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Optimal Monetary Policy in a Dual Exchange Rate Regime

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Abstract

In this study, we design a structural macro model for Iran's economy in which there is a dual exchange rate regime, namely, official (fixed) and unofficial (floated) rates. The central bank determines the official rate, whereas the unofficial rate is set in the free market. The structural parameters of the designed model are estimated using quarterly data in the 1991-2019 period and the Bayesian method. The main finding of this paper is that establishing a dual exchange rate regime cannot prevent the harmful effects of exchange rate dynamics on macro variables. Therefore, it is better to abandon this strategy, and instead, the central bank put forward the optimal response to exchange rate dynamics. To do this, we derive an optimal policy rule for the central bank and show that the best policy is assigning equal weights to the inflation rate and output gap in loss function and active response to both inflation rate and exchange rate in the policy rule.

Highlights

- This study aims to model dual exchange rate regime in Iran and then derive the optimal monetary policy in the presence of exchange rate volatilities.
- The structural model includes one regime for official exchange rate and one regime for unofficial rate.
- In order to minimize social loss function, central bank should react to exchange rate volatilities.

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1. Introduction

Open and modern economies depend heavily on exchange rate dynamics. In such countries, this variable has crucial effects on macro variables such as inflation rate, output gap, unemployment rate, and consumption that may lead to disequilibrium in markets and create inefficiencies in resource allocation. For this reason, policymakers try to mitigate the effects of exchange rate shocks by designing policy rules that bring minimum loss. The set of policy rules in an open economy describes two characteristics: the first one is that how the exchange rate evolves during time; in other words, what is the exchange rate regime? Is it fixed or flexible? The second one is that how the central bank reacts to exchange rate dynamics; in other words, is the central bank currently set its policy rule in response to exchange rate dynamics or not? Moreover, should the central bank react to a measure of exchange rate dynamics? (Wollmershäuser, 2006).

The literature of exchange rate regimes traces back to Friedman (1953) and Mundell (1960, 1964, 1968). These classical works reveal differences between fixed versus floating regimes. Suppose that the economy is experiencing a rise in money for demand. In the case of the flexible regime, one may expect an appreciation that reduces the production of final goods. However, in the case of fixed-rate, the central bank has to sell money to prevent appreciation that leaves the economy unaffected. Thereby, under a floating exchange rate, the monetary authority can change its policy tool freely, but policy rules cannot set under a fixed rate, regardless of exchange rate dynamics.

When exchange rate policy is determined, another question arises: does the central bank responses to exchange rate fluctuations? If not, should it responses? The answer to this question is significant in the field of monetary economics (Corsetti et al. (2010)). Typically, central banks worldwide respond to macro fluctuations by altering policy rates (the interest rates at the interbank markets) in a kind of Taylor rule. Standardly used variables in Taylor's rules are inflation rate and the output gap, among others (Bilbiie, (2019)), but those countries where exchange rate volatilities have significant and foremost effects on macroeconomy performance measure the exchange rate may include in the rule.

Iran's economy, as a small open economy, depends crucially on the exchange rate movements. It has suffered from large volatilities in the nominal exchange rate in recent years, but it seems that the country's central bank did not respond appropriately to these fluctuations by resetting the policy rate. This study designs a dynamic stochastic general equilibrium model for Iran's economy equipped with several nominal and real rigidity. Based on observations of recent years, exchange rate dynamics are modeled by a dual system, in which one is a fixed-rate regime, and another is a floated regime. Using this structure, we propose an optimal monetary policy rule that contains a nominal exchange rate, and the parameters assigned to each variable of the optimal rule are determined by minimizing a measure of the loss function.

This paper is structured as follows: in the second part, we review related literature, and in the third and fourth part, stylized fact and the theoretical foundation is reviewed. Then, we propose our structural model in the fifth part, where the estimated parameters will report, and then we derive optimal policy rule based on estimated parameters. In the end, the conclusion will be reported.

2. Literature Review

Hyuk-jae and Turdaliev (2013) analyzed the optimal monetary policy for a small open economy model where prices and wages are sticky. These authors derive a second-order approximation of welfare losses regarding the output gap fluctuations, inflation, and wage inflation. The optimal policy is to minimize these volatilities. The finding of this paper is that price inflation targeting leads to relatively significant welfare losses, but CPI inflation targeting works as the optimal rule.

Faia and Monacelli (2008) analyzed optimal monetary policy in a small open economy. This study shows that domestic bias in consumption is a cause for policymakers to deviate from strict inflation stabilization and inclined to exchange rate stabilization. The paper focuses on the optimal policy where firms' prices are one period ahead and gradual to adjustment costs.

Lama and Medina (2007) study optimal monetary policy in a two-sector small open economy model under multi-part asset markets. The Ramsey problem of the paper is solved that characterizes the optimal monetary policy. The paper results show that the optimal solution mimics the allocations, and, under the optimal policy, the volatility of non-tradable inflation is close to zero. Moreover, stabilizing non-tradable inflation is optimal.

Mahmudzadeh and Sadeghi (2017) compared monetary rules to various exchange rate regimes for Iran's economy when faces nominal shocks such as money base growth. The reaction of important macro variables to these shocks under monetary policy rules stabilizing the exchange rate, inflation targeting, and Taylor rule is analyzed. The results show that the effects of domestic and foreign shocks on the macro variables depend on monetary rule channels so that each of shocks under Taylor rule with exchange rate leads to more volatilities in investment and output in both tradable and non -tradable sectors, but the reaction of the inflation rate and exchange rate under this rule is more justifiable.

Salavitabar and Shirinbakhsh (2013) study optimal monetary policy in the two exchange rate regimes, namely floated and managed, using a DSGE model. The model is based on an oil exporter country and had assumed that the central bank in the floated exchange regime uses an optimal policy rule in order to stabilize macroeconomy and in the managed regime, uses two policy rules, one for nominal interest rate and one for exchange rate dynamics, and determines its decisions based on the interactions between these two regimes. The results show that the central bank chooses optimal rule if controlling inflation be more important than economic growth.

3. Stylized Facts

The balance of payments (BoP) is a financial statement that includes all international transactions in goods, services, and assets over a year. It serves as the most crucial variable in the open economy since it determines exactly how the domestic economy trades with the world. Any transaction registered in the BoP means purchasing a foreign asset or sailing a domestic commodity abroad, and such transaction leads to demand for or supply of the foreign currency. Therefore, changes in the components of the BoP affect the supply and demand of foreign currency. Demand for foreign currency provides foreign currency from foreign country reserves, and the supply of foreign currency adds to foreign reserves. Therefore, the volume of foreign reserves has a critical role in determining the exchange rate.

The variable that equilibrates the supply and demand for foreign currency is the nominal exchange rate. If a domestic resident wants to buy another country's currency, the exchange rate states the price for each unit of foreign currency. Formally the exchange rate is defined as the price of one unit of foreign currency in terms of the domestic currency.

Understanding the relevance of the balance of payments and the exchange rate is the key to grasping all concepts of the open economy. The BoP does not only represent a statistical account of a country's international transactions. The fundamental insight is that any change in the BoP sets off by definition a change in the market for foreign currency. Throughout our study of the model, we must recall that changes in the balance of payments fundamentally drive changes in the exchange rate.

In Iran, revenues from exporting oil and its differentiated products are the most important sources of foreign reserves. For this reason, the price of one unit of a foreign currency depends on how much oil is sold. In some periods, this revenue supports all needs, and therefore the central bank of Iran was able to provide enough exchange at a given price determined by the central bank. However, in the periods where there were some limitations in selling oil, a gap between the official rate (rate determined by the central bank) and the unofficial rate (rate determined at the free market) has been formed. This leads to shaping a dual exchange rate regime in Iran, as mentioned in Figure 1.

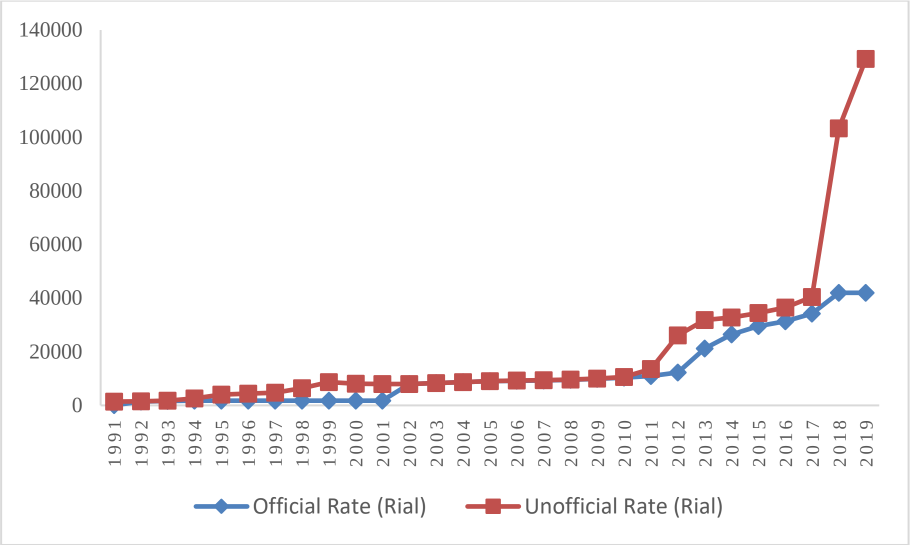


Figure 1. Official and unofficial rate (in terms of Rial) during 1991–2019.

As Figure 1 reveals, during 1991–2019, we observe a dual exchange rate in some periods, 1994–2002 and 2011–2019. Since the central bank has the monopoly of supplying foreign reserves, it determines the official rate, but the unofficial rate is set free-market by supply and demand forces. Adjustment economic policies in the 1991 decade and economic sanctions in the 2011 decade are essential in creating the gap between official and unofficial rates.

As Triffin (1947, 60) emphasizes, whenever the balance of payment difficulties is due, not to international price disparities but accidental factors or cyclical fluctuations in foreign income and demand, compensatory policies should be followed fullest possible extent to a high level of reserves. When reserves are insufficient, foreign or international assistance-such as contemplated under the International Monetary Fund-will be necessary. Failing to act appropriately requires exchange control as a third defense line to continue compensatory policies and avoid the greater evils inseparable from deflation or devaluation. The disadvantage of the latter policies, as compared to exchange control, is that their curative effect on the balance of payments is likely to depend on a contraction of income several times as severe as the international deficit to be plugged.

The official rate has just allocated to a specific part of imported goods in dual rates, and unofficial rates support other exchange needs. This policy means that the central bank allows forming two exchange markets because it wants to minimize the adverse effects of exchange rate shocks by providing an official rate to a subset of needs.

Figure 2 shows how the exchange rate gap evolves with oil exports. We define the exchange rate gap as the difference between unofficial and official rates. This diagram depicts this point that oil revenues lead exchange rate gap, i.e., whenever oil exports fall, the exchange rate gap increases; in other words, this forces policymakers to choose a dual exchange rate.

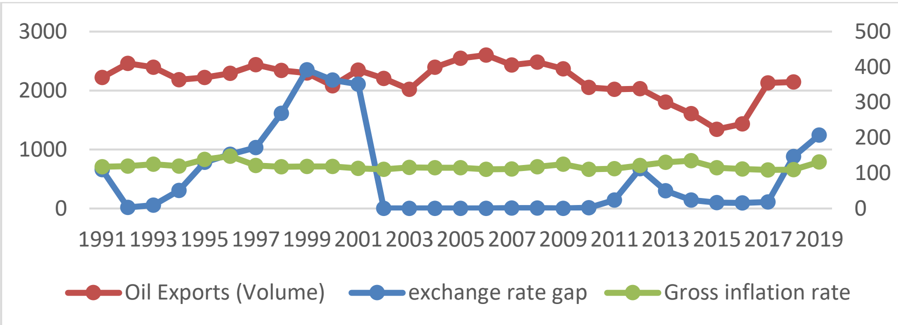


Figure 2. Oil exports (thousands barrel- left-hand axis), gross inflation rate (percent- right-hand axis), and exchange rate gap (percent -right-hand axis)

Moreover, we can observe a co-movement between the exchange rate gap and the inflation rate. This co-movement occurs because of purchasing power parity, there is a direct relation from inflation rate to exchange rate, and from exchange rate pass-through, exchange rate dynamics will reflect the inflation rate.

4. Theoretical Foundation

Some countries choose dual exchange rates for their foreign transactions. The motivation for implementing two-tier (or dual) exchange rate regimes reduces the effects of barriers fronting the macroeconomy. In a world with capital mobility, monetary policy is restricted in achieving final objectives. The problem will increase when an external shock, like oil price falls or economic sanctions, happens. Thus, the policy-induced interest rate adjustments to dampen these shocks may lead to substantial exchange rate movements that disturb aggregate supply. Thereby, the monetary authority cannot stabilize both output and price in the face of an exchange rate shock. Since costs related to exchange rate jumps may be significant, some central banks set a dual exchange rate by intervening in the exchange market.

The literature on exchange rate intervention, Boyer (1978), Roper and Turnovsky (1983), and Cox (1980), assumes that the central bank implements policies for foreign exchange reserves conditional on the current exchange rate. These articles assume UIP (uncovered interest rate parity) as well as a single exchange rate system. Thus, monetary stabilizers are indistinguishable from exchange rate intervention; that is, the intervention rule determines the money supply. In this article, the money supply is conditioned on both exchange rates and the interest rate. Current account exchange rate intervention is also allowed with any degree of sterilization.

In this regard, Aizenman and Frenkel (1985, 1986), and Devereux (1988), study optimal monetary policy. These authors assume UIP and PPP, with a single exchange rate system. Along with these papers, there are articles incorporating models with two-tier exchange rates, such as Gros (1988), Cumby (1984), Dornbusch (1986), Lizondo (1984), Flood (1978) and Fleming (1974), where instead of controlling capital flows as many papers, have introduced a two-tier exchange market in order to insulate fluctuations in exchange rate caused by short term shocks. In practice, this has allowed the central bank to keep more autonomy than generally in a fixed-exchange-rate regime environment by focusing its policy decisions on internal economy considerations. Although this is an intervention kind policymaking in the exchange rate market, in some cases, it able to achieve some economic benefits, such as controlling the inflation rate. By the way, one can introduce the optimal monetary policy in this context.

Three distinct theories are related to designing optimal monetary policy (Khan et al., 2003). The first one is the Fisherian view: in this theory, it is argued that the economic fluctuations were "largely a dance of the dollar" and proposed stabilizing the price level, and advised this policy as the central task of the monetary authority. Coupled with other Fisher's studies on determining the real interest rate (1930) and the nominal interest rate (l896), the Fisherian view says that the nominal interest rate would fluctuate with variations in real activity, which occur when the price level is stable.

The second one is the Keynesian view: since the market-generated output level could be inefficient, this view proposed stabilizing real economic activity by fiscal and monetary authorities. Such stabilization policy mandates, particularly those to aggregate demand, affected the economic system. The third one is Friedman's view: by looking at monetary policy in a long-run context with fully flexible prices, Friedman (1969) found that applying a standard microeconomic principle of policy analysis-that social and private cost should be equated-indicated that the nominal interest rate should be approximately zero.

5. The Model

Our DSGE model includes household, producer, foreign economy, monetary and fiscal sectors. We assume nominal rigidity in the behavior of households and firms, along with the law of one price gap in prices of home and foreign countries. Moreover, we specify a Taylor rule for analysis of monetary policy behavior. Fiscal policy is active, which means that the central bank finances the budget deficit; therefore, our analysis implicitly assumes passive monetary policy.

5.1 Household

There are continuum households with infinite time horizon, where the representative household seeks maximizing following utility function[1]:

$$U_t = E\sum_{t=0}^{\infty}\beta^t \varepsilon_t^u\left[\frac{(C_{p,t}-hC_{p,t-1})^{1-\sigma}}{1-\sigma}+\frac{(M_t/P_t)^{1-\varpi}}{1-\varpi}-\frac{L_{p,t}^{1+\varphi_L}}{1+\varphi_L}\right] \quad (1)$$

[1] The structure of household part is given from Smets and Wouters (2003).

The discount factor, C_t consumption, M_t nominal balance of the money, P_t general level of prices, L_t working hours, σ_C and intertemporal substitution elasticity of consumption. Moreover, h the habit persistence parameter, the inverse of money demand elasticity, the inverse of labor supply elasticity, and household preferences shock. Household budget constraint is:

$$P_tC_t + B_t + M_t + P_tI_t \leq W_tL_t + R_{t-1}B_{t-1} + M_{t-1} + P_t(r_t^k Z_t K_{t-1} - \psi(Z_t)K_{t-1}) + TR_t - T_t \qquad (2)$$

Where B_t Is Government bonds, I_t is an investment, W_t is the wage, R_{t-1} gross nominal interest rate ($R_{t-1} = 1 + i_{t-1}$), and r_t^k is the real interest rate on capital, K_t volume of the capital, Z_t shows what percentage of capital is utilized, TR_t transfer payment, and paid tax. Capital accumulates according to the following equation:

$$K_t = (1-\delta)K_{t-1} + \left(1 - S\left(\frac{\varepsilon_t^I I_t}{I_{t-1}}\right)\right)I_t \qquad (3)$$

Where $S(.)$ is the adjustment cost of transferring investment into capital, and ε_t^I is investment shock?

Consumption is a composite consumption index given by a constant elasticity of substitution (CES) function:

$$C_t = \left[(1-\alpha_c)^{\frac{1}{\mu_c}} C_{H,t}^{\frac{\mu_c - 1}{\mu_c}} + \alpha_c{}^{1/\mu_c} C_{F,t}^{(\mu_c-1)/\mu_c}\right]^{\mu_c/(\mu_c-1)} \qquad (4)$$

Where α_c is the share of foreign goods in the domestic consumption bundle, and $C_{H,t}$ and $C_{F,t}$ represent the usual Dixit–Stiglitz aggregates of the domestic and foreign-produced goods; one can write the followings:

$$C_{H,t} = \left[\int_0^1 C_{H,t}(i)^{(\varepsilon_c-1)/\varepsilon_c} di\right]^{\varepsilon_c/(\varepsilon_c-1)} \quad C_{F,t} = \left[\int_0^1 C_{F,t}(i)^{(\varepsilon_c-1)/\varepsilon_c} di\right]^{\varepsilon_c/(\varepsilon_c-1)} \qquad (5)$$

Where notation ε_c represents the elasticity of substitution between every two goods. Optimal allocation of the household expenditure across each suitable type gives rise to the demand functions:

$$C_{H,t}(i) = (P_{H,t}(i)/P_{H,t})^{-\varepsilon_c} C_{H,t} \ , C_{F,t}(i) = (P_{F,t}(i)/P_{F,t})^{-\varepsilon_c} C_{F,t} \qquad (6)$$

where the aggregate price levels are defined as:

$$P_{H,t} = \left[\int_0^1 P_{H,t}(i)^{1-\varepsilon_c} di\right]^{1/(1-\varepsilon_c)} \quad P_{F,t} = \left[\int_0^1 P_{F,t}(i)^{1-\varepsilon_c} di\right]^{1/(1-\varepsilon_c)} \qquad (7)$$

The optimal consumption demand of home and foreign goods can be derived as:

$$C_{H,t} = (1-\alpha_C)(P_{H,t}/P_t)^{-\mu_c} C_t \ , C_{F,t} = \alpha_C (P_{F,t}/P_t)^{-\mu_c} C_t \qquad (8)$$

where P_t is the domestic price consumer price index (CPI):

$$P_t = \left[(1-\alpha_c)P_{H,t}^{1-\mu_c} + \alpha_c P_{F,t}^{1-\mu_c}\right]^{1/(1-\mu_c)} \qquad (9)$$

The household problem is maximizing (1) subject to (2) and (3), which results in first-order conditions. By log-linearizing first-order conditions around the steady-state, we reach the following linear structural equations:

$$\hat{C}_t = \frac{h}{1+h}\hat{C}_{t-1} + \frac{1}{1+h}E_t\hat{C}_{t+1} - \frac{1-h}{\sigma_c(1+h)}\left(\hat{r}_t^d - E_t\hat{\pi}_{t+1}\right) - \frac{1-h}{\sigma_c(1+h)}(\varepsilon_{t+1}^u - \varepsilon_t^u) \quad (10)$$

$$\hat{m}_t = \frac{\sigma_c}{\sigma_m}\left[\frac{1}{1-h}\hat{c}_t - \frac{h}{1-h}\hat{c}_{t-1}\right] - \frac{1}{\sigma_m}\frac{1}{\bar{i}}\hat{i}_t - \frac{1}{\sigma_m}(\varepsilon_{t+1}^u - \varepsilon_t^u) \quad (11)$$

$$\hat{I}_t = \left(\frac{\varphi}{(1+\beta)}\right)\hat{q}_t + \left(\frac{1}{1+\beta}\right)\hat{I}_{t-1} + \left(\frac{\beta}{1+\beta}\right)\hat{I}_{t+1} + (\varepsilon_{t+1}^I - \varepsilon_t^I) \quad (12)$$

$$\hat{q}_t = -\left(\hat{r}_t^d - E_t\hat{\pi}_{t+1}\right) + \frac{1-\delta}{1+\bar{r}^k-\delta}\hat{q}_{t+1} + \frac{\bar{r}^k}{1+\bar{r}^k-\delta}\hat{r}_{t+1}^k \quad (13)$$

$$\hat{w}_t = \frac{1}{1+\beta}\hat{w}_{t-1} + \frac{\beta}{1+\beta}\left(E(\hat{w}_{t+1}) + E(\hat{\pi}_{t+1})\right) - \frac{1+\iota_w\beta}{1+\beta}\hat{\pi}_t + \frac{\iota_w}{1+\beta}\hat{\pi}_{t-1} - \frac{1}{1+\beta}\frac{(1-\xi_w)(1-\beta\xi_w)}{\xi_w}\hat{\mu}_t^w + \varepsilon_t^w \quad (14)$$

$$\hat{\mu}_t^w = \hat{w}_t - \sigma_l\hat{l}_t - \frac{\sigma_c}{1-h}(\hat{c}_t - h\hat{c}_{t-1}) \quad (15)$$

$$\hat{\pi}_t^w = \hat{w}_t - \hat{w}_{t-1} + \hat{\pi}_t \quad (16)$$

$$\hat{L}_t = \frac{1}{\sigma_l}\hat{w}_t - \frac{\sigma_c}{\sigma_l}\left(\frac{1}{1-h}\hat{C}_t - \frac{h}{1-h}\hat{C}_{t-1}\right) \quad (17)$$

Where variables with the sign ^ show linearized logarithm of variables around a steady-state and notation $\hat{\pi}_t$ Denotes the inflation rate.

5.2 Exchange Rate Regimes

One characteristic of the exchange market in Iran's economy is that there is no unique exchange rate regime, and one can often observe multiple rates for a foreign currency. Multiple rates in the exchange market are due to exogenous shocks that severely hit Iran's economy and led policymakers to opt for a dual-rate system, where both fixed and floating rates for the same currency during the same period[2].

The fixed-rate only applies to a specific market segment such as "essential goods"; the fixed (subsidize) rate applied by policymakers supports households and firms from exchange rate shocks. Thus fixed exchange rates allocate this rate only to a set of predetermined commodities; the other needs for import financed by the secondary rate that is not fixed and volatile along with inflation rate and the volume of foreign reserves. We assume that α_{s1} and α_{s2} as the proportions of financing imports by fixed and floated rates, respectively.

If S_{1t} and S_{2t} be fixed and floated exchange rate, respectively, then we assume these rates evolve during time as follow (it should be noted that $S_{1,t} < S_{2,t}$, for all times):

[2] Equations and theorems of this part is designed and proved by authors and does not retrieved from any previous publications.

$$S_{1,t} = \bar{S}_1 + \varepsilon_t^{s1} \tag{18}$$

$$\hat{S}_{1,t} = \left(\frac{1}{\bar{S}_1}\right)\varepsilon_t^{s1}$$

$$\hat{S}_{2,t} = \rho_{s2}\hat{S}_{2,t-1} + \rho_{s\pi}\hat{\pi}_t + \rho_{soil}\widehat{oil}_{t-1} + \varepsilon_t^{s2} \tag{19}$$

Equation (18) shows dynamics of fixed-rate, where $\bar{S}_1$ do the central bank and determine the fixed-rate and shock change; the fixed rate is ε_t^{s1}. Equation (19) shows dynamics of floated rate in which oil_t are revenue of oil-exporting and stochastic shock of Equation (18) is ε_t^{s2}. If Υ_t be the vector of endogenous macro variables, and then it is evident that with a rise in α_{s2}, then $\left|\frac{\partial \Upsilon_t}{\partial \varepsilon_t^{s2}}\right|$ will increase; in other words, the effects of nominal exchange rate shocks on the economy will be higher.

Moreover, $\rho_{s2} > 0$, $\rho_{s\pi} > 0$ and $\rho_{soil} < 0$ are model parameters. Therefore, the overall effects of exchange rate fluctuations on the macroeconomy depend on four factors: the share of fixed and floated rate in the process of financing imported goods, the level of $\bar{S}_1$, oil revenues and inflation.

The share of fixed-rate in the total cost of import determines what extend exchange shocks transmit to the economy; the more the share of this rate means lower effects of nominal exchange rate shocks, and vice versa. Nevertheless, it should be noted that a country with a dual exchange rate has not enough reserves to provide a fixed rate to all exchange needs; inevitably, a portion of exchange rate shocks hits the economy. In the fixed regime (18), the value of $\bar{S}_1$ remains unchanged during a specific period, may discard in the future, and the central bank set a new rate equal to $\bar{S}_1 + \varepsilon_{t+n}^{s1}$ (for $n > 1$). If for $n \longrightarrow \infty$, we have $\bar{S}_1 + \varepsilon_{t+n}^{s1} \longrightarrow S_{2,t+n}$It will then be clear that central banks abandon the fixed regime, so this regime is no longer effective. But if, for large enough value of n, we have $\bar{S}_1 + \varepsilon_{t+n}^{s1} \neq S_{2,t+n}$, then the gap between two rates, $gs_t = (\bar{S}_1 + \varepsilon_{t+n}^{s1}) - S_{2,t+n}$, it has a meaningful effect on transmitting exchange rate shocks into the economy.

The value of gs_t , depends on the country's oil revenues and inflation rate. The effects of a rise in oil revenue on gs_t in ambiguous, since $\varepsilon_{t+n}^{s1} \longrightarrow 0$ and $S_{2,t+n}$ declines; therefore, the net effect is unknown. On the other hand, the net effect of a rise in inflation rate is straightforward in short-run: for short periods $\bar{S}_1 + \varepsilon_{t+n}^{s1} \cong \bar{S}_1$ and because $\rho_{s\pi} > 0$, $S_{2,t+n}$ will rise; therefore gs_t increases in absolute value in the short run. But its effect, in the long run, is not apparent because we expect $\varepsilon_{t+n}^{s1} > 0$ along with a rise in $S_{2,t+n}$, that makes variations of gs_t unambiguous. Based on these results, we conclude the following proposition:

Proposition 1. If $\rho_{s\pi} = |\rho_{soil}|$, then in both the short and long run gs_t , increases in absolute value, where its growth, in the long run, is more than the short run.

Proof. With $\rho_{s\pi} = |\rho_{soil}|$, from (13), we have $\Delta\hat{S}_{2,t} = \rho_{s2}\Delta\hat{S}_{2,t-1} + \rho_{s\pi}(\Delta\hat{\pi}_t - \Delta\widehat{oil}_{t-1})$. Since in the short run$\rho_{s2}\Delta\hat{S}_{2,t-1} \cong 0$, then $\dot{S}_{2,t} = \rho_{s\pi}(\dot{\pi}_t - \dot{oil}_{t-1})$, where $\dot{x} = dLn(x_t)$. Now, if the rate of growth of inflation rate is more significant than the growth rate of oil income, then $\dot{S}_{2,t} > 0$ and gs_t increases in absolute value. In the long run, $\dot{S}_{2,t} = \frac{\rho_{s\pi}}{1-\rho_{s2}}(\dot{\pi}_t - \dot{oil}_{t-1})$. And since $\frac{\rho_{s\pi}}{1-\rho_{s2}} > \rho_{s\pi}$, then $(\dot{S}_{2,t})_{long-run} > (\dot{S}_{2,t})_{short-run}$. By this result, we conclude that $\left|\bar{S}_1 - (\dot{S}_{2,t})_{long-run}\right| > \left|\bar{S}_1 - (\dot{S}_{2,t})_{short-run}\right|$.

Following proposition 1, we provide proposition 2, as follows:

Proposition 2. In a dual exchange rate regime, the effects of exchange rate shocks on macro variables, in the long run, are bigger than their effects in the short run.

Proof. When the economy faces exchange rate shocks, we expect that $\dot{\pi}_t - \dot{oil}_{t-1}$ rises during the time, where leads to $\dot{\pi}_t - \dot{oil}_{t-1}$ in both the short and long run, such that $(\dot{\pi}_t - \dot{oil}_{t-1})_{long-run} > (\dot{\pi}_t - \dot{oil}_{t-1})_{short-run}$. In such an environment, the central bank has two choices: injects a more share of oil revenues to floated rate market in order to controls $S_{2,t}$, or allow $S_{2,t}$ freely to adjust, and provides resources for imports with fixed-rate, as before. If the central bank decides to run the first policy, it is clear that α_{s2} rises and therefore $\left|\frac{\partial Y_t}{\partial \varepsilon_{t+n}^{s2}}\right|_{n>1} > \left|\frac{\partial Y_t}{\partial \varepsilon_{t+n}^{s2}}\right|_{n<1}$. Otherwise, under the second policy, $\varepsilon_{t+n+i}^{s2} > \varepsilon_{t+n+i-1}^{s2} > \cdots > \varepsilon_{t+n}^{s2} > \varepsilon_t^{s2}$For all $n > 0$, and $i > 1$, which means that: $\left|\frac{\partial Y_t}{\partial \varepsilon_{t+n+i}^{s2}}\right| > \left|\frac{\partial Y_t}{\partial \varepsilon_{t+n+i-1}^{s2}}\right| > \cdots > \left|\frac{\partial Y_t}{\partial \varepsilon_{t+n}^{s2}}\right| > \left|\frac{\partial Y_t}{\partial \varepsilon_t^{s2}}\right|$.

Propositions 1 and 2 reveals two critical points: first, under an exchange rate shock, if the central bank tries to make a difference between the official rate (fixed rate) and unofficial market rate (floated rate), this leads to create a dual exchange rate regime, where the gap between two rates grows up during the time. This gap may lead to inefficient resource allocation, which brings welfare losses. Second, due to inflation pressures and foreign reserve limitations, setting a fixed rate regime and a floated regime cannot prevent transmitting nominal exchange shocks to the economy; in other words, in the long run, one can observe that all macro variables will be adjusted to exchange rate shocks.

5.3 Terms of Trade and Real Exchange Rate

Using the definition of terms of trade, $TOT_t = \frac{P_{f.t}}{P_{h.t}}$, where $P_{h.t}$ and $P_{f.t}$ is the price index of domestic produced and imported goods, respectively, we arrive following linear equation for terms of trade (Gali, 2007):

$$\Delta\widehat{TOT}_t = \hat{\pi}_{f.t} - \hat{\pi}_{h.t} \quad (20)$$

Where$\pi_{f.t}$ and $\pi_{h.t}$ are imported goods and domestic produced inflation rates, respectively. Moreover, following the uncovered interest rate parity condition, we reach the following linear relation for the real exchange rate (rer_t):

$$\Delta\widehat{rer}_t = -(\hat{\imath}_t - E\hat{\pi}_{t+1}) - (\hat{\imath}_t^f - E\hat{\pi}_{t+1}^f) \quad (21)$$

Where, $\pi_t$is the overall inflation rate, i_t^f foreign interest rate and π_t^f , is foreign inflation. Assuming monopolistic power of importers, the domestic price of imported goods is different from its foreign price; this can leads to the gap of the law of one price (ψ_t) that its linear form is as follow:

$$\hat{\psi}_t = -[\widehat{qq}_t + (1-\tau)\hat{s}_t] \tag{22}$$

5.4 Domestic Firms

Like other papers, such as Smets and Wouters (2003), there is a continuum of intermediate firms where each produced one commodity in a monopolistic competition market. We assume that domestic firms produce goods and services using the following production function technology (Y_t):

$$Y_t = (K_t^s)^\alpha L_t^{1-\alpha} \tag{23}$$

Effective capital, K_t^s and labor is input for intermediate firms, where effective capital in proportion to capital ($K_t^s = z_t K_t$). Firms have a two steps problem. At the first step, they choose optimal capital and labor forces to minimize the cost of production. At this step, nominal wage and rental cost of capital are given; the first-order condition of this problem yields real marginal cost, which its linear form is as follows:

$$\widehat{mc}_t = \alpha\left(\widehat{K}_t^s - \hat{L}_t\right) - \widehat{w}_t + \alpha\varepsilon_t \tag{24}$$

At the second step, firms choose an optimal price to maximize their expected discounted profit over an infinite period. Due to the price rigidity assumption, we use Christiano, Eichenbaum, and Evans (2005) approach in modeling price dynamics and deriving the Phillips curve. A portion of firms chooses optimal prices in each period from this approach, whereas remaining firms indexed their prices to past inflation. This modeling yields the following hybrid New-Keynesian Phillips curve:

$$\hat{\pi}_{h,t} = \frac{1}{1+\beta}\hat{\pi}_{h,t-1} + \frac{\beta}{1+\beta}E_t(\hat{\pi}_{h,t+1}) + \frac{(1-\omega\beta)(1-\omega)}{\omega(1+\beta)}m\hat{c}_t + \varepsilon_t^p \tag{25}$$

Where ε_t^p represents cost pressure shock.

5.5 Importing Firms

Because of the dual exchange rate regime, we have two different kinds of importers: the first group receives a fixed (subsidized) rate and has to sell imported good subject to the following rule[3]:

$$P_t^{1m} = (1+\mu)\bar{S}_1 P_{A,t} \tag{26}$$

Where P_t^{1m} is a good price in-country, and $\mu > 0$ is commercial profit for importers, usually equal to 20% in Iran. This equation result following Phillips curve for imported good financed with fixed rate:

$$\hat{\pi}_t^{1m} = \hat{\pi}_{A,t} \tag{27}$$

[3] Modelling Equations (26) and (27) is designed and derived by authors.

Equation (27) shows that the inflation rate of goods financed by fixed-rate ($\hat{\pi}_t^{1m}$) solely depends on price variations of those goods in the foreign country ($\hat{\pi}_{A,t}$).

The second group of importers receives floated rate and has the power to change their prices optimally. For this reason, we assume a share of $(1-\theta_f)$ of firms reset their prices optimally since others adjust regarding past inflation. The gap of the law of one price makes the Phillips curve of these set of importers as follow:

$$\hat{\pi}_t^{2m} = \beta(1-\theta_f)E\hat{\pi}_{t+1}^{2m} + \theta_f\hat{\pi}_{t-1}^{2m} + \lambda\hat{\psi}_t \qquad (28)$$

5.6 Overall Inflation Rate

Since the imported inflation rate is determined by Equations (27) and (28), therefore overall imported inflation rate equals:

$$\hat{\pi}_{f.t} = \alpha_{s1}\hat{\pi}_t^{1m} + \alpha_{s2}\hat{\pi}_t^{2m} \qquad (29)$$

Where $\alpha_{s1} = 1-\alpha_{s2}$. Moreover, the overall inflation rate is equal to:

$$\hat{\pi}_t = \alpha_{\pi 1}\hat{\pi}_{h.t} + (1-\alpha_{\pi 1})\hat{\pi}_{f.t} \qquad (30)$$

5.7 Monetary Policy

We suppose following McCallum rule type (McCallum, 1989) for monetary policy rule:

$$\hat{\mu}_{m,t} = \rho_i\hat{\imath}_{t-1} + (1-\rho_i)\left[\rho_{i.\pi}\hat{\pi}_t + \rho_{i.y}\hat{Y}_t + \rho_{s.y}\hat{s}_{2,t}\right] + \varepsilon_t^i \qquad (31)$$

Where $\hat{\mu}_{m,t} = \widehat{M}_t - \widehat{M}_{t-1} = \widehat{m}_t - \widehat{m}_{t-1} + \hat{\pi}_t$, is the money growth rate and the central bank tool for controlling the economy. Moreover, ε_t^i , is monetary policy shock.

5.8 Fiscal Policy

Fiscal policymaker faces budget constraint as follow (Walsh, 2010):

$$G_t + (1+i_{t-1})B_{t-1} = T_t + B_t + (M_t - M_{t-1}) \qquad (32)$$

Equations (33) shows that for government spending (G_t) and repayment past gross debt ($(1+i_{t-1})B_{t-1}$), three sources are available: tax revenue (T_t), issuing new debt (B_t) and seigniorage ($M_t - M_{t-1}$). Linearizing this equation around steady state yields the following relation for dynamics of government debt:

$$\hat{b}_t = \frac{\bar{g}}{\bar{b}}\hat{g}_t + \frac{1}{(1+\bar{\pi})}\hat{b}_{t-1} - \frac{\bar{t}}{\bar{b}}\hat{t}_t - \left(\frac{\bar{m}}{\bar{b}}\widehat{m}_t - \frac{\bar{m}}{\bar{b}(1+\bar{\pi})}\widehat{m}_{t-1}\right) \qquad (33)$$

Moreover, we assume a first-order Markov process for both government expenditure ($\hat{g}_t$) and tax revenues ($\hat{t}_t$):

$$\hat{g}_t = \rho_{ga}\hat{g}_{t-1} + \varepsilon_t^g \qquad (34)$$

$$\hat{t}_t = \rho_{ta}\hat{t}_{t-1} + \varepsilon_t^t \qquad (35)$$

Where $0 < \rho_{ga} < 1$ and $0 < \rho_{ta} < 1$. The terms ε_t^g and ε_t^t , are independent exogenous shocks that are distributed identically and independently.

5.9 Dynamics of Foreign Trade

We decompose foreign trade into exports and imports. Export (Ex_t) includes oil (Oil_t) and non-oil ($Noil_t$) revenues that its linearized form is as follows:

$$\widehat{Ex}_t = \frac{\overline{Oil}}{\overline{Ex}}\widehat{Oil}_t + \frac{\overline{Noil}}{\overline{Ex}}\widehat{Noil}_t \tag{36}$$

Net export (Nex_t) is defined as the difference between export revenues and import expenditures (Im_t):

$$\widehat{Nex}_t = \frac{\overline{Ex}}{\overline{Nex}}\widehat{Ex}_t - \frac{\overline{Im}}{\overline{Nex}}\widehat{Im}_t \tag{37}$$

Since $\widehat{Im}_t = \hat{C}_{F,t}$, therefore from household demand functions for home and foreign goods, we can derive the following equation for imported goods:

$$\widehat{Im}_t = \widehat{Im}_{t-1} + \mu_c(\hat{\pi}_t - \hat{\pi}_{f.t}) + (\hat{C}_t - \hat{C}_{t-1})$$

5.10 The Market Clear Condition

Summing up the demand side of the economy, we reach the following equation for the market clear condition:

$$\hat{Y}_t = \frac{\bar{C}}{\bar{Y}}\widehat{oil}_t + \frac{\bar{I}}{\bar{Y}}\hat{I}_t + \frac{\bar{g}}{\bar{Y}}\hat{g}_t + \frac{\overline{Nex}}{\bar{Y}}\widehat{Nex}_t \tag{38}$$

6. Model Estimation

After linearizing the model first-order conditions and identities, we implement the Bayesian approach to estimate structural model parameters. The first step in doing that is to test whether the model structure along with initial values defined for parameters verify a unique saddle point solution or not. This test was done by Blanchard – Kahn method; the results show that there are nine eigenvalues larger than 1 in modulus for nine forward-looking variables; therefore, this condition is verified for the designed model.

The second step is choosing a data sample. We use seasonal-adjusted quarterly data over the period 1991–2019. Then the used sample for Estimation was constructed by log-differencing data. Then, we need to define priors' distribution functions for every parameter that would be estimated. The estimation results are mentioned in Table 1:

Table 1. The results of the model parameter estimation

Symbol	**Parameters**	**Prior Distribution Function**	**Prior mode**	**Sources**	**Posterior Mode**	**Standard Error**
H	Habit formation	Beta	0.5	Manzour et al. (2015)	0.45	**0.2**
β	Discount Factor	Beta	0.97	Manzour et al. (2015)	0.97	**0.02**
δ	Depreciation Rate	Beta	0.04	Manzour et al. (2015)	0.046	**0.02**
α	Capital Weight in Production Function	Beta	0.42	Shahmoradi (2008)	0.75	**0.1**
ψ	Utilization Rate Cost	Beta	0.6	Authors computations	.54	**0.05**
θ_f	Share of Non-Optimizing Importer Firms	Beta	0.5	Manzour et al. (2015)	0.71	**0.1**
ω	Share of Non-Optimizing Domestic Firms	Beta	0.5	Tavakolian (2012)	0.46	**0.1**
σ_m	The inverse of Money Demand Elasticity	Gamma	1.34	Manzour et al. (2015)	2.4	**0.2**
σ_c	The inverse of Consumption Intertemporal Elasticity	Gamma	1.5	Smets and Wouters (2003)	1.54	**0.2**
φ	Adjustment Cost	Gamma	3.93	Manzour et al. (2015)	7.7	**2**
ξ_w	Share of Non-Optimizing Households	Beta	0.75	Authors computations	0.63	**0.1**
ι_w	Indexation of wage to Past Inflation	Beta	0.5	Authors computations	0.53	**0.25**
τ	Share of Terms of Trade in LOPG	Beta	0.45	Authors computations	0.51	**0.1**
$\in$	Share of Domestic Inflation in Total Inflation	Beta	0.6	Authors computations	0.31	**0.2**
λ	Share of LOPG in Importing Inflation	Beta	0.45	Authors computations	0.48	**0.1**

Table 1 (Continued). The results of the model parameter estimation

ρ_i	Coefficient of Lagged money in monetary rule	Beta	0.75	Tavakolian (2012)	0.85	**0.1**
$\rho_{i.\pi}$	The reaction of a monetary rule to inflation	Gamma	1.55	Tavakolian (2012)	1.71	**0.5**
$\rho_{i.y}$	The reaction of the monetary rule to Output Gap	Normal	1.7	Tavakolian (2012)	1.68	**0.02**
$\rho_{s.y}$	The reaction of a monetary rule to exchange rate	Beta	0.2	Manzour et al. (2015)	0.21	**0.05**
α_{s2}	proportions of financing imports by floated rate	Beta	0.6	Authors computations	0.54	**0.2**
ρ_{s2}	The reaction of exchange floated rate to its first lagged	Beta	0.67	Authors computations	0.8	**0.15**
$\rho_{s\pi}$	The reaction of exchange floated rate to inflation rate	Beta	0.5	Manzour et al. (2015)	0.45	**0.1**
ρ_{soil}	The reaction of exchange floated rate to oil revenues	Normal	0.49	Authors computations	0.49	**0.12**
μ_c	Substitution between an importer and homemade goods	Gamma	1.1	Manzour et al. (2015)	1.1	**0.05**
Eg	Government Spending Shock	Inv-Gamma	0.005	Authors computations	0.17	**INF**
ε_t^a	Productivity Shock	Inv-Gamma	0.005	Authors computations	0.004	**INF**
ε_t^α	Marginal Cost Shock	Inv-Gamma	0.005	Authors computations	0.004	**INF**
Eq	q- Tobin Shock	Inv-Gamma	0.005	Authors computations	0.003	**INF**
$\mathcal{E}_t^I$	Investment Shock	Inv-Gamma	0.005	Authors computations	0.08	**INF**
$\mathcal{E}_t^p$	Domestic Inflation Shock	Inv-Gamma	0.005	Authors computations	0.02	**INF**
ε_t^w	Wage Inflation Shock	Inv-Gamma	0.005	Authors computations	0.004	**INF**

Table 1 (Continued). The results of the model parameter estimation

ε_t^i	Monetary Policy Shock	Inv-Gamma	0.005	Authors computations	0.02	**INF**
ε_{t+1}^m	Money Demand Shock	Inv-Gamma	0.005	Authors computations	0.03	**INF**
ε_t^f	Importer Inflation Shock	Inv-Gamma	0.005	Authors computations	0.005	**INF**
ε_t^u	Consumption Shock	Inv-Gamma	0.005	Authors computations	0.09	**INF**
ε_t^b	Exchange rate Shock	Inv-Gamma	0.005	Authors computations	0.004	**INF**
ε_t^{nex}	Net Export Shock	Inv-Gamma	0.005	Authors computations	0.005	**INF**

***Source**: results from Bayesian estimation*

Estimated results show that the fraction of imports financed by floated exchange rate is about 54 percent, and the remaining 46 percent will have financed by a fixed rate. This finding reveals that unofficial market rates finance a more significant portion of imports.

Estimating results of the Taylor rule show that the inertia of the policy rate is about 0.85, and therefore every period, the current policy rate includes 85 percent of the lagged rate. This degree of stickiness reveals this property of policy rate that did not experience jumps during inflationary periods and exchange rate shocks. Moreover, its responses to the inflation gap and output gap are 1.71 and 1.68, respectively. This finding acknowledges the passive behavior of the central bank of Iran during the 1991-2019 period, where not respond sufficiently to fluctuations in inflation rate and business cycles did to restore equilibrium. Therefore monetary policy was not efficient in reducing macroeconomics fluctuations.

On the other hand, the coefficient of the nominal exchange rate in the policy rule is estimated at 0.21. This unproportioned response of policy rate suggests that Iran's central bank was not able or unwilling to has an active reaction to exchange rate volatilities. Therefore, we can conclude that exchange rate shocks are less critical in determining the policy rate than the inflation rate. One reason why the central bank has a passive behavior in the face of exchange shocks is that to reduce the effects of shocks, the central bank is more interested in implementing a dual exchange rate regime than changing interest rates. The observations of the sample period reveal these phenomena, where except for 2002–2011, in the other years, we could see a dual-rate system.

The estimation results of floated exchange rate show that lagged rate has a share of about 80 percent in the dynamics of the current rate. The coefficient of inflation gap shows that for every 10 percent increase in inflation rate above its long-run trend, the exchange rate will increase 4.5 percent above its steady-state. On the other hand, the coefficient of oil income shows that for a 10 percent reduction in oil sales, the exchange rate would rise about 4.9 percent.

6.1 Validity Analysis of Estimation Results

Since the Bayesian method has been used to estimate structural parameters, we need to employ related statistics to check whether estimation results are valid. In doing so, we use three statistics: MCMC result, Kolmogorov-Smirnov test, and identification test.

- *MCMC result*

Markov chain Monte Carlo (MCMC) method includes procedures for sampling from a probability distribution. By constructing a Markov chain, one can determine a series of distributions. Having more steps, it is more likely that the distribution of the sample matches the actual distribution. Bayesian Estimation uses the Metropolis-Hastings algorithm for constructing chains which enable Bayesian statistics to compute big structural models that require integrations over a set of unknown parameters. To interpreting MCMC statistics, one should choose a sampling method and then determines under which condition the results are sensible. Among many methods, we use Gibbs sampling. Under This method, estimated parameters are valid if conditional distributions of the target distribution to be sampled exactly. Figure 3 shows distribution at first through third moments, where reveals convergence among the distribution of samples; in other words, based on these statistics, estimate parameters are valid.

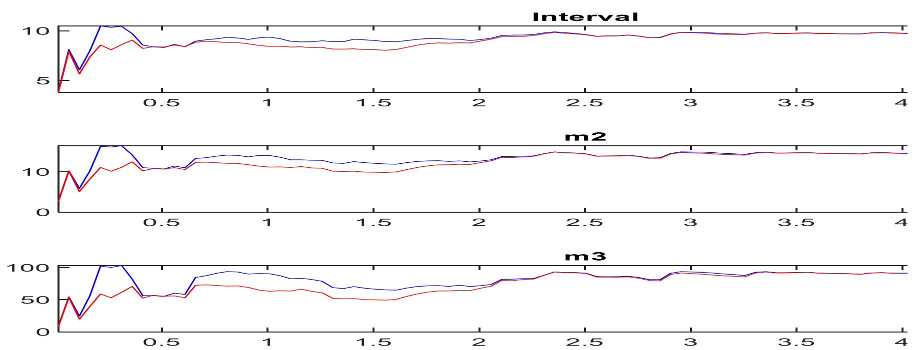


Figure 3. MCMC result of the estimated model.

- *Kolmogorov-Smirnov test*

The Kolmogorov–Smirnov statistic measures the distance between the distribution function and the cumulative distribution function of the reference distribution. The null distribution is calculated under the null hypothesis that the sample is drawn from the reference distribution. Using Bayesian Estimation, one can find whether structural parameters are drawn from the prior distribution. If so, then it means that primary distribution functions give a unique saddle-path solution. This statistic reports in Figure 4.

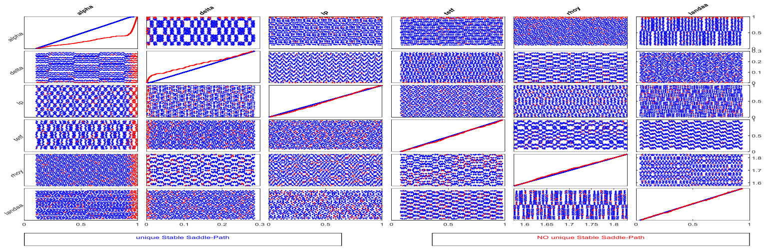


Figure 4. Unique saddle-path era using Kolmogorov–Smirnov statistic

These statistics show that only 0.2 percent of the prior support gives indeterminacy, whereas 99.8 percent of the prior support gives determinacy.

- Identification test

The idea behind identification in DSGE models is that mapping from objective function to the parameters needs to be well behaved. Doing this requires satisfying three conditions: firstly, the Objective function has a unique minimum at initial values of parameters; secondly, the Hessian matrix be positive definite and has full rank and thirdly, the curvature of the objective function be sufficient. Form identification tests show that based on reduced-form analysis, only the parameter ω is not identified in the model, and other parameters are identified. This finding refers to limited information identification, where a subset of the model's parameters cannot be identified because the objective function uses only a portion of the restrictions of the solution. The strength of identification is shown in Figure 5:

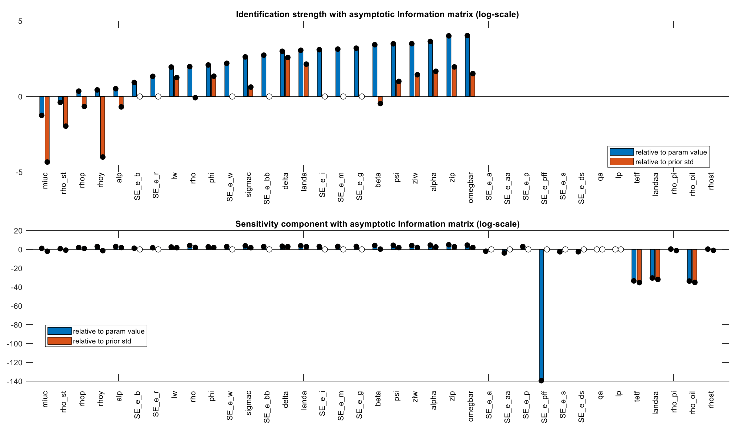


Figure 5. Identification strength

6.2 Optimal Monetary Policy

The estimation results from the previous sector show that the central bank has insufficient and efficient responses to state variables, inflation rate, output gap, and exchange rate. For this reason, herein we present a welfare-based structure to derive an optimal monetary policy rule, which delivers more effective weights for state variables and simultaneously brings minimum social loss.

The literature on optimal monetary policy starts with defining a social loss function. To derive this function, we need the second-order approximation of the utility function of a representative household. This approximation yields a quadratic form in terms of the inflation rate and output gap. However, to consistency with our objective, we add exchange rate volatilities in the loss function. For this reason, we introduce the following loss function as our benchmark for the analysis of optimal monetary policy:

$$L_t = \lambda_1(\pi_t - \pi^*)^2 + \lambda_2(y_t - y^*)^2 + \lambda_3(s_t - s^*)^2 \tag{39}$$

Where L_t denotes loss function, and π^* and s^* ; are targeted inflation rate and nominal exchange rate and y^* ; is an efficient output gap. The coefficients λ_1, λ_2 and λ_3 are weights of state variables in the loss function and denote each variable's importance for the central planner. The value assigned for each λ_i, depends on the planner view over minimization volatilities and thereby is a subjective phenomenon. Our objective is that for which values of $\rho_{i.\pi}$, $\rho_{i.y}$ and $\rho_{s.y}$, the loss function in (39) will be minimized.

In order to find optimal weights of state variables in policy rule, we have to determine two criteria. The first one is assigning quantitative values to λ_1, λ_2 and λ_3. As noted above, these weights denote planner attitude towards their importance in the social loss function. A weight means a more critical counterpart state variable and leads to a different value for loss function. The second one is the lower and upper bounds of the reaction of the planner to state variables fluctuations. The parameters $\rho_{i.\pi}$, $\rho_{i.y}$ and $\rho_{s.y}$, show how policymakers respond to deviations of state variables. The lower bound of these parameters denotes the minimum sensitivity of policy rule to volatilities, and the upper bound reveals the highest possible reaction of the policy rule.

Based on these two criteria, we compute optimal weights under four different cases:

1- Inflation rate, output gap, and exchange rate shocks have the same importance in the loss function, i.e. $\lambda_1 = \lambda_2 = \lambda_3 = 1$.

2- Inflation rate is more critical than and the output gap, and exchange rate shocks have the same importance in the loss function, i.e. $\lambda_1 > \lambda_2 = \lambda_3 = 1$.

3- Output gap is more important than the inflation rate, and exchange rate shocks have the same importance in the loss function, i.e. $\lambda_2 > \lambda_1 = \lambda_3 = 1$.

4- The exchange rate is more important than the inflation rate, and the output gap has the same importance in the loss function, i.e. $\lambda_3 > \lambda_1 = \lambda_2 = 1$.

5- Exchange rate be less important, and Inflation rate and output gap have the same importance in the loss function, i.e. $\lambda_3 < \lambda_1 = \lambda_2$.

6- Output gap be less important, and Inflation rate and exchange rate have the same importance in the loss function, i.e. $\lambda_2 < \lambda_1 = \lambda_3$.

7- Inflation rate be less important, and exchange rate and output gap have same importance in the loss function, i.e. $\lambda_1 < \lambda_1 = \lambda_3$.

The optimal weights under these four cases are derived and reports in the Table 2 by numerical iteration. The results of optimal parameter values reported in Table 2 reveal some critical rules. Our first finding is that if the central bank assigned more weights to the inflation rate or exchange rate, it reaches minimum loss. In other words, when facing the problem of choosing one variable as most important, there is no difference between opting for inflation rate and exchange rate. The reason is that there is a direct and meaningful relation between nominal exchange rate and general price level: whenever the exchange rate rises, it is evident that the inflation rate will rise, proportionally and whenever price level increases, it is expected to have a rise in the exchange rate. Therefore, controlling one of them means stabilizing the other. So, it is expected and meaningful that attributing more weight to one of these two state variables will lower loss.

Table 2. Optimal values for policy rule parameters

Loss function weights	Parameter	Lower bound	Upper bound	Optimal value	Estimated value	Loss value
$\lambda_1 = 1$ $\lambda_2 = 1$ $\lambda_3 = 1$	$\rho_{i.\pi}$	1	2.5	1.52	0.32	0.012
	$\rho_{i.y}$	0	2.5	0.14	0.1	
	$\rho_{s.y}$	0	2.5	0.12	0.16	
$\lambda_1 = 1.5$ $\lambda_2 = 1$ $\lambda_3 = 1$	$\rho_{i.\pi}$	1	2.5	1.52	0.32	0.013
	$\rho_{i.y}$	0	2.5	0.08	0.1	
	$\rho_{s.y}$	0	2.5	0.1	0.16	
$\lambda_1 = 1$ $\lambda_2 = 1.5$ $\lambda_3 = 1$	$\rho_{i.\pi}$	1	2.5	1.46	0.32	0.012
	$\rho_{i.y}$	0	2.5	0.17	0.1	
	$\rho_{s.y}$	0	2.5	0.11	0.16	
$\lambda_1 = 1$ $\lambda_2 = 1$ $\lambda_3 = 1.5$	$\rho_{i.\pi}$	1	2.5	1.52	0.32	0.15
	$\rho_{i.y}$	0	2.5	0.08	0.1	
	$\rho_{s.y}$	0	2.5	0.11	0.16	
$\lambda_1 = 1$ $\lambda_2 = 1$ $\lambda_3 = 0.5$	$\rho_{i.\pi}$	1	2.5	1.49	0.32	0.007
	$\rho_{i.y}$	0	2.5	0.15	0.1	
	$\rho_{s.y}$	0	2.5	0.12	0.16	
$\lambda_1 = 1$ $\lambda_2 = 0.5$ $\lambda_3 = 1$	$\rho_{i.\pi}$	1	2.5	1.51	0.32	0.011
	$\rho_{i.y}$	0	2.5	0.07	0.1	
	$\rho_{s.y}$	0	2.5	0.1	0.16	
$\lambda_1 = 0.5$ $\lambda_2 = 1$ $\lambda_3 = 1$	$\rho_{i.\pi}$	1	2.5	1.47	0.32	0.009
	$\rho_{i.y}$	0	2.5	0.16	0.1	
	$\rho_{s.y}$	0	2.5	0.11	0.16	

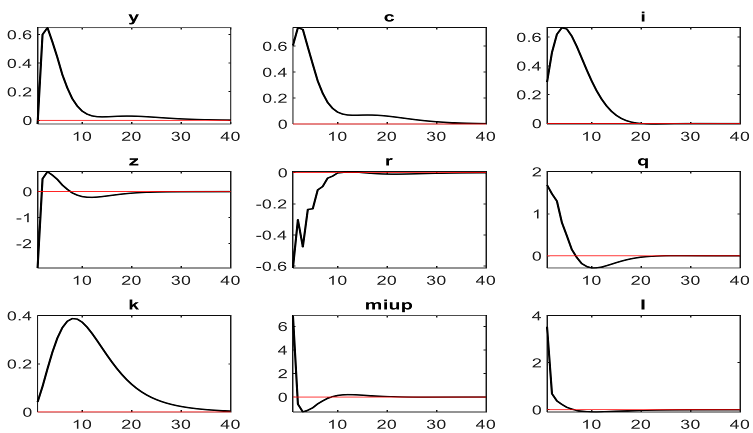
***Source**: Results are from model calculations*

The three last experiments confirm the prior result. Whenever the central bank decides to choose two more important variables among three states, it is optimal to opt for inflation rate and the output gap—in other words, assigning equal weights to the inflation rate and output and lower weight to exchange rate yields minimum loss than other two cases. Moreover, comparing these seven cases appears that giving equal weights to the inflation rate and output gap and lower weight to exchange rate leads to minimum social loss. Therefore, the optimal rule has the following form:

$$\widehat{m}_t = -2.51\widehat{\pi}_t - 1.5\widehat{Y}_t - \hat{s}_{2,t} \quad (40)$$

6.3 Simulation

In this part, we simulate the effects of one unit shocks to monetary policy rule (one-unit growth in money base) on the macro variables, depicted in Figure 6.



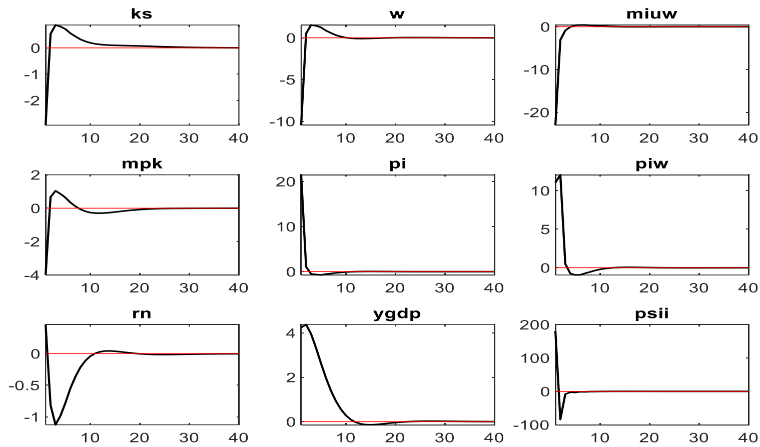


Figure 6. Response of variables to one unit rise in money base growth

This simulation shows that an expansionary monetary policy leads to a rise in consumption, investment, and output, bringing a rise in the inflation rate. The rising inflation rate declines the real interest rate by decreasing the real interest rate, which increases investment spending, leading to a rise in capital formation. Moreover, we compare some simulated model variables with moments of actual data, reported in Table 3.

Table 3. Second moments of model variables and actual data

Correlation	Consumption and output	investment and output	Money and nominal unofficial exchange rate	consumption and nominal unofficial exchange rate	output and nominal unofficial exchange rate
Real data	0.476	0.35	0.56	-0.17	-0.45
Simulated data	0.5	0.46	0.57	-0.5	-0.26
Standard Deviation	**Consumption**	**output**	**Investment**	**nominal unofficial exchange rate**	**Money**
Real data	0.03	0.06	0.18	0.21	0.54
Simulated data	0.01	0.02	0.04	0.1	0.23

***Source**: Model calculations*

7. Conclusion

In this paper, we design a structure for Iran's economy in which there is a dual exchange rate regime. In this dual system, the central bank determines the official rate, and market forces set the unofficial rate. The official rate was consistently below the unofficial rate because the motivation behind this policy was to support households and firms and prevent the economy from hitting exchange rate shocks.

Our finding shows that although the central bank desires to mitigate exchange rate shocks by establishing a dual system, most imported goods are financed by an unofficial rate, and indeed the official rate was not able to support the economy from exchange rate shocks which mean that a dual system has less efficiency than a unique regime. Based on this finding, we compute the optimal rule that makes the central bank reduce welfare losses. This part shows that the central bank should concern equally about inflation rate and exchange rate volatilities.

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