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The Determinants of Indian Rupee Exchange Rate Volatility: An Empirical Evidence

By

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Abstract

The study focused on exploring the effect of various macroeconomic variables on the volatility of real effective exchange rate (REER) of Indian Rupee using monthly time series data spanning over November 1997 to December 2020. The Generalized Autoregressive Conditional Heteroskedasticity GARCH (1,1) modelling approach has been applied to measure the volatility. Autoregressive Distributed Lag (ARDL) bounds testing approach for cointegration has been applied to test the long-run and short-run association among the endogenous and the exogenous variables. The analysis revealed that the volatility of the Indian exchange rate was caused by macroeconomic factor such as inflation, foreign institutional investments, economic growth, exports, foreign exchange reserve and trade openness. It has been observed that an increase in Indian exports, foreign exchange reserve and trade openness have decreasing impact on the volatility of the Indian rupee exchange rate. While increased inflation has increasing impact on the volatility of REER. Thus, better macroeconomic indicators such as increased exports and forex reserves contribute to stability but worsened macroeconomic factors such as heightened inflation cause instability by increasing the volatility.

Keywords: Real Effective Exchange Rate, Volatility, ARDL, Error Correction.

Introduction

After the Bretton Woods system collapsed in 1973, the fixed exchange rate system was abandoned which enabled the countries to let their currencies fluctuate freely. Compared to a fixed exchange rate, the floating/flexible exchange rate regime is more vulnerable to volatility. Hence, exchange rate volatility has become an unavoidable fact for nations that have been adopting a floating exchange rate system. These fluctuations in exchange rate have negative effects since they cause economic uncertainty and raise corporate and investment risks. This holds really true for the emerging market economies.

Volatility or fluctuations in exchange rate refers to all movements and adjustments leading to the currency's depreciation or appreciation due to changes in the price of one currency to another currency. It is defined as the uncertainty associated with unforeseen and unpredicted exchange rate movements. The fluctuation in the exchange rate level is always a matter of concern for the several participants involving in an economy whether they fall in the category of developed or developing nation. Exchange rate fluctuations affect the value of international investment portfolios, competitiveness of exports and imports, value of international reserves, currency value of debt payments, and the cost to tourists in terms of the value of their currency (Dua & Ranjan, 2011). Thus, it has significant implications for the business cycle, trade and capital flows of the economy. The stable exchange rates are generally seen as an indication of sound economic management whereas the volatility in the level of exchange rate uncovers significant influence that may negatively impact the overall economy. Therefore, timely and accurate forecasts of exchange rates will provide decision makers and stakeholders in the fields of international finance, trade and policy making with valuable and relevant information about its appreciation or depreciation in the near future.

For attaining the various macroeconomic policy objectives in both developed and developing economies, exchange rate stability plays a pivotal role. To create a realistic and stable exchange rate, governments have developed several exchange rate management strategies, particularly for developing economies. Due to exchange rate fluctuations, which have become extremely uncertain or volatile, several countries have been affected adversely. Exchange rate volatility is the one of the significant aspects that enhances risk in the financial industry. Since exchange rate fluctuation is frequently recognized as a risk, it would increase costs for risk-averse traders and thus discourage trading (Arize et al., 2000). In other words, higher exchange rate risk makes trade earnings much riskier, which discourages risk-averse traders from trading.

Moreover, excessive exchange rate volatility cause delay in the investment decisions and raises the risk of economic uncertainty. This uncertainty in turn leads to an adverse impact on economic growth by affecting the investor’s confidence and their investment, consumption, productivity, international trade and capital flows (Oaikhenan & Aigheyisi, 2015). As a consequences of exchange rate volatility, determining macroeconomic and monetary policy objectives becomes a challenge as the volatility poses high degree of uncertainty.

Literature Review

The fluctuation of exchange rate in the era of globalisation cannot be ruled out completely but it has to be managed with sound economic policies. The ever-emerging volatility of exchange rates has received a due attention in economic research since the inception of floating exchange rate regime. The plethora of empirical studies are available which applied time series or panel data techniques on the exchange rate of different countries. The existing literature which has been reviewed for the purpose of analysis is mentioned below in chronological order:

Choudhary (2005) analysed the impact of exchange rate variability during the current flexible exchange rate era i.e., from the year 1974 to 1998 on real exports from the United States to Canada and Japan. For this purpose, the conditional variance has been measured by applying univariate GARCH (1, 1) model. This variance was computed for the first difference of the exchange rate log series to measure the volatility for both real and nominal exchange rates. Thereafter, author applied the multivariate cointegration and constrained error correction model to examine the relationship between real exports and its determinants such as export price ratio, real income and exchange rate volatility. In the majority of relationships, normalized equations suggest that volatility in exchange rates has a negative and significant impact on real exports. The results of the error correction suggest the existence of causality from exchange rate variability to the real exports in the context of both the countries.

In most of the causality tests applied evidence from all the determinants to the real export to Canada and Japan has been found. Hence, the consideration of exchange rate volatility is vital to modelling the export behaviour of the United States to Canada and Japan.

Lee-Lee and Hui-Boon (2007) intends to examine the probable reasons of volatility in the exchange rates in four ASEAN countries i.e., Indonesia, Malaysia, Thailand and Singapore. The volatility of the Malaysian ringgit, the Indonesian rupiah, the Thai baht and Singapore dollar were measured on the basis of exponential E-GARCH Model. Both the Johansen-Juselius cointegration test and the autoregressive distributed lag (ARDL) model were used to estimate the long-run relationships with the vector-error correction model (VECM). Granger causality test has been used to measure short-run relationships. In order to capture short-term adjustment among cointegrated variables, error correction mechanism (ECM) has also been applied. The relative terms of interest rates (RI), money supplies (RM), trade balances (RTB), consumer price indices (RCPI), and composite indices (RCI) have been analysed to assess their impact on the volatility of the four countries' exchange rates. The results indicate that volatility of exchange rates seem to be influenced by a set of macroeconomic variables. The study found that the exchange rate volatility and macroeconomic factors are moving simultaneously to attain the long run equilibrium for the three nations i.e., Malaysia, Indonesia and Singapore.

Choudhary (2008) investigated the impact of exchange rate volatility on real imports of United Kingdom (UK) from Canada, New Zealand and Japan from the year 1980–2003 by applying the multivariate cointegration method and constrained error correction methods. Both the nominal and real exchange rates have been considered. The results indicate that the real import is positively impacted by exchange rate volatility implying increases international trade flows.

Amadou (2011) examined the impact of real exchange rate misalignment and volatility on total exports for a panel of 42 developing countries for the period spanning over 1975 to 2004 using panel data cointegration approach. The findings demonstrated that exports are negatively impacted by both real exchange rate misalignment and volatility. The findings also suggested that the effect of REER volatility is more than that of misalignment. Estimations based on subsamples from low and middle-income countries further validate these findings.

Srinivasan & Kalaivani (2013) empirically investigated the impact of exchange rate volatility on the real exports in India by employing the annual time series data ranging over the period 1970 to 2011. The findings of the ARDL Bounds test approach revealed that real exports are cointegrated with real exchange rate and its volatility, gross domestic product of India and foreign economic activity which is proxied by world GDP. The ARDL results indicated that the exchange rate volatility has a significant negative impact on real exports both in the short and long run, suggesting that higher exchange rate volatility tends to decrease real exports in India. Additionally, both the real exchange rate and the foreign economic activity have positive long-run and negative short-run impact on real exports of India. Moreover, GDP has a positive and significant long-run impact on India's real exports but the impact is insignificant in the short run.

Chang & Su (2014) performed a cross country analysis considering Pacific Rim countries and explored the relationship between nominal exchange rate and various macroeconomic fundamentals. For all country-pairs except Taiwan, the traditional vector error correction mechanism (VECM) cointegration tests failed to find any the long-run relationship among variables considered. But when the structural break variables were taken into consideration, then the results suggested that exchange rates and fundamentals for Canada, Japan, South Korea and Thailand are well cointegrated in relation to the United States. This suggests that in these countries the long-run equilibrium between the two investigated variables i.e., nominal bilateral exchange rate and fundamental values has a characteristic of structural break. The bootstrap rolling window Granger causality test based on residual bootstrap technique was used to observe the causality between exchange rates and corresponding fundamental series. In Canada-U.S., Thailand-U.S., and Japan-U.S. country-pairs, the results revealed that a uni-directional causality exist. In addition, time-varying causal relationship was also detected among the exchange rates and fundamentals of these pairs of countries.

Sharma & Setia (2015) employed monthly data on the nominal rupee-dollar exchange rate and independent macroeconomic variables for conducting empirical research. The variables taken were money supply, real income or output, general price level or consumer price index (CPI), short-term interest rate and the overall trade balance for India and the USA for the period from April 1994 to March 2010. The structural breaks in the data have been tested firstly by conventional unit root test, Lagrange multiplier (LM) test and break points (BP) test. In order to evaluate the monetary model both in the long and short-run, the Johansen cointegration test, fully modified ordinary least square (FMOLS), Wald's coefficient constraint and impulse response functions (IRF) has been applied. The findings of the analysis suggested that exchange rates were significantly influenced by the macroeconomic fundamentals, but their influence varies significantly over time and the coefficients of the macroeconomic variables are dynamic in the long run. The IRF highlighted the significance of the interest rate on managing the volatility of exchange rate. The major implication derived from the study is that in order to control the exchange rate, macroeconomic fundamentals serve as a vital tool while at the same time these fundamentals are quite dynamic which add to complexity in managing exchange rate.

An another study conducted by Barguellil et al. (2018) examined the impact of exchange rate volatility on the economic growth of 45 developing and emerging countries over the period from the year 1985-2015 using the difference and system generalized method of moments estimators. The GARCH (1,1) model has been used to measure the volatility of both the nominal and real exchange rates. The study observed that the measure of nominal and real exchange rate volatility based on generalized autoregressive conditional heteroskedasticity have a negative impact on the economic growth. Also, it revealed that the volatility has negative impacts in countries following the flexible exchange rate regimes whereas no significant impact could be traced in nations with fixed exchange rate regimes. Moreover, the volatility of exchange rate is also dependent on degree of financial openness as it has been confirmed that volatility is relatively more detrimental if countries follow flexible exchange rate regime as well as financial openness.

Kilicarslan (2018) emphasised on exploring the variables influencing the volatility of the Turkish currency from the period 1974 to 2016 using the ADF and PP unit root tests, Johansen cointegration tests and Fully Modified Ordinary Least Square (FMOLS) tests. The study also examined the real effective exchange rate volatility using the GARCH (1,1) model. The results of ADF and PP unit root test show that all the variables have been stationary at first difference. As per Johansen cointegration test results, there exist a long-run relationship among the variables considered. The FMOLS revealed that domestic investment, money supply and trade openness positively affect real effective exchange rate volatility, while foreign direct investment, output and government expenditure negatively affect the exchange rate volatility.

Based on annual data from year 1980 to 2014, Kumar et al. (2019) investigated the impact of external debt and exchange rate volatility on domestic consumption of Pakistan. To examine the short-run and long-run effects bounds testing cointegration approach and error correction model have been applied. The results of bounds test revealed that interest rate, income, external debt, exchange rate and volatility of exchange rate have long-run cointegration relationship with domestic consumption. The main findings revealed that both external debt and exchange rate volatility negatively affect the domestic consumption whereas income, interest rates and exchange rate have positive effects on the consumption both in the short and long run. Moreover, the sign of error correction term (ECM) is negative and significant implying the contribution towards equilibrium in long-run through short-run adjustments.

Above review of literature indicate that both academicians and policymakers have developed a keen interest in the causes and effects of exchange rate volatility. A huge volume of the literature focuses on the impact of exchange rate volatility on economic growth in the field of international trade and finance. Numerous studies demonstrate that exchange rate volatility has an adverse effect on macroeconomic variables, such as productivity, consumption, investment, capital flows and trade. However, a very few studies have emphasized on the determinants of exchange rate volatility. Therefore, in this study an effort has been made to fill this existing gap in literature by providing insight into the relationship between exchange rate volatility and various macroeconomic determinants of India.

Database and Methodology

To examine the various determinants of the volatility of real effective exchange rate (REERVOL) of Indian Rupee, Autoregressive Distributed Lag (ARDL) method based on bounds test approach proposed by Pesaran et al., (2001) has been applied. The study examined the co-integration relationship between REERVOL and various macroeconomic determinants in India. The REER volatility of Rupee has been conducted applying Generalized Autoregressive Conditional Heteroskedasticity (GARCH) model proposed by Bollerslev (1986). The monthly data is undertaken for the period from November 1997 to December 2020 for the study.

Exchange rate volatility measures using Univariate GARCH (1,1) Model:

In earlier studies, various other measures of exchange rate volatility have been employed. But in our study conditional variance is applied as a measure of exchange rate volatility which is estimated by the means of GARCH model. This model has the advantage of including heteroscedasticity into the estimation process of the conditional variance, where the conditional variance is depends on the squared residuals of the process (Bollerslev, 1986). This is a symmetric model which captures the effects of persistence of shocks and volatility clustering into the model. The model can be expressed by the following equations:

$$Y_t = c + \varepsilon_t \quad (1)$$

$$\sigma_t^2 = \sigma_0 + + \sum_{i=1}^{p} \alpha_1 \varepsilon_{t-1}^2 + \sum_{i=1}^{q} \beta_1 \sigma_{t-j}^2 \quad (2)$$

Equation (1) represents the mean equation whereas equation (2) represents the conditional variance, c is constant and ε_t is error term. α_1 represents the presence of ARCH process (volatility clustering) in the residuals and β_1 represents that the conditional variance depends on the previous period conditional variance. The sum of α_1 and β_1 measures the persistence of the volatility.

Prior to conducting the cointegration tests, the stochastic properties (presence of unit roots) of each variable series is need to determine. We have applied Augmented Dickey Fuller test (ADF) developed by Dickey and Fuller (1979) to check the presence of unit root in the variables.

The ARDL model of co-integration which was originally developed by Pesaran and Shin (1999) and further extended by Pesaran et al., (2001) is applied to check the co-integration among variables. This approach can be applied irrespective of whether the underlying variables are I(0), I(1) or mutually co-integrated (Pesaran & Shin, 1999). Another advantage of using this model is that under it the short as well as long-run coefficients can be estimated simultaneously. The ARDL model can be estimate by using simple Ordinary Least Square (OLS) method in the form of following equation:

$$REERVOL_t = \beta_0 + \sum_{i=1}^{p} \beta_1 \Delta REERVOL_{t-1} + \sum_{i=1}^{p} \beta_2 \Delta CPI_{t-1} + \sum_{i=1}^{p} \beta_3 \Delta EXP_{t-1} + \sum_{i=1}^{p} \beta_4 \Delta FII_{t-1} + \sum_{i=1}^{p} \beta_5 \Delta FOREX_{t-1} + \sum_{i=1}^{p} \beta_6 \Delta IIP_{t-1} + \sum_{i=1}^{p} \beta_7 \Delta TO_{t-1} + \lambda_1 REERVOL_{t-1} + \lambda_2 CPI_{t-1} + \lambda_3 EXP_{t-1} + \lambda_4 FII_{t-1} + \lambda_5 FOREX_{t-1} + \lambda_6 IIP_{t-1} + \lambda_7 TO_{t-1} + \mu_t \quad (3)$$

Where REERVOL is Real Effective Exchange Rate Volatility, CPI is consumer price index, EXP is total exports of India, FII is foreign institutional investments, FOREX is foreign exchange rate, IIP is index of industrial production, TO is trade openness, β_0 is a constant, μ_t is the white noise error term and Δ is the first difference operator. The short-run dynamics for the error correction are denoted by Δ terms with summation signs, whereas the long-run relationship is represented in the remaining part of the equation, which is represented by sign λ. The Akaike Information Criteria (AIC) has been used to determine the optimum lag length for the model.

In order to test for the presence of a long-run relationship among the variables, the first step in the ARDL bounds testing approach is to conduct the F-test for the joint significance of the variables. The null and alternative hypotheses under the bounds test approach can be symbolically presented as below:

Null hypothesis (H0):

$\mu_2 = \mu_3 = \mu_4 = \mu_5 = \mu_6 = \mu_7 = 0$

Alternate Hypothesis (H1):

$\mu_2 {}^1 \mu_3 {}^1 \mu_4 {}^1 \mu_5 {}^1 \mu_6 {}^1 \mu_7 {}^1 0$

Pesaran et al., (2001) generated two sets of critical value ranges for the F statistic and present the two bounds i.e., upper and lower bound. If the calculated F statistic value is less than the lower bound range, it indicates that there is no cointegration among the variables meaning that the null hypothesis of no cointegration is accepted. On the other hand, if F statistic value is higher than upper bound value, the null hypothesis is rejected implying that there is co-integration among variables. Nevertheless, if the F-statistics falls within the upper and lower critical bound, it indicates the inconclusive result.

After confirming the existence of long-run cointegration relationship, the next step is to determine the long-run coefficients by using following long-run ARDL model:

$$REERVOL_t = \alpha_0 + \sum_{i=1}^{p} \alpha_1 REERVOL_{t-1} + \sum_{i=1}^{p} \alpha_2 CPI_{t-1} + \sum_{i=1}^{p} \alpha_3 EXP_{t-1} + \sum_{i=1}^{p} \alpha_4 FII_{t-1} + \sum_{i=1}^{p} \alpha_5 FOREX_{t-1} + \sum_{i=1}^{p} \alpha_6 IIP_{t-1} + \sum_{i=1}^{p} \alpha_7 TO_{t-1} + \mu_t \ldots \quad (4)$$

Where all the variables are same as previously defined, α_0 is the constant, α_1, α_2, α_3, α_4, α_5, α_6 and α_7 are the long run coefficients and μ_t is error term. In last step, we obtain short-run dynamics by estimating error correction model by using following equation:

$$\Delta REERVOL_t = \beta_0 + \sum_{i=1}^{p} \beta_1 \Delta REERVOL_{t-1} + \sum_{i=1}^{p} \beta_2 \Delta CPI_{t-1} + \sum_{i=1}^{p} \beta_3 \Delta EXP_{t-1} + \sum_{i=1}^{p} \beta_4 \Delta FII_{t-1} + \sum_{i=1}^{p} \beta_5 \Delta FOREX_{t-1} + \sum_{i=1}^{p} \beta_6 \Delta IIP_{t-1} + \sum_{i=1}^{p} \beta_7 \Delta TO_{t-1} + \phi ECM_{t-1} + \mu_t \ldots \quad (5)$$

In the above equations, β_0 is constant term, β_1, β_2, β_3, β_4, β_5, β_6 and β_7 are the short-run dynamic coefficients and ϕ is the coefficient of error correction term (ECM_{t-1}) which indicates the speed of adjustment towards long-run equilibrium needed to restore after having shock in a short run.

Results and Discussion

Before measuring the volatility, the ARCH Lagrange multiplier (LM) test given by Engle (1982) has been applied to check whether a variable contains ARCH or not which the preliminary condition to apply a GARCH model is. In case the p-value of chi-square is significant, the null hypothesis of no arch is rejected. After confirming the existence of ARCH, the GARCH (1,1) model is used to estimate volatility of REER.

Table 1. *Lagrange Multiplier Test of Heteroskedasticity*

Heteroskedasticity Test: ARCH			
F-statistic	357.45	Prob. F (1,5404)	0.0000
Observed R^2	335.40	Prob. Chi-Square (1)	0.0000

Table 1 shows the results of ARCH LM test. The probability value of chi-square (χ^2) is found to be significant at 1% level implying that the null hypothesis of no ARCH effect is rejected. In other words, there is the ARCH effect in the daily exchange rate series and therefore the volatility persists. Considering this, the GARCH variance series is used to measure volatility of REER.

Table 2. *Estimated Parameters of GARCH (1,1) Model Method: ML ARCH – Generalized error distribution (GED) (BFGS / Marquardt steps) Presample variance: backcast (parameter = 0.7)*

Coefficient	Value of Coefficient	Z- Statistic	P-Value
Intercept	0.0007*	12.637	0.0000
ARCH	0.1622*	18.894	0.0000
GARCH	0.7794*	88.386	0.0000
AIC	-0.9929	SIC	-0.9855

* and ** denotes significant at 1% and 5% level of significance.

Having confirm the primary condition of existence of ARCH, we estimate volatility by applying GARCH model. Table 2 shows the results of parameter estimates from the GARCH (1,1) model for daily exchange rates of Indian rupee. The value of ARCH coefficient (α_1) is 0.1622 which is significant implying the presence of volatility clustering. The short-run dynamic of the resulting volatility time series is determined by the magnitude of the ARCH and GARCH parameters. The sum of α_1 i.e., ARCH and β_1 i.e., GARCH is 0.9416 which is lesser than and close to Unity (1) indicating that volatility shocks are quite persistent in exchange rates of Indian rupee. Large GARCH coefficient denotes the persistence of volatility whereas large ARCH coefficient represents a less persistent and more spiky form of volatility. Here in our model GARCH coefficient value is larger than ARCH coefficient implying that there is persistence of volatility shocks in Indian rupee exchange rate series. In order to analyse the impact of macroeconomic system of the economy on the volatility persistence of Indian rupee exchange rate, the variables such as inflation, foreign institutional investments, economic growth, exports, foreign exchange reserve and trade openness have been considered for further analysis using ARDL equation. Since the data on the macroeconomic variables is available in monthly series, the data on REER has also been considered in monthly form. This monthly REER has been converted into conditional variance series.

Figure 1. *Real Effective Exchange Rate Volatility over time*

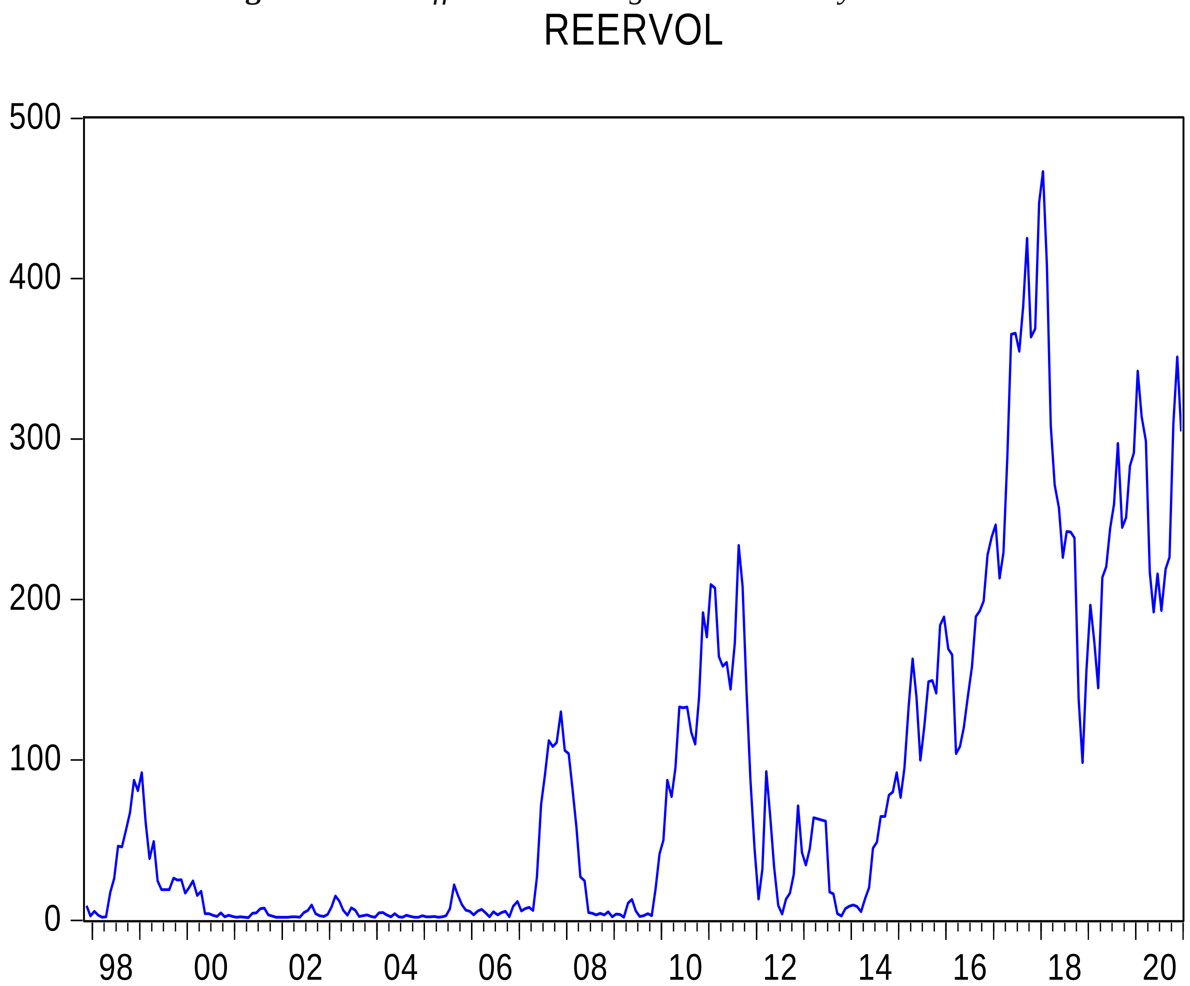

Figure 1 *presents the trends in real effective exchange rate volatility over time.*

Table 3. *Result of ADF and PP Unit Root Test for REER and its Determinants*

	Augmented Dickey Fuller Test (ADF)				Phillips-Perron test (PP)			
	Levels		First Diff.		Levels		First Diff.	
Variables	Intercept	Trend and Intercept	Intercept	Trend and Intercept	Intercept	Trend and Intercept	Intercept	Trend and Intercept
REERVOL	0.5220	0.1699	0.0000*	0.0000*	0.5003	0.1271	0.0000*	0.0000*
CPI	0.9999	0.6035	0.0000*	0.0000*	1.0000	0.8329	0.0000*	0.0000*
EXP	0.9217	0.2707	0.0002*	0.0013*	0.7597	0.0000*	0.0001*	0.0001*
FII	0.0000*	0.0000*	0.0000*	0.0000*	0.0000*	0.0000*	0.0000*	0.0000*
FOREX	1.0000	0.9875	0.0000*	0.0000*	0.9953	0.0000*	0.0001*	0.0001*
IIP	0.7274	0.3987	0.0001*	0.0007*	0.1583	0.0295**	0.0000*	0.0000*
TO	0.1278	0.0000*	0.0000*	0.0000*	0.0000*	0.0000*	0.0001*	0.0001*

*, ** and *** shows 1%, 5% and 10% level of significance respectively.

Table 3 indicates the result of ADF and PP unit root test which shows that FII and TO are stationary at levels I(0) while REERVOL and CPI are non-stationary at level I(1) under both methods. As per the overall outcome of both the tests, some of our variables are stationary at level and the remaining are stationary at first difference, thus none of the variables are integrated of order two i.e., I(2). Following these results where variables series are mixture of I(0) and I(1), the ARDL bounds testing procedure is valid to conduct here.

Table 4. *Results of Bounds Test of Cointegration for Normalizing REERVOL*

Variables	F-Statistic	Probability	Result
$F_{REERVOL}$ (REERVOL/CPI, EXP, FII, FOREX, IIP, TO)	10.5183	0.0000	Cointegration
Critical Value	Lower Bound		Upper Bound
1% Level	3.15		4.43
5% Level	2.45		3.61
10% Level	2.12		3.23

Table 4 presents the results of F-statistics under bound testing approach. The value of F-statistic i.e., 10.5183 is clearly greater than upper bound critical value at 1 percent significance level which reveal that cointegration exists among the considered variables. Here the null hypothesis

Of no cointegration among the variables is clearly rejected. Once the existence of cointegration relationship is confirmed, the estimates of coefficients using the ARDL (3,3,4,1,3,0,4) model based on equation (4) are determined and the results are presented in Table 5.

Table 5. *Estimated OLS coefficients for REERVOL and its Determinants*

Variables	Coefficient	Std. Error	t-Statistic	Prob.*
REERVOL(-1)	1.1769*	0.071322	16.50144	0.0000
REERVOL(-2)	-0.5050*	0.114611	-4.4066	0.0000
REERVOL(-3)	0.2436*	0.080381	3.031204	0.0027
CPI	-0.5465	0.477155	-1.14548	0.2531
CPI(-1)	3.0887*	0.903861	3.417259	0.0007
CPI(-2)	-3.4447*	0.896791	-3.84123	0.0002
CPI(-3)	1.1549*	0.442936	2.607581	0.0097
EXPORT	-0.0003***	0.000178	-1.74899	0.0815
EXPORT(-1)	0.0004*	0.000141	2.934351	0.0037
EXPORT(-2)	-0.00023	0.000145	-1.56537	0.1188
EXPORT(-3)	0.000155	0.000152	1.019741	0.3088
EXPORT(-4)	-0.00023***	0.000137	-1.67636	0.0949
FII	0.00039	0.000265	1.47582	0.1413
FII(-1)	0.0015*	0.000339	4.485853	0.0000
FOREX	5.44E-05	3.75E-05	1.449773	0.1484
FOREX(-1)	-0.0001*	3.94E-05	-3.27108	0.0012
FOREX(-2)	3.57E-05*	5.09E-06	7.022709	0.0000
FOREX(-3)	1.19E-05	1.07E-05	1.109646	0.2682
IIP	0.1519***	0.08481	1.791558	0.0744
TO	-0.00073	0.000608	-1.20496	0.2294
TO(-1)	-0.0022*	0.000455	-4.86007	0.0000
TO(-2)	0.0014*	0.000397	3.577012	0.0004
TO(-3)	0.0055	0.004512	1.232148	0.2191
TO(-4)	-0.0148*	0.004982	-2.9788	0.0032
C	-91.088*	24.89958	-3.65823	0.0003
R-squared	0.9737	Akaike info criterion		8.7362
Adjusted R-squared	0.9711	Schwarz criterion		9.0658
F-statistic	384.4191	Durbin-Watson stat		1.8885
Prob (F-statistic)	0.0000			

*, ** and *** shows 1%, 5% and 10% level of significance respectively

The results of selected OLS based ARDL model which indicate that REER volatility is significantly affected by its own lagged values as its coefficients are statistically significant. The CPI is not significant at its level but its lags are significant at 1% level of significance. The export and its fourth lag are negatively significant at 10% level of significance meaning that increase in export decrease the volatility. However, its first lag is positive and significant. The second and third lag have insignificant impact on REER volatility. The first lag of FII is positive and significant. The impact of foreign exchange reserve is rather diverse in the first and second lag. The first lag of forex exhibits a significant negative relationship whereas second lag depicts an increase in the REER volatility. Similar results have been showcased by trade openness. TO exerts a significant negative effect in the first lag at 1 percent level of significance leading to decrease in REER volatility, while, on the contrary, in the second lag it has positive relationship with REER volatility. Also, its fourth lag is highly negatively significant. IIP exerts positive influence on REER volatility as expected. The intercept term in the model is highly significant. The explanatory power of the model represented by adjusted R^2 is 0.97 (97 percent) which is fairly good meaning that 97% variation in volatility of REER is explained by the exogeneous variables of the study. The Durbin-Watson value is 1.888 which clearly indicate the absence of autocorrelation in the model. The F-statistic value is also significant which reveals that the results of the model are quite robust.

Table 6. *Estimated ARDL Long-run coefficients for REERVOL and its Determinants*

Variable	Coefficient	Std. Error	t-Statistic	Prob.
CPI	2.9872*	1.0159	2.9404	0.0036
EXPORT	-0.0023***	0.0013	-1.7878	0.0750
FIIs	0.0226**	0.0093	2.4301	0.0158
FOREX	-0.0003**	0.0001	-2.0022	0.0463
IIP	1.7985	1.0538	1.7065	0.0900
TO	-0.1278**	0.0592	-2.1583	0.0319
C	-1078.2	398.84	-2.7033	0.0073

*, ** and *** shows 1%, 5% and 10% level of significance respectively

Table 6 indicates the result of the long-run ARDL approach derived on the basis of equation (4). These long-run coefficient more clearly bring out the relationship among selected macroeconomic variables and REER volatility. The results indicate that almost all the variables considered have a statistically significant impact on Indian exchange rate volatility. CPI has significant positive effect on exchange rate volatility while exports have expected negative effect on the same in the long run. It implies that increase in CPI leads to increase in exchange rate volatility and vice-a-versa. On the contrary, an increase in exports will decrease in volatility of exchange rate as expected. Thus, increased level of exports contributes to the stability of exchange rate. Coefficient of FIIs shows the positive and significant effect on exchange rate volatility in the long run implying that activities of trading strategies of FIIs do cause instability in the macroeconomic system through increased volatility of Indian rupee exchange rate. Similarly, the long run coefficients of forex and trade openness are negative and statistically significant implying that both are having inverse relationship with volatility of exchange rate. The negatively significant sign of forex suggested that an increase in the India's foreign exchange reserve holdings is associated with lesser volatility and thus greater stability of the exchange rate. Similarly, the results of trade openness implying that the more open the Indian economy is, the less volatile will be the exchange rate of currency. These findings are in consonance with the findings of existing studies such as Calderón & Kubota (2009) and Al Samara (2009). Thus, the paper has further supported the earlier findings. As far as the impact of IIP considered as a proxy for economic growth on the volatility of exchange rate, the results of long run equation do not provide conclusive evidence of contribution to the volatility of exchange rate in either way. Since this is due to the fact that IIP is almost insignificant (even at 10 percent).

Table 7 depicts the results of short-run dynamics associated with the long-run relationships determined on the basis of equation (5) following ARDL specification of (3,3,4,1,3,0,4). The coefficient of the error correction term (ECT-1) is negative and significant as expected implying that the deviation of REER volatility from its long-run equilibrium is restored by adjustments in short-run drivers i.e., independent variables. But the speed of adjustment is quite low which is just 8 per cent. The short-run dynamics impact on the volatility of REER is approximately in accordance with the previously estimated long-run coefficients. The REER volatility is significantly affected by its own lags. The first lag leads to increase whereas the second lag decrease the volatility as a result of change in its own current value.

Table 7. *Error-Correction Model Derived on the basis of ARDL model for REERVOL and its Determinants*

Variable	Coefficient	Std. Error	t-Statistic	Prob.
D(REERVOL(-1))	0.2613*	0.0718	3.6364	0.0003
D(REERVOL(-2))	-0.2436*	0.0803	-3.0312	0.0027
D(CPI)	-0.5465	0.4771	-1.1454	0.2531
D(CPI(-1))	3.4447*	0.8967	3.8412	0.0002
D(CPI(-2))	-1.1549*	0.4429	-2.6075	0.0097
D(EXPORT)	-0.0003***	0.0001	-1.7489	0.0815
D(EXPORT(-1))	0.0002	0.0001	1.5653	0.1188
D(EXPORT(-2))	-0.0001	0.0001	-1.0197	0.3088
D(EXPORT(-3))	0.0002***	0.0001	1.6763	0.0949
D(FII)	0.0003	0.0002	1.4758	0.1413
D(FOREX)	0.0000	0.0000	1.4497	0.1484
D(FOREX(-1))	-3.6E-05*	0.0000	-7.0227	0.0000
D(FOREX(-2))	-1.2E-05	0.0000	-1.1096	0.2682
D(IIP)	0.1519***	0.0848	1.7915	0.0744
D(TO)	-0.0007	0.0006	-1.2049	0.2294
D(TO(-1))	-0.0014*	0.0003	-3.5770	0.0004
D(TO(-2))	-0.0055	0.0045	-1.2321	0.2191
D(TO(-3))	0.0148*	0.0049	2.9787	0.0032
ECM (-1)	-0.0844*	0.0278	-3.0370	0.0026
R-squared	0.4746	Akaike info criterion		8.7430
Adjusted R-squared	0.4239	Schwarz criterion		9.0727
F-statistic	9.3726	Durbin-Watson stat		1.8798
Prob(F-statistic)	0.0000			

*, ** and *** shows 1%, 5% and 10% level of significance respectively.

The first lag of CPI is positive and significant at 1 percent level of significance which is similar to the results as obtained in long-run model. However, the second lag of CPI is inverse consist of negative sign. The first difference of export of current period demonstrates negative and significant impact on REER volatility as expected. The FII exerts expected positive relationship though insignificant. The first lag of forex and trade openness indicate the expected negative relationship with REER volatility implying that increase in forex and TO lead to decrease in REER volatility. However, the third lag of TO possess positive sign. Lastly, IIP significantly boosts the REER volatility at 10 per cent level of significance in the short-run.

Diagnostic Test

Table 8. *Breusch-Godfrey Serial Correlation LM Test*

F-statistic	1.499650	Prob. F (4,245)	0.2029
Observed R^2	6.548310	Prob. Chi-Square (4)	0.1618

Table 8 and 9 shows the result of diagnostic tests i.e., Breusch-Godfrey Serial Correlation LM test and Ramsey RESET specification test in order to examine the reliability and validity of the ARDL-ECM model. The result of Breusch Godfrey Serial Correlation LM test shows that value of observed R^2 is insignificant as its P-value is greater than 0.05 which clearly indicates that the residuals of data have no serial correlation or autocorrelation. Similarly, both t and F-statistic of Ramsey RESET specification test are presented which are also insignificant. Hence, our model does not have any specification error and it is correctly specified.

Table 9. *Ramsey RESET Specification Error Test*

Statistic	Value	df	Probability
t-statistic	0.710485	248	0.4781
F-statistic	0.504789	(1, 248)	0.4781

Heteroscedasticity Test

As far as we discuss about heteroscedasticity, the null hypothesis that residuals have no heteroscedasticity is rejected at 1% significance level. In order to solve this problem of heteroscedasticity, we have been proceeded by considering the Newey-West estimator while selecting the model in EViews and therefore create the final estimates of our ARDL model by making standard errors more robust.

Stability of the ARDL model

Figure 2 depicts the CUSUM graph which is used to analyse the consistency of the coefficient of the long run ARDL model. The graph clearly shows that the blue line is in the range of critical bonds of 5% significance level, indicating that the ARDL model is stable. There is no structural instability in the residuals of our model.

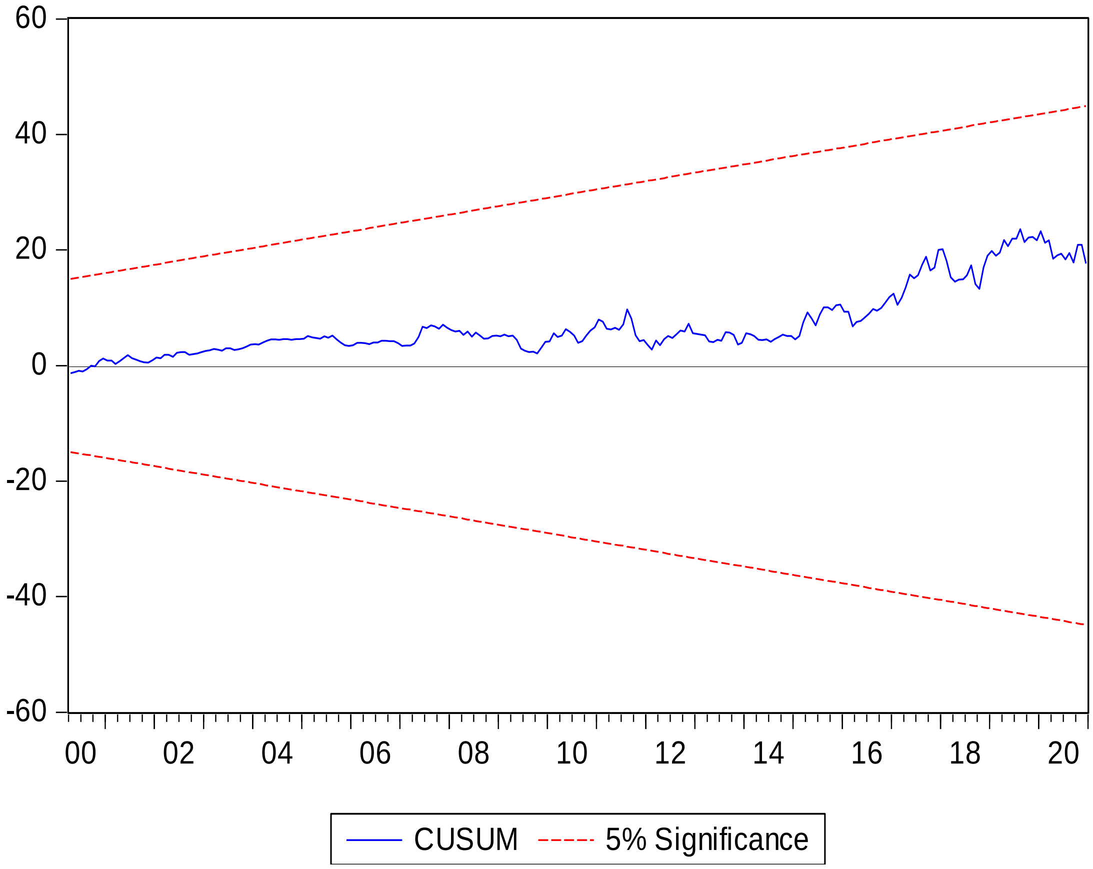

Figure 2. *Plot of Cumulative Sum of Recursive Residual (CUSUM) at 5% significance level.*

Causality Analysis

Granger (1969) causality test is one of the most popular statistical techniques to determine the direction of causality between endogenous and explanatory variables. In order to conduct the causality analysis, lag one has been used. Jones (1989) argues that the ad hoc selection method is superior over all other methods in order to determine the optimum lag length.

Table 10. *Results of Granger Causality Test*

Variables	F-Statistic	Probability
CPI does not Granger Cause REERVOL	8.348	0.004
REERVOL does not Granger Cause CPI	13.06	0.000
EXPORT does not Granger Cause REERVOL	5.160	0.023
REERVOL does not Granger Cause EXPORT	3.495	0.062
FII does not Granger Cause REERVOL	33.07	0.000
REERVOL does not Granger Cause FII	8.486	0.003
FOREX does not Granger Cause REERVOL	5.399	0.020
REERVOL does not Granger Cause FOREX	5.622	0.018
IIP does not Granger Cause REERVOL	1.367	0.243
REERVOL does not Granger Cause IIP	3.107	0.079
TO does not Granger Cause REERVOL	0.092	0.761
REERVOL does not Granger Cause TO	29.16	0.000

Note: *The lag length of all the variables is one.*

Table 10 indicate the findings of Granger causality test and disclosed the presence of a bidirectional causal relationship of REER volatility with CPI, export, FIIs and foreign exchange reserve in India. It implies that these explanatory variables granger cause REERVOL and vice-a-versa. However, REERVOL granger cause economic growth (IIP) and trade openness both, implying that IIP and TO possess the unidirectional causality which runs only from these explanatory variables to REERVOL of the country.

Conclusion

This study examines the macroeconomic determinants of the volatility of real effective exchange rate (REER) in India by using the monthly time-series data ranging from November 1997 to December 2020. After confirming the existence of ARCH, the GARCH (1,1) model is used to estimate volatility of REER. Thereafter the stationarity property of the selected variables has been checked using ADF and PP unit root tests and their results show that the order of integration of the series of variables under consideration is a combination of I(0) and I(1). Hence, the ARDL bound test approach has been applied accordingly. The result of ARDL bound testing co-integration approach indicate the existence of long-run association among the variables considered. The estimations of long run ARDL model reveal the significant and positive association of REER volatility with Inflation (CPI) and FIIs. On the contrary, Indian exports, foreign exchange reserve and trade openness have a negative and significant impact on volatility. It implies that increase in Indian exports, foreign exchange reserve as well as trade openness can help to mitigate the volatility of the India’s real effective exchange rate. It has been also observed that inflation and FIIs have the potential to aggravate the volatility in Indian exchange rate. As far as the impact of IIP considered as a proxy for economic growth on the volatility of exchange rate, the results of long run equation do not provide conclusive evidence of contribution to the volatility of exchange rate in either way. Since this is due to the fact that IIP is almost insignificant. The coefficient of the error correction term (ECM-1) is negative and significant as expected implying that the deviation of REER volatility from its long-run equilibrium is restored by adjustments in short-run drivers i.e., explanatory variables. The ECM value is −0.0844 suggests that about 8% of disequilibrium in REER volatility is corrected in the current period. This implies that the speed of adjustment is quite low.

The implication of the study highlights the fact that the volatility of exchange rates poses a significant obstacle to macroeconomic stability of a country. Thus, the macroeconomic policies construed for the specific objective may fail due to this persistence of volatility in rupee exchange rate. This study can be used to safeguard the success of the macroeconomic policies if such findings are considered while formulating these macroeconomic policies. We attempted to empirically identify the determinants that policymakers may modify to minimise the volatility in the real effective exchange rate of India to the U.S. dollar. The government should take such measures which aim at attracting permanent source of foreign capital such as FDI rather than FIIs to provide stability to the Indian rupee exchange rate. Further even SEBI should formulate such stringent rules so that FIIs could not withdraw their capital during the times of adversity. Such actions by SEBI and government will provide strength to the Indian rupee exchange rate by holding its exchange rate within the tolerance levels. With respect to exports and trade openness, policies that are aimed at further integrating the Indian economy with the worldwide economy should be implemented. Moreover, the country's foreign exchange reserves position needs to be strengthened and retained at optimum as well as sustainable levels in order to mitigate the volatility of the currency.

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