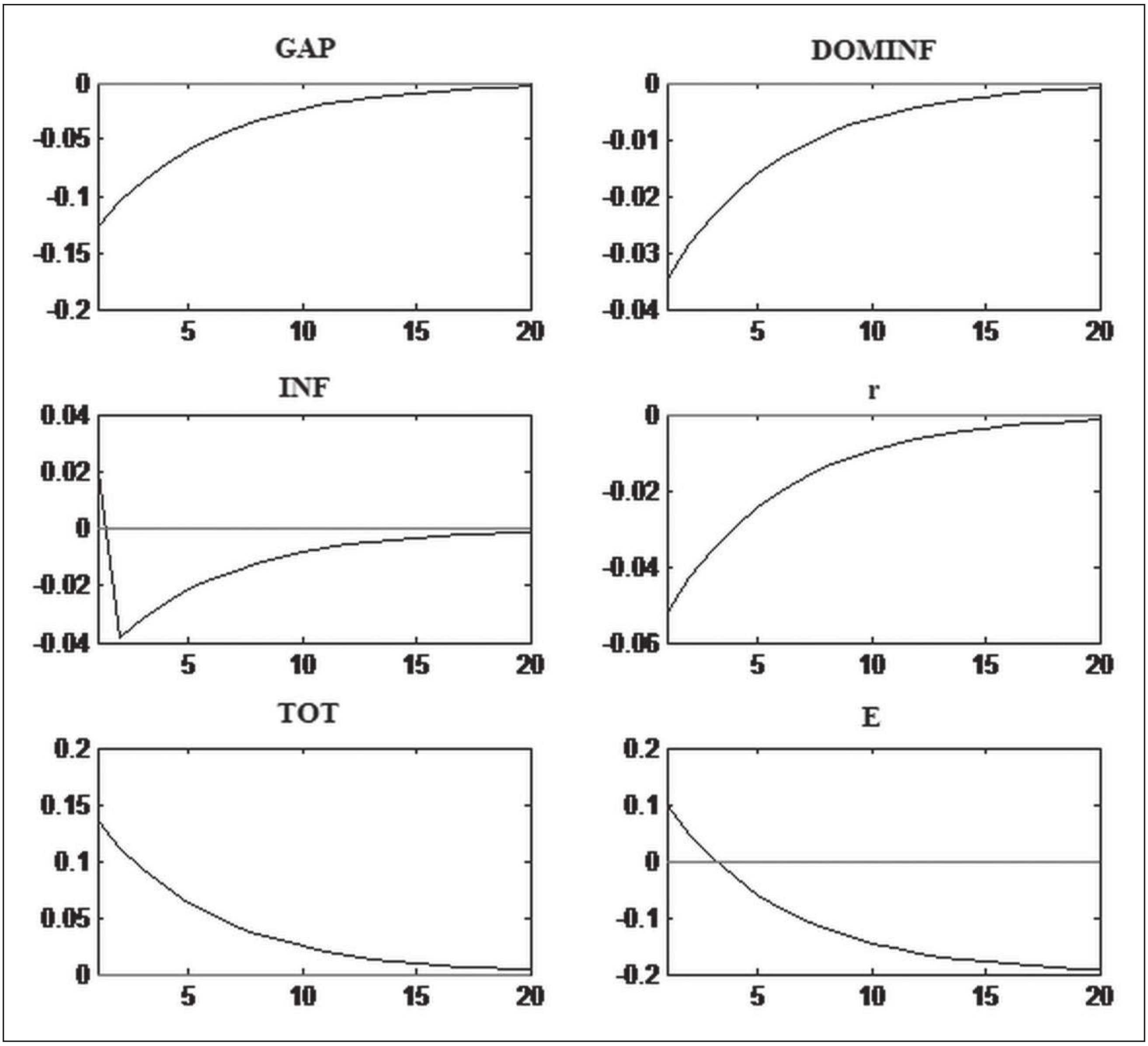
Source: Author's calculation, MATLAB R2014a and Dynare 4.4.2.

Figure C.2: The impact of foreign demand shock in DSGE model, CIT rule



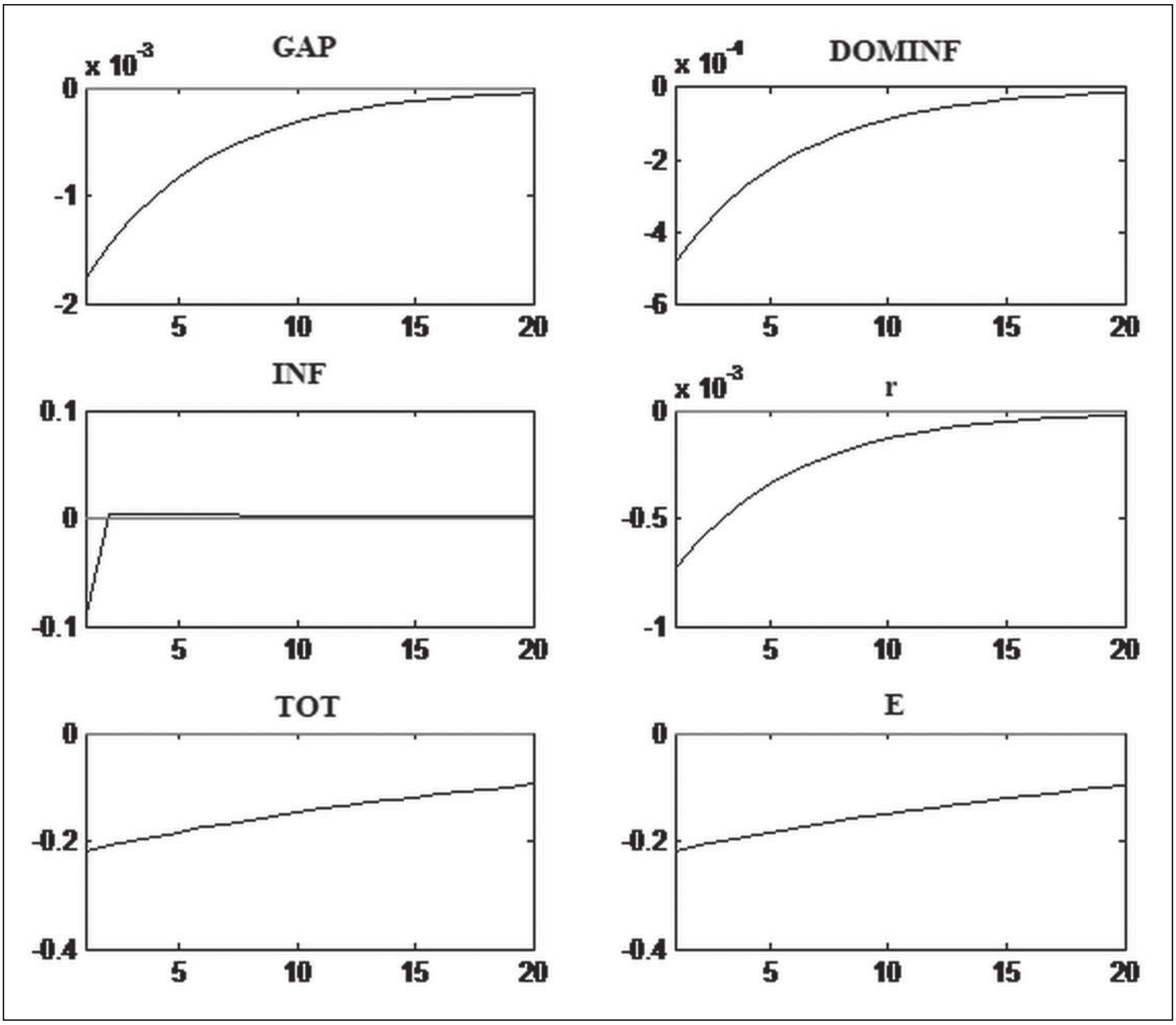
Source: Author's calculation, MATLAB R2014a and Dynare 4.4.2.

Figure C.3: The impact of productivity shock in DSGE model, DIT rule



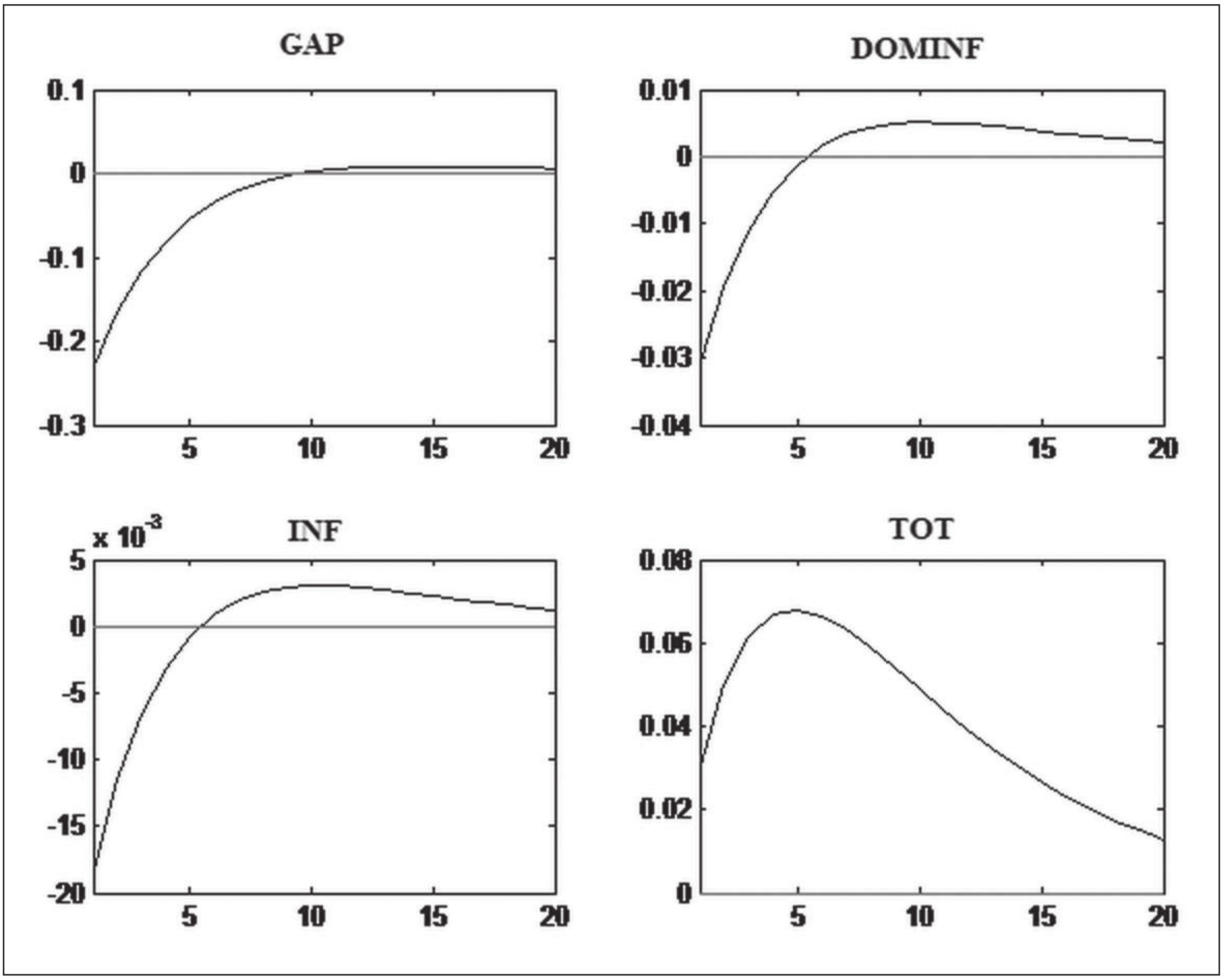
Source: Author’s calculation, MATLAB R2014a and Dynare 4.4.2.

Figure C.4: The impact of foreign demand shock in DSGE model, DIT rule



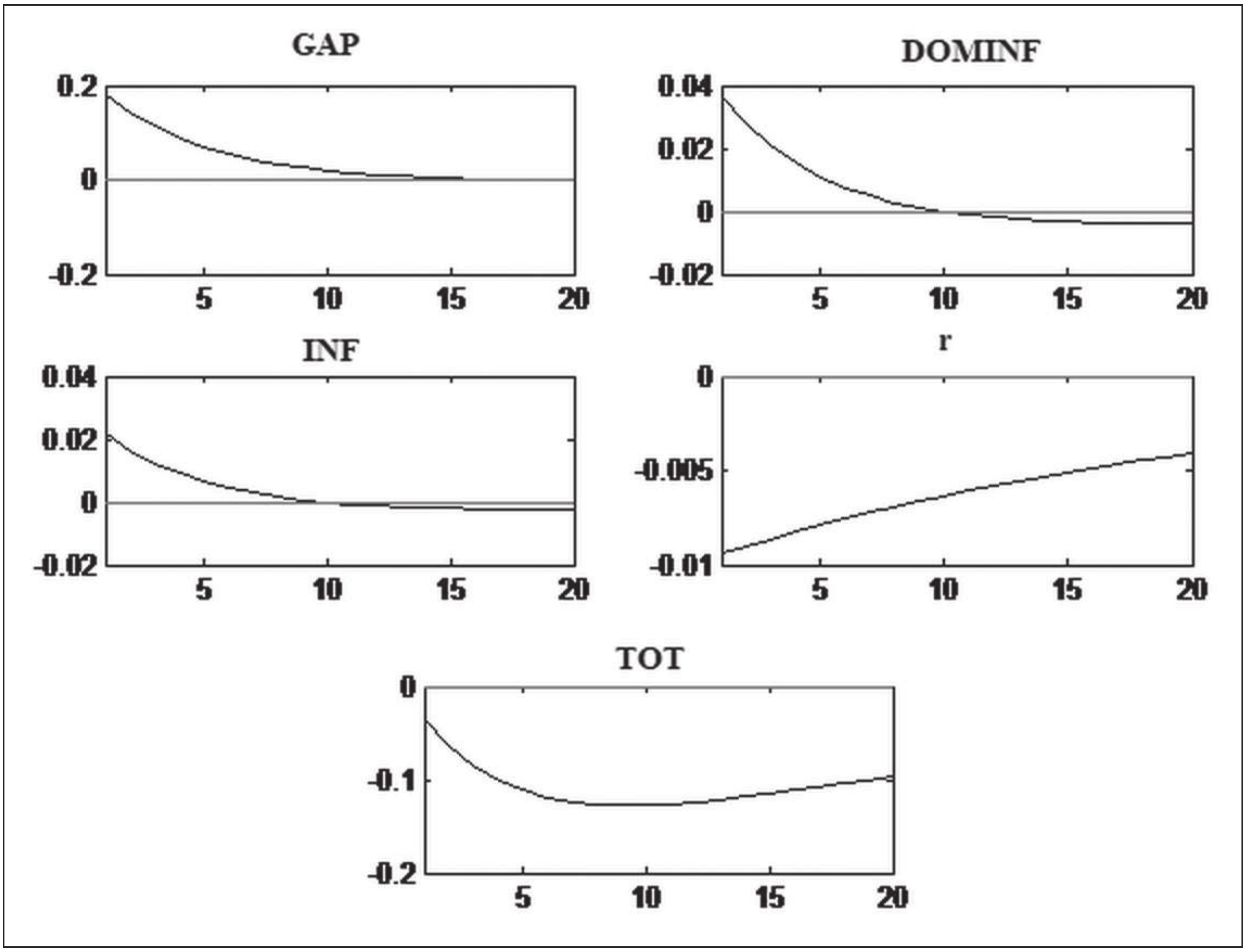
Source: Author's calculation, MATLAB R2014a and Dynare 4.4.2.

Figure C.5: The impact of productivity shock in DSGE model, PEG rule



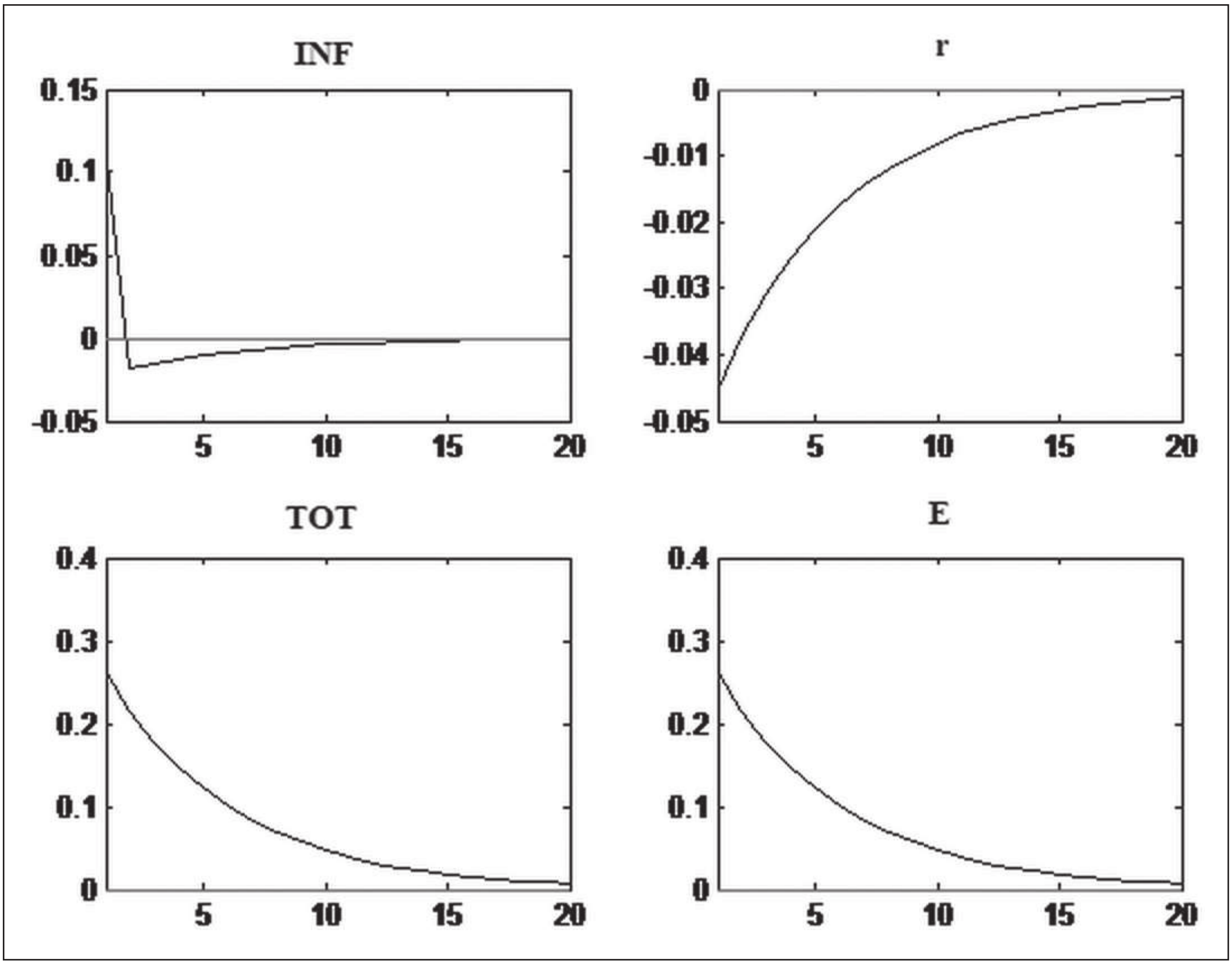
Source: Author's calculation, MATLAB R2014a and Dynare 4.4.2.

Figure C.6: The impact of foreign demand shock in DSGE model, PEG rule



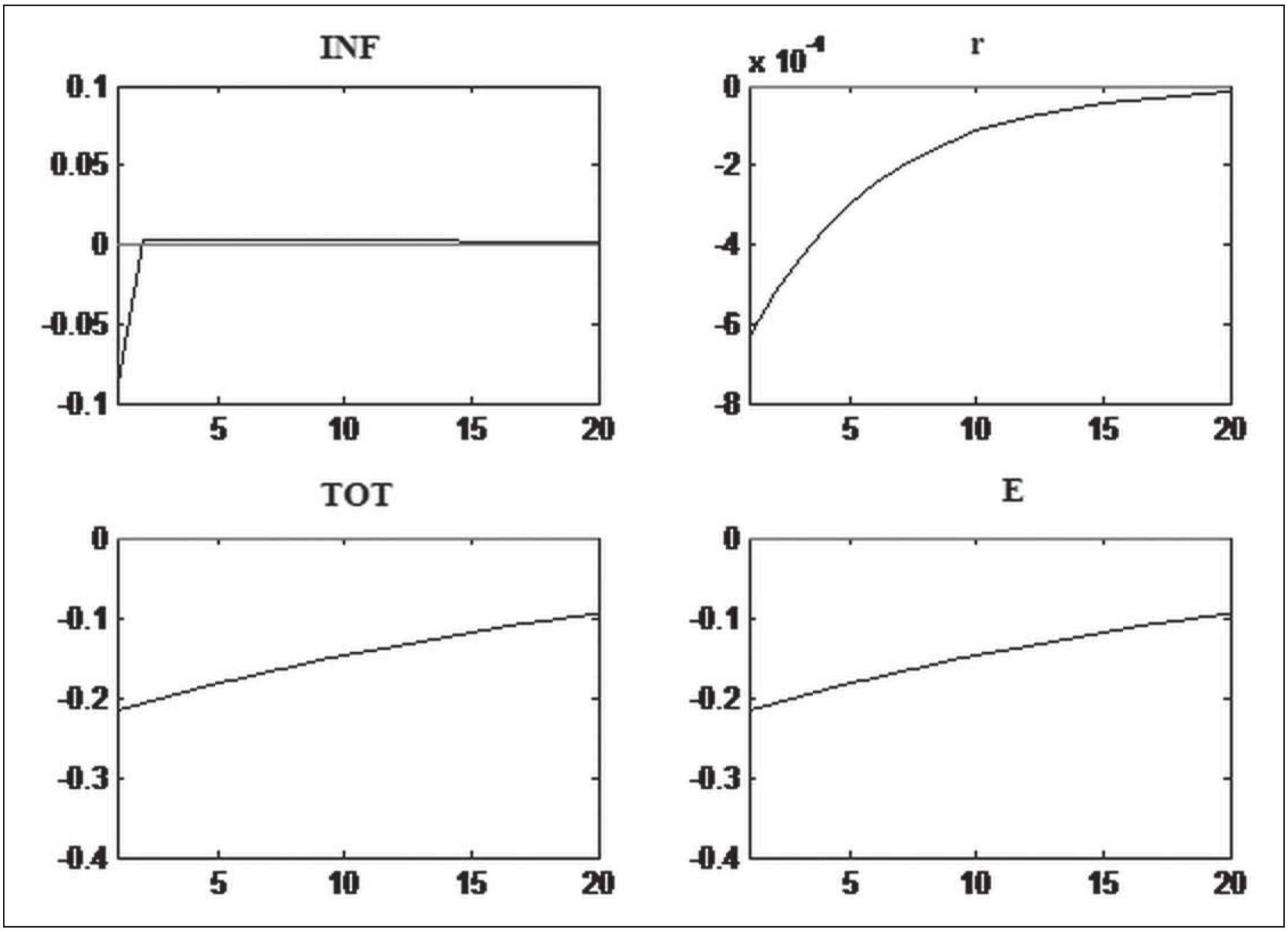
Source: Author's calculation, MATLAB R2014a and Dynare 4.4.2.

Figure C.7: The impact of productivity shock in DSGE model, OPTIDIT rule



Source: Author’s calculation, MATLAB R2014a and Dynare 4.4.2.

Figure C.8: The impact of foreign demand shock in DSGE model, OPTIDIT rule



Source: Author's calculation, MATLAB R2014a and Dynare 4.4.2.

Empirijska evaluacija pravila monetarne politike u DSGE modelu male otvorene ekonomije: slučaj Hrvatske

Sažetak

Cilj rada je empirijski ocijeniti usklađenost četiriju *različitih pravila monetarne politike u DSGE modelu s empirijskim karakteristikama malog otvorenog gospodarstva. Malo otvoreno gospodarstvo u modelu je Republika Hrvatska, dok je inozemni sektor europodručje bez Hrvatske. Kalibriran je neokejnzijanski DSGE model male otvorene ekonomije s* četiri *pravila monetarne politike. Budući da je bitna karakteristika malog otvorenog gospodarstva egzogenost inozemnih varijabli, kako bi se empirijski testirali učinci* šokova *u malom otvorenom gospodarstvu, procijenjen je model strukturne vektorske autoregresije (SVAR) s blok egzogenim ograničenjima, pri* čemu *se varijable europodručja tretiraju kao egzogene. Analiza funkcija impulsnog odziva upućuje na zaključak da fiksni tečaj najbolje odgovara empirijskim učincima analiziranih* šokova *u Hrvatskoj. Rezultati istraživanja važni su u kontekstu nedavnog pristupanja Hrvatske europodručju i oblikovanja monetarne politike u malim otvorenim gospodarstvima.*

Ključne riječi: DSGE model, evaluacija monetarne politike, Hrvatska, mala otvorena ekonomija, SVAR model, restrikcije blok egzogenosti