Chapter V

Exchange Rate Volatility

CHAPTER V

EXCHANGE RATE VOLATILITY

5.1 INTRODUCTION

In the foreign exchange market, the currency exchange rate plays a predominant role for the traders, hedgers, investors and other players in the market who deal in the currency transaction worldwide. The currency exchange rate volatility is to be observed and analysed for the economic measures taken by the government. The presence of volatility in the exchange rate can be measured through the econometric tools to avoid the risk factor.

Volatility

Volatility refers to a high fluctuations in the exchange rate with unpredicted change and level of risk. It is the measurement of frequency change that occurs in the value of exchange rate from time to time. It is measured by the standard deviation reflecting the degree of fluctuations of the observed values from the mean (Krishna Murari, 2015). The financial time series data, namely, foreign exchange rates over a certain period of time show cases of volatility clustering. It means clustering of information for the specific period of time. The high volatility in the exchange rate would tend to have a high changes and low volatility leads to small changes in the value of exchange rate. Such extreme variations in exchange rates have significant effects on the foreign exchange markets and it can be examined with the exchange rate returns over a time period. In the exchange rate, it is also an essential aspect to evaluate the risk variations in the currency while analysing the volatility clustering. Hence, it is an essential aspect to study about the measurement of volatility in the exchange rate returns.

This chapter analyses the volatility of the four major currencies, namely, Indian rupee against US Dollar, Pound Sterling, Japanese Yen and Euro and the daily data for the study period from 2007-08 to 2016-17, with the 2413 days of daily observations have been taken i. e the days on which the trading took place have been considered. The daily data have been taken in this chapter to analyse the presence of volatility in the exchange rate. To identify the presence of volatility in the exchange rate, the econometric tools, such as, Unit root test (Augmented Dickey Fuller test and Phillips – Perron test), ARCH LM test and GARCH models have been applied.

In a time series data, to evaluate the volatility of foreign exchange rate, the returns of foreign exchange rate has been calculated which is essential for estimating and predicting the exchange rate volatility models. The daily exchange rate of return of Indian rupee against US Dollar, Pound Sterling, Japanese Yen and Euro is the first difference in natural logarithm of the exchange rate which can be calculated by following equation

$$R_t = \log (E_t / E_{t-1}) \qquad \_\_\_\_\_ (1)$$

Where,

R_t is the percentage of daily foreign exchange rate return of Indian Rupee against the foreign currency,

E_t - Current day of the exchange rate

E_{t-1} - Previous day exchange rate

The log difference of exchange rate is the returns of exchange rate i.e., for exchange rate of US dollar returns it is written as DLOGUSD in the study.

Descriptive statistics of daily exchange rate of Indian rupee

The Descriptive statistics of daily exchange rate of Indian rupee against US Dollar, Pound Sterling, Euro and Yen for the period 2007-08 to 2016-17 are given in table 5.1

Table 5.1

Descriptive statistics of Exchange rate

	USD	**GBP**	**EURO**	**YEN**
Mean	53. 53	84. 93	68. 94	54. 49
Median	52. 48	83. 08	68. 93	54. 92
Maximum	68. 77	106. 03	91. 47	72. 12
Minimum	39. 27	65. 65	54. 32	32. 69
Std. Dev.	9. 18	10. 42	7. 69	9. 25
Skewness	0. 13	0. 26	0. 26	-0. 65
Kurtosis	1. 61	1. 87	2. 59	3. 02
Jarque-Bera	199. 17	156. 16	44. 09	171. 43
Probability	0. 00	0. 00	0. 00	0. 00
Observations	2413	2413	2413	2413

Source: Computed.

Table 5.1 depicts the descriptive statistics of the daily exchange rate of an Indian rupee against US Dollar, Pound Sterling, Euro and Yen for the period from 2007-08 to 2016-17. The mean exchange rate of an Indian rupee against Pound Sterling is Rs.84.93, it has been found to be the highest among the currencies in the study, followed by Euro Rs.68.94, Yen Rs.54.49 and US Dollar Rs.53.53. The standard deviation of US Dollar, Pound Sterling, Euro and Yen are 9.18, 10.42, 7.69 and 9.25 respectively. The standard deviation of exchange rate of Pound Sterling has shown a large extent variation during the study period. The value of exchange rate of pounds has ranged from Rs.65.65 – Rs.106.03. Skewness is zero value in a normal distribution, positive and negative value of skewness with a data asymmetry. The exchange rate of US Dollar, Pound Sterling and Euro shows a positively skewed asymmetric data relative to normal distribution and exchange rate of Yen has negatively skewed in the study. Kurtosis is a measure of peakedness and flatness of normal distribution. The kurtosis values of all the currencies shows positive values resulting a playkurtic of normal distribution. Jarque –Bera test is a goodness-of –fit to test the normality of the series indicating the p-values of Jarque –Bera test is between 0 and 1. The Jarque bera test has shown higher values for all the currencies indicating that the data is not normally distributed.

Descriptive statistics of daily exchange rate return of Indian rupee

The Descriptive statistics of daily exchange rate return of an Indian rupee against US Dollar, Pound Sterling, Euro and Yen for the period 2007 - 08 to 2016 -17 are given in table 5.2. DLOGUSD, DLOGGBP, DLOGEURO, DLOGYEN denotes the exchange rate returns.

Table 5.2

Descriptive statistics of Exchange rate returns

	DLOGUSD	DLOGGBP	DLOGEURO	DLOGYEN
Mean	0. 01	0. 02	0. 03	0. 02
Median	0. 00	0. 00	0. 02	0. 00
Maximum	0. 04	0. 03	0. 04	0. 05
Minimum	-5. 03	-4. 06	-3. 03	-3. 04
Std. Dev.	0. 05	0. 07	0. 06	0. 01
Skewness	0. 18	-0. 74	0. 01	0. 16
Kurtosis	7. 48	10. 46	6. 04	5. 23
Jarque-Bera	2038. 38	5818. 22	932. 64	513. 16
Probability	0. 00	0. 00	0. 00	0. 00
Observations	2412	2412	2412	2412

Source: Computed.

Table 5.2 depicts the descriptive statistics of the daily exchange rate return series of an Indian rupee against US Dollar, Pound Sterling, Euro and Yen for the period from 2007-08 to 2016-17. The mean exchange rate return of Indian rupee against US Dollar, Pound Sterling, Euro and Yen are 0.0.1, 0.02, 0.03 and 0.02. The standard deviation of US Dollar, Pound Sterling, Euro and Yen are 0.05, 0.07, 0.06 and 0.01 respectively. The exchange rate returns of US Dollar, Euro and Yen have been positively skewed asymmetric data relative to normal distribution and exchange rate of Pound Sterling has been negatively skewed in the study. Kurtosis is a measure of peakedness and flatness of normal distribution. The kurtosis values of all the exchange rate return series shows a positive values resulting a leptokurtic, it results in the excess of normal distribution. Jarque –Bera test is a goodness-of –fit to test the normality of the series indicating the p-values of Jarque – Bera test is between 0 and 1. The Jarque bera test has shown higher values for all the currencies indicating that the data is not normally distributed

A visual plot of the data is usually the first step in the analysis of any time series data (Damodar N Gujarthi, 1995). From the graph of the time series data, the trend of the variable either moving upward and downward can be identified. It graphically shows the presence of volatility in the exchange rate.

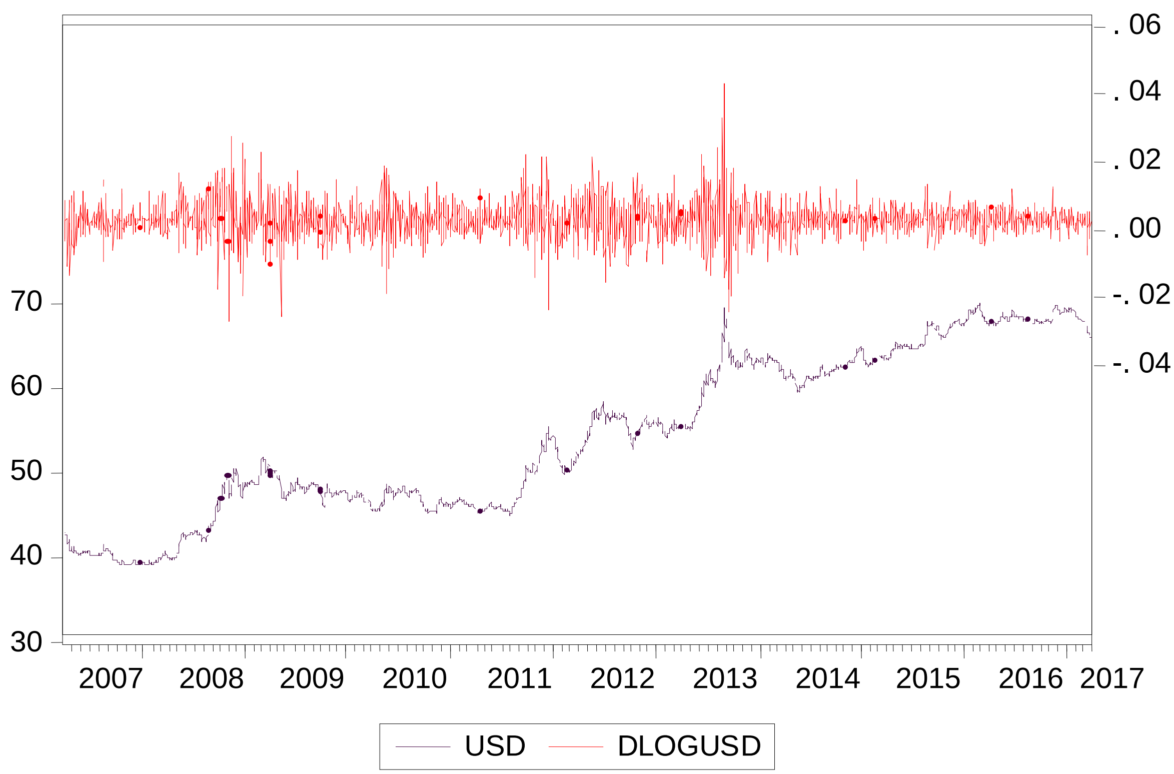
5.2 VOLATILITY OF EXCHANGE RATE OF INDIAN RUPEE AGAINST US DOLLAR

The volatility of Indian rupee against US dollar have been analysed for the daily data. First, the movement of Indian rupee against US dollar have been known through graph. Further, unit root test, ARCH-LM test and GARCH models have been done.

Movement of Indian rupee against US dollar

The graph 5.1 exhibits the movement of exchange rate of Indian rupee against US Dollar as well as the log differences of Indian rupee against US Dollar exchange rate have been plotted for the period 2007-08 to 2016-17, for ten years with the daily data. The log differences represent the returns, i.e., relative changes in the actual values.

Graph 5.1 Movement of Indian rupee against US dollar (USD) and D LOG USD



The Graph 5.1 shows that the Indian rupee has initially appreciated against the US dollar from 2007 with the value of Rs.39 against dollar. Due to global crisis in the economy an Indian currency has sharply depreciated from Rs.40 to Rs.45 per US$ during the year from 2008 to 2010, Gradually the currency has appreciated in the year 2010 and from the year 2011 to 2017 the rupee has shown a trend of depreciation with intermittent falls against the dollar rates till 2017. The rupee depreciated from Rs.47 to Rs.67 per US$. However, it is noticed from the jig-saw pattern of the series the appreciation/ depreciation is not stable. There may be presence of volatility in the exchange rates of Indian rupee against dollar. i.e, these changes are well captured in the log differences of the actual exchange rates. The swings in the daily returns continue for some time and it is said to be auto correlated. It refers to that today's rate is influenced by previous day's rate.

Unit root test

Unit root test is a test of time series data to verify whether the variable is stationary (Absence of unit root) or non stationary (Presence of unit root). A unit root test, tests whether the time series variable is non stationary and possesses unit root. The null hypothesis is generally defined as the presence of unit root test and the alternative hypothesis is either stationary or non stationary. Before proceeding analysis for times series data, it is necessary to prove the assumption of stationary of the variable. Generally, the time series data are non stationary and the results of non stationary data will be spurious. So, the unit root tests, such as, Augmented Dickey Fuller Test (ADF) and Phillips-Perron (PP) Test have been applied to verify whether the variable confirms to stationary or non stationary. Augmented Dickey fuller test and Phillip Perron test is the tests of time series data which is employed for large frequency of data that change from time to time. 't' statistic value is computed and compared with the relevant critical value and probability values to state the significance level. If the "t" statistic value has the more negative values, then the null hypothesis is rejected. So, the unit root test has been done to confirm the stationary of the exchange rate.

Unit root test for exchange rate of Indian rupee against US dollar for the period 2007-08 to 2016-17

Table 5.3 presents the Unit root test for exchange rate of India rupee against US dollar for the period 2007-08 to 2016-17. The following null and alternative hypotheses is framed to prove the assumption.

H_0: Exchange rate of an Indian rupee against US dollar has unit root test

H_1: Exchange rate of an Indian rupee against US dollar does not have unit root

Table 5.3

Augmented Dickey fuller test and Phillips –Perron test for exchange rate of India rupee against US dollar

Name of the variable	Levels	Augmented Dickey fuller test		Phillips – Perron test		S/NS
		t-statistics	p-values	t-statistics	p-values	
Exchange rate of Indian rupee against US dollar DLOGUSD	Level I(0)	-0. 786	0. 8222	-0. 830	0. 8096	NS
	First Difference I(1)	-48. 480	0. 0001	-48. 548	0. 0001	S

Source: Computed ** Significant at 1 per cent level

Table 5.3 depicts the t-statistics and p-values of unit root test by applying Augmented Dickey Fuller (ADF) test and Phillip Perron test for the exchange rate of an Indian rupee against US dollar series. It has been applied to determine the stationary of the series. It is found that at origin level, the t-statistic value (-0.786) and p value (0.8222) of Augmented Dickey Fuller test and the t-statistic value (-0.830) and the respective p value (0.8096) of Phillips Perron test were resulted non stationary at I(0). The result of exchange rate of an Indian rupee against US dollar series are not significant at 1 per cent level. The non stationary series cannot be used to proceed for further analysis. So, to make it stationary the first difference has been done. It is clear from the above table that at first difference the t-statistics of Augmented Dickey Fuller (ADF) test (-48.480) and

Phillip Perron test (-48.548) and their respective p-values (0.0001) become significant at 1 per cent level. Thus, exchange rate of an Indian rupee against US dollar are stationary at first difference with the order of I (1) and rejected the null hypothesis at 1 per cent level of significance and accepted the alternative hypothesis. It has indicated that exchange rate of Indian rupee against US dollar do not have unit root test. However, the exchange rate with stationarity may exhibit volatility clustering and implies that it can be estimated for model specification.

A simple measure of volatility is the variance of the time series data. But it does not show where the volatility is clustered, since the variance is unconditional i.e, the variance calculated over the entire period of the study. The variance does not capture the presence of volatility in the exchange rate returns on various time period. One such measure that observes volatility of the past values is known as Autoregressive Conditional Heteroscedasticity (ARCH) test. Generally, autocorrelations are found in the time series data. In a high frequency data like exchange rate of returns, there is a presence of autocorrelation and heteroscedasticity which indicates large variation and small variation from one period to another period. It means that the variation in current day's exchange rate is influenced by previous day's exchange rate. Heteroscedasticity (i.e., variances which are time variant) at different time periods shows how the values are autocorrelated.

Engle developed Autoregressive Conditional Heteroscedasticity (ARCH) for the time series data to capture the autocorrelation. The stationarity test is necessary before estimating the volatility models ARCH and GARCH models. The extension form of ARCH model is GARCH- (Generalized Autoregressive Conditional Heteroscedasticity). The GARCH model at lag 1 (i.e time period) can be given as

$$\sigma^2_t = \lambda_0 + \lambda_1 \mu^2_{t-1} + \lambda_2 \sigma 2_{t-1} \qquad \text{\_\_\_\_(1)}$$

The error variance at time t is dependent on the residual term at time t-1 as well as error variance at time t-1. GARCH (1,1) model (1,1) refers to the Autoregressive order 1 and Moving Average order 1. However, if the model exhibit homoscedasticity, which denotes unconditional variance, then volatility cannot be estimated in the exchange rate. Before modelling the exchange rate volatility it is necessary to test the heteroscedasticity.

Test of heteroscedasticity is done for the estimated residuals obtained from ARMA (Autoregressive Moving Average) of order 1 and then the presence of heteroscedasticity in residuals is tested. ARMA (Autoregressive Moving Average) is a model which considers the past values i.e., the autoregressive component and on the earlier residual values which is the moving average (Shanmugasundaram, 2012). The following is the ARMA of order (1,1) used to estimate the residuals.

$$\mathbf{Y_{t} = \theta + \varphi_1 Y_{t-1} + \pi_0 \in_t + \pi_1 \in_{t-1}} \qquad \text{\_\_\_\_(2)}$$

Where, θ is the constant term

π_0 and π_1 are residual coefficients

Y_{t-1} is the lagged dependent variable

φ_1 is the regression coefficient

$\in_t$ is the residual term and

$\in_{t-1}$ is the previous values of the residual

HETEROSCEDASTICITY TEST

ARCH-LM (Lagrange Multiplier- Autoregressive Conditional Heteroscedasticity) test developed by Engle was used to test the ARCH effect in the exchange rate. In forecasting the financial time series data there will be presence of autocorrelation and heteroscedasticity in the exchange rate. The presence of heteroscedasticity has been tested in the exchange rate by applying ARCH – LM test. The ARCH and GARCH models have been applied for estimating the volatility of exchange rate.

ARCH – LM Results of Exchange rate of Indian rupee against US dollar during the period 2007-08 to 2016-17

Table 5.4 shows the ARCH – LM results of Exchange rate of Indian rupee against US dollar during the period 2007- 08 to 2016 - 17. The results of the ARCH-LM test is given below and respective null hypothesis have been framed

H_0: There is no presence of heteroscedasticity in the exchange rate of Indian rupee against US dollar.

Table 5.4

ARCH – LM Results of Exchange rate of Indian rupee against US dollar

Heteroscedasticity Test: ARCH -LM			
F-statistic	117.5035	**Prob.F (1,2408)**	0.0000
Obs*R-squared	112.1295	**Prob.Chi-Square (1)**	0.0000

Source: Computed

The table 5.4 shows the Heteroscedasticity test for the exchange rate of INR/USD. The F-statistic and the chi-square values show that both the tests are significant at 1 per cent level thus confirming the presence of ARCH at lag1. The result of the study indicates that the dollar exchange rate returns have presence of ARCH effect. Hence, the null hypothesis is rejected.

Since, there is a presence of heteroscedasticity in the exchange rate, the GARCH model has been estimated and applied using the above equation (2) to analyse the exchange rate volatility.

GARCH model

GARCH (Generalised Autoregressive Conditional Heteroscedasticity) model is the symmetric model has been applied to measure the volatility of the currencies. In GARCH model, the sum of the coefficient values ($\alpha + \beta$) helps to measure the presence of volatility in the exchange rate to verify whether the present value of exchange rate is volatile for the previous day's shock.

GARCH models for exchange rate of Indian rupee against US dollar

The GARCH (1, 1) and GARCH (2,1) model have been estimated for the exchange rate of Indian rupee against US dollar were presented in table 5.5 and 5.6

Table 5.5

GARCH (1, 1) model for exchange rate of Indian rupee against US dollar

Estimation of GARCH (1,1) model				
Variable	**Coefficient**	**Std.error**	**z- statistic**	**Probability**
Exchange rate of Indian rupee against US dollar				
Constant	6.49E-07	9.67E-08	6.705613	0.0000
ARCH Effect α_1	0.149681	0.013090	11.43506	0.0000
GARCH Effect β_1	0.830888	0.013186	63.01440	0.0000
$\alpha_i + \beta_j$	0.980569			

Source: Computed.

Residual diagnostics test : ARCH LM test			
F-statistic	6.060494	**Prob. F(1,2408)**	0.0139
Obs*R-squared	6.050304	**Prob. Chi-Square(1)**	0.0139

Source: Computed.

The table 5.5 shows the results of the GARCH (1,1) model which has been applied to estimate the volatility of the dollar exchange rate returns (log difference of the USD series) for the period from 2007-08 to 2016-17. The result shows that both the ARCH effect ($\alpha 1$) and the GARCH ($\beta 1$) effect are significant at 1 per cent level for GARCH (1,1) model. Further, the heteroscedasticity test (ARCH-LM test) has been conducted which shows the presence of ARCH effect in the residual of the GARCH (1,1) model. The residual diagnostics test, namely, ARCH-LM test run for the residual of GARCH (1,1) found that the (F-statistic is 6.060494) and the chi-square statistic (Obs * R-squares - 6.050304). Both are significant at 5 per cent level which shows the presence of ARCH in the residuals.

Due to the presence of heteroscedasticity in the residuals of exchange rate, GARCH (2,1) model was estimated and consequently the residuals were tested for further ARCH effect using ARCH-LM Test. GARCH(2,1) model has been estimated for the exchange rate of Indian rupee against US dollar.

Table 5.6 presents the estimation results of GARCH (2,1) for exchange rate of Indian rupee against US dollar. Further, the heteroscedasticity test (ARCH-LM test) has been conducted to show the presence of ARCH effect in the residual series of the GARCH(2,1) model.

Table 5.6

GARCH (2,1) model for exchange rate of Indian rupee against US dollar

Estimation of GARCH (2,1) model				
Variable	**Coefficient**	**Std. error**	**z- statistic**	**Probability**
Exchange rate of Indian rupee against US dollar				
Constant	2.86E-07	6.09E-08	4.699262	0.0000
ARCH Effect α_1	0.217390	0.028596	7.602017	0.0000
ARCH Effect α_2	-0.123793	0.029065	-4.259223	0.0000
GARCH Effect β_1	0.898533	0.010989	81.76584	0.0000
$\alpha_i + \beta_j$	0.99213			

Source: Computed.

Residual diagnostics test: ARCH LM test			
F-statistic	0.216569	**Prob. F (1,2409)**	0.6417
Obs*R-squared	0.216730	**Prob. Chi-Square (1)**	0.6415

Source: Computed.

Table 5.6 depicts the results of GARCH (2,1) model for the exchange rate of Indian rupee against US dollar. GARCH (2,1) model which was estimated and consequently the residuals were tested for further ARCH effect using ARCH-LM Test in the exchange rate. It shows that the (F-statistic is 0.216569) and Chi-square test (Obs *

R-squares- 0.216730) and their P-values are not statistically significant. This shows that the GARCH (2,1) model does not have heteroscedasticity in the residual series.

The coefficients given in the GARCH (1,1) and GARCH (2,1) models are the ARCH term (α) and GARCH term (β). The sum of the persistent coefficients (αi + βj) are near to one for the series which shows that the shocks to the conditional variance are highly persistent and volatile. It is also inferred from the results that the volatility clustering is implied in exchange rate return series.

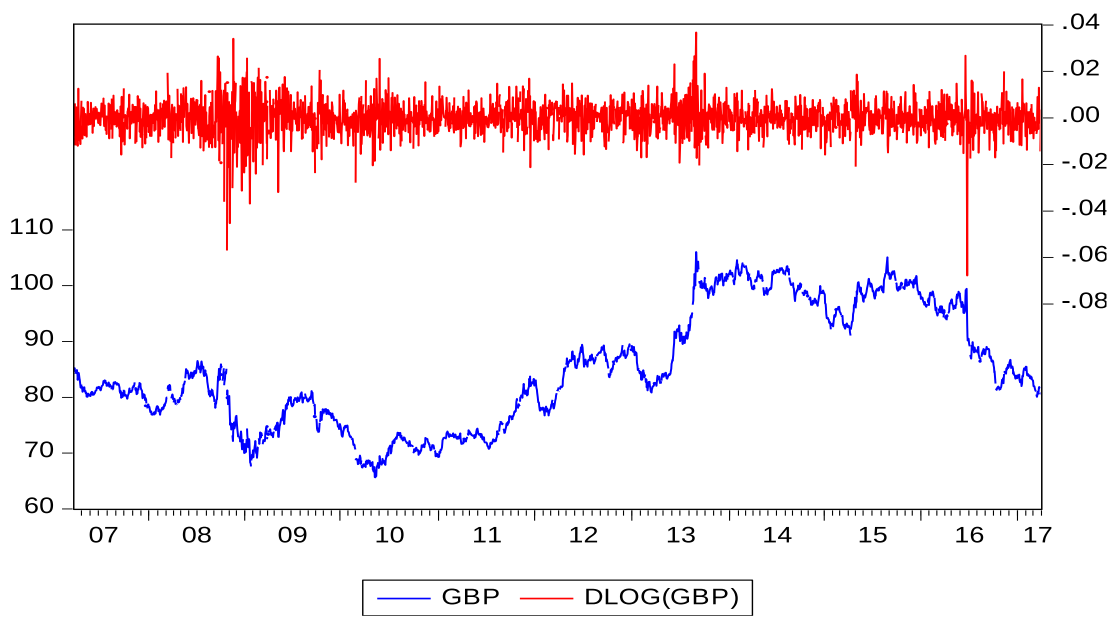
5.3 VOLATILITY OF EXCHANGE RATE OF INDIAN RUPEE AGAINST POUNDS STERLING

The volatility of Indian rupee against Pounds sterling have been analysed for the daily data. First, the movement of Indian rupee against Pounds sterling have been known through graph. Further, unit root test, ARCH-LM test and GARCH models have been done.

Movement of Indian rupee against Pound sterling

The figure given below exhibits the movement of exchange rate of Indian rupee against Pounds sterling as well as the log differences of Indian rupee against Pounds sterling exchange rate were plotted for the period 2007-08 to 2016-17, for ten years with the daily data. The log differences represent the returns, i.e., relative changes in the actual values.

Graph 5.2 Movement of Indian rupee against Pound sterling (GBP) and D LOG GBP



The Graph 5.2 shows that the Indian rupee has initially appreciated against the Pound Sterling from 2007 to 2011. It has appreciated from Rs.80 to Rs.70.Then steadily the currency rupee tends to depreciate against pounds sterling from the year 2012 - 2016. It has depreciated form Rs.85 to Rs.98. There may be presence of volatility in the exchange rates of Indian rupee against pounds. i.e, these changes are well captured in the log differences of the actual exchange rates. At the end of the year rupee has appreciated against pounds by Rs.87 per pounds sterling. The swings in the daily returns continue for some time and it is said to be autocorrelated. It refers to that today's rate is influenced by previous day's rate

Unit root test for exchange rate of India rupee against GBP for the sample period 2007-08 to 2016-17

Table 5.7 depicts the Unit root test for exchange rate of India rupee against Pound sterling. The following null and alternative hypotheses is framed to prove the assumption

H_0: Exchange rate of an Indian rupee against Pound sterling has unit root test

H_1: Exchange rate of an Indian rupee against Pound sterling does not have unit root

Table 5.7

Augmented Dickey fuller test and Phillips –Perron test for exchange rate of Indian rupee against Pounds Sterling

Name of the variable	Levels	Augmented Dickey fuller test		Phillips –Perron test		S/NS
		t-statistics	p-values	t-statistics	p-values	
Exchange rate of Indian rupee against Pound sterling DLOGGBP	Level I(0)	-1.456	0.5556	-1.470	0.5486	NS
	First Difference I(1)	-47.874	0.0001	-47.861	0.0001	S

Source: Computed ** Significant at 1 per cent level

Table 5.7 shows the t-statistics and p-values of unit root test by using Augmented Dickey Fuller (ADF) test and Phillip Perron test for the exchange rate of Indian rupee against Pound sterling series. It has been applied to determine the stationary of the series. It is found that at origin level the t-statistic value (-1.456) and p value (0.5556) of Augmented Dickey Fuller test and t-statistic value (-1.470) and p value (0.5486) of Phillips Perron test are not significant resulting non stationary at level I(0). The result of exchange rate of Indian rupee against Pound sterling series are not significant at 1 per cent level. The non stationary series cannot be used to proceed for further analysis. So to make it stationary the first difference has been done. It is clear from the above table that the t-statistics value of augmented dickey fuller test (-47.874) and phillip perron test (-47.861) and the p-values (0.0001) become significant at 1 per cent level. Thus, exchange rate of Indian rupee against Pound sterling are stationary at first difference with the order of I(1) rejected the null hypothesis and accepted the alternative hypothesis. Thus, the series with stationarity may also exhibit volatility clustering that the residual variances.

ARCH –LM Results of Exchange rate of Indian rupee against Pound sterling during the period 2007-08 to 2016-17

Based on the equation (1) and (2) given above the test of heteroscedasticity test and GARCH models have been estimated. The results are given in table 5.8 and respective null hypothesis have been framed

H_0: There is no presence of heteroscedasticity in the exchange rate of Indian rupee against Pound sterling.

Table 5.8

ARCH –LM Results of Exchange rate of Indian rupee against Pound sterling

Heteroscedasticity Test: ARCH LM test			
F-satistic	23.29398	**Prob.F(1,2408)**	0.0000
Obs*R-squared	23.08996	**Prob.Chi-Square(1)**	0.0000

Source: Computed.

Table 5.8 shows the Heteroscedasticity test for the exchange rate INR/GBP. The (F-statistic -23.29398) and the chi-square (Obs*R-squared - 23.08996) are the values show that both the tests are significant at 1 per cent level thus confirming the presence of ARCH at lag1.The result indicates that the exchange rate returns of GBP have the presence of ARCH. Hence, the null hypothesis is rejected.

Since there is a presence of heteroscedasticity in the exchange rate, the GARCH model has been estimated and applied using the above equation (2) to analyse the volatility

GARCH models for exchange rate of Indian rupee against Pound sterling

The results of GARCH (1, 1) and GARCH (2, 1) model for exchange rate of Indian rupee against GBP have been estimated and presented in table 5.9 and 5.10

Table 5.9

GARCH (1,1) model for exchange rate of Indian rupee against Pound sterling

Estimation of GARCH (1,1) model				
Variable	**Coefficient**	**Std.error**	**z- statistic**	**Probability**
Exchange rate of Indian rupee against Pound sterling				
Constant	1.38E-06	2.59E-07	5.325527	0.0000
ARCH Effect $\boldsymbol{\alpha_1}$	0.083546	0.006798	12.28930	0.0000
GARCH Effect $\boldsymbol{\beta_1}$	0.888664	0.010679	83.21464	0.0000
$\boldsymbol{\alpha_i + \beta_j}$	0.97221			

Source: Computed.

Residual diagnostics test : ARCH LM test			
F-statistic	1.618775	**Prob. F (1,2409)**	0.2034
Obs*R-squared	1.619031	**Prob. Chi-Square (1)**	0.2032

Source: Computed.

The table 5.9 shows the GARCH (1,1) model which estimate the volatility of the Pound sterling exchange rate returns (log difference of the Pound sterling series) for the period from 2007-08 to 2016-17. From the table it can be seen that both the ARCH effect

(α_1) and the GARCH (β_1) effect are significant at 1 per cent level for GARCH (1,1) model. Thus, the heteroscedasticity test (ARCH-LM test) was conducted to show the presence of ARCH effect in the residual of the GARCH (1,1) model. The residual diagnostics test namely ARCH-LM test run for the residual of GARCH (1,1) found that the (F-statistic - 1.618775) and the chi-square statistic (Obs * R-squares - 1.619031). Both are significant at 5 per cent level which shows the presence of ARCH in the residuals.

Due to the presence of heteroscedasticity in the residuals of exchange rate Indian rupee against Pound sterling, GARCH (2,1) model was estimated and consequently the residuals were tested for further ARCH effect using ARCH-LM Test. GARCH(2,1) model has been estimated for the exchange rate of Indian rupee against GBP.

Table 5.10 presents the estimation results of GARCH (2,1) for exchange rate of Indian rupee against Pound sterling. Further, the heteroscedasticity test (ARCH-LM test) has been applied shows the presence of ARCH effect in the residual of the GARCH (2,1) model.

Table 5.10

GARCH (2,1) model for exchange rate of Indian rupee against Pound sterling

Estimation of GARCH (2,1) model				
Variable	**Coefficient**	**Std.error**	**z- statistic**	**Probability**
Exchange rate of Indian rupee against Pound sterling				
Constant	1.67E-06	3.03E-07	5.515501	0.0000
ARCH Effect $\alpha 1$	0.028037	0.020343	1.378166	0.1682
ARCH Effect $\alpha 2$	0.066311	0.019309	3.434283	0.0006
GARCH Effect $\beta 1$	0.871541	0.012194	71.47296	0.0000
αi+ βj	0.965889			

Source: Computed

Residual diagnostics test: ARCH LM test			
F-statistic	0.002143	**Prob.F (1,2409)**	0.9631
Obs*R-squared	0.002145	**Prob.Chi-Square(1)**	0.9631

Source: Computed

Table 5.10 shows the results of GARCH (2,1) model for the exchange rate of Indian rupee against pounds sterling. GARCH (2,1) model which was estimated and consequently the residuals were tested for further ARCH effect using ARCH-LM Test in the exchange rate. It shows that the (F-statistic 0.002143) and Chi-square test statistic (Obs*R-squared 0.002145) are statistically not significant. This shows that the GARCH (2,1) model have do not have the presence of heteroscedasticity in the residual series.

The coefficients given in the GARCH (1,1) and GARCH (2,1) models are the ARCH term (α) and GARCH term (β).The sum of the persistent coefficients (αi + βj) are near to one for the series which shows that the shocks to the conditional variance are highly persistent and volatile. The results have inferred that there is presence of volatility clustering is the exchange rate return series of Pound sterling.

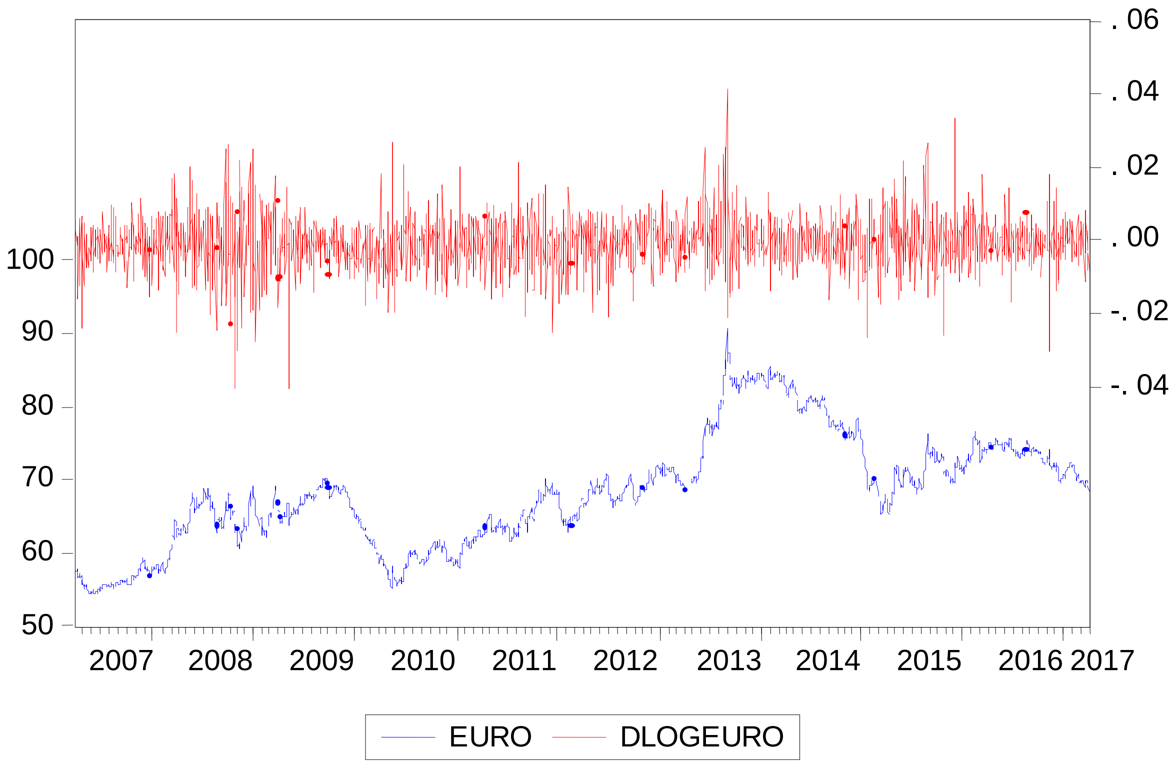
5.4 VOLATILITY OF EXCHANGE RATE OF INDIAN RUPEE AGAINST EURO

The volatility of Indian rupee against Euro have been analysed for the daily data. First, the movement of Indian rupee Euro have been known through graph. Further, unit root test, ARCH-LM test and GARCH models have been done.

Movement of Indian rupee against Euro

The graph 5.3 exhibits the movement of exchange rate of Indian rupee against Euro as well as the log differences of Euro have been plotted for the period 2007-08 to 2016-17, for ten years with the daily data. The log differences represent the returns, i.e., relative changes in the actual values.

Graph 5.3 Movement of Indian rupee against Euro and D LOG EURO



The Graph 5.3 shows the movement of Indian rupee against Euro. It could be seen that the Indian rupee has initially appreciated against Euro from the year 2007. It stood at Rs.57 per Euro. Due to global crisis in the economy an Indian currency has sharply depreciated from Rs.64 to Rs.67 per Euro during the year from 2008 to 2010. There was appreciation in the Indian currency in the year 2010. From the year 2011 the rupee has shown a trend of depreciation till the year 2014 -15 by Rs.77 per Euro. From the middle of the year 2014-15 till 2015-16 the rupee has appreciated to Rs.72 per euro. In the year 2016-17 the rupee depreciated to Rs.73 per euro. This indicates that there exist the presence of volatility clustering and autocorrelation in the Indian rupee against Euro.

Unit root test for exchange rate of Indian rupee against Euro for the sample period 2007-08 to 2016-17

Table 5.11 portrays the Unit root test for exchange rate of India rupee against euro. The following null hypotheses is framed to prove the assumption

H_0 : Exchange rate of an Indian rupee against Euro has unit root test

H_1 : Exchange rate of an Indian rupee against Euro does not have unit root

Table 5.11

Augmented Dickey fuller test and Phillips –Perron test for exchange rate of India rupee against Euro

Name of the variable	**Levels**	**Augmented Dickey fuller test**		**Phillips – Perron test**		**S/NS**
		t-statistics	**p-values**	**t-statistics**	**p-values**	
Exchange rate of Indian rupee against euro DLOGEURO	Level I(0)	-1.110	0.7137	-1.159	0.6938	NS
	First Difference I(1)	-47.878	0.0001	-47.886	0.0001	S

Source: Computed ** significant at 1 per cent level

Table 5.11 depicts the t-statistics and p-values of unit root test by using Augmented Dickey Fuller (ADF) test and Phillip Perron test for the exchange rate of Indian rupee against US dollar series. It has been applied to determine the stationary of the series. It is found that at origin level the t-statistic value (-1.110) and p value (0.7137) of Augmented Dickey Fuller test and t-statistic value (-1.159) and p value (0.6938) of Phillips Perron test which shows their p values are not significant resulting non stationary at I(0). The non stationary series cannot be used to proceed for further analysis. So to make it stationary the first difference has been done. It is clear from the above table that the t-statistics value of Augmented Dickey Fuller test (-47.878) and Phillip Perron test (-47.886) and their p-values (0.0001) become significant at 1 per cent level. Thus, exchange rate of Indian rupee against Euro are stationary at first difference with the order of I(1) rejected the null hypothesis at 1 per cent level of significance and accepted the alternative hypothesis. However, the series with stationarity may also exhibit volatility clustering that the residual variances.

ARCH – LM Results of Exchange rate of Indian rupee against Euro during the period 2007-08 to 2016-17

Based on the equation (1) and (2) given above the test of heteroscedasticity test and GARCH models have been estimated. The results are given in table 5.12 and respective null hypothesis have been framed

H_0: There is no presence of heteroscedasticity in the exchange rate of Indian rupee against Euro.

Table 5.12

ARCH –LM Results of Exchange rate of Indian rupee against Euro

Heteroscedasticity Test: ARCH			
F-statistic	63.31969	**Prob.F(1,2408)**	0.0000
Obs*R-squared	61.74856	**Prob.Chi-Square(1)**	0.0000

Source: Computed

Table 5.12 shows the Heteroscedasticity test for the exchange rate INR/EURO. The F-statistic and the chi-square values show that both the tests are significant at 1 per cent level thus confirming the presence of ARCH at lag1. The result indicates that the euro exchange rate returns have the presence of ARCH. Hence, the null hypothesis is rejected.

Since there is a presence of heteroscedasticity in the exchange rate, the GARCH model has been estimated and applied using the above equation (2) to analyse the volatility.

GARCH models for the exchange rate of Indian rupee against Euro

The estimation results of GARCH (1, 1) and GARCH (2,1) model for exchange rate of Indian rupee against Euro have been estimated and presented in table 5.13 and 5.14.

Table 5.13

GARCH (1, 1) model for exchange rate of Indian rupee against Euro

Estimation of GARCH (1,1) model				
Variable	**Coefficient**	**Std.error**	**z- statistic**	**Probability**
Exchange rate of Indian rupee against Euro				
Constant	7.82E-07	1.49E-07	5.241196	0.0000
ARCH Effect $\alpha 1$	0.056254	0.004989	11.27499	0.0000
GARCH Effect $\beta 1$	0.927461	0.005630	164.7337	0.0000
αi+ βj	0.983715			

Source: Computed

Residual diagnostics test: ARCH LM test			
F-statistic	4.486144	**Prob.F(1,2408)**	0.0343
Obs*R-squared	4.481523	**Prob.Chi-Square(1)**	0.0343

Source: Computed

The table 5.13 shows the GARCH (1,1) and GARCH(2,1) results which estimate the volatility of the Euro exchange rate returns (log difference of the EURO series) for the period from 2007-08 to 2016-17. From the table it is observed that the ARCH effect ($\alpha 1$) and the GARCH ($\beta 1$) effect are significant at 1 per cent level for GARCH (1,1) model. Further, the heteroscedasticity test (ARCH-LM test) conducted shows the presence of ARCH effect in the residual of the GARCH (1,1) model. The residual diagnostics test namely ARCH-LM test run for the residual of GARCH (1,1) found that the (F-statistic - 4.486144) and the chi-square statistic (Obs * R-squares - 4.481523). Both are significant at 5 per cent level which shows the presence of ARCH in the residuals.

Due to the presence of heteroscedasticity in the residuals of exchange rate, GARCH (2,1) model was estimated and consequently the residuals were tested for further

ARCH effect using ARCH-LM Test. GARCH (2,1) model have been estimated for the exchange rate of Indian rupee against Euro.

Table 5.14 depicts the estimation results of GARCH (2,1) for exchange rate of Indian rupee against Euro. Further, the heteroscedasticity test (ARCH-LM test) conducted shows the presence of ARCH effect in the residual of the GARCH (2,1) model.

Table 5.14

GARCH (2,1) model for exchange rate of Indian rupee against Euro

Estimation of GARCH (2,1) model				
Variable	**Coefficient**	**Std.error**	**z- statistic**	**Probability**
Exchange rate of Indian rupee against Euro				
Constant	5.47E-07	1.19E-07	4.592603	0.0000
ARCH Effect $\alpha 1$	0.132725	0.018720	7.090137	0.0000
ARCH Effect $\alpha 2$	-0.090182	0.019638	-4.592173	0.0000
GARCH Effect $\beta 1$	0.945949	0.005873	161.0583	0.0000
αi+ βj	0.988492			

Source: Computed

Residual diagnostics test: ARCH LM test			
F-statistic	0.002178	**Prob.F(1,2409)**	0.9628
Obs*R-squared	0.002180	**Prob.Chi-Square(1)**	0.9628

Source: Computed

Table 5.14 shows the results of GARCH (2,1) model for the exchange rate of Indian rupee against Euro. GARCH (2,1) model which was estimated and consequently the residuals were tested for further ARCH effect using ARCH-LM Test in the exchange rate. It shows that the (F-statistic - 0.002178) and (Chi-square test value - 0.002180) both the p values are not statistically significant. This shows that the GARCH (2,1) model does not have a heteroscedasticity in the residual series.

The coefficients given in the GARCH (1,1) and GARCH (2,1) models are the ARCH term (α) and GARCH term (β). The sum of the persistent coefficients ($\alpha i + \beta j$) are near to one for the series which shows that the shocks to the conditional variance are highly persistent and volatile. The results have inferred that there is presence of volatility clustering is the exchange rate return series of euro.

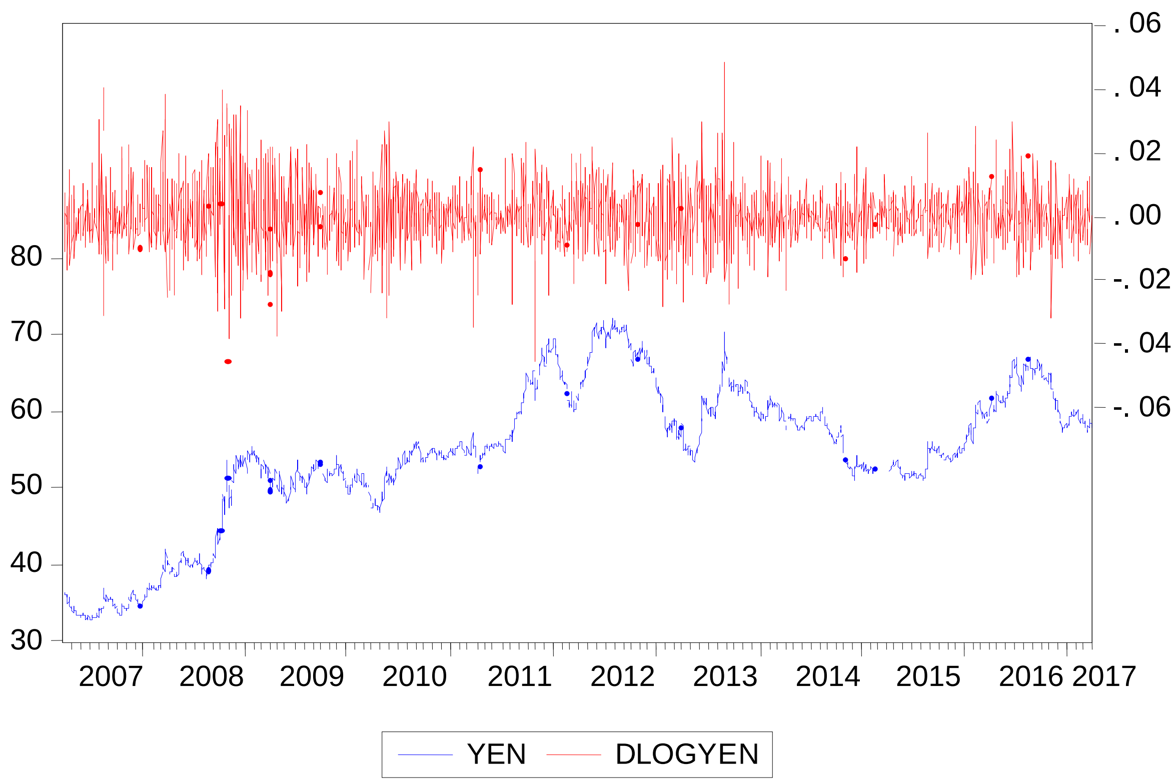
5.4 VOLATILITY OF EXCHANGE RATE OF INDIAN RUPEE AGAINST YEN

The volatility of Indian rupee against Yen have been analysed for the daily data. First, the movement of Indian rupee against Yen have been known through graph. Further, unit root test, ARCH-LM test and GARCH models have been done.

Movement of Indian rupee against Yen

The graph 5.4 given below exhibits the movement of exchange rate of Yen as well as the log differences of Yen were plotted for the period 2007-08 to 2016-17, for ten years with the daily data. The log differences represent the returns, i.e., relative changes in the actual values.

Graph 5.4 Movement of Indian rupee against Yen and D LOG Yen



The Graph 5.4 shows that the Indian rupee has appreciated by Rs.35 against the Yen in the year 2007 and from the year 2008 Indian currency has sharply depreciated from 2008 to 2013. However, rupee tends to depreciate against Yen it depreciated from Rs.46 to Rs.64 per Yen. In the middle of the year 2013-14 the rupee appreciated from Rs.60 to Rs.54 per Yen till the year 2015-16. At the end of the year 2016-17 the rupee has depreciated by Rs.62. This appreciation and depreciation indicates that there may be presence of volatility in the exchange rates of Indian rupee against Yen. i.e, these changes are well captured in the log differences of the actual exchange rates.

Unit root test for exchange rate of India rupee against Yen for the sample period 2007-08 to 2016-17

Table 5.15 presents the Unit root test for exchange rate of India rupee against Yen. The following null hypotheses is framed to prove the assumption

H_0: Exchange rate of an Indian rupee against Yen has unit root test

H_1: Exchange rate of an Indian rupee against Yen does not have unit root

Table 5.15

Augmented Dickey fuller test and Phillips – Perron test for exchange rate of India rupee against Yen

Name of the variable	Levels	Augmented Dickey fuller test		Phillips – Perron test		S/NS
		t-statistics	p-values	t-statistics	p-values	
Exchange rate of Indian rupee against Yen DLOGYEN	Level I(0)	-0.395	0.9076	-0.287	0.9243	NS
	First Difference I(1)	-50.069	0.0001	-50.135	0.0001	S

Source: Computed.

Table 5.15 depicts the t-statistics and p-values of unit root test by using Augmented Dickey Fuller (ADF) test and Phillip Perron test for the exchange rate of Indian rupee against Yen. It has been applied to determine the stationary of the series.

It is found that at origin level the t-statistic value (-0.395) and p value (0.9076) of Augmented Dickey Fuller test and t-statistic value (-0.287) and p values (0.9243) of Phillips Perron test are not significant resulting non stationary at I(0). So to make it stationary the first difference has been done. It is clear from the above table that the t-statistics at first difference with the two test, the t –statistic of Augmented Dickey Fuller test (-50.069) and Phillip Perron test (-50.135) and the p-values (0.0001) become significant at 1 per cent level. Thus, exchange rate of Indian rupee against Yen are stationary at first difference with the order of I(1) rejected the null hypothesis at 1 per cent level of significance and accepted the alternative hypothesis. However, the series with stationarity may also exhibit volatility clustering that the residual variances.

ARCH – LM Results of Exchange rate of Indian rupee against Yen during the period 2007-08 to 2016-17

Based on the equation (1) and (2) given above the test of heteroscedasticity test and GARCH models have been estimated. The results are given in table 5.16 and respective null hypothesis have been framed

H_0: There is no presence of heteroscedasticity in the exchange rate of Indian rupee against Yen.

Table 5.16

ARCH –LM Results of Exchange rate of Indian rupee against Yen

Heteroscedasticity Test: ARCH LM test			
F-statistic	139.9583	**Prob.F(1,2408)**	0.0000
Obs*R-squared	132.3803	**Prob.Chi-Square(1)**	0.0000

Source: Computed

The table 5.16 shows the Heteroscedasticity test for the exchange rate of **Indian** rupee against Yen. The F-statistic and the chi-square statistic show that both the tests are significant at 1 per cent level thus confirming the presence of ARCH at lag1. It is inferred that the exchange rate returns of Indian rupee against yen have presence of ARCH. Hence the null hypothesis is rejected.

Since there is a presence of heteroscedasticity in the exchange rate, the GARCH model has been estimated and applied using the above equation (2) to analyse the volatility.

GARCH models for the exchange rate of Indian rupee against Yen

The estimation results of GARCH (1, 1) and GARCH (2,1) model for exchange rate of Indian rupee against Yen have been estimated and presented in table 5.17 and 5.18

Table 5.17

GARCH (1, 1) model for exchange rate of Indian rupee against Yen

Estimation of GARCH (1,1) model				
Variable	**Coefficient**	**Std.error**	**z- statistic**	**Probability**
Exchange rate of Indian rupee against Yen				
Constant	2.48E-06	4.21E-07	5.902302	0.0000
ARCH Effect $\alpha 1$	0.112148	0.010710	10.47101	0.0000
GARCH Effect $\beta 1$	0.861253	0.012406	69.41986	0.0000
αi+ βj	0.973401			

Source: Computed.

Residual diagnostics test: ARCH LM test			
F-statistic	5.669095	**Prob. F (1,2409)**	0.0173
Obs*R-squared	5.660481	**Prob. Chi-Square(1)**	0.0174

Source: Computed

It is evident from the table 5.17 it shows the GARCH (1,1) results which estimate the volatility of the Yen exchange rate returns (log difference of the YEN series) for the period from 2007-08 to 2016-17. From the table it can be seen both the ARCH effect ($\alpha 1$) and the GARCH ($\beta 1$) effect are significant at 1 per cent level for GARCH (1,1) model. Further, the heteroscedasticity test (ARCH-LM test) conducted shows that the presence of ARCH effect in the residual of the GARCH (1,1) model. The residual diagnostics test namely ARCH-LM test run for the residual of GARCH (1,1) found that the (F-statistic is 5.669095) and the chi-square statistic (Obs* R-Square) is 5.660481 both are significant at 5 per cent level which shows the presence of ARCH in the residuals.

Due to the presence of heteroscedasticity in the residuals of exchange rate. Hence, GARCH (2,1) model was estimated and consequently the residuals were tested for further ARCH effect using ARCH-LM Test. GARCH(2,1) model have been estimated for the exchange rate of Indian rupee against Yen.

Table 5.18 presents the estimation results of GARCH (2,1) for exchange rate of Indian rupee against Yen. Further, the heteroscedasticity test (ARCH-LM test) conducted shows that the presence of ARCH effect in the residual of the GARCH (2,1) model.

Table 5.18

GARCH (2,1) model for exchange rate of Indian rupee against Yen.

Estimation of GARCH (2,1) model				
Variable	**Coefficient**	**Std.error**	**z- statistic**	**Probability**
Exchange rate of Indian rupee against Yen				
Constant	0.188509	0.020844	9.043713	0.0000
ARCH Effect $\alpha 1$	-0.109381	0.022232	-4.920069	0.0000
ARCH Effect $\alpha 2$	0.904823	0.012686	71.32610	0.0000
GARCH Effect $\beta 1$	0.188509	0.020844	9.043713	0.0000
α**i+ βj**	0.983951			

Source: Computed.

Residual diagnostics test: ARCH LM test			
F-statistic	0.141364	**Prob. F (1,2409)**	0.7070
Obs*R-squared	0.141474	**Prob. Chi-Square(1)**	0.7068

Source: Computed.

Table 5.18 shows the results of GARCH (2,1) model for the exchange rate of Indian rupee against Yen. GARCH (2,1) model which was estimated and consequently the residuals were tested for further ARCH effect using ARCH-LM Test in the exchange rate. It shows that the (F-statistic 0.141364) and Chi-square test statistic (Obs*R-Square 0.141474) both showing statistically not significant. This shows that the GARCH (2,1) model does not have heteroscedasticity in the residual series.

The coefficients given in the GARCH (1,1) and GARCH (2,1) models are the ARCH term (α) and GARCH term (β). The sum of the persistent coefficients (αi + βj) are near to one for the series which shows that the shocks to the conditional variance are highly persistent and volatile. It is inferred from the results that the volatility clustering is implied in exchange rate return series.

5.4 CONCLUSION

This chapter has concluded that there exist a presence of volatility clustering in the exchange rate and its returns. It is clearly depicts that there is greater persistence of exchange rate volatility in the Indian currency for the external shocks in the economy. The extreme variation in the currency indicates that, the current day's exchange rate is affected by previous day's exchange rate. Indian rupee has shown higher volatility against foreign currencies for the study period. The GARCH (2,1) is the best fit model to measure the volatility of the currency in the foreign exchange market, which would be helpful for the investors and policy makers to know how the exchange rate is volatile for the external shocks in the economy.