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Optimal Intervention in the Foreign Exchange Market: The Case of Iran

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Abstract

In a managed floating exchange rate regime, one of the most important issues is the degree to which the monetary authorities intervene in the foreign exchange market. The appropriate level of intervention in the foreign exchange market can be discussed in a framework which emphasizes the trade-off between changes in the country's level of international reserves and minimizes the country's real exchange rate misalignment. In this paper we derived an optimal intervention rule for the period of post managed floating regime in Iran applying a dynamic programming approach. The derived rule indicates that, in the context of the Iranian economy, how the monetary authorities can manage the foreign exchange market with minimum possible cost.

Keywords: Foreign exchange market intervention, Foreign reserves management, Optimal rule, Dynamic programming.
JEL Classification: F31, C61, O24.

1. Introduction

Following the collapse of Bretton Woods in 1973, foreign exchange intervention has been at the center of the debate in international finance for a long time. So there exists extensive literature on intervention in foreign exchange market. Many of these studies focus

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on the selection between extremes of complete intervention and no intervention that is the choice between exchange rate fixity and flexibility. Therefore, a number of discussions regarding advantages as well as disadvantages of each are presented.[2]

A group of economists are in favor of no intervention in the market. Friedman (1953) and Sohman (1969) provide the classic argument against central bank interventions in foreign exchange markets. These economists note that the exchange rate is merely a price – the price of foreign currency. Demand for or supply of foreign currency is a derived demand or a supply which arises as individuals make or receive payments for foreign goods and assets. In a world of free markets, the equilibrium exchange rate is the one which equilibrates the demands for and supplies of foreign exchange. These economists believe that, as all other prices, it will be determined in a general equilibrium system comprising supplies of and demands for all goods and assets, both domestic and foreign. Furthermore, in the absence of externalities, the resulting competitive equilibrium will be Pareto optimal. World resource allocation will be efficient and world welfare will be maximized (Dee, 1983: 16-17).

This argument is a powerful one against any degree of intervention. Proponents of this argument maintain that the existence of market imperfections is by itself insufficient justification for intervention. If a market distortion exists, the appropriate action is to directly remove the distortion. (Ibid: 17)

Later, the introduction of models that allowed for imperfect information led to the conclusion that exchange rate policies could be used for stabilization purposes (Brainard, 1967; Poole, 1970).

The most influential arguments against no intervention and freely floating exchange rates indicated that this regime would lead to excessive fluctuations, and exchange rate fluctuations are disruptive and should therefore be smoothed. These fluctuations would lead to excessive changes in domestic price, and generate social costs and reduce social welfare. On the other hand, it has negative effects on growth, investment, competitiveness, and trade.

Boyer's (1978) work on optimal foreign exchange market intervention helped achieve a consensus in the theoretical literature. It was shown that optimal exchange rate policies lie between the theoretical extremes of complete exchange rate fixity and flexibility, and some degree of intervention is acceptable.

Later, extensive studies are done in this context which adopte some degree of exchange rate flexibility and intervention. They believe that this policy is more likely to be successful in achieving economic goals. Some studies such as Calvo and Rienhart (2002), and Rienhart and Rogoff (2004) indicate that even countries that claim to implement a fully floating exchange rate regime, have intervened in the market.

So, today some interventions in currency markets are accepted. Here comes the question of what degree of flexibility should exist? In other words, what level of intervention in the currency market is desirable?

In fact, choosing the best policy and intervention in the currency exchange market depends on several factors. Among these factors one can point to the economic structure and its properties. Different assumptions about these factors can be effective in the amount and degree of intervention in foreign exchange markets. So there is no single best exchange rate policy for all countries or at all times.

This paper aims at finding the optimal level of intervention in Iran. To reach this purpose we apply the method of dynamic programming. The structure of the paper is as follows: in Section 2 we introduce the objective and instrument of intervention in the foreign exchange market. We analyze the framework and the model in section 3. In section 4 we estimate real exchange rate misalignment in Iran by applying the STR (Smooth Transition Regression) model. In section 5 the numerical solution for monetary authority's intervention and optimal rule for management of the central bank's foreign reserves will be presented. Section 6 is the summery and conclusion of this paper.

2. Objective and instrument of intervention

Foreign exchange intervention is defined generally as foreign exchange transactions conducted by the monetary authorities with the aim of influencing exchange rates. This definition is presented in many studies such as Sarno and Taylor (2001), Garcia (2002), Kriljenko et al (2003), and Hassan (2009). Regarding this definition and the properties of Iran's economy, we can introduce the objective and instrument of intervention in the foreign exchange market.

2.1 Objective of intervention

One of the important factors to consider in selecting the degree of intervention is the objectives of policymakers. Several objectives may include: control of exchange rates deviations from target levels, misalignment or volatility adjustment, internal stability of the economy which stabilize the production and the price level, accumulation of international reserves or protecting its level, providing balance of payments, etc. (Kriljenko et al, 2003).

Among the goals listed for the foreign exchange market intervention, reducing the real exchange rate misalignments can be considered the most important goal for intervention. Galati and Melick (2002), Ito (2002), Kim and Sheen (2002), Horvath (2007), and Pontines and Rajan (2011) have confirmed this by estimating the reaction function of central banks.

The exchange rate (price of one country's money in terms of another's) is one of the most important prices in an open economy. It influences the flow of goods, services, and capital in a country, and exerts strong pressure on the balance of payments, inflation and other macroeconomic variables. If it experiences instability, severe imbalances in the economy may occur. Disequilibrium in the exchange rate can reduce economic efficiency, poor distribution of resources, trade imbalances and increase capital flight. By controlling instability and fluctuations in the exchange rate, the economy can achieve both internal and external balance, increase competitiveness and economic growth [Moosa, 2005].

This paper looks into Iran's central bank interventions in foreign exchange market which confirmed by the central bank in its Annual Report and Balance Sheet of 1381.

2.2 Instrument of intervention

The most popular proxy for intervention is the change in foreign exchange reserves. The central bank can directly increase or decrease the supply of foreign currencies by adjusting its stock of foreign reserves. For example, if policymaker tends to reduce the exchange rate on the market, he will sell foreign currency. This move will cause the foreign reserves of the central bank to reduce. Changes in exchange rates on the market can depend on the amount of reserves that are sold in the foreign exchange market.

Overview of the studies on foreign exchange intervention show that change in foreign exchange reserves is the most widely used index for intervention. Taylor (1982), Kearny and McDonald (1986), Tagaki (1991), Almekinders (1996), Im (2001), Garcia (2002), and Ito (2002) are some of the numerous authors that have used change in foreign exchange reserves as a proxy for intervention.

In Iran's foreign exchange market, the government plays a dominant role. On the one hand, due to foreign exchange earnings from oil exports, the government is the largest supplier of foreign currency in exchange market. On the other hand, the government as a major importer is a large applicant for foreign currency. Since there are very high shares of oil revenues in the budget, the government changes foreign currency with Rials, in each period. The central bank should manage the volume of these reserves, and an optimal amount of them should be saved and the remainder should be sold in the market. In fact, the central bank is faced with the problem of how to perform foreign exchange reserves management in order to achieve its goal that is the control of real exchange rate misalignments.

2.3 The costs of intervention

Maintaining foreign exchange reserves of central banks in many countries especially after the monetary crisis became an important issue. In this way, they can preserve power of investment and foreign debt repayment. The accumulating of reserves and thus increasing the monetary base, lead to adding the liquidity of money. This can have negative effects on the economy. On the other side, reduction of reserves declines the country’s power in foreign policy and maintains the desired level of future exchange rate. So many policymakers are concerned about small changes in this variable, and try to adopt a policy that has minimal change compared to prior periods. This is known as the policy smoothing. Sudden change in the policy, due to its different costs, is not desirable for the authorities. These costs increase with the level of intervention. Therefore, any optimal intervention in the market should be limited and minimized the relevant costs.

3. The Model

In this paper, we solve the problem of optimal intervention in the foreign exchange market by using methods of dynamic programming. Generally, in this method optimal rule passes through the maximization (or minimization) of an intertemporal objective (loss) function subject to behavioral relationships between control variable and the objective variable.

As mentioned in section 2-1, the objective of the central bank is to keep real exchange rate as close as possible to its equilibrium values. In the other words, the real exchange rate misalignments should be minimized. Also, due to the intervention costs, minimal intervention should be applied in the market, as noted in section 2-3. Thus the objective function of monetary authorities in recent studies including Kercheval and Moreno (2009), Yannacopoulos (2005), Cadenillas and Zapatero (1999), Mundaca and Oksendal (1998) and Miller and Zhang (1996) formed basis on it.

So this paper aims at finding the optimal level of intervention by controlling real exchange misalignments along with the minimum possible interventions. Therefore, the central bank intervenes in the foreign exchange market to minimize the following intertemporal loss function:

$$\min E_t \sum_{r=0}^{\infty} \delta^r L_{t+r} \qquad (1)$$

Where δ is the discount factor and L_t is the period loss function.

We specify the loss function in quadratic form:

$$L_t = [(e_t - \bar{e}_t)^2 + \lambda (R_t - R_{t-1})^2] \qquad (2)$$

This function contains two parts. In the first part, e_t and $\bar{e}_t$ are actual and equilibrium value of real exchange rate, respectively. This part indicates real exchange rate misalignment. The next part represents the change in foreign reserves (R is foreign reserves of central bank), because of the costs of intervention increases with the amount of intervention, this part shows these costs. $\lambda > 0$ is the relative weight on reserves smoothing. One can rewrite this function as

$$L_t = [Mis_t^{\ 2} + \lambda DR_t^{\ 2}] \tag{3}$$

Where, Mis is real exchange misalignment, and DR is the change in foreign exchange reserves.

The objective of monetary authority is minimizing this function over time. This minimization is subject to behavioral relationships between control variable (the change in reserves) and the objective variable (misalignment), that is known as transmission mechanism.

In general, the transmission mechanism can be represented as

$$Mis_{t+1} = \alpha_0 + \sum_{i=0}^{p} \alpha_i Mis_{t-i} + \sum_{i=0}^{q} \beta_i DR_{t-i} + \varepsilon_{t+1} \tag{4}$$

To solve this problem in the dynamic programming framework, it is necessary to convert it to standard matrixes and vectors form. Therefore, the dynamic programming problem can be stated as below. (For simplicity we considered 3 lags for DR and 2 for Mis.) The following matrices and vectors rewrite our problem including Equations 1 to 4, in matrix form.

$$\min_{\{dr\}} \sum_{t=0}^{\infty} (x_t' R x_t + DR_t' Q DR_t) \tag{5}$$

s.t. $x_{t+1} = Ax_t + BDR_t + \omega_{t+1}$

Where, $x_t^{'} = [Mis_t, Mis_{t-1}, Mis_{t-2}, DR_{t-1}, DR_{t-2}, DR_{t-3}, 1]$

$$R = \begin{bmatrix} 1 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 \end{bmatrix} \qquad A = \begin{bmatrix} \alpha_1 & \alpha_2 & \alpha_3 & \beta_1 & \beta_2 & \beta_3 & \alpha_0 \\ 1 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 1 \end{bmatrix}$$

$$B = \begin{bmatrix} \beta_0 \\ 0 \\ 0 \\ 1 \\ 0 \\ 0 \\ 0 \end{bmatrix} \qquad Q = [\lambda]$$

x_t and B are (7×1), R and A are (7×7) matrixes. α_i and β_i are the coefficients in equation (4).

In such problems that loss function has quadratic form and the constraint (transmission mechanism) is linear, the starting point is making an initial guess on the functional form of the value function. This guess is that it has a quadratic form. So the Bellman Equation becomes:

$$x'Px = \min_{DR} \{x'Rx + DR'QDR + (Ax + BDR)'P(Ax + BDR)\} \qquad (6)$$

Where, P is a semidefinite symmetric matrix. The first-order necessary condition of the optimization problem is

$$(Q + B'PB)DR = -B'PAx \qquad (7)$$

Therefore the feedback rule can be stated as

$$DR = -(Q + B'PB)^{-1} B'PAx \qquad (8)$$

Or

$$DR = -Fx$$
$$F = (Q + B'PB)^{-1} B'PA$$

Where, F is a (1×7) vector which contains the optimal response coefficient of each element of the x_t vector. This rule is an optimal one. In this equation P is an unknown matrix. Under a particular condition, it has a unique positive semidefinite solution, which is approached in the limit as j→∞ by iteration on the following matrix Riccati difference equation:

$$P_{j+1} = R + A'P_j A - \beta A'P_j B(Q + \beta B'P_j B)^{-1} B'P_j A \qquad (9)$$

Revealing the matrix P, and its placement in F, the optimal rule can be obtained (Sargent, 1987).

4. The estimation of real exchange rate misalignment

As mentioned, we considered control of real exchange rate misalignment as objective of intervention in the foreign exchange market. So initially, these values should be identified. In this section, we estimate the equilibrium real exchange rate path and misalignments associated with the deviations between the actual and the equilibrium value of real exchange rate based on various macroeconomic fundamentals suggested in economic literature by Edwards (1988). The economic fundamentals are productivity growth, terms of trade, government consumption to GDP, capital formation to GDP, openness, and net capital inflow.

Numerous factors such as transaction costs, presence of target zones, and central bank interventions can imply a nonlinear relationship between the exchange rates and the economic fundamentals [Bereau, et al, 2008]. So, here we consider a Smooth Transition Regression (STR) model for this relationship. These models suggest that the exchange rate can be modeled as a regime-switching process.

4.1 STR model

The STR models are a general class of state-dependent nonlinear models capable of accounting for deterministic changes in coefficients over time. The STR approach has several advantages, one of which is that it makes possible to have several systems to illustrate the relationship between variables. Such a system is characterized by a variable called transition variable. In other words, the effects of variables in the model, depend on the state of transition variable and its distance from threshold value. However, unlike the threshold model that varies from one system to another occurs suddenly; in STR Model this change occurs smoothly.

Generally, The STR model can be stated as follows:

$$y_t = \pi' w_t + (\theta' w_t) F(s_t, \gamma, c) + u_t \qquad (10)$$

Where $w_t = (1, y_{t-1}, ..., y_{t-p1}, x_t, x_{t-1}, ..., x_{t-p2})$ is a vector of regressors, θ and π are parameter vectors. Transition variable, s_t, can be a lagged endogenous variable, an exogenous variable or just another variable such as trend. $F(s_t, \gamma, c)$ is transition function, customarily bounded between 0 and 1, making the STR coefficients vary between π and $\pi + \theta$. γ is slope parameter and c is a vector of location parameters. Transition function is usually the logistic function and has a standard form as follows:

$$F(s_t, \gamma, c) = \{1 + \exp[-\gamma \prod_{j=1}^{J} (s_t - c_j)]\}^{-1}, \gamma > 0 \qquad (11)$$

In this model the most possible states are for j=1 and j=2. If j=1, the parameters $\pi + \theta F(s_t, \gamma, c)$ change monotonically as a function of s_t from π to $\pi + \theta$. For j=2, the parameters $\pi + \theta F(s_t, \gamma, c)$ change symmetrically around mid-point $\frac{c_1 + c_2}{2}$ (Terasvirta, 1994).

We estimate the equilibrium model of real exchange rate in this framework. The parameters of the model will be estimated by Newton-Raffson algorithm in a way of maximization of conditional maximum likelihood function.

In final estimation only the significant coefficients were considered, because the fitted value of this model will be used as equilibrium values. The results of estimation for Iran by quarterly data of the period 1994:2- 2008:2 indicate that equilibrium real exchange rate is determined by terms of trade, productivity growth, and government consumption to GDP.

4.2 Data description

We used quarterly data of the period 1994:2-2008:2 for Iran. All data are sourced from *Indicators of Iran's Central Bank*. Real exchange rate (e), is defined as the nominal exchange rate adjusted for relative national price levels, terms of trade (TOT) is defined as the ratio of price index of exportable to import price index, G is government consumption to GDP, and productivity growth (P) is defined as the ratio of production to employment in large industrial firms.

Prior to estimation of the STR model, we tested stationarity of the variables. We conclude from ADF test that all variables are I(1), but, at least, there exist three cointegration relationship between variables.

4.3 Linearity Test

Before estimating the STR model it is important to determine whether the nonlinearity is statistically significant. The null hypothesis of this test is $\gamma = 0$. If the null hypothesis of linearity is not rejected, the conclusion is that the real exchange rate can be adequately described by a linear model. For this test we need to select the appropriate transition variable that has minimum probabilities of F test through the potential variables.

The results of the tests are presented in Tables 1. The first column in the table shows transition variables, the second column shows the probabilities of F tests for null hypothesis of linearity. For each potential variable, the test has been calculated, and the lagged real exchange rate has been the lowest p-value of all, and selected as transition variable. For this variable, the linearity null hypothesis is significantly rejected and alternative hypothesis, smooth transition has been accepted.

F4, F3, and F2 tests are the tests for hypotheses on 5th assumption of Trasvierta (1994) decision making process in selecting the form of transition function. LSTR1 model is specified for past of real exchange rate.

Table 1: The result of linearity test

Transition variable	Prob F	Prob F4	Prob F3	Prob F2	Suggested model
e(t-1)*	0.00000	0.90915	0.00068	0.00000	LSTR1
e(t-2)	0.00021	0.01995	0.71999	0.00006	LSTR1
P(t)	0.13310	0.01014	0.94340	0.72038	Linear
TOT(t)	0.10511	0.05792	0.14149	0.76011	Linear
G(t)	0.10734	0.57307	0.10811	0.08217	Linear
TREND	0.00591	0.12935	0.00105	0.73374	LSTR2

Source: results of research, calculated by Jmulti software

4.4 Model Estimation

After choosing the appropriate model LSTR1 for our data, the model is estimated by using Newton-Raphson algorithm, and maximization of the conditional maximum likelihood function. The results of estimation are presented in Table 2. As mentioned before, because the fitted value of this model will be used as equilibrium value, the significant coefficient has been considered.

Table 2: The result of STR estimation

Explanatory variables	Coefficient	Prob F
	Linear part	
Intercept	11066.46	0.0000
P	-2870.18	0.0000
TOT	5081.19	0.0091
	Nonlinear part	
Intercept	20407.38	0.0008
P	8552.50	0.0001
TOT	-28546.69	0.0003
G	-19419.26	0.0451
γ	4.04	0.0003
c	13833.78	0.0000

Source: results of research, estimated by Jmulti software

As table 2 reveals, we can show the equilibrium model of real exchange rate as

$$\begin{aligned}\hat{e}_t &= 11066.46 - 2870.18P_t + 5081.19TOT_t \\ &+ (20407.38 + 8552.50P_t - 28546.69TOT_t - 19419.26G_t)* \\ &\{1 + \exp[-4.04*(e_{t-1} - 13833.78)]\}^{-1}\end{aligned} \tag{12}$$

Our results show that the real exchange rate dynamics in the long run is determined by terms of trade, productivity growth, and government consumption to GDP. The coefficients of the variables vary between the linear part and sum of the linear and nonlinear part. The real exchange rate misalignments are associated with the deviations between the actual and the fitted value. Figure 1 depicts the series of misalignment.

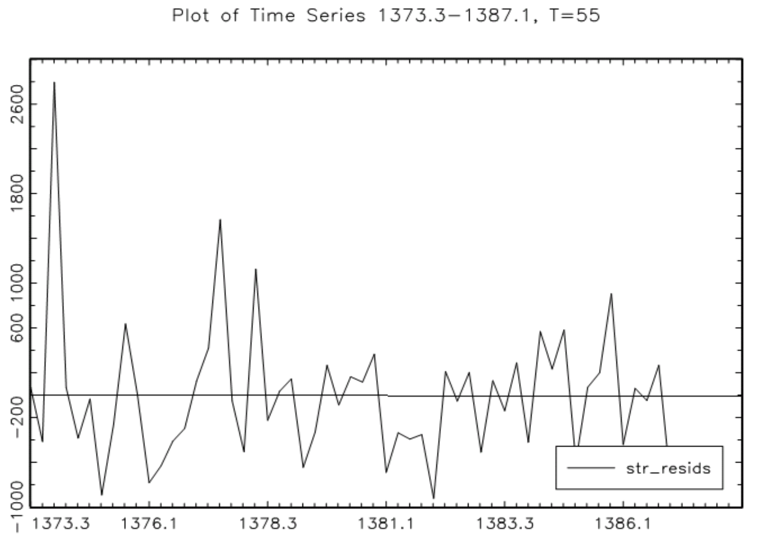

Figure 1: Real exchange rate misalignment

5. Solution of optimal intervention

In this section the numerical solution of the problem is represented. First, and before any estimation, stationarity variables should be assessed. In equation of transmission mechanism there are two variables: misalignment and change in foreign reserves. In Table 3 statistical results of the stationarity test for these two variables is presented. The results of this test show that the unit root hypothesis for both variables is rejected at the 95% level. So the stationarity of them is confirmed.

Table 3: The result of unit root test

Variables	ADF Without trend	ADF With trend
Mis	-4.10	-5.66
DR	-5.32	-5.32

Critical value at 95% with trend is 2/91 and without trend is 3/49.

5.1 Estimation of transmission mechanism

In order to find the solution, we have estimated the transmission mechanism. This equation represents the effect of instrument on objective. So we have regressed misalignment on change in foreign reserves by data of the period 2002:2-2008:2. The reason for selecting this period is the implementation of integration exchange rate policy and managed float system.

As mentioned before, the general form of the transmission mechanism can be stated as:

$$Mis_{t+1} = \alpha_0 + \sum_{i=0}^{p} \alpha_i Mis_{t-i} + \sum_{i=0}^{q} \beta_i DR_{t-i} + \varepsilon_{t+1} \quad (13)$$

Both misalignment and change in foreign reserve have lagged value. The first stage is to determine the optimal lag length, p and q. The order of lags on the equation was obtained from the Akaike Information Criterion (AIC). The maximum order of lag that was considered for two variables was 4. Therefore 20 equations with different combination of these lags should be estimated. Test statistic for these equations is represented in Table 4. The best order of lags has the minimum value among others, so 2 lags for misalignment and 4 for change in reserves were selected.

Table 4: lag order selection

variables		AIC
Mis	DR	
0	1	14.59
	2	14.57
	3	14.62
	4	14.60
1	1	13.04
	2	13.12
	3	13.09
	4	13.14
2	1	13.01
	2	13.06
	3	13.03
	4	12.99
3	1	13.05
	2	13.18
	3	13.10
	4	13.05
4	1	13.01
	2	13.02
	3	13.03
	4	13.03

Source: results of research, calculated by Eviews software

After selecting the order of lags we can estimate equation of transmission mechanism. Since the coefficients of this equation are used in obtaining the optimal rule, their significance is very important. So the lags that were not statistically significant were omitted from final estimation. The results of estimation are presented in Table 5.

Table 5: The results of estimation of transmission mechanism

variable	coefficient	prob
Intercept	1333.28	0.010
Mis(-1)	1.245	0.000
Mis(-2)	-0.443	0.025
DR(-1)	0.003	0.025
DR(-4)	0.002	0.053
R-squared=0.87	prob(F-statistic)=0.000	

Source: results of research, estimated by Eviews software

All coefficients of variables are significant in the above estimation (Dr(-2) and DR(-3) were omitted from estimation due to insignificant coefficient). Also, the classical assumptions of regression are established. The coefficients of the change in foreign reserves are positive. It means that if the reserve of central bank increases, real exchange rate will grow from equilibrium value, and a positive misalignment will rise. The result is consistent with expectations and with existing theories in international economics. Based on theoretical arguments the central bank's foreign exchange reserves reduction means that the central bank has sold part of its foreign exchange reserves. If the supply increases, the real value of foreign currency in the market can face decline.

5.2 Optimal rule for intervention

After estimating the transmission mechanism, coefficients of linear constraints for the optimization problem have been identified (α_i and β_i), and this problem can be solved numerically. In this regard, half of misalignment has been considered the relative importance of the cost of the intervention. Because, the main goal is to control real exchange rate misalignment.

With replacement of coefficients (α_i and β_i), in R, A, B and Q matrixes, and formation of Bellman's equation, we solved Riccati Equation. So the F matrix in feedback rule is

$$F = [0.0329, -0.0185, 0, 0.0001, 0.001, 0.0001, -32.10]$$

The optimal rule from dynamic programming in this study is as follows

$$DR_t = 32.10 - 0.0329\, Mis_t + 0.0185\, Mis_{t-1}$$
$$- 0.0001\, DR_{t-1} - 0.0001\, DR_{t-2} - 0.0001\, DR_{t-3}$$

Optimal rule, in fact, is an instruction to adjustment of changes in foreign reserves of central bank based on the values of existing variables. This is the guideline that governs the dynamic relationships between changes in foreign exchange reserves and real exchange rate deviations from its equilibrium path (real exchange rate misalignment).

In this rule we can see that the coefficient of misalignment is negative. It means that when the central bank faced a positive deviation in the real exchange rate it should have a negative change in its foreign exchange reserves. Thus increasing the currency supply in the market by the monetary authorities will cause the real value of foreign exchange to reduce, and exchange rate to return to its equilibrium level.

Also, as noted before, the coefficients associated with foreign exchange reserves of central banks are negative. In this respect we can say, first, the existence of these terms in optimal rule is due to the presence of change in foreign exchange reserves at the objective function. Second, a negative coefficient indicates that the policy makers should care for changes in the prior period. For example, if the changes in central bank's foreign exchange reserves in the previous period were positive, part of it should be adjusted in this period. So, the volume of foreign exchange reserves has not large deviations from its previous level. In this way, smoothing policy of change in reserves is intended.

It is necessary to point out favorable change in foreign exchange reserves of central banks is obtained from sum of these terms, and the analysis of this rule must be done with consideration of all the terms in it in each period.

5.3 Different scenarios regarding the relative weight

In the previous section, to obtain the optimal amount of intervention in the foreign exchange market, half of deviations of real exchange rates from its equilibrium level have been considered. This weight can be changed based on policy preferences and care for each of the objectives. By changing this parameter, the obtained rule will change. Here, according to various scenarios imaginable in this respect, the optimal rule can be obtained. In the following table, different values for the parameters are considered, and the optimal rule with different relative weights is presented.

Table 6: The optimal rules with different value of λ

Weight of change in reserves (λ)	Optimal rule
٠	$DR_t = 4.29 - 0.0402\,Mis_t + 0.0143\,Mis_{t-1}$
0.25	$DR_t = 64.12 - 0.0658\,Mis_t + 0.0371\,Mis_{t-1} - 0.0003\,DR_{t-1} - 0.0003\,DR_{t-2} - 0.0002\,DR_{t-3}$
0.5	$DR_t = 32.10 - 0.0329\,Mis_t + 0.0185\,Mis_{t-1} - 0.0001\,DR_{t-1} - 0.0001\,DR_{t-2} - 0.0001\,DR_{t-3}$
0.75	$DR_t = 21.41 - 0.0220\,Mis_t + 0.0124\,Mis_{t-1} - 0.0001\,DR_{t-1} - 0.0001\,DR_{t-2} - 0.0001\,DR_{t-3}$
1	$DR_t = 16.06 - 0.0165\,Mis_t + 0.0093\,Mis_{t-1} - 0.0001\,DR_{t-1} - 0.0001\,DR_{t-2} - 0.0001\,DR_{t-3}$

Source: results of research, calculated by Matlab software

We can see that absolute value of misalignment's coefficient increases with decreasing weight of change in reserves. Perhaps in this way a good comparison between the rules cannot be found. As mentioned, the rules should be interpreted in total. Therefore, the appropriate decision can be made by comparing the policies formed on the basis of these rules. To clarify this in the following diagram, rules obtained by value of $\lambda = 0.5$, $\lambda = 0.75$ and $\lambda = 1$, at the period 2002:2-2008:2 are compared. In this diagram the optimal rate of change in reserves, based on three optimization rules and variable values in each period is extracted.

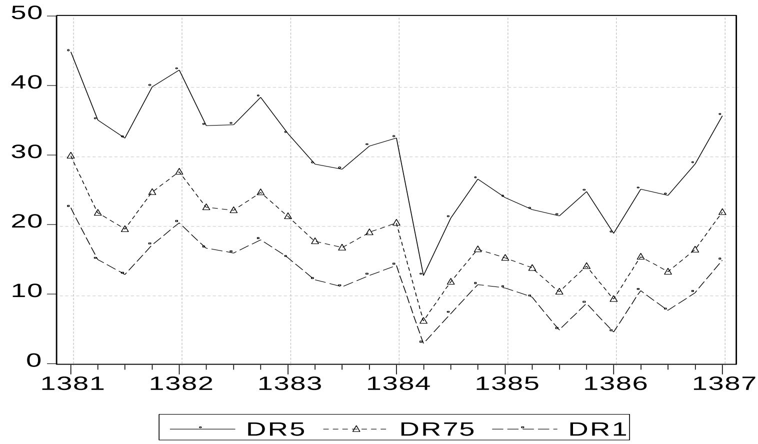

Figure 2: Optimal rate of change in reserves based on different rules

In the above chart, DR5, DR75, and DR1 are curves obtained with regard to $\lambda = 0.5$, $\lambda = 0.75$ and $\lambda = 1$ respectively. Mathematical equations of these curves in the third, fourth and fifth rows of Table 6 are shown. Note that the direction of optimal change in volume of foreign exchange reserves of central banks in all three cases is similar. But as expected, by declining the weight given to the change in central bank's foreign reserves, the change in this variable will be great. With the highest degree of its importance, the optimal change in central bank reserves allocated to the lowest. In this case, the monetary authority would prefer more deviations of exchange rates in return of foreign exchange reserves have fewer changes, and more smoothly process follows. In contrast, if the importance of foreign reserves is reduced, the optimal change in foreign exchange increases. In this case the main objective of central bank is to keep real exchange rate as close as possible to its equilibrium value and to achieve this goal, central bank reserves may further change. Finally monetary authority can make the optimal policy choices, based on the importance of any component of the objective function.

6. Summery and conclusion

In this paper, the optimal policy for exchange market intervention in Iran has been investigated. The objective of the Central Bank is considered to keep the real exchange rate as close as possible to the equilibrium value, so there is a cost associated with the difference between the exchange rate and the equilibrium value. Additionally, there are also some costs associated with each intervention that increase with more intervention. The objective of Central Bank is to minimize the total cost. We solved this problem by applying the method of dynamic programming.

In empirical part of this paper firstly, we estimated real exchange misalignment by using the quarterly data over the period of 1994:3-2008:2 in framework of STR model. Linearity was strongly rejected and dynamic Smooth Transition Regression (STR) model was specified, and logistic STR1 was estimated by using Newton-Raphson algorithm, and maximization of the conditional maximum likelihood function. Afterward the transmission mechanism was estimated. Using this equation's coefficients and a dynamic programming method, numerical solution of optimal rule for intervention in foreign exchange market is derived.

This rule can be used as a tool to guide the foreign exchange market intervention. Because of the exchange rate is one of the macroeconomic policy instruments available to the government to help maintain external and internal balances simultaneously, it could be an effective instrument only if it is used in coordination with other instruments and supported by requisite institutional and regulatory structures.

Endnotes

1. This article is a part of her Ph.D. thesis in Shiraz University
2. For more information, see the following articles: Kenen, 2000; Domac et al, 2001; Poirson, 2001; Frenkel, 2003.

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