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Identifying the adopted Monetary Policy Rule by the Central Bank of Iran

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Abstract

It is obvious that an optimal policy should consider main the dimensions of the phenomenon that can affect the transmission mechanism of that policy. In an open economy, it is expected that variables of the foreign sector play important role in its economic behavior. Therefore, it needs that any optimal policy in an open economy should be designed in such a way which involves changes in the foreign sector. Due to this fact, this paper is aimed at assessing the monetary policy of Central Bank of Iran to determine whether this policy takes a right way or not. To do so, a DSGE model along with MCMC criteria is employed.

The main result indicates that the decision of Central Bank on monetary policy follows McCallum rule without any response to exchange rate shocks.

1. Introduction

It is obvious that an optimal policy should consider main the dimensions of the phenomenon that can affect the transmission mechanism of that policy. In an open economy, it is expected that variables of the foreign sector play important role in its economic behavior. Therefore, it is required that any optimal policy in an open economy should be designed in such a way which involves changes in the foreign sector. Due to this fact, this paper is aimed at assessing the monetary policy of Central Bank of Iran to determine whether this policy takes a right way or not. To do so, a DSGE model along with MCMC criteria is employed.

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Exchange rate is one of the key factors in determining the value of imported goods in the country due to the fact that it determines the nominal value of imported and exported goods in terms of the national currency. Therefore, the value of this rate can affect the flow of exports and imports as well as the allocation of resources to these two sectors. As a result, how to determine, control and stabilize the exchange rate will undoubtedly affect the economy.

Since Iran operates an open economy, the flow of exports and imports plays an important role in the economic equilibrium and the volume of goods supplied in the economy. As a consequence, the level of the prices of imported goods will affect the purchasing power of the economic agents as well as the supply of imported and exported goods.

Accordingly, the involvement of policy institutions in this area seems to be necessary. Since one of the goals of the central bank is to maintain stability and track the price of foreign exchange, one of the central bank policies will be to determine the exchange rate or at least control its market, thereby guaranteeing the macroeconomic stability to some extent.

The reaction to exchange rate fluctuations in Iran, due to the nature of its oil economy, is different from that of countries with market mechanisms. Foreign exchange interventions in Iran are carried out by the central bank and are done due to the legal requirement to provide Rials for the government. The annual budget laws of government characterize the exchange fund management of the country by the amount of allocable foreign currency, issuing a permit for the allocation of oil revenues, and confirming the procedure for receipt and payment of the currency by the central bank. In other words, since the central bank is obliged to provide the budget, the surplus will be purchased by the bank in order to manage the exchange rate. Accordingly, the analysis of the role of exchange rate in determining the optimal monetary policy by the central bank in Iran's economy, which is heavily dependent on oil revenues, is of great importance. The purpose of this study was to investigate the performance of monetary policy rules by considering the exchange rate in Iran. To do this, a new Keynesian dynamic stochastic general equilibrium model is used. Among the economic models, new Keynesian dynamic stochastic general equilibrium model is a new analytical tool with the ability to assess economic policies.

Due to the small open economic structure of Iran, it is expected that not only the model variables but the monetary policy is also affected by the variables of the foreign sector economy. Therefore, the model is designed in such a way that the transmission mechanism of monetary policy involves changes in the foreign sector of the economy. In the next step, six different models of monetary policy rules that are estimated using available data are considered. This means that both the Taylor and McCallum models are used, and according these models, different models that include nominal or real exchange rates, or none of them, are estimated, and finally, by comparing the models, this paper presents which model could better show the behavior of the central bank policy. Ultimately, using existing statistics, the performance of the models is compared and the model which is more consistent with the Iran economy is chosen.

The paper is organized as follows; Section 2 is devoted to literature review, Section 3 states theoretical considerations, Section 4 sets up the model and Section 5 draws conclusions.

2. Literature Review

Several studies have been conducted to investigate the effect of foreign exchange policies on the monetary policy. Here a few studies that are more relevant to this research subject were collected:

Mimir and sunel (2015) documented empirically the 2007-09 Global Financial Crisis exposed emerging market economies (EMEs). Using a small open New-Keynesian DSGE model, they investigated simple and operational monetary policy rules that respond to domestic/external financial variables alongside inflation and output. The results suggest that such a policy rule involves direct and non-negligible responses to lending which spreads over the cost of foreign debt, the real exchange rate and the US policy rate, together with a mild anti-inflationary policy stance in response to domestic and external shocks. The most important finding is the reaction of policy rule to inflation and exchange rate, simultaneously.

Gali and Monacelli (2005) investigated the monetary policy and exchange rate fluctuations in a small open economy. The initial structure of this model was based on the Calvo-style sticky price model (Calvo, 1983) and showed that the dynamics of the economy can be written in terms of domestic inflation and production gap. Then, using this structure, the results of three different rules based on policy regimes have been analyzed: The Taylor rule based on domestic inflation, the Taylor rule based on the price index and fixed exchange rate. The authors have shown that the fundamental difference between these three regimes depends on the relative value of exchange rate fluctuations. Since exchange rate has not anchored, the fluctuations of exchange rate can dramatically determine changes in monetary policy.

Wollmershauser (2006), studied the reaction of central bank to fluctuations in exchange rate. Accordingly, the performance of the monetary policy rules in an open economy has been analyzed. Given the uncertainty about the exchange rate, this study shows that those policy rules that include the real exchange rate can better reflect uncertainty exchange rate. In addition, if policy rules are designed and evaluated in a closed economy, then the result is not satisfactory. The main critique of the findings of this paper is that generally central banks do not respond to real exchange rate.

Hosseini (2011) studied the business cycle of Iran's economy using DSGE model. The results of the study show that if an increase in oil revenues passes through the channel of the growth of money, inflation increases to about 0.15% of the deviation from its steady state. On the other hand, when this increase in oil revenues is not financed through foreign exchange sale to the central bank, the increase in inflation will be less than 0.1% of the deviation from its steady state.

Khiybani and Amiri (2014) designed an open DSGE model for Iran's economy. They investigated the effect of price and oil price shocks on macroeconomic variables in the open economy. The simulation results of the model show that oil shocks negatively affect production, investment and capital stock, but increases inflation, consumption and marginal costs. On the other hand, oil shocks have a positive impact on government expenditures and the volume of money. These results indicate that oil shocks play a key role in monetary and fiscal policies.

The recent financial crisis and commodity price fluctuations improves the argument that the cost of foreign exchange plays a crucial role in the macroeconomic performance. In this study attempt was made to formally assess this claim by introducing a foreign exchange constraint experienced by firms into a small Open economy New Keynesian DSGE model.

In the standard New Keynesian DSGE models, it is implicitly assumed that the economy is closed. In other words, these models are silent about the constraint faced by firms that significantly depend on imported inputs.

A key equation in open economy DSGE models is the uncovered interest rate parity (UIP) condition, which in its simplest formulation suggests that the difference between domestic and foreign nominal interest rates equals the expected future change in the nominal exchange rate. The UIP condition is a key equation in open economy models, not only for the exchange rate, but also for many macroeconomic variables, since there is a lot of internal propagation of exchange rate movements working through fluctuating relative prices.

3. Theoretical Considerations

With the introduction of exchange rate into the model, it can be shown that the transmission mechanism of monetary policy has also been modified in such a way that the exchange rate will be in the monetary effect chain (Ball, 1999). An important point in this mechanism is that in the case of an open economy, two important divisions must be made. Firstly, because of the flow of exports and imports, consumer goods in the economy comprise two types of goods: domestic goods and imported goods. This separation is important because in this case household demand and thus the optimal decision of the household is divided into two parts and will affect the derivation of the total demand of the economy. Secondly, the price levels in this case will be affected by both internal and external sectors. In other words, the index of total inflation in this case is equal to the aggregated inflation of domestic goods and inflation from the foreign sector of the economy, which can be attributed to two factors: depreciation of national currency against foreign currencies or the growth of inflation in foreign countries and therefore the growth of the price of imported goods. By entering the exchange rate into general equilibrium analyses, not only will the supply and demand structure change, but also the monetary rule of the central bank may also be affected. In other words, in the open economy, there is a discussion of whether the monetary policy maker responds to foreign exchange fluctuations or not. This review is possible by analyzing and estimating the Taylor rule in an open economy. Wollmershauser (2006) showed that although the exchange rate will change the structure of the economy, whether the central bank reacts to foreign exchange fluctuations varies from one country to another. Accordingly, the Central Banks of some countries, in spite of having open economics, do not react to currency fluctuations, while others are forced to react due to some considerations (Lubik and Shorfheide, 2007).

4. The Model

Generally, dynamic stochastic general equilibrium models consist of three parts: Demand, supply, and policy makers; the demand and the supply sides are determined by studying the consumer and producer behavior, respectively, and the policy maker behavior is recognized by the analysis of monetary and fiscal policies. In an open economy, foreign sector is considered as the third part.

In this section, the economic model is designed and reviewed based on the conditions of Iran’s economy. For this purpose, three parts of the household, firm, and policy maker are considered, and in each section, modeling assumptions are expressed.

4.1 Households

The modeling of the household sector, depending on the functional form of utility function, can be done in a variety of ways which ultimately affects the results of the final relationships. In this study, the most important assumption is the persistence in consumer's habit, according to which the relative increase in the current consumption will increase its utility and the increase in utility will, respectively change the total consumption demand function of the economy. The household aims to maximize the intertemporal utility function with respect to its budget constraint:

$$E\sum_{t=0}^{\infty}\beta^{t}U_{t} \tag{1}$$

where U_t is instant utility function and β is subjective discount factor. The utility of the household is assumed to be a function of consumption, the real money balance and working hours, and is defined as follows[1]:

$$U_t = \frac{(C_t - hC_{t-1})^{1-\sigma}}{1-\sigma} + \frac{M_t^{1-\varpi}}{1-\varpi} - \frac{N_t^{1+\varphi}}{1+\varphi} \tag{2}$$

In this function, C_t is consumption index, M_t is real money balance, N_t is working time, σ is Reverse elasticity of substitution of intertemporal

[1] This kind of utility function known as MIU model; for further reading reader can refer to Walsh (2010).

consumption, h is habit persistence parameter, φ is Inverse elasticity of labor supply, ϖ is income elasticity of money demand.

In this economy, goods are divided into two categories: tradable and non-tradable, which C_t is a composite indicator of tradable and non- tradable goods and is defined as follows:

$$C_t = \left[(1-\gamma_1)^{1/\theta_1} C_{T,t}^{(\theta_1-1)/\theta_1} + \gamma_1^{1/\theta_1} C_{N,t}^{(\theta_1-1)/\theta_1}\right]^{\theta_1/(\theta_1-1)} \tag{3}$$

In the above relation, $C_{T,t}$ and $C_{N,t}$ are the indices of consumption of tradable and non- tradable goods, respectively. θ_1 Indicates the elasticity of intertemporal substitution consumption between tradable and non- tradable goods, the larger the value of which the higher is the degree of substitution of goods. γ_1 is the share of non- tradable goods in total consumption. Before determining the optimal consumption, there is a need to improve household demand for each tradable and non- tradable goods. Since the total household consumption is equal to the weighted average of cost for tradable and non-tradable goods, the optimal demand for them is derived from the minimization of the total cost function. Therefore, we have:

$$Min_{C_T,C_N} P_t C_t - P_{N,t} C_{N,t} - P_{T,t} C_{T,t}$$

$$S.t \quad C_t = \left[(1-\gamma_1)^{1/\theta_1} C_{T,t}^{(\theta_1-1)/\theta_1} + \gamma_1^{1/\theta_1} C_{N,t}^{(\theta_1-1)/\theta_1}\right]^{\theta_1/(\theta_1-1)}$$

$P_{T,t}$, $P_{N,t}$ and P_t are tradable goods price index, non- tradable goods price index and total goods price index, respectively. By solving this problem, the optimal demand for tradable and non- tradable goods is specified:

$$C_{T,t} = (1-\gamma_1)\left(\frac{P_{T,t}}{P_t}\right)^{-\theta_1} C_t \tag{4}$$

$$C_{N,t} = (\gamma_1)\left(\frac{P_{N,t}}{P_t}\right)^{-\theta_1} C_t \tag{5}$$

By replacing (4) and (5) in (3) the total price index is obtained:

$$P_t = \left[(1-\gamma_1)P_{T,t}^{1-\theta_1} + \gamma_1 P_{N,t}^{1-\theta_1}\right]^{1/(1-\theta_1)} \tag{6}$$

Tradable and non- tradable goods consumption index are also a combination of a large number of different commodities that can be defined based on the Dixit - Stiglitz Index, as follows:

$$C_{T,t} = \left[\int_0^1 \left(C_{T,t,(j)}\right)^{(\zeta-1)/\zeta} dj\right]^{\zeta/(\zeta-1)} \tag{7}$$

$$C_{N,t} = \left[\int_0^1 \left(C_{N,t,(j)}\right)^{(\zeta-1)/\zeta} dj\right]^{\zeta/(\zeta-1)} \tag{8}$$

j shows each good in the composite index and ζ is Elasticity of substitution between different goods.

Tradable goods are either imported or domestic. Therefore, the index of consumption of tradable goods in relation (7) can be considered as a combination of domestic goods and imported goods as follows:

$$C_{T,t} = \left[(1-\gamma_2)^{1/\theta_2} C_{H,t}^{(\theta_2-1)/\theta_2} + \gamma_2^{1/\theta_2} C_{F,t}^{(\theta_2-1)/\theta_2}\right]^{\theta_2/(\theta_2-1)} \quad (9)$$

θ_2 is elasticity of substitution of intertemporal consumption between domestic tradable goods ($C_{H,t}$) and imported tradable goods ($C_{F,t}$). γ_2 is the share of imported goods in tradable goods index. By solving the problem of minimizing expenditures on tradable goods, demand functions for domestic and imported goods are obtained:

$$C_{H,t} = (1-\gamma_2)\left(\frac{P_{H,t}}{P_{T,t}}\right)^{-\theta_2} C_{T,t} \quad (10)$$

$$C_{F,t} = (\gamma_2)\left(\frac{P_{F,t}}{P_{T,t}}\right)^{-\theta_2} C_{T,t} \quad (11)$$

$P_{H,t}$ and $P_{F,t}$ are price of domestic and imported tradable goods, respectively. By substituting the relations (10) and (11) in (9), the price index of tradable goods is obtained:

$$P_{T,t} = \left[(1-\gamma_2)P_{H,t}^{1-\theta_2} + \gamma_2 P_{F,t}^{1-\theta_2}\right]^{1/(1-\theta_2)} \quad (12)$$

The total household consumption expenditure is equal to the total expenditure on tradable and non- tradable goods, which according to the separation of tradable goods, can be written as follows:

$$P_t C_t = P_{T,t}C_{T,t} + P_{N,t}C_{N,t} = P_{F,t}C_{F,t} + P_{H,t}C_{H,t} + P_{N,t}C_{N,t} \quad (13)$$

Household income sources include wage, nominal money balance in the previous period, and profit from the maintenance of the previous period bonds. Also, household expenses consist of the cost of purchasing consumer goods, the purchase of new bonds, as well as the demand for maintaining the nominal money balance. The household budget constraint, in real form, is expressed as follows:

$$C_t + B_t + M_t + I_t \le W_t N_t + \frac{(1+R_{t-1})}{1+V_t} B_{t-1} + \frac{1}{1+V_t} M_{t-1} + r_{t,k} K_{t-1} + TR_t - T_t \quad (14)$$

Where R_{t-1} is nominal interest rate of the previous period, B_t is government bonds, W_t is labor wage, I_t is investment, r_k is rate of capital rent, K_t is capital, and TR_t and T_t are transfer payment from government and tax paid by household, and V_t is inflation rate. Moreover, we assume following relationship for capital accumulation:

$$K_t = (1-z)K_{t-1} + [1 - S(\frac{e_{I,t} I_t}{I_{t-1}})]I_t \qquad (15)$$

Where z and e_I are depreciation rate and investment shock, respectively. $S(.)$ is adjustment shock which shows the costly and lag process of transforming investment to capital. The purpose of the household is to maximize its utility in (1) with respect to (14) and (15), in order to find the optimal consumption path, the real money balance, real bonds, investment, capital and the optimal supply of labor. In order to solve household problem, Lagrange equation is first constituted as follows:

$$Max_{C,L,b,m} E \sum_{t=0}^{\infty} \beta^t \left\{ \begin{array}{l} \frac{(C_t - hC_{t-1})^{1-\sigma}}{1-\sigma} + \frac{M_t^{\,1-\varpi}}{1-\varpi} - \frac{L_t^{1+\varphi}}{1+\varphi} - \lambda_{1,t}[C_t + b_t + M_t + I_t \\ -W_t N_t - \frac{(1+R_{t-1})}{1+V_t} b_{t-1} - \frac{1}{1+V_t} M_{t-1} - r_{t,k} K_{t-1} - TR_t + T_t] \\ -\lambda_{2,t}[K_t - (1-z)K_{t-1} - [1 - S(\frac{e_{I,t} I_t}{I_{t-1}})]I_t] \end{array} \right\}$$

Where $\lambda_{1,t}$ and $\lambda_{2,t}$ are Lagrange multipliers for budget constraint and capital accumulation, respectively. The first-order conditions relative to consumption, labor supply, real bonds and real money balance, investment and capital are:

$$(C_t - hC_{t-1})^{-\sigma} = \lambda_{1,t} \qquad (16)$$

$$N_t^{\varphi} = \lambda_{1,t} W_t \qquad (17)$$

$$\beta E \lambda_{1,t+1} \frac{1+R_{t-1}}{1+V_t} = \lambda_{1,t} \qquad (18)$$

$$M_t^{-\varpi} = \lambda_{1,t} - \frac{1}{1+V_t} \beta E \lambda_{1,t+1} \qquad (19)$$

$$\begin{aligned} -\lambda_{1,t} + \lambda_{2,t} - \lambda_{2,t} S\left(\frac{\varepsilon_t^I I_t}{I_{t-1}}\right) - \lambda_{2,t} I_t \frac{\varepsilon_t^I}{I_{t-1}} S'\left(\frac{\varepsilon_t^I I_t}{I_{t-1}}\right) \\ + \beta E_t \lambda_{2,t} \varepsilon_{t+1}^I \left(\frac{I_{t+1}}{I_t}\right)^2 S'\left(\frac{\varepsilon_{t+1}^I I_{t+1}}{I_t}\right) = 0 \end{aligned} \qquad (20)$$

$$\beta^{t+1}\left[\lambda_{1,t+1} r_{t+1}^k + \lambda_{2,t+1}(1-z)\right] - \beta^t \lambda_{2,t} = 0 \qquad (21)$$

By using Taylor expansion, the log – linear version of the relations (16) - (21) are as follows:

$$c_t = \frac{h}{1+h} c_{t-1} + \frac{1}{1+h} E_t c_{t+1} - \frac{1-h}{\sigma(1+h)}(r_t - E_t \pi_{t+1}) \qquad (22)$$

$$m_t = \frac{\sigma}{\varpi}[\frac{1}{1-h} c_t - \frac{h}{1-h} c_{t-1}] - \frac{1}{\varpi} \frac{1}{\overline{R}} r_t \qquad (23)$$

$$i_t = \frac{1}{1+\beta} i_{t-1} + \frac{\beta}{1+\beta} E_t i_{t+1} + \frac{\varphi}{1+\beta} q_t, \quad \varphi = \frac{1}{S''(1)} \tag{24}$$

$$q_t = -(r_t - E_t \pi_{t+1}) + \frac{1-z}{\bar{r}} E_t q_{t+1} + \frac{\bar{r}^k}{1+\bar{r}^k - \delta} r_{t+1}^k \tag{25}$$

where lower case letters and π_t are deviation of variable and inflation rate around their steady state.

4.2 variables in an open economy

An important feature that can occur in an open economy is the deviation of prices from the Law of One Price which is known as the One Price gap. This gap arises because importing firms act as monopolistic competition and therefore have the power to set prices. This market power causes differences between the price of goods inside and outside the country, and therefore the law does not hold. The gap in the law of One Price can be considered as follows:

$$\Psi_t = \frac{e_t P_t^*}{P_{F,t}} \tag{26}$$

e_t is nominal exchange rate and P_t^* is foreign price index. Where the numerator is foreign price of imported goods and the denominator is domestic price of the same goods. Obviously, if the law of one price holds, then $\Psi = 1$. The real exchange rate is defined as follows:

$$S_t = \frac{e_t P_t^*}{P_t} \tag{27}$$

By using uncovered interest rate parity, log linearized version of equation (27) can be written in terms of difference of domestic real interest rate from foreign real rate as:

$$E s_{t+1} - s_t = (r_t - E\pi_{t+1}) - (r_t^* - E\pi_{t+1}^*) \tag{28}$$

Where variables with star sign in the above equation are foreign nominal interest rate and inflation rate, respectively.

4.3 Behavior of Firms

In this study, firms are divided into two categories: domestic firms and importing firms. Domestic firms produce tradable and non-tradable goods. Because of the diversity and variety of manufactured goods their markets are assumed to be monopolistic competitive and as a result they have the ability to determine prices. Therefore, the problem of the firms is divided into two parts; in the first step, the firms' goal is to determine the optimal demand for the production factor depending on the level of wage and production. After determining the optimal demand, in the second step the firm forms its own profit function and determines the path of the price level that makes maximum profits during a specified period.

4.3.1 Production of Tradable and Non-tradable Goods

The production function in both the tradable and non-tradable sectors is assumed to be:

$$Y_{j,t} = A_t K_{j,t}^{\alpha} L_{j,t}^{1-\alpha}, \quad j = N, T \tag{29}$$

Where A_t is common productivity, N and T shows non- tradable and tradable sectors, respectively. A firm goal in this section is to minimize the cost of production conditioned to a certain level of production:

$$Min_{L_{j,t}} w_t L_{j,t} + r_t K_{j,t}$$
$$S.t \quad Y_{j,t} = A_t K_{j,t}^{\alpha} L_{j,t}^{1-\alpha} \tag{30}$$

Marginal cost of production of domestic tradable goods is obtained by the first-order condition as follows, where mc is log – linearized real marginal cost:

$$w_t = A_t mc(1-\alpha) K_{j,t}^{\alpha} L_{j,t}^{-\alpha}$$

4.3.2 Pricing Path by Domestic Producers

This model assumes that the price of domestic firms is not fully flexible and is modeled based on Calvo's sticky price model (Calvo, 1983). Based on this method it is assumed that at any point of time, a random ratio of firms ($\in_j$) is not able to adjust their prices, and the rest of the firms ($1-\in_j$) change their price ($j = T, N$). Furthermore, it is assumed that there are Forward-Looking and Backward-Looking Firms in both tradable and none- tradable sectors. Forward-Looking firms, include those firms that change their prices based on Calvo's model. Backward-Looking Firms those that change their prices based on inflation in the past period. It is assumed that the random ratios ς_H and ς_N in the tradable and none- tradable sectors are Backward-Looking while others are Forward-Looking firms. This method of price adjustment by firms, results in the hybrid new Keynesian Phillips curve by Gali and Gertler (1999) for tradable and none- tradable goods as it comes in the following:

$$\pi_{j,t} = k_{b,j} \pi_{j,t-1} + k_{F,j} E_t \pi_{j,t+1} + \lambda_j mc_{j,t} \tag{31}$$

$$k_{b,j} = \frac{\varsigma_j}{\in_j + \varsigma_j (1-\in_j (1-\beta))}, \quad k_{F,j} = \frac{\beta \in_j}{\in_j + \varsigma_j (1-\in_j (1-\beta))},$$

$$\lambda_j = \frac{(1-\varsigma_j)(1-\in_j)(1-\beta \in_j)}{\in_j + \varsigma_j (1-\in_j (1-\beta))}$$

4.3.3 Pricing Behavior in Imports

The gap of law of one price is a key factor in the derivation of imported goods price behavior. Based on this factor, the price index of imported goods is not equal to the nominal exchange rate in the foreign price index. In fact pricing imported goods is similar to domestic goods and follows the Gali - Gertler sticky price model.

The problem confronting importer firms is maximizing their profit over an infinite period of time:

$$E\sum_{T=t}^{\infty}\beta^{t}\,\Pi_{t.T}C_{F.T}\left[P_{F.t}(i)\left(\frac{P_{F.T-1}}{P_{F.t-1}}\right)^{\varsigma_F}-\frac{\Theta}{\Theta-1}e_T P_{F.T}^{*}\right]$$

Where $\Pi_{t.T}$, Θ and $P_{F.T}^{*}$ are stochastic discount factor, mark-up and optimal price, respectively. Log-linearizing eq (23) and then substituting ψ_t for e_t, one can find following Phillips curve for importing sector:

$$\pi_{F,t}=k_{b,F}\pi_{F,t-1}+k_{f,F}E_t\pi_{F,t+1}+\lambda_F\psi_t \quad (32)$$

$$k_{b,F}=\frac{\varsigma_F}{\in_F+\varsigma_F(1-\in_F(1-\beta))},\quad k_{F,N}=\frac{\beta\in_F}{\in_F+\varsigma_F(1-\in_F(1-\beta))},$$

$$\lambda_F=\frac{(1-\varsigma_F)(1-\in_F)(1-\beta\in_F)}{\in_F+\varsigma_F(1-\in_F(1-\beta))}$$

Where $\in_j$ is ratio of importing firms that are not able to adjust their prices and ς_F is the ratio of Backward-Looking importing firms. π_F is linearized import inflation rate.

4.3.4 Inflation Rate

Inflation of tradable goods is equal to the average weighted inflation of domestic goods and imported tradable goods, because each sectoral inflation has a share in total inflation:

$$\pi_{T,t}=(1-\gamma_2)\pi_{H,t}+\gamma_2\pi_{F,t} \quad (33)$$

The total inflation rate is also the average weighted rate of tradable and none- tradable inflation:

$$\pi_t=(1-\gamma_1)\pi_{T,t}+\gamma_1\pi_{N,t} \quad (34)$$

4.4 Fiscal and Monetary Policies

In Iran, the government and the Central Bank are responsible for implementing fiscal policy and monetary policy, respectively. Although sometimes, monetary policy is influenced by the behavior of the government and its demands, it is still not possible to ignore the role of the Central Bank in conducting monetary policy. Accordingly, in the current section, first, the behavior of the fiscal policymaker and then the behavior of the monetary policymaker will be analyzed.

4.4.1 Fiscal Policymaker's Behavior

Usually, the government budget reflects the behavior of the fiscal policymaker. Government revenues consist of oil revenues (OIL_t), Tax (T_t), Borrowing from the central bank (D_t) and Issue Participation Bonds (B_t).

Government spending are expenditure (G_t) and Payment of principal and interest of bonds ($(1+R_{t-1})B_{t-1}$). Part of the oil revenues is paid to the National Development Fund (DF_t), and another part is consumed by the government (L_t). Therefore, oil revenues relation can be written as follows:

$$OIL_t = L_t + DF_t$$

and government budget constraint is:

$$G_t + (1+R_{t-1})B_{t-1} = L_t + T_t + D_t + B_t \quad (35)$$

and real government budget constraint is as follow:

$$g_t + \frac{(1+R_{t-1})}{1+\pi_t} b_{t-1} = l_t + t_t + d_t + b_t \quad (36)$$

National Development Fund stock (EDF_t) is determined as follows during each period:

$$EDF_t = EDF_{t-1} + DF_t - XDF_t \quad (37)$$

According to the equation (35), National Development Fund stock in each period equals the National Development Fund stock in the end of the period plus the inputting stock paid to the National Development Fund, minus the output fund.

The government selles his share of oil revenue to the Central Bank and receives exchange. Therefore central bank foreign reserves (ζ_t) is as the fallowing:

$$\zeta_t = \zeta_{t-1} + L_t - \vartheta_t \quad (38)$$

where ϑ_t is the Central Bank sale of foreign currency.

Change in the foreign exchange reserves of the central bank alters its relationship in terms of the monetary base, M_t is defined as follows:

$$M_t = \zeta_t + D_t \quad (39)$$

4.4.2 Monetary Policymaker's Behavior

Monetary base and interest rate are two variables that are mainly used by central banks as monetary instruments. The instruments, the Taylor rule and McCallum rule, are based on the interest rate and monetary base. Banking without USB in Iran shows that the interest rate has not responded adequately to economic fluctuations. On the other hand, the trend of monetary base shows that it has been changed by the central bank in response to economic conditions, in such a way that it can influence financing government budget, economic growth and inflation. Therefore, McCallum rule is more compatible with the present and the past behavior of the Central Bank of Iran.

Accordingly, in the present study different models are estimated based on the McCallum rule and finally, by comparing those models we try to select the best model that can explain Central Bank policy behavior. The monetary policy rules are assumed to be as follows:

$$r_t = a_r r_{t-1} + (1-a_r)(a_1\pi_t + a_2 y_t) + a_3\Phi(s_t, e_t) + \chi_t$$
$$m_t = a_m m_{t-1} - (1-a_m)(b_1\pi_t + b_2 y_t) - b_3\Phi(s_t, e_t) + v_t \quad (40)$$

Here the first model is based on Taylor rule and the second model on McCallum rule. v_t and χ_t are monetary policy shocks. $\Phi(s_t, e_t)$ Indicates a measure of policy response to exchange fluctuations. In a closed economy $a_3, b_3 = 0$, but in an open economy might be $a_3, b_3 \neq 0$. Therefore, three case can be considered for each of the above rules:

- $a_3, b_3 = 0$ the central bank reacts only to inflation and output fluctuations.
- $a_3, b_3 \neq 0$ the central bank adds the nominal or real exchange rate to its monetary rule, and so two different situations can be considered for monetary policy.

Regarding the three mentioned cases depending on the rule, six different models can be estimated. Our goal is to find the best rule that can explain the behavior of the monetary policymaker.

4.5 Model Estimation

In this study, using the Bayesian method and seasonal data during 1990-2014, model parameters for six different monetary policy models are estimated:

$$r_t = a_r r_{t-1} + (1-a_r)(a_1\pi_t + a_2 y_t) + \chi_t \quad (41)$$
$$r_t = a_r r_{t-1} + (1-a_r)(a_1\pi_t + a_2 y_t) + a_3 e_t + \chi_t \quad (42)$$
$$r_t = a_r r_{t-1} + (1-a_r)(a_1\pi_t + a_2 y_t) + a_3 s_t + \chi_t \quad (43)$$
$$m_t = a_m m_{t-1} - (1-a_m)(b_1\pi_t + b_2 y_t) + v_t \quad (44)$$
$$m_t = a_m m_{t-1} - (1-a_m)(b_1\pi_t + b_2 y_t) - b_3 e_t + v_t \quad (45)$$
$$m_t = a_m m_{t-1} - (1-a_m)(b_1\pi_t + b_2 y_t) - b_3 s_t + v_t \quad (46)$$

Bayesian method employs maximum likelihood to derive parameters estimation. Combining prior information and data, and by using Metropolis – Hastings and Monte – Carlo Markov Chain algorithms, this method tries to generate posterior distribution function. The mod of this distribution function is point estimate of parameters[1]. System of equations for estimation includes (20) – (22), (23) – (25), (29) – (32), (34) – (39) and related policy rule.

Estimation results of the six monetary rules presented in equations (41) – (46), reported in the table (1):

[1] The reader can refer to Koop (2003) for further discussion.

Table 1. The results of estimating model parameters using Bayesian

Parameter	Prior distribution	Prior amount	posterior amount	standard error	parameter	Prior distribution	Prior amount	posterior amount	standard error
The results of estimating model (41)					The results of estimating model (44)				
a_1	beta	1.5	0.81	0.2	b_1	beta	1.5	1.55	0.2
a_2	beta	0.12	0.1	0.01	b_2	beta	0.12	0.12	0.01
a_r	beta	0.75	0.25	0.1	a_m	beta	0.75	0.35	0.1
The results of estimating model (42)					The results of estimating model (45)				
a_1	beta	1.5	1.22	0.2	b_1	Beta	1.5	1.65	0.2
a_2	beta	0.12	0.12	0.01	b_2	Beta	0.12	0.12	0.01
a_3	beta	0.6	0.48	0.1	b_3	Beta	0.6	0.54	0.1
a_r	beta	0.75	0.69	0.1	a_m	beta	0.75	0.44	0.1
The results of estimating model (43)					The results of estimating model (46)				
a_1	beta	1.5	1.32	0.1	b_1	Beta	1.5	1.55	0.2
a_2	Beta	0.12	0.11	0.01	b_2	Beta	0.12	0.12	0.01
a_3	Beta	0.6	0.39	0.1	b_3	Beta	0.6	0.51	0.1
a_r	beta	0.75	0.86	0.1	a_m	Beta	0.75	0.36	0.1

Source: Research finding. All prior amounts determined from authors computations.

Since six different rules are estimated, it is necessary to compare them using existing statistics to determine which of the monetary rules are more consistent with the model data. Then a suitable model is chosen.

4.5.1 Monte Carlo Markov Chain (MCMC) Univariate Diagnostics

The result of Monte Carlo Markov Chain is the most important source to ensure the results of the model. The above criteria including parameters inside and between the chains are shown in red and blue lines, respectively. To obtain more accurate results, these lines should be fairly stable (although some fluctuations in them are acceptable) and converge.

It should be fairly explained that:

- The confidence interval about 80% around the average of parameters shown with *interval*.
- The variance of the parameters is shown with *m2*.
- The third momentum of the parameters is shown with *m3*.

The result of this statistic for policy rules (41), (42), (43), (44), (45) and (46) is shown in Figures (1) - (6), respectively. Figure (1) shows the MCMC for the model with the monetary rule (41), where all moments are diverged and unstable.

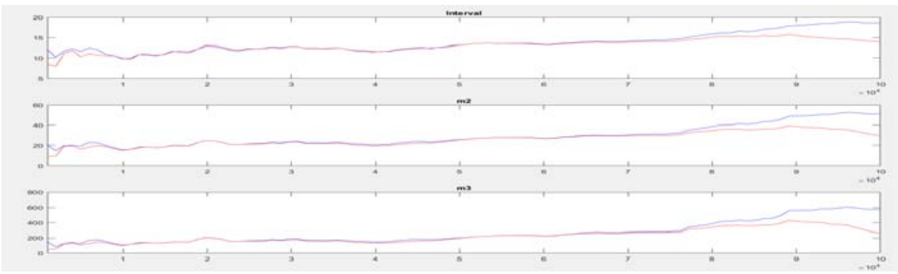

Figure 1. MCMC result for monetary rule (41)

Figure (2) shows the MCMC for the model with the monetary rule (42), where the first moment is converged but second and third one diverged. Moreover, the red and blue lines have relative stability.

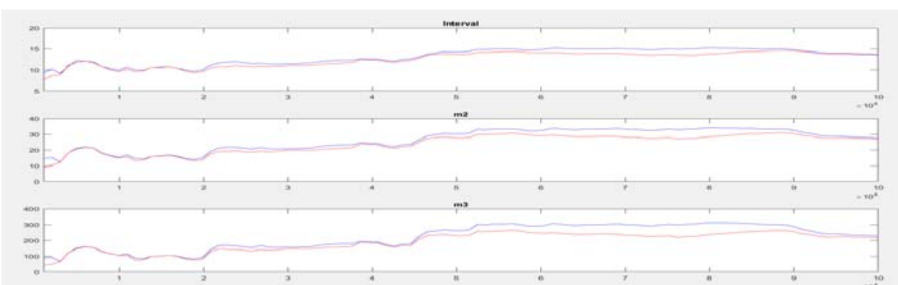

Figure 2. MCMC result for monetary rule (42)

Figure (3) shows the MCMC for the model with the monetary rule (43), where all moments are fully diverged and unstable.

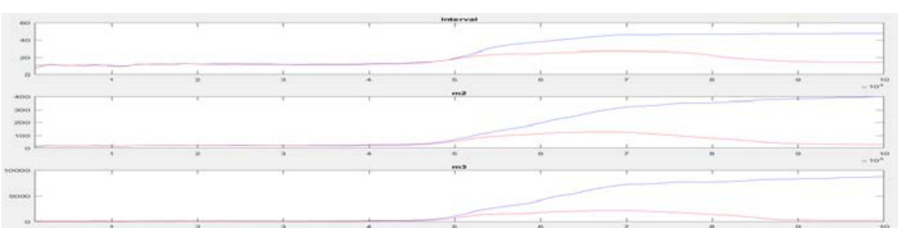

Figure 3. MCMC result for monetary rule (43)

Figure (4) shows the MCMC for the model with the monetary rule (44), where all moments are fully converged and stable.

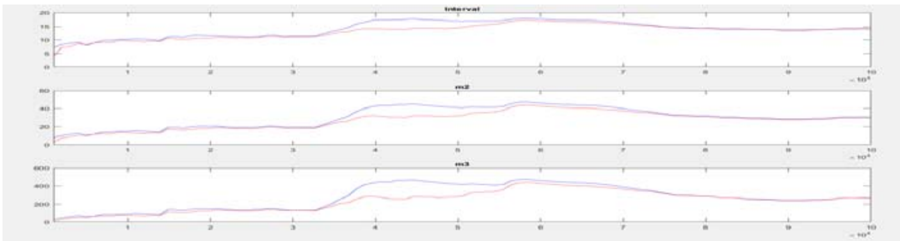

Figure 4. MCMC result for monetary rule (44)

Figure (5) shows the MCMC for the model with the monetary rule (45), where all moments are fully converged and stable.

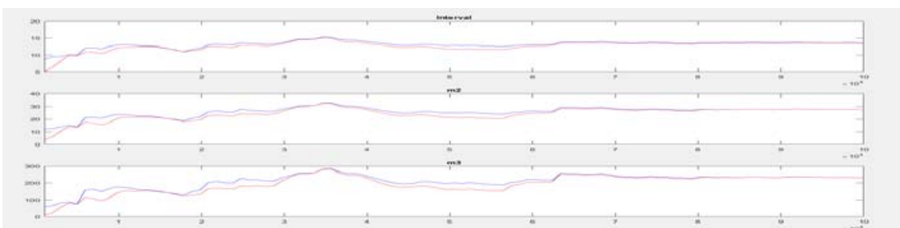

Figure 5. MCMC result for monetary rule (45)

Figure (6) shows the MCMC for the model with the monetary rule (46), where all moments are fully diverged and unstable.

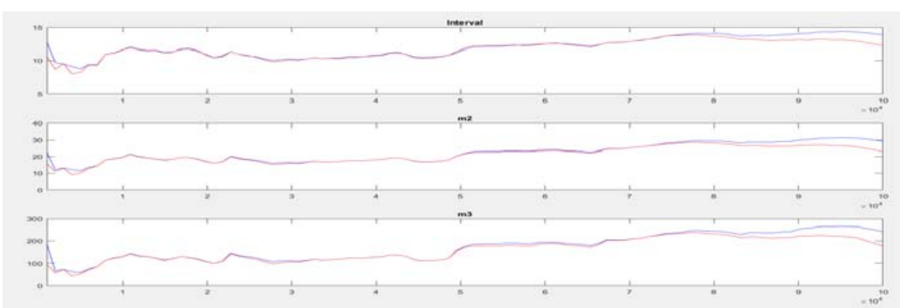

Figure 6. MCMC result for monetary rule (46)

The results from MCMC statistics shows that just models (44) and (45) are stable and converged first through third moments while other rules do not have such properties. Therefore, based on the main Bayesian statistics for judgment about model performances, the McCollum rule without reaction to exchange rate and McCollum rule with reaction to nominal exchange rate has better performance. Thus, other rules do not have enough capability to reproduce data and explain policymaker behavior.

4.5.2 Maximum Likelihood Statistics

One of the most important outputs of the Bayesian method is the maximum likelihood statistics derived from the estimation of parameters. The higher the value of likelihood, the closer is the estimated model to the actual data. The amount of likelihood of the six above monetary rules is shown in Table (2):

Table 2. The likelihood of models under four different monetary rules

Row	Model	Amount of likelihood
1	Monetary rule(41)	232
2	Monetary rule(42)	280
3	Monetary rule(43)	238
4	Monetary rule(44)	258
5	Monetary rule(45)	265
6	Monetary rule(46)	259

Source: Research finding

Since from MCMC statistics just models (44) and (45) has good performance, in this section we compare the likelihood of those to select the more consistent model with the data. To do this, we test a hypothesis in which the null is $a_3 = 0$. For this reason, first we write likelihood ratio as:

$LR = -2\,log(44) + 2\,log(45) = 14 \sim \chi^2(9)$

From table of Chi Square, at the 95% confidence level, χ^2 is equal to 16.92, thereby the null hypothesis is accepted and model (44) has more better performance than model (45).

4.5.3 Gelman – Brooks Statistics

MCMC algorithms used for simulating posterior distributions are indispensable tools in Bayesian analysis. A major consideration in MCMC simulations is that of convergence. A common approach in assessing MCMC convergence is based on running and analyzing the difference between multiple chains.

The Gelman–Brooks (GB) diagnostics evaluates MCMC convergence by analyzing the difference between multiple Markov chains. The convergence is assessed by comparing the estimated between-chains and within-chain variances for each model parameter. Large differences between these variances indicate non convergence. For model (44), GB results are presented in figure (7):

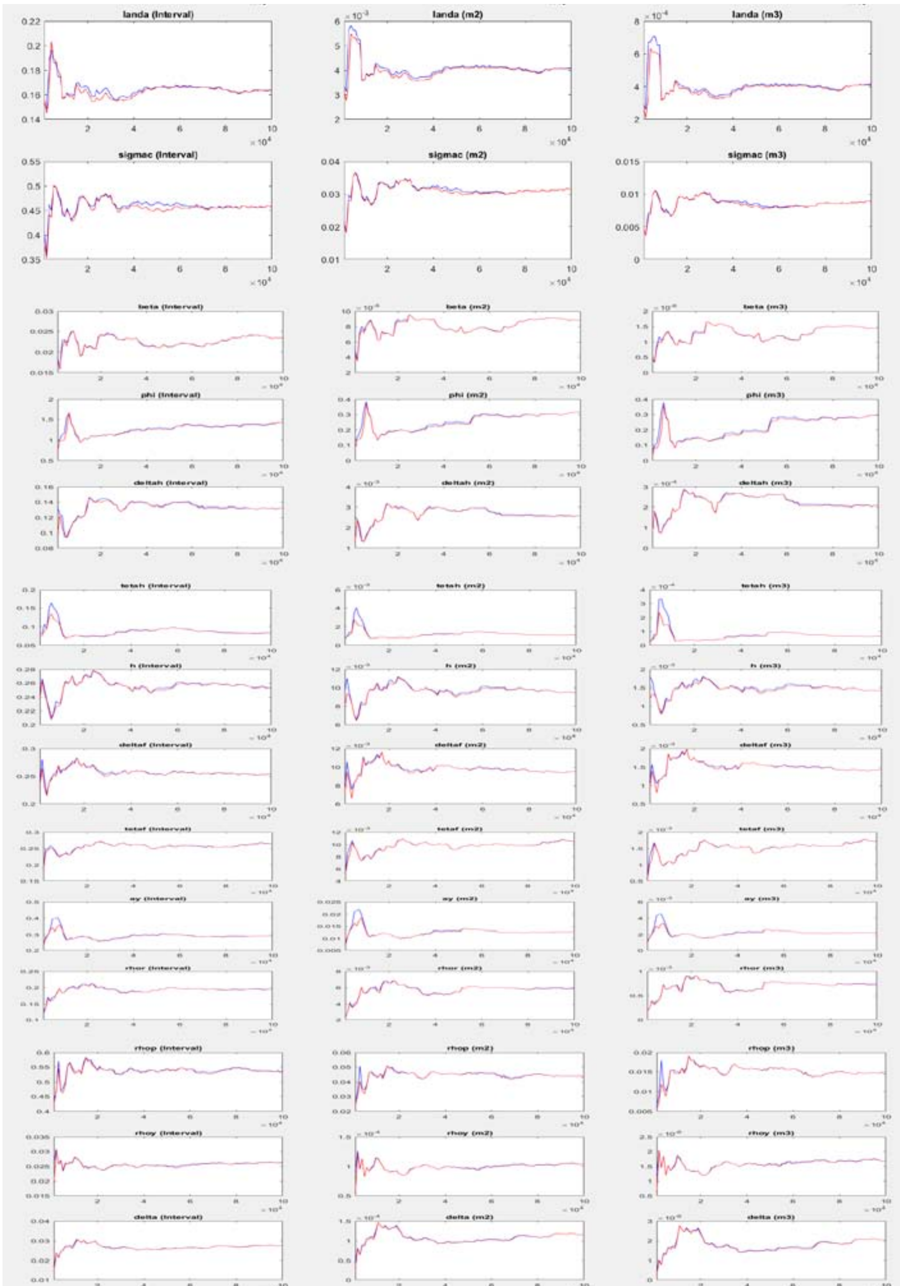

Fig 7. GB statistics for model (44) parameters

As fig (7) shows, GB for model parameters all converged within and between chains, thus by using this statistic it can be concluded that all model parameters estimated with confidence.

4.5.4 Choosing a Suitable Model

According to MCMC result, rules (44) and (45) have a convergent behavior and more stable behavior. Based on the likelihood ratio of models (44) and (45), the monetary rule (44) is chosen as a suitable model.

It seems that rule (44) is more consistent with the behavior of the central bank of Iran. Because the Central bank usually injects exchange rate to the market in order to stabilize it.

As a matter of fact, interest rates in Iran are fixed at least in a one-year period and changes are mainly related to reactions to fluctuations in inflation and output. Therefore, a direct relationship between the interest rate and the real exchange rate cannot actually reflect the behavior of the central bank. The central bank does not react to the fluctuations of the exchange market by raising (or decreasing) the money base. This behavior of the Central Bank usually has two reasons: Firstly, in the period in which an increase is observed in the exchange rate, the money base has also been increased which causes further depreciation of the national currency and this is in contrast with the rise in exchange rates. Secondly, due to the fact that Iran’s economy depends on a certain level of imports, exchange market fluctuations impact the price level indices and therefore inflation rate. This impact has forced the government to borrow from the central bank and therefore the money base has increased to finance a part of government budget deficit, as a result it offsets increased prices.

5. Concluding Remarks

In this study, a dynamic stochastic general equilibrium model, using the Bayesian method, was designed to investigate Iran's monetary policy during 1990-. The main innovation of this study was comparing different policy rules for Iran as an open economy.

In order to study the monetary policy rule in Iran, six different monetary rules were introduced and the related models were estimated. These rules consist of Taylor rule, with and without exchange rate and McCallum rule with and without exchange rate. The results indicated that models with the Taylor rule including nominal exchange rate, were not converged. This is not, however, a far-fetched result, because even if the Central bank is willing to intervene in the exchange rate market, typically what matters is exchange rate injections.

Therefore, the focus of the present study was to compare the six relevant models. To select the appropriate model, likelihood ratio, MCMC and Gelman - Brooks were used. The results of the estimation of these six rules indicate that the Taylor rules have no convergence and stability in MCMC. The results of LR show that the McCallum rule without exchange rate is more compatible than other rules.

Therefore, according to the two above-mentioned statistics, McCallum rule without the exchange rate has a more acceptable performance than the other rules in explaining the behavior of the central bank. The Gelman – Brooks statistics also confirmed consistency of parameters estimations of model (44).

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