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FORECASTING EXCHANGE RATE VOLATILITY IN INDIA UNDER UNIVARIATE AND MULTIVARIATE ANALYSIS

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ABSTRACT

This paper addresses the issue of variation in the exchange rate of the Indian Rupee (IR) against the US Dollar (USD) under a flexible exchange rate regime using monthly data spanning January 2005 to December 2020. We find that exchange rate volatility is largely affected by its lag value rather than the inflation rate and the interest rate differential. The results of forecast accuracy suggest that the prediction performance of the ARIMA model is better than the VAR model. We also find that apart from other factors, the sharp changes in the exchange rate should be controlled by the economy because its effect will be reflected in the next period and thus creating a chain event to bring further instability in the exchange rate.

Keywords: Exchange rate; Time series analysis; ARIMA; VAR; India.
JEL Classifications: C22; C52; F31.

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I. INTRODUCTION

Financial liberalization has been considered to increase investment and accelerate economic growth in developing countries (Shaw,1973). Higher integration of the financial sector in an economy led to higher capital mobility which affects the exchange rate. Furthermore, the financial markets of developing economies have a low degree of organisational structure and therefore high capital mobility leads to exchange rate volatility (Oreiro, 2005). The impact of capital mobility on the domestic economy varies with the existing exchange rate regime. Although the fixed exchange rate policy moderates the effect of capital inflows on domestic front but fail to protect the economy from external shocks; while flexible exchange rate policy enhances the effect of capital mobility on domestic front and guards the economy from external shocks (Mussa, 1979).

The stability of exchange rates promotes growth through trade (Frankel and Rose, 2002) and macroeconomic stability. A reduction in exchange rate uncertainty increases the efficiency of the price mechanism at the international level (Schnabl, 2008) which affects growth performance by increasing capital market efficiency in capital allocation (Mckinnon, 1963). Lower exchange rate volatility is also associated with the enhancement of economic growth through higher stocks of foreign direct investment (FDI) and higher credit excess (Arratibel *et al*., 2011).

In the literature, variation in the exchange rate has been understood through many approaches/theories. Studies based on monetary models of exchange rate determination consider money supplies, real output, interest rates, and inflation rates as the key factors of exchange rate volatility (Mpofu, 2021; Phuc and Duc, 2021; Xie and Chen, 2018; Ibhagui, 2018; Shastri and Shastri, 2016; Bhanumurthy *et al*., 2019; Hina and Qayyum, 2015; Hsing, 2015; Sharma and Setia, 2015; Kurihara, 2012; Papadamou and Markopoulous, 2012; Maitra and Mukhopadhyay, 2011; Lee-Lee and Hui-Boon, 2007; Jonson *et al*., 1982). On the other hand, studies based on the optimum currency area models observes that trade linkages, economic shocks, and country size affect exchange rate volatility (Hasnat, 2019; Maepa and Muzindutsi, 2017; Mohapatra and Rath, 2017; Bannaga and Badawai, 2014; Rashid and Saedan, 2013; Petreski, 2010; Kasman and Ayhen, 2008; Kemal *et al*., 2004). Some studies explain the volatility of the exchange rate in terms of news about socio-political-economic shocks (e.g., Narayan *et al*., 2021; Narayan *et al*., 2018). The literary evidence of new open economy macroeconomic models suggests trade openness and financial openness as the vital factors of exchange rate determination (Raksong and Sombatthira, 2021; Vural, 2019; Kaltenbrunner, 2015; Jayaraman and Choong, 2011; Egert *et al*., 2006; Alba and Papell, 1998). Some studies also examine the purchasing power parity hypothesis which advocates price differential as a major factor behind exchange rate determination (Xie *et al*., 2021; Aixala *et al*., 2020; Gozen *et al*., 2016; Kargbo, 2012; Kargbo, 2006). The portfolio balance approach suggests a positive link between exchange rate and stock prices (Morana, 2017; Jayashankar and Rath, 2017; Bagchi, 2016; Hsing, 2016; Mishra, 2016; Yadav, 2016; Kumari and Mahakud, 2012; Kumar, 2010). The interest rate parity hypothesis proposes the difference in interest rate as a determinant of exchange rate volatility (Garg and Prabheesh, 2021; Bozovic, 2020; Perera *et al*., 2018; Corakci *et al*., 2017; Tsen, 2014). Furthermore, some studies reveal a causal relationship between GDP

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growth and exchange rate (Adusei and Gyapong, 2017; Habib *et al*., 2017; Rai and Sharma, 2017).

Although there are numerous studies to understand the causes of exchange rate volatility, there are very few studies explaining the exchange rate variation in term of its lagged values (e.g., Petrica *et al*., 2016; Ouyang, 2011). It raises some important questions – whether lagged values of exchange rate significantly affect its variability? Moreover, since it is always difficult to get data about different variables affecting macro-economic indicators, particularly in the developing countries, can we forecast exchange rate using its lagged values? Can univariate analysis be used as a reliable method in comparison to multivariate analysis for understanding and predicting variation in the exchange rate?

The available literature, especially in terms of its forecasting accuracy, has not discussed the issue of exchange rate volatility extensively in the context of India. However, the economic time series like exchange rate, inflation, and differential interest rate are providing vital input in policy development through its own dynamics as well as their interaction with other macroeconomic series.

The present study has applied both univariate analysis and multivariate analysis for the exchange rate between Indian Rupees (INR) and US Dollar (US$) over the period 2005 to 2020. In the multivariate analysis, explanatory variables include lags of exchange rate, inflation rate, and differential interest rate, consistent with the literature. Our findings show that the forecasting accuracy of ARIMA model on monthly data is higher than restricted multivariate VAR model. Further, among all explanatory variables, considered in the study, lagged value of exchange rate is the most effective to define the variation in exchange rate.

The rest of the paper is structured as follows: Section II describes methodology that contains description about source of data and variables. Section III presents results and discussions and finally, Section IV summarizes the findings of the study.

II. DATA AND METHODOLOGY

A monthly average rate of the nominal exchange rate of Indian Rupees (IR) against the United States Dollar (USD) has been considered from January 2005 to December 2020. For the multivariate analysis apart from exchange rate we have considered inflation rate and differential interest rate. The monthly data of the aforesaid variables have been taken from the Reserve Bank of India (RBI, 2021) and the Organisation for Economic Co-operation and Development (OECD). The detailed description of variables along with how it is measured has been given in Table 1. The entire data is divided in two parts- the period from January 2005 to April 2019 is considered for the development of model. The second part of the data set from May 2019 to December 2020 is used to check the forecasting accuracy of the developed model.

Table 1.
Description of Variables

This table shows the list of variables- their symbol, full names, definitions, and the source of variables.

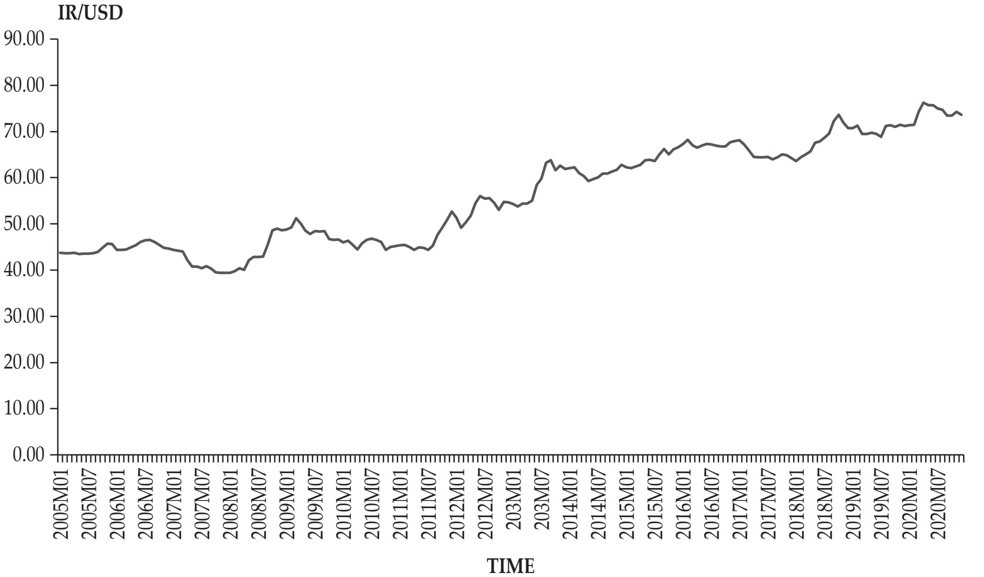
Symbol	Variable	Definition	Source
ER	*Exchange Rate*	Measured as a nominal exchange rate of IR against USD.	Reserve Bank of India
IFR	*Inflation Rate*	Wholesale price index is used to measure *inflation rate* and refers to a mix of agricultural and industrial goods at various stages of production, including import duties.	Reserve Bank of India
DIR	*Differential Interest Rate*	Measured as a difference between long-term interest rates on India and US government bonds maturing in ten years.	Organisation for Economic Co-operation and Development

III. RESULTS AND DISCUSSION

In regression analysis involving time series data, a critical assumption is that the time series under consideration must be stationary. If a time series is non-stationary, we can study its behaviour only for the period under consideration and it is not possible to generalize it to other time periods. For the reason stated, it is important to find out whether the exchange rate series is stationary or not. Therefore, the time paths of the nominal Rupee/US Dollar exchange rates have been depicted in Figure 1. The figure suggests that the exchange rate series is not stationary, and it is generally drifting upward with a great deal of variation.

Figure 1.
Movement of Indian Rupee – US Dollar Exchange Rate

This figure shows the trend of Indian Rupee and US Dollar exchange rate. Source: Authors' calculation using exchange rate data from Reserve Bank of India (RBI).



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A. Unit Root Tests Outcomes

To confirm non-stationarity of the concerned series, augmented Dickey-Fuller (ADF), Phillips and Perron (PP) (1998), and Kwiatkowski *et al*. (KPSS) (1992) tests have been conducted. The third lag order has been selected based on minimum value of AIC for unit root test. Results reported in Table 2 suggest that all series are stationary at their first difference that means they are integrated at first order I(1).

Table 2.
Unit Root Tests Results

This table reports results from unit root tests. The list of the different tests appears in column 1. Akaike information criteria is applied for appropriate lag selection. All tests are conducted at levels and first difference. The critical values for LM-stat are 0.74, 0.46 and 0.35 at the 1%, 5% and 10% levels of significance respectively. * and *** represent significant at 1% and 10% level respectively. Source: Authors' calculation.

Variables	ADF-test		PP-test		KPSS test	
	Levels	First Diff.	Levels	First Diff.	Levels (LM-stat)	First Diff. (LM-stat)
ER	-2.7555 (0.2161)	-9.5472 (0.0000)*	-2.1699 (0.5028)	-9.3632 (0.0000)*	4.6194	0.0816***
IF	-1.8491 (0.3559)	-25.2198 (0.0000)*	-0.1307 (0.9433)	-20.9747 (0.0000)*	4.6239	0.2100***
DIR	-0.2868 (0.5814)	-8.0804 (0.0000)*	-0.3354 (0.5633)	-11.4788 (0.0000)*	1.5944	0.0385***

B. ARIMA Model Outcomes

For the identification of appropriate ARMA model, the correlogram of the integrated exchange rate series has been applied. To see which correlations are statistically significant, the standard error of correlation coefficient has been calculated by $\sqrt{1/n} = \sqrt{1/171} \approx 0.0764$, where n is the sample size. Therefore, the 95% confidence interval for the true correlation coefficients is about 0 ± 1.96 (0.0764) = (- 0.1498 to 0.1498) and correlation coefficients lying outside these bounds are statistically significant at the 5% level of significance (Gujarati, 2011). On this basis, it seems ACF at lags 1, 17 and 36 and PACF at lags 1, 5, 13, 17 and 28 appear to be statistically significant. The statistically significant value of ACF at different lags will provide the value of AR (p) while the value of PACF will give the value of MA (q) for ARMA model.

Based on obtained value of autoregressive (AR) and moving average (MA), the possible sets of fifteen (15) ARIMA models has been shown in the Table 3. Based on lowest value of the Akaike and Schwarz information criteria, we have selected three ARIMA models- ARIMA (36,1,1), ARIMA (17,1,1), and ARIMA (1,1,5) for further analysis.

Table 3.
ARIMA Model

This table reports results of the possible sets of fifteen (15) ARIMA models. Based on the lowest value of the Akaike and Schwarz information criteria; we have considered three model for prediction as (1,1,5), 17,1,1) and (36,1,1). ARIMA model (36,1,1) is found to be more significant among the selected best three ARIMA model. * denotes significant at 1 per cent level.
Source: Authors' calculation.

	AR (1)	AR (17)	AR (36)	MA (1)	MA (5)	MA (13)	MA (17)	MA (28)	Adj. *R2*	D-W Statistics	AIC	SC	*F*-statistics
ARIMA (1,1,1)	-0.21			0.54*					0.09	1.98	2.78	2.86	6.62*
ARIMA (1,1,5)	0.31*				0.19*				0.10	1.94	2.77	2.83	7.28*
ARIMA (1,1,13)	0.30*					-0.21*			0.11	1.93	2.77	2.84	7.96*
ARIMA (1,1,17)	0.29*						-0.25*		0.12	1.94	2.76	2.84	8.41*
ARIMA (1,1,28)	0.30*							-0.12	0.09	1.93	2.79	2.86	6.48*
ARIMA (17,1,1)		-0.20*		0.34*					0.12	2.03	2.76	2.83	8.63*
ARIMA (17,1,5)		-0.21*			0.17*				0.05	1.40	2.84	2.91	3.75*
ARIMA (17,1,13)		-0.23*				-0.22*			0.07	1.41	2.82	2.89	4.95*
ARIMA (17,1,17)		0.61*					-1.00		0.15	1.49	2.84	2.91	11.20*
ARIMA (17,1,28)		-0.23*						-0.12	0.04	1.42	2.84	2.92	3.39*
ARIMA (36,1,1)			0.25*	0.33*					0.13	2.01	2.75	2.82	9.67*
ARIMA (36,1,5)			0.28*		0.18*				0.06	1.39	2.83	2.90	4.90*
ARIMA (36,1,13)			0.25*			-0.17*			0.07	1.41	2.83	2.90	5.03*
ARIMA (36,1,17)			0.23*				-0.21*		0.07	1.42	2.82	2.89	5.27*
ARIMA (36,1,28)			0.26*					-0.07	0.05	1.41	2.85	2.92	3.75*

C. VAR Model Outcomes

To check the consistency of findings of ARIMA, we have applied multivariate restricted VAR model to estimate the effect of inflation and differential interest rate along with its lagged value on exchange rate. Since all the three variables are integrated at first order i.e. I(1), Johansen cointegration tests are applied to check the long run relationship among the concerned time series. The cointegration results (reported in the Appendix, Table A.1.) confirm the non-existence of cointegration among these variables which allow us to apply the restricted VAR model. The results of VAR model, shown in Table 4, confirm the findings of ARIMA model that exchange rate is positive and significantly affected by its lagged value. Further, the results indicate that exchange rate is also affected by rate of inflation and differential interest rate, but the coefficient of these explanatory variables are comparatively lesser than the coefficient of lagged value of exchange rate. Additionally, differential interest rate is statistically significant at its third lag only, which is inconsistent with the interest rate parity hypothesis. This happen because in the present study, the interest rate differential is considered for the long run with maturity in ten years. Under uncovered interest parity postulates, the interest rate differential is affecting the exchange rate in short run and dilute in the long run (Clarida and Gall, 1994; Cheng, 1999; Chaboud and Wright, 2005; Hecker *et al*, 2014).

Table 4.
VAR Results

This table reports the results of restricted VAR. Akaike information criterion has been used to select the lag length. * and *** represents the significant at 1% and 10% respectively. Source: Authors' calculation.

$$ER = C(1)*ER(-1) + C(2)*ER(-2) + C(3)*ER(-3) + C(4)*IF(-1) + C(5)*IF(-2) + C(6)*IF(-3) + C(7)*DIR(-1) + C(8)*DIR(-2) + C(9)*DIR(-3) + C(10)$$

Independent Variables	Coefficient	*t*-Statistics	Prob.
ER(-1)	0.4384	5.4265	0.0000*
ER(-2)	-0.0977	-1.1438	0.2544
ER(-3)	0.0416	1.6043	0.0947***
IF(-1)	-0.0634	-0.4993	0.6182
IF(-2)	0.2187	1.7064	0.0899***
IF(-3)	-0.0092	-0.1828	0.8552
DIR(-1)	-0.0307	-0.1379	0.8904
DIR(-2)	-0.1555	0.2237	0.4881
DIR(-3)	0.4070	1.8425	0.0673***
C	0.0729	0.8485	0.3974
Adjusted *R*2		0.1847	

D. Forecasting Performance Outcomes

The forecasting performance of all the selected three ARIMA models and VAR model has also been evaluated on difference performance parameters such as Root Mean Square Error (RMSE), Mean Absolute Error (MAE), Mean Absolute Percent Error (MAPE), and Theil Inequality Coefficient (TIC). The results have been reported in Table 5. The value of all these parameters is indicating that ARIMA model (36,1,1) is found to be more significant among all the selected three

ARIMA model and restricted VAR model. Both the coefficients of opted model are statistically significant, and AR (36) and MA (1) explain around thirteen (13) percent variation in exchange rate in this model. The findings of the study are consistent with the results of other India based studies, like, Rai and Sharma (2017), and Thomakos and Bhattacharya (2005).

Table 5.
Measurement of Forecasting Performance

This table shows the comparative evaluation among the selected model. Root Mean Square Error (RMSE), Mean Absolute Error (MAE), Mean Absolute Percent Error (MAPE), and Theil Inequality Coefficient have been applied to check the performance of the model**.** Source: Authors' calculation.

Selected Model / Performance Parameter	ARIMA (36,1,1)	ARIMA (17,1,1)	ARIMA (1,1,5)	VAR
RMSE	1.0651	2.1349	1.9823	5.0593
MAE	0.7513	1.6274	1.2891	3.9110
MAPE	1.0278	2.2164	1.9234	8.0280
Theil Inequality Coefficient	0.0073	0.1245	0.0135	0.0447

E. Diagnostic Tests Outcomes

Diagnostic tests tell us about the robustness of estimated coefficients. The estimated ARIMA model has passed a series of diagnostic tests of normality, heteroscedasticity, and serial correlation of the estimated residual. The results of the test have been depicted in Table 6 and it is evident that the estimated model is a stable one while VAR model fail to satisfy the requirement of normal distribution of residuals.

Table 6.
Diagnostic Test Results

This table reports results of diagnostic test. LM-test, ARCH test and normality test refer to the Breusch-Godfrey Lagrange multiplier test for residual serial correlation, the autoregressive conditional Heteroscedasticity test and the Jarque-Bera normality test. ** denote statistical insignificant at 5% level. Source: Authors' calculation.

Model	LM-Test		ARCH-Test		Normality Test	
ARIMA(36,1,1)	Obs.* *R*-squared	Prob. Chi-Square	Obs.* *R*-squared	Prob. Chi-Square	Jarque-Bera	*P*-value
	0.1071	0.9478**	1.4610	0.2268**	4.1539	0.0924**
VAR	2.3676	0.4997**	0.0104	0.9184**	10.2991	0.005

After a particular ARIMA model is fitted, it can be used for forecasting and the result of dynamic forecast has been shown in Figure 2. The forecast period is considered from May 2019 to December 2020.The value of Theil Inequality Coefficient and Root Mean Squared Error is low, suggesting that the fitted model is quite relevant. The accuracy of ARIMA model over VAR model can also be verified from Figure 3 that the forecasted value of VAR model is less accurate.

Figure 2.
Actual and Forecast Exchange Rates- ARIMA (36, 1, 1)

This figure shows the trends of actual exchange rate (*ER*) and exchange rate forecasted (*ERF*). Source: Authors' calculation.

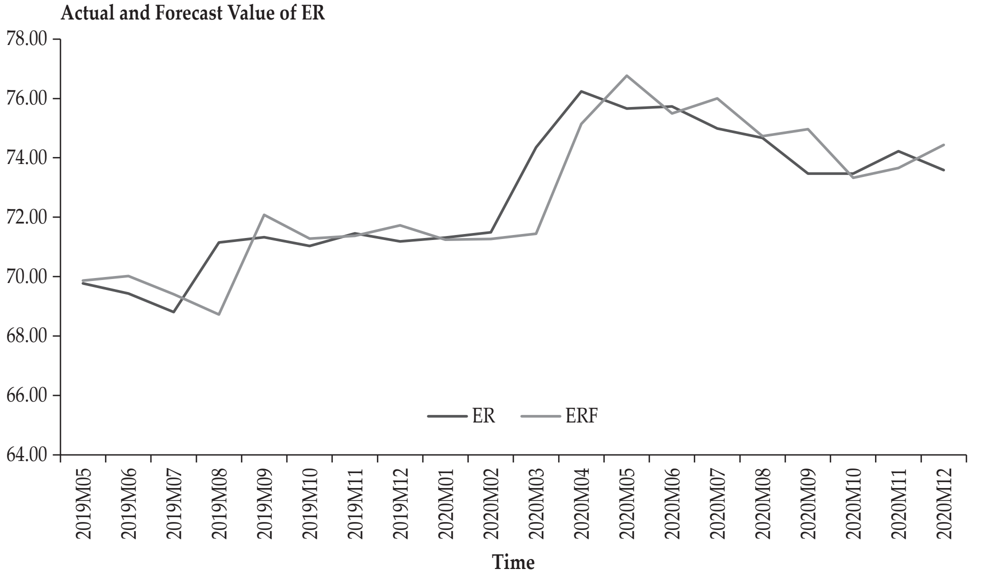
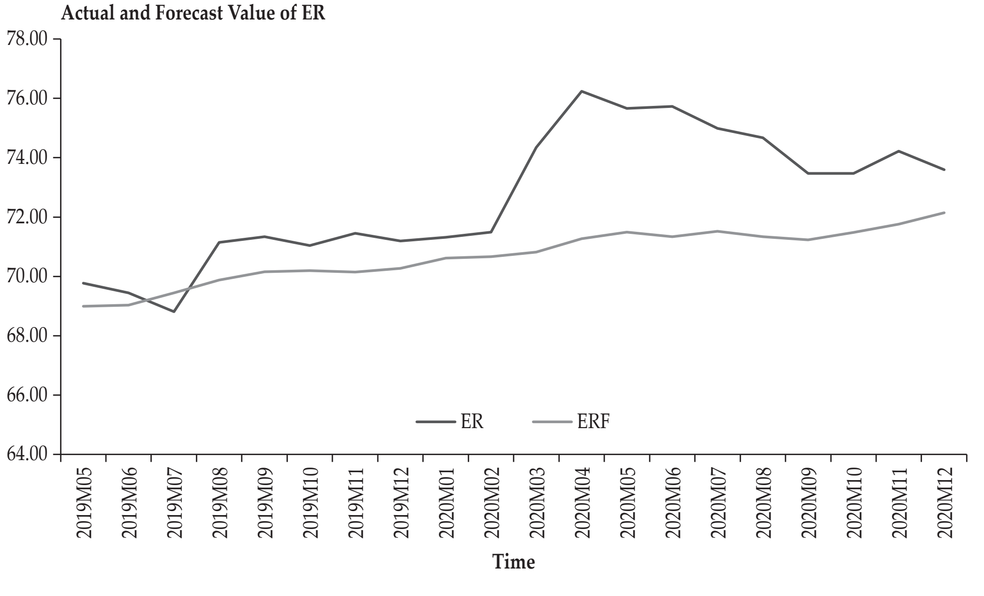


Figure 3.
Actual and Forecast Exchange Rates (VAR)

This figure shows the VAR of actual exchange rate (*ER*) and exchange rate forecasted (*ERF*). Source: Authors' calculation.



IV. CONCLUSION

The purpose of this study was to understand whether lagged values of exchange rate significantly affect its variability, providing some understanding around the question, can we forecast exchange rate using its lagged values and can univariate analysis be used as a reliable method in comparison to multivariate analysis for understanding and predicting variation in the exchange rate? For this purpose, the study examines the issue of variation in exchange rate of Indian Rupee (IR) against US Dollar (USD) under flexible regime by employing an AutoRegressive Integrated Moving Average (ARIMA) model and multivariate restricted VAR model during the period between January 2005 and December 2020. India being one of the fastest growing economies in the world needs capital inflow to fill the capital deficit in the domestic market for maintaining its high growth. The volatility in the exchange rate adversely affects macroeconomic stability and subsequently the capital inflows needed to achieve a high growth rate of the economy. Therefore, identification of a model that can successfully predict the volatility in the exchange rate may be highly useful to policy makers, researchers, and other stakeholders. In many theoretical and empirical research, it has been observed that volatility of exchange rate is affected by its own previous values. However, this aspect has been less attended in the Indian context.

The present study tried to address the issue of volatility in exchange rate through its lagged values and lagged values of random error term and demonstrated that selected ARIMA (36,1,1) model can be used to predict the exchange rate of Indian currency against US Dollar with a high degree of accuracy. The findings indicate that the value of exchange rate in Indian economy of a period is affected by its 36^{th} month's previous value by around 13 percent. It infers that volatility in exchange rate has potential to affect the exchange for a duration of almost three years, which is quite a long-time duration under flexible exchange rate. Further, it also emphasises the role of government for monitoring factors other than exchange rate, which affects its volatility.

A highly volatile exchange rate market, on the one hand, discourages entrepreneurs from exporting or importing or investing in financial assets and, on the other hand, encourages speculative activities in the foreign exchange market that may further accentuate fluctuations in it. For the policy perspective, apart from other factors the policy makers are advised to control the sharp changes in the exchange rate because its effect will be reflected in the next period and thus creating a chain of instability in the exchange rate. The paper potentially adds to discussions on determination of exchange rate volatility and appropriate model specification. The result of this analysis may be seen as an exploratory one and the validity of results entirely depends on the quality of data.

The present study uses lagged values of exchange rates and lagged values of random error term as an explanatory variable to estimate the variations in exchange rates of IR against USD. The findings of the study may be more valid with the addition of some relevant variables in the model as a predictor. However, this may discard the objectives of the present study. Future research in this area could use lagged value of exchange rates as a determinant to increase the efficacy of study based on different hypothesis of exchange rates theory.

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APPENDIX

Table A.1.
Johansen Cointegration Tests Results

This table shows the result of cointegration test. Akaike information criteria is applied for appropriate lag selection. r is representing number of cointegration. The p-value has been given in parentheses. Source: Authors' calculation.

Null Hypothesis	Trace Statistics	Max-Eigen Statistics
$r = 0$	14.0775 (0.1269)	12.0640 (0.1188)
$r \leq 1$	8.0135 (0.4640)	14.2646 (0.5997)
$r \leq 2$	1.9082 (0.1672)	1.9082 (0.1672)

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