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Research Paper

The Monetary Channel of Foreign Exchange Interventions: A Mixed Frequency Data Sampling (MIDAS) Approach

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Abstract
This study aims to analyze the effectiveness of foreign exchange interventions by the Central Bank of Iran on the Iranian foreign exchange market from 2002 to 2017. For this purpose, we use a mixed frequency data sampling regression model (MIDAS). This enables us to use the available data at different frequencies and has a better forecast of the exchange rate. Examining the Iranian Rial/U.S. dollar exchange rate, we find that the Iranian Central Bank intervention effectively reduces the exchange rate level deviations. In this regard, a 1 percent increase in foreign exchange interventions in each period decreased the exchange rate level by 0.094 percent. Also, we find that the GDP has a negative effect on the exchange rate and the government deficit and growth money supply have a positive effect on the exchange rate level. In addition, using the statistics of 2018, we examine the predictive power of the model. The result shows that the predicted values and the actual values are close in terms of direction. However, regarding the value, there is a difference.

Keywords: Foreign Exchange Intervention, Mixed Frequency Data Sampling, Exchange Rate Level.

JEL Classification: E58, F31, B41.

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1. Introduction

Foreign exchange intervention is the action by which central banks change the amount of their foreign reserves to stabilize the foreign exchange market. In fact, foreign exchange market intervention is an essential tool widely used by central banks to manage fluctuations or influence exchange rate levels. The purpose of this process is to control the internal and external balance, prevent resource misallocation or preserve competitiveness and boost growth, and prevent or deal with disorderly markets or crises (Mwansa, 2009).

In this study, we investigate the effect of foreign exchange interventions on the Iranian exchange rate level. In doing so, we ask whether the period from 2002 to 2017 intervention by the Iranian Central Bank in the foreign exchange market effectively reduces the deviation of the foreign exchange rate. The answer to this question is valuable to understanding the effectiveness or ineffectiveness of Iranian foreign exchange interventions.

One of the channels that the monetary authorities' intervention affects the exchange rate is the portfolio balance channel. Accordingly, foreign exchange intervention can affect investors' portfolio, which consists of international assets by changing their expected returns. Under the signaling channel, intervention causes new information to enter the market, which can affect exchange rate expectations. According to the microstructure channel, by changing the order flow, which contains relevant information about the underlying factors, market pressure, or traders' expectations, foreign exchange intervention can impact the exchange rate. In addition, changing the future expectations of noise traders can be a channel through which intervention affects the exchange rate (Sarno andand Taylor, 2001; Chutasripanich and Yetman, 2015). Regarding the monetary channel, changes in money supply, interest rates, and market expectations can be a channel for the intervention to affect the exchange rate. The monetary channel only works if the intervention is non-sterilized. The Central Bank increases the supply of domestic assets by buying foreign currency. By doing this, monetary authorities show their aim to depreciate the domestic currency without compensation for the further money supply. The result is that short-term interest rates in the domestic currency market fall and investors sell domestic assets for foreign assets. Eventually, the value of the domestic currency decreases (Li, 2017, p. 28).

Extensive studies in the literature have shown the effectiveness of foreign exchange interventions on the exchange rate (e.g. Kearns and Rigobon (2005), Hoshikawa (2008), Utsunomiya (2013), Suardi (2008) in Japan, and Ding and Wang (2022) in Vietnam). However, several empirical studies found that Central Bank interventions did not move the exchange rate in the monetary authorities' desired direction (Baillie and Osterberg, 1997; Galati, et al., 2005). In recent works, Santos (2021) concluded that Brazilian discretionary interventions are effective more than pre-announced interventions. Further to this, Viziniuc (2021) find out interventions have benefits in the case of foreign financial shocks, especially when the level of currency mismatch in the economy is high. Adler, et al. (2019) concluded that the buying and selling of currency by central banks affects the level of the nominal and real exchange rates. Alla, et al. (2017) find that foreign exchange intervention affects reducing economic fluctuations. Regarding fluctuations, Disyatat and Galati (2007) find that the Czech National Bank intervention had some statistically significant effect on the spot rate but not on its short-term volatility. Onder and Villamizar-Villegas (2018), on the other hand, conclude both announced and unannounced purchases of foreign currency by the Turkish Central Bank have a significant effect on reducing the exchange rate volatility.

In the case of Iranian interventions, Saadatnejad, et al. (2020) find that the foreign exchange intervention of the Iranian Central Bank has a heavy cost on the macroeconomic. In another study, Ebadi and Jahangard (2012) find that the Iranian Central Bank intervention reduced the economy's productive capacity.

Our study contributes to the existing literature in this field from several fronts. It is the first study that examines the effect of Iranian foreign exchange interventions on the exchange rate. Second, unlike previous works that have used proxies for foreign exchange interventions, in this study, we use the official data on foreign exchange interventions published by the Iranian Central Bank. This is the first study that uses official data on foreign exchange interventions to estimate the factors affecting the exchange rate.

Since the data on foreign exchange interventions in Iran has been disclosed for a period of 17 years with an annual frequency, to benefit from all the information available in high-frequency variables, in this work, we use the MIDAS regression model to evaluate the effectiveness of foreign exchange interventions. The MIDAS regression model is a very general type of autoregressive distributed lag model, where high-frequency variables are used to predict the low-frequency variable. Accordingly, this study is organized into four sections, including this introduction. Section 2 summarizes the history of Iranian foreign exchange interventions. Section 3 is the general introduction to the MIDAS regression model. It describes the methodology and the data used, presents the results, and shows the predictive power of the model. The last section (Section 4) contains the conclusions and several suggestions for Iranian intervention.

2. An Overview of Iran’s Exchange Rate Policy

After the establishment of a managed floating system in 2002, Iranian intervention followed more seriously and the monetary authorities have intervened in the foreign exchange market by selling foreign exchange many times. Iranian foreign exchange intervention is one-sided, which means that intervention is mainly done by selling foreign exchange in the market to reduce fluctuations or control undesirable exchange rate deviations. In fact, regardless of the requirements of the managed floating system, Iranian monetary authorities intervene in the foreign exchange market, mainly in the form of exchange rate stabilization. In this case, the exchange rate has a high convergence with inflation, the exchange rate variable becomes a key variable in the Iranian economy and is very important to the public. Therefore, governments in Iran have tried to control the exchange rate level by selling foreign exchange in order to create acceptance among the people (Khosravi, 2021).

On the other hand, Iranian foreign exchange intervention is non-sterilized. Therefore, such an intervention affects the relative supplies of domestic and foreign assets, but the interest rate remains constant. In fact, the interest rate in Iran is not determined by the supply and demand of money and the Central Bank keeps its rate constant not by open market operations but by ordering on a fixed basis (Abbaszadeh, et al., 2022). Therefore, Iranian foreign exchange interventions do not affect short-term interest rates but such interventions will affect the growth of the money supply as a proxy for interest rates.

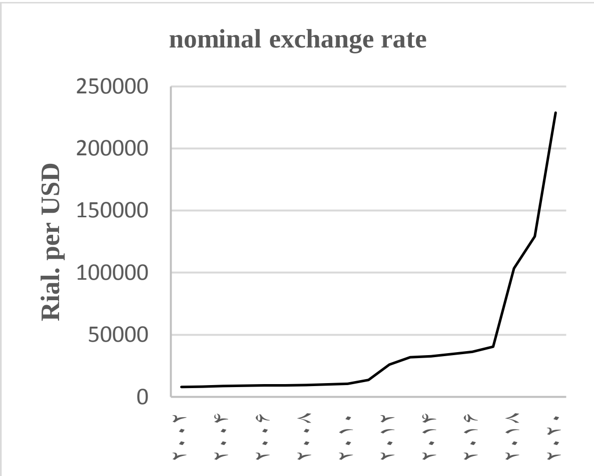

Fig. 1- Nominal Exchange Rate (US Dollar)
Source: Authors

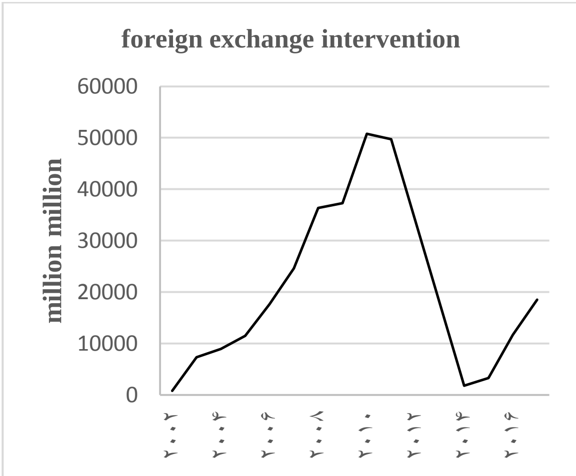

Fig. 2- Foreign Exchange Interventions (Million Dollars)
Source: Authors

Figure 1 shows the trend of the nominal exchange rate and Figure 2 depicts the value of foreign exchange interventions of the Central Bank. According to the figures, whenever the foreign exchange reserves of the Iranian Central Bank have a favorable level, by increasing interventions in the foreign exchange market, the Central Bank is able to successfully stabilize the nominal exchange rate. In particular, the stability of the nominal exchange rate during the 2010s is evident. In fact, in this period, the Central Bank played a key role in determining the exchange rate. But in the 2020s, banking, and oil sanctions and rising prices due to the policy of targeting subsidies caused the power of intervention to decrease. No information has been disclosed regarding the volume of foreign exchange interventions after 2018. However, the exchange rate trend shows that, in recent years, the intervention power of the Central Bank of Iran authorities has decreased and the Central Bank has been unable to control the exchange rate. Therefore, the Central Bank has not been able to continue the currency stabilization policy as before, and the country's currency system has mainly been a two-rate system.

3. The Effect of Foreign Exchange Intervention on Iran’s Exchange Rate Levels

3.1 MIDAS Regression Analysis: Theoretical Framework

In conventional time series methods, both dependent and independent variables must be at the same frequency. This situation may cause serious problems, especially in macroeconomic analyses due to the publication of data at different time intervals and frequencies. In practice, the most common solution for using different frequency data in the same model is to reduce the high-frequency data to the frequency of the low-frequency data before proceeding with the prediction of the model (Armesto, Engemann, and Owyang, 2010, p. 521; Guliyev, 2018, p. 15). This is done by aggregating or averaging depending on whether the series is a stock or flow variable. However, as a result of this reduction process, the loss of information contained in the high-frequency series may occur and the distribution properties of the original series may be differentiated (Marcellino, 1999, p. 129). One way to avoid loss of information is to compensate for missing observations in low-frequency series by interpolation (Foroni and Marcellino, 2013, p. 2). Another option is to exclude low-frequency variables from the model, which is likely to result in a loss of efficiency due to variable exclusion errors.

The Mixed-Data Sampling (MIDAS) approach developed by Ghysels, Santa-Clara, and Valkanov (2002) offers a different option between these two approaches. In this method, the frequency of the dependent variable must always be lower than the frequency of the independent variable(s). Thus, the MIDAS approach can use the maximum information in each observation of the high-frequency series (Guliyev, 2018, p. 15).

Suppose a set of high-frequency data $X^{(m)}$ be sampled m times faster than low-frequency data. For example, for annual data m=4 and we write that quarterly data are sampled at the frequency $X^{(4)}$.

Using this notation, Ghysels et al. (2002) derived the MIDAS model as follows:

$$Y_t = \beta_0 + \beta_1 B\left(L^{\frac{1}{m}}:\gamma\right) X_t^{(m)} + \epsilon_t^{(m)} \tag{1}$$

In our case, the dependent variable Y_t, which is the interpolated variable, is sampled at the quarterly frequency. The term t defines the time for model estimation up to $1T$. The regressors $X_t^{(m)}$ are sampled m times faster than Y_t, here m=3. The term $B\left(L^{\frac{1}{m}}\right) = \sum_{j=0}^{j\,max} B(J) L^{\frac{j}{m}}$ is a polynomial of length j^{max}in the $L^{\frac{1}{m}}$ lag operator, which is defined as $L^{\frac{j}{m}} X_t^{(m)} = X_{t-j/m}^{(m)}$. The operator $L^{\frac{j}{m}}$ produces the value of X_t^m lagged by $\frac{j}{m}$ periods.

An annual/quarterly example would imply that the above equation is a projection of yearly Y_t onto quarterly data $X_t^{(m)}$ using up to j^{max} quarterly lags.

A parsimonious regression model is now formulated as:

$$Y_t^L = \sum_{i=1}^{q} \beta_i \, W_{t-i}^L + \lambda \, f\left(\gamma . X_{J.t}^H\right) + \varepsilon_t \tag{2}$$

The term Y_t^L is the dependent variable sampled at low frequency. The W_t^L is the set of regressors sampled at the same frequency as the dependent variable. $X_{J.t}^H$ is the set of explanatory variables sampled at a higher frequency. The β_i, λ and γ are the parameters to be estimated. The F() is a function translating the higher frequency data into a lower frequency, and ε_t is a white noise process with mean zero and constant variance.

The following step can be to take the average of the high-frequency data that occur between samples of the lower frequency variable.

$$X_t^L = \frac{1}{m}\sum_{j=0}^{m-1} X_{t-j}^H \quad (3)$$

The term m is the number of periods in the higher frequency corresponding to a single period in the lower frequency. The X_t^H are the high-frequency variables corresponding to the last observation in period t of the lower frequency. The regression model in equation (4) can be re-estimated with the time aggregation in (5), that is,

$$Y_t^L = \sum_{i=1}^{q} \beta_i W_{t-i}^L + \lambda X_t^L + u_t \quad (4)$$

One main issue, however, with this regression model is that the estimated coefficients of each high-frequency regressor of X at time t are equal. However, it is not difficult to allow for non-equal coefficients for each lag of the high-frequency regressor ($t-j$). For that, equation (6) can be updated using different coefficients.

$$Y_t^L = \sum_{i=1}^{q} \beta_i W_{t-i}^L + \sum_{j=0}^{m-1} \gamma_{t-j} X_{t-j}^H + u_t \quad (5)$$

The issue with this model is that the number of coefficients can be quite large. However, it makes sense, certainly in our application, to put higher weights on closer lags than those that are far from the contemporaneous value through implementing a parsimonious MIDAS model. The model in (7) can be updated to the MIDAS model, like:

$$Y_t^L = \sum_{i=1}^{q} \beta_i W_{t-i}^L + \lambda \sum_{j=0}^{m-1} W_{t-j}(\gamma)\ X_{t-j}^H + u_t \quad (6)$$

where the weighting function $w(..)$ transforms high-frequency parameters into low-frequency parameters.

The parameterization of the lagged coefficients ($W_{t-j}(\gamma)$) in a parsimonious fashion is one of the key features of MIDAS models (Karagöz and Ergün, 2020). In our application below, we will estimate the MIDAS regression model with Almon Lag Weighting specifications.

3.2 Data and Model

We use Ding and Wang's (2022) model and adjust it with the characteristics of Iran's economy to estimate the effect of foreign exchange interventions on the exchange rate.

$$Exc_t = \beta_0 + \beta_1 Int_t + \lambda \sum_{j=0}^{m-1} W_{t-j}(\gamma)\ GDP_{t-j} + \lambda \sum_{j=0}^{m-1} W_{t-j}(\gamma) Def_{t-j} + \lambda \sum_{j=0}^{m-1} W_{t-j}(\gamma) M_{t-j} \quad (7)$$

where:

Int_t : The amount of foreign exchange that the Iranian Central Bank sales to manage the exchange rate in the foreign exchange market.

Def_{t-j}: Government budget deficit, seasonal frequency

M_{t-j}: the money supply growth rate, seasonal frequency. Since the interest rate in the Iranian economy is not determined by the supply and demand of money and is determined by order, the use of the money supply growth variable to control the effect of simultaneous changes in the money supply that may be caused by non-sterilization intervention is necessary.

GDP_{t-j}: is GDP, seasonal frequency. It is necessary to consider this variable to examine the effect of sanctions.

The explanations of the variables used in Equation (7) are given in Table 1.

Table 1. Definition of Variables

Variable	Description	Measurement method
Exc_t	Exchange rate level	Nominal , Annual exchange rate level
Int_t	Central Bank foreign exchange intervention	The logarithmic difference of the annual value of foreign exchange interventions
Def_t	Government budget deficit	The logarithmic difference of the seasonal government budget deficit, Seasonally adjusted
M_t	Money growth rate	The logarithmic difference of seasonal liquidity, Seasonally adjusted
GDP_t	GDP	Logarithmic difference of GDP, Seasonally adjusted

Source: Authors

Table (1) provides the description as well as the method of measuring all the variables used in Equation (7). Accordingly, the nominal exchange rate level and foreign exchange intervention have an annual frequency, and the other explanatory variables including foreign exchange interventions, government budget deficit, money growth rate, and GDP have a seasonal frequency. Also, saying this point is necessary that all data in this work have been collected from the Iranian Central Bank website.

Table 2. Descriptive Statistics of Variables

Variable	mean	Maximum	minimum	Standard deviation	Number of observations
Exc_t	0.108122	0.652649	0.014099	0.164864	16
Int_t	0.102653	2.196080	-1.984385	0.968901	16
Def_t	0.002270	2.632633	-2.361083	0.552182	64
M_t	-0.000653	6.230440	-6.221801	1.109417	64
GDP_t	0.046264	0.197582	-0.072470	0.051975	64

Source: Authors

Table (2) reports descriptive statistics related to the variables of foreign exchange intervention, exchange rate level, GDP, budget deficit, and money supply growth during the period from 2002 to 2017.

The non-stationary time-series data makes statistical inferences invalid. Therefore, variables should be considered for stationary before estimating time series models. In Table 2, the results of the Augment Dickey-Fuller test for the model variables are reported.

To ensure the stationary of all variables, in this study, all variables are in the form of logarithmic differences. The results of the Augment Dickey-Fuller unit root test show that all variables are stationary.

Table 3. Unit Root Test

Variable	**Augmented Dickey-Fuller**	**p-value**
Exc_t	-2.146555	(0.0347)
Int_t	-2.792632	(0.0085)
Def_t	-4.875438	(0.0000)
M_t	-67.08071	(0.0000)
GDP_t	-111.3395	(0.0000)

Note: values in () are p-values
Source: Authors

The Sum of Squared Residuals (top 20 models) is as follows:

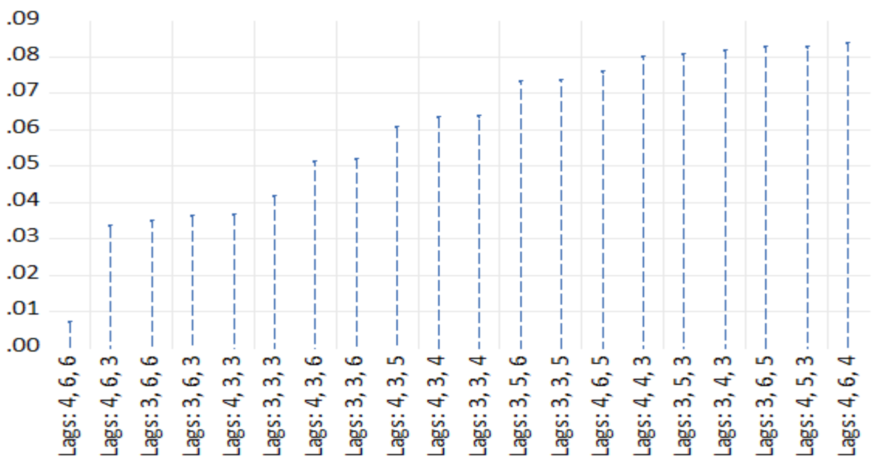

Fig. 3- Optimal lag

Source: Authors

Figure (3) shows the results of the optimal lag selection for high-frequency variables of equation (7). The results based on the Henan Quinn criterion, which has the lowest value in terms of the sum of squared residuals criterion, show that 6 Lags for the GDP, 6 Lags for the money supply growth, and 4 Lags for the government deficit are selected as the optimal lag for estimating the exchange rate level model.

Table 4. Estimation of Midas Regression for Exchange Rate Level

Variable	**Coefficient**	**t Statistics**

C	0.021087	-0.318166 (0.7663)
$\mathbf{Int_t}$	-0.093738	-5.640552 (0.0049)
	GDP_t	
$PDL(1)$	0.533555	6.716635 (0.0040)
$PDL(2)$	-1.776221	-6.966372 (0.0022)
$PDL(3)$	0.263934	6.852874 (0.0024)
	$\mathbf{M_t}$	
$PDL(1)$	19.54859	5.949444 (0.0040)
$PDL(2)$	15.59389	5.674457 (0.0048)
$PDL(3)$	-3.137873	-5.713964 (0.0046)
	$\mathbf{Def_t}$	
$PDL(1)$	9.150979	8.886115 (0.0009)
$PDL(2)$	-6.928894	-8.964644 (0.0009)
$PDL(3)$	1.235520	8.952469 (0.0009)
R^2	0.98	

Note: values in () are p-values
Source: Authors

Table (4) shows the results of estimating Equation (7). We can see that during the period from 2002 to 2017, an increase in the foreign exchange intervention of the Central Bank causes a decrease in the level of the exchange rate. This means that interventions by the Iranian Central Bank have been effective. This confirms the results of Utsunomiya (2013), Suardi (2008), and Adler et al. (2019). According to our results, a 1 percent increase in foreign exchange interventions in each period decreased the exchange rate level by 0.094 percent.

Therefore, during the period under review, whenever the Central Bank of Iran had a suitable level of foreign exchange reserves, it was able to prevent exchange rate deviations by selling currency in the foreign exchange market. In fact, because in Iran the main source of government foreign exchange earnings comes from the sale of oil and gas, with the increase in oil and gas revenues, the power of the Central Bank intervention increases. But with declining oil revenues, due to sanctions, the power of the Central Bank intervention in the foreign exchange market also decreases (Abbaszadeh et al., 2022).

To examine the overall effect of each of the high-frequency variables on the exchange rate level, it is necessary to use the Wald test. Table 5 shows the results of the Wald test for each of the variable's GDP, government budget deficit, and money growth rate.

Table 5. Results of the Wald Test

Variable	Statistical value	p-value
GDP_t	17.51849	(0.0000)
M_t	33.67928	(0.0000)
Def_t	52.04328	(0.0000)

Note: values in () are p-values
Source: Authors

As the results of Table (5) show, all three variables have a significant effect on the exchange rate level. Therefore, according to the results for Almon parameters in Table 4 and also the lag coefficients of the variables presented in the appendix, we can see the GDP has a negative effect on the exchange rate and the government deficit and growth money supply have a positive effect on the exchange rate level.

Table 6. Review of Classical Hypotheses

Jarque-Bera	Box- Ljung		Arch effect	
1.34 (0.50)	$Q(12)$	10.614 (0.562)	$Q^2(12)$	8.7554 (0.724)

Note: values in () are p-values
Source: Authors

Table (6) shows the results of the classical hypotheses in the estimated model. Based on Jarque-Bera statistics and the probability value, we can see the normality of the Residuals not rejected. Therefore, all tests related to coefficients are valid.

Additionally, Ljung Box statistics and related probabilities are reported in Table (6). According to the null hypothesis of this test, there is no autocorrelation between the error terms. According to the results, it is clear that the null hypothesis to 12 lags is not rejected. As a result, the absence of serial autocorrelation of the error terms is confirmed. Also, according to the results of the Arch effect, the absence of serial autocorrelation between the squares of the Residuals in the 12 lags is not rejected. As a result, the variance homogeneity of the error terms is confirmed.

3.3 Trend Forecasting of Exchange Rate

Figure (4) shows the relationship between simulated and actual values of the exchange rate levels. The brown lines represent the simulated values and the blue lines represent the actual values. The very high consistency of the actual diagrams confirms the high coefficient of determination obtained in Table (4). Therefore, it can be said that the model considered in this study (Equation (7)) has performed well in predicting the exchange rate.

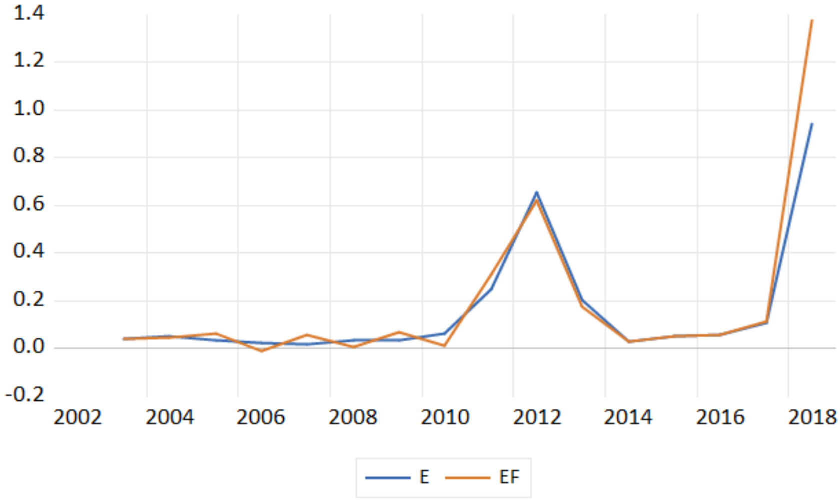

Fig. 4-Predicted Values and Actual Values during the Period from 2002 to 2018

Source: Authors

Now, using quarterly and annual data related to 2018, we predict the exchange rate level in 2018.

Table 7. Exchange Rate Level Forecast

Exchange rate level in 2018	Predicted value	actual value
Using seasonal and annual statistics of 2018	1.38	0.94

Source: Authors

Table (7) shows the results of the exchange rate forecast. Data related to 2018 were not included in the initial estimate, so using this information, the predictive power of the model could be examined.

By entering the information related to 2018, we observed the exchange rate level in 2018 estimated at 1.38, while the actual value is equal to 0.94. We can see the variables considered in the model, including foreign exchange interventions, GDP, government budget deficit, and money supply growth rate, predict the exchange rate in the right direction. However, regarding the values, there is a difference. The difference between the predicted and actual value can be due to the transformation of interventions. In 2018, in addition, to directly intervening and selling foreign exchange in the foreign exchange market, the Central Bank managed the market by other measures such as the establishment of the secondary market or Nima system and also encouraging domestic exporters to return foreign exchange earned from exports to the country's economic cycle. The Central Bank officials also used verbal intervention to thwart media rumors and provocations and manage exchange rate expectations. In fact, in 2018, foreign exchange interventions in Iran were not limited to direct interventions. In addition, the Iranian monetary authorities tried to manage the foreign exchange market in other ways. Therefore, we can say that part of the gap between the predicted value and the actual value in 2018 is due to such actions from the Central Bank.

4. Conclusions

The present study examined the effectiveness of Iranian foreign exchange intervention on the exchange rate levels. The results showed a negative relationship between exchange rate and intervention, which means that the intervention of the monetary authorities of Iran has been effective. According to this, whenever the Iranian Central Bank's foreign reserve had a good level, monetary authorities can control the fluctuation and undesired deviations of the exchange rate.

In this study, we find that an increase in the GDP causes a decrease in the level of the exchange rate. One of the main factors in Iranian GDP is oil export. In Iran, oil export is the most crucial source of foreign currency revenues for the government, and the volume and frequency of foreign exchange intervention of the Central Bank in Iran's foreign exchange market are highly dependent on foreign exchange earnings from oil exports. In fact, something that controls intervention intensity is oil export revenues. Such conduct from Iranian monetary authorities shows that foreign exchange intervention in Iran is discretion.

In addition, we find that the money growth rate and budget deficit positively affect the exchange rate level. So, regularity in monetary and fiscal policy are two main requirements for effective foreign exchange intervention. In fact, although in the short-term the Central Bank can manage the foreign exchange market by foreign exchange intervention, with regard to the irregularity of the monetary and financial policies of the government, foreign exchange intervention continually can't be effective.

Therefore, according to the results of this study, the Central Bank of Iran should reduce its discretionary intervention policies and use more rule-based currency intervention policies. Also, in order to increase the effectiveness of foreign exchange interventions, the monetary and financial policies of the government should be regularized.

Declaration of Competing Interests

We declare that there are no conflicts of interest related to this paper, and this research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

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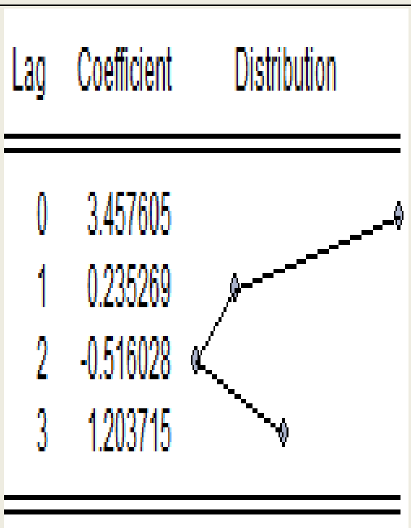
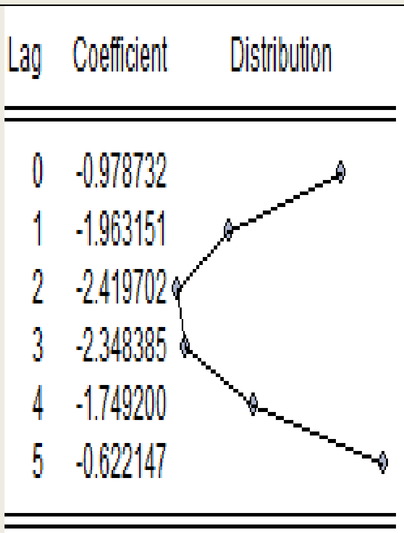
Appendix. Distribution of Lags Coefficients

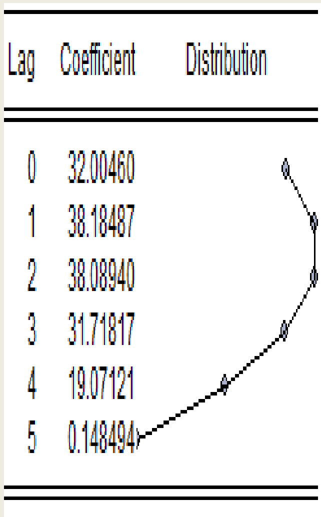
Distribution of lags coefficients based on the weighting function of the Almon		
Budget deficit lag coefficients	GDP lag coefficients	Money supply growth lag coefficients



Lag	Coefficient	Distribution
0	3.457605	
1	0.235269	
2	-0.516028	
3	1.203715	



Lag	Coefficient	Distribution
0	-0.978732	
1	-1.963151	
2	-2.419702	
3	-2.348385	
4	-1.749200	
5	-0.622147	



Lag	Coefficient	Distribution
0	32.00460	
1	38.18487	
2	38.08940	
3	31.71817	
4	19.07121	
5	0.148494	

Source: Research Resul