Post-Financial Crisis Rupee-Euro Volatility

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European countries underwent economic consolidation and a monetary union was established in 1999 which came into full force in 2002, composed of 28EU member states using euro after DM phasing out and are key trade partners. This paper examines and draws statistical inferences for Rupee Euro volatility since 1st April 2008 till 31st March 2016. It studies the impact of global financial crisis that stimulated volatility in this currency pair. ARCH models have been used to model financial time series with time-varying volatility post recession. This paper helps exporters and importers to plan, predict & hedge their currency volatility risk.

Keywords: Indian National Rupee, Euro, Recession, Volatility, ARCH GARCH Model

1. Introduction

The international financial markets turmoil, which started around mid-2007, has depreciated substantially since August 2008. The financial market crisis has led to the collapse of major financial institutions. Nevertheless, crashes and crises are not confined to only developed markets and even developing countries including India are not excluded from this risk and can face any such a condition.

One rupee at the time of independence has grown in last sixty plus years and is not the same old one rupee, specifically in terms of purchasing power as well. From 1950-1951 until mid-December 1973, India had an exchange rate regime with the rupee pegged to the pound sterling, except for the devaluations in 1966 and 1971. In 1975, the rupee's ties to the pound sterling were severed and India established a float exchange regime, with the rupee's exchange rate being linked on a controlled, floating basis to a "basket of currencies" of India's major trading partners. During 1990-91 Indian economy faces sever macroeconomic problems like trade deficit, problems of balance of payment and foreign exchange rate reserve etc., which led the Government of India and Reserve Bank of India (RBI) to take on number of structural adjustments to correct the economic pressure. Post liberalization, the rupee underwent change from a controlled regime to a "managed" or "dirty" float regime, where the market determines the exchange rate but the central bank can intervene to protect it.

The Reserve Bank of India initiated a sequential phase wise process to regulate the exchange rate system starting from downward adjustment in 1991 and followed by a dual (market determined) system of exchange rate called Liberalised Exchange Rate Management System (LERMS) in 1992. But this system inherent practical difficulty in implicit tax on exports proceedings. Hence in1993, the Government of India and RBI introduced a unified market driven foreign exchange rate system by replacing the LERMS. Since 1993 to until now India followed this system of market determined foreign exchange rate but under managed float regime.

The international financial markets turmoil, which started around mid-2007, has depreciated substantially since August 2008. The financial market crisis has led to the collapse of major financial institutions. Nevertheless, crashes and crises are not confined to only developed markets and even developing countries including India are not excluded from this risk and can face any such a condition. A number of studies try to find out the real causes of volatility in foreign exchange market but still final root causes remain unknown and even predictability models are in question. A gauge of expected swings in India's rupee fell to a steep low as a revival in seasonal rains tempered concern inflation and will accelerate over time and this becomes like a vicious circle.

Why Euro? - Importance of Euro-INR Currency Pair

If we look at the Trade picture of both India and European Zone as a whole we find that both hold high rankings in terms of trade with each other. The EU is India's top most trading partner (13% of India's overall trade with the world in 2014-15), which is ahead of China (9.5%), USA (8.5%), UAE (7.8%) and Saudi Arabia (5.2%). If we look at the India in EU Trade rankings partnership we find that India is the EU's 9th trading partner in 2015 (2.2% of EU's overall trade with the world), after South Korea (2.6%) and Brazil (1.9%) which is substantial. The value of EU exports to India grew from €21.3 billion in 2005 to €38.1 billion in 2015. The key sectors included engineering goods, gems and jewelry and chemicals ranking at the top. The value of EU imports from India also increased regularly likewise in 2015 from €19.1 billion in 2005 to €39.4 billion, with top sectors being textiles and clothing, chemicals and engineering goods. Trade in services has also almost tripled in the past decade, increasing from €5.2billion in 2002 to €14 billion in 2015. (European Commission, 2014)

2. Literature Review and Methodology

To investigate foreign exchange rate volatility, this study follows the methodology adopted by recent empirical literature and authors such Yasir Kamal et.al.,(2012), Md. Zahangir Alam & Md. Azizur Rahman (2012) Seok Yoon and Ki Seong Lee(2008) and currency futures volatility have been studied by Somnath Sharma (2011), Santhosh Kumar et.al (2011. Also the paper discusses in details about the Depreciating Indian Rupee *visavis* all four hard currencies considering four time zones. (Mehrotra, Jain , & Dashora, 2015)

But the gap remains as most studies are confined to US Dollar and not Euro, though being significantly important in terms of our trade benefits. Also mostly currency futures or stock market volatility have been compared rather than its own impact of previous period volatility in terms of daily forex returns.

This study uses time series data of daily Exchange Rate of Indian Rupee against Euro from April 2008 to March 2016. The total observations are 1924. The daily exchange rate of Indian rupee against Euro was collected from Reserve Bank of India and these are RBI quoted reference rates.

The scheduled procedure for determining the order of integration of a time series is the ADF. To evaluate the stationarity of time series data ADF is most common test. It is one among the several ways of testing the presence of unit root test of the data series. It controls the serial correlation by adding lagged first difference to the auto regressive equation. So for both Absolute exchange rate prices and return series we conducted this test. There are evidences of non-stationarity in the absolute currency pair prices was also there.

In this paper, as we investigate the Euro/INR movements in the foreign currency market to detect volatility. There have been evidences that any time series trend analysis may be linear or not but the stochastic nature may persist there in time series data series of such type. The various methods have been employed to examine the volatility of Euro/INR currency pair. We found out that returns of such financial time series data largely follow stochastic process and are away from normality. Considering the distinctive features of the a long financial time series data of Forex such as volatility clustering, leverage effects, asymmetric nature, persistence volatility, the time series data have been attempted with models of ARCH/GARCH(Eq.1) and family initiated by Engle (1982) and further popularized by Bollerslev (1986) and Taylor (1986). The study uses GARCH (1, 1) specification to detect the persistence level of volatility in the residuals. Also further, a series of models TARCH and EGARCH (Eq.2) are used to study leverage effect of returns and residual hetroskedasticity and asymmetric volatility. As the normal standard GARCH model does not allow to measure asymmetric behaviour of the forex volatility parameters. We attetmpt to understand how volatility responds to good and bad news, so we use Exponential GARCH (EGARCH – Eq2.) specification popularized by Nelson (1991).

$$ht = \alpha 0 + \sum_{i=1}^{q} \alpha i \varepsilon_{t-i}^{2} + \sum_{j=1}^{p} \beta jht - j \text{.....(} \quad Eq\ 1)$$

$$\ln(h_t) = \omega + \theta\left[\frac{\varepsilon t-1}{\sqrt{ht-1}}\right] + \gamma\left[\left|\frac{\varepsilon t-1}{\sqrt{ht-1}}\right| - E\left(\left|\frac{\varepsilon t-1}{\sqrt{ht-1}}\right|\right)\right] + \phi \ln(ht-1) \qquad \text{..... } Eq\ 2$$

Key Objectives

1. To study the time series trend of Euro-INR currency pair in post recession scenario (2nd April, 2008 to 31st March, 2016)
2. To find out and analyze the prime long term as well as short term reasons of Euro-INR volatility in the mentioned period
3. To measure the foreign exchange volatility of euro-INR currency pair

3. Data Analysis and Interpretation

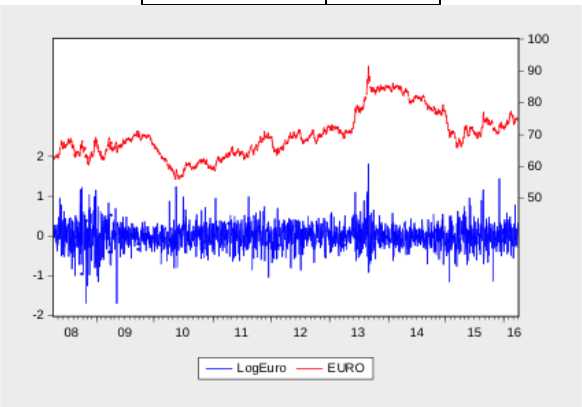
The times series data of this currency pair has totally 1924 observations and it has been analyzed using EViews9. Below is the time series trend from April 2008 to March2016. Both in terms of absolute reference rates (as quoted by RBI) as well as the returns series have been plotted in the graph below. First we want convert this raw data into a return series or we can say continuously compounded return series by using the following step (Eq3). This is also the natural log of the reference rates.

$R_t = \log [E_t/E_{t-1}] * 100$…… (3)

Table 1

Descriptive Stat-EURO (Et)	
Mean	69.8973
Median	68.9505
Maximum	91.4682
Minimum	56.07
Std. Dev.	7.15699
Skewness	0.6025
Kurtosis	2.7145
Jarque-Bera	122.97
Probability	0

Observations	1924



Graph 1

We can observe that there are points of extremities at few intervals both in reference currency exchange rates as well as the Return series. Also we see there is an upward trend in time series which is absolute exchange rate of the Euro-INR pair. Upwards trend hints us on the stationarity of the data set, which is crucial for volatility study. These extreme crests and troughs indicate the volatility of returns. A positive/negative value of skewness of a data shows asymmetry. In our result it shows a positively skewed relative to normal distribution, a non-symmetric data series. The Kurtosis is 2.7145 for reference rate series. In a standard normal distribution Kurtosis is 3. A value lesser or greater than 3 kurtosis coefficient indicate flatness and peakedness of the data series. Table 1 shows that kurtosis coefficient is marginally lower than 3, that indicate data series follow flatness of distribution. The Jarque Bera test of normality test is rejected the hypothesis of normality at 1% significant level.

Hence the next step is to check our data series is stationary or not and for this purpose we can run unit root test like ADF for both series.

Table 2

Currency Pair Euro/INR	**Augmented DickeyFuller (ADF) Test**	
	Particulars	At Level
Absolute Ex.Rate prices of Euro/INR (Et) (at intercept)	ADF stat	-1.6305
	Test Critical Value at5% level	-2.86284
	P-Value	0.4667
Return series of Euro/INR (Rt) (at intercept)	ADF stat	-41.7737
	P-Value	0.0000
	Test Critical Value at5% level	-2.8628

For Exchange rate of Euro-INR in absolute exchange rate terms, ADF test has Null Hypothesis: 'Et' has a unit root at level and Alternative Hypothesis is 'Et' is stationary at level. Asper the test result output we see test statistic is less than crtical value and also p value is more than 5% hence cannot reject null hypothesis. Hence this Et series is non-stationary. Where as in return series we find that pvalue is also less than 5% and ADF test statistic is also more than critical value in absolute terms hence we conclude saying that Return series null hypothesis is rejected and our data seires is stationary at level by accepting the Alternative hypothesis.

As the unit root shows the return series is stationary so we can proceed to GARCH modeling. First we can check ARCH effect in return series of EuroINR return series. Now we have to use the Rt (Return series as that's only stationary). We will estimate the ARMA (1, 1) model of INR Euro return series and then test the presence of ARCH effect in return series. Autoregressive Moving Average Model (ARMA MODEL) is used as it indicates the present value of a time series depends upon it past values, which is the autoregressive component, and on the preceding residual values, which is the moving average component. The ARMA (p,q) model has the following general form

$$R_t = \varphi_1 R_{t-1} + \varepsilon_t + w_1 \varepsilon_{t-1}$$

Where, Rt is the dependent variable at time t; Rt-1 is the lagged dependent variable; φ1 is the regression coefficient ; εt is

the residual term; εt−1, is the previous values of the residual; and w1is the weights. After obtaining the residuals εt, the next step is regressing the squared residuals for test the null hypothesis that there are no ARCH effects in the residual series. The value of εt2 is the squared residual calculated by equation (3); εt2-1, εt2-2,...., εt2-q is the lagged squared residuals up to q lags; α0 is the constant and α1, α2... αq is regression coefficients of different lags.

Table 3

ARMA Equation				
Dependent Variable: LOGEURO				
Method: ARMA Maximum Likelihood (OPG - BHHH)				
Sample: 4/03/2008 3/31/2016				
Included observations: 1923				
Convergence achieved after 21 iterations				
Coefficient covariance computed using outer product of gradients				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.00424	0.007442	0.56968	0.569
AR(1)	-0.138967	0.369298	-0.3763	0.7067
MA(1)	0.188384	0.36787	0.512093	0.6086
SIGMASQ	0.095752	0.002011	47.61685	0

For estimation volatility of foreign exchange rate (Indian rupee against Euro), when we use different ARCH/GARCH models we need to test the heteroscedasti city, we cannot use homoscedastic model to estimate volatility. The presence of heteroscedasti city in the residuals of Euro INR exchange rate return by running the ARCH test with lag1. The presence of ARCH effect in residuals in different lag periods, or the null hypothesis that there are no ARCH effects in residual series of EuroINR is tested by below Table 4.

Table 4

Heteroskedasticity Test: ARCH				
F-statistic	49.37804	Prob. F(1,1920)		0.0000
Obs*R-squared	48.19013	Prob. Chi-Square(1)		0.0000
Test Equation:				
Dependent Variable: RESID^2				
Method: Least Squares				
Sample (adjusted): 4/04/2008 3/31/2016				
Included observations: 1922 after adjustments				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.080618	0.005171	15.58911	0.0000
RESID^2(-1)	0.158348	0.022534	7.026951	0.0000
R-squared	0.025073	Mean dependent var		0.095788
Adjusted R-squared	0.024565	S.D. dependent var		0.208596
S.E. of regression	0.206018	Akaike info criterion		-0.320665
Sum squared resid	81.49143	Schwarz criterion		-0.314879
Log likelihood	310.1595	Hannan-Quinn criter.		-0.318536
F-statistic	49.37804	Durbin-Watson stat		2.021533
Prob(F-statistic)	0.0000			

As above table is Test for hetroscedasti city we find that the null hypothesis of there is no arch effect is strongly rejected (since $p<0.05$). So we can proceed with this data series for ARCH/ GARCH models for this return residual series. Now we can estimate GARCH model. The output is as follows for the Return Euro/INR series.

As both ARCH coefficient (Resid Sq 0.0498) and corresponding p value is small and GARCH coefficient (0.9340) and p value are shown significant. This indicates that the lagged conditional variance as well as the lagged squared variance has an impact on current volatility. This means that the current volatility of foreign exchange market is predictable on previous trends and is determined by the news originating from previous period's volatility. The highly significant ARCH effect substantiates the presence of volatility clustering in GARCH (1,1) model. We can also conclude that the past squared residual term (ARCH term) is significantly affecting the volatility risk in Indian foreign exchange market. The coefficient of GARCH effect also shows highly statistical significance and indicates that the past volatility of Indian foreign exchange rate is significantly influencing the current volatility of Indian foreign exchange rate. The sum of coefficients of ARCH term and

GARCH term is also very close to one (0.98), which indicates that the volatility shocks are quite persistent. Thus therefore, confirming that volatility clustering is observed in the Euro/INR return series.

Table 5

Dependent Variable: Return EURO-INR				
Method: ML ARCH - Normal distribution (BFGS / Marquardt steps)				
Sample (adjusted): 4/04/2008 3/31/2016				
Included observations: 1922 after adjustments				
Convergence achieved after 35 iterations				
Coefficient covariance computed using outer product of gradients				
MA Backcast: 4/03/2008				
Presample variance: backcast (parameter = 0.7)				
GARCH = C(4) + C(5)*RESID(-1)^2 + C(6)*GARCH(-1)				
Variable	Coefficient	Std. Error	z-Statistic	Prob.
C	0.0008	0.0066	0.1266	0.8993
AR(1)	0.0019	0.3593	0.0054	0.9957
MA(1)	0.0621	0.3578	0.1736	0.8622
Variance Equation				
C	0.0016	0.0004	4.4512	0.0000
RESID(-1)^2	0.0498	0.0057	8.7696	0.0000
GARCH(-1)	0.9340	0.0066	141.5222	0.0000

Then we run in EGARCH model through the Eviews to find out the structure of asymmetric nature of market volatility. The appropriate model appears to be EGARCH (1, 1) and the estimation output is given in the Table 6 below.

Table 6

Dependent Variable: Return EURO-INR				
Method: ML ARCH - Normal distribution (BFGS / Marquardt steps)				
Sample (adjusted): 4/04/2008 3/31/2016				
Included observations: 1922 after adjustments				
Convergence achieved after 54 iterations				
Coefficient covariance computed using outer product of gradients				
MA Backcast: 4/03/2008				
Presample variance: backcast (parameter = 0.7)				
LOG(GARCH) = C(4) + C(5)*ABS(RESID(-1)/@SQRT(GARCH(-1))) + C(6)				
***RESID(-1)/@SQRT(GARCH(-1)) + C(7)*LOG(GARCH(-1))**				
Variable	Coefficient	Std. Error	z-Stati	Prob.
C	0.0050	0.0068	0.7355	0.4620
AR(1)	-0.0391	0.3156	-0.1239	0.9014
MA(1)	0.1077	0.3129	0.3442	0.7307
Variance Equation				
C(4)	-0.1338	0.0142	-9.4023	0.0000
C(5)	0.1132	0.0113	10.0124	0.0000
C(6)	0.0255	0.0070	3.6155	0.0003
C(7)	0.9807	0.0042	231.2867	0.0000
R-squared	0.0021	Mean dependent var		0.0042
Adjusted R-squared	0.0010	S.D. dependent var		0.3100
S.E. of regression	0.3098	Akaike info criterion		0.3921
Sum squared resid	184.1828	Schwarz criterion		0.4123
Log likelihood	-369.7863	Hannan-Quinn criter.		0.3995
Durbin-Watson stat	2.0394			

Table 7

Dependent Variable: Return EURO-INR				
Method: ML ARCH - Normal distribution (BFGS / Marquardt steps)				
Sample (adjusted): 4/04/2008 3/31/2016				
Included observations: 1922 after adjustments				
Convergence achieved after 42 iterations				
Coefficient covariance computed using outer product of gradients				
Presample variance: backcast (parameter = 0.7)				
GARCH = C(4) + C(5)*RESID(-1)^2 + C(6)*RESID(-1)^2*(RESID(-1)<0) + C(7)*GARCH(-1)				
Variable	Coefficient	Std. Error	z-Statistic	Prob.
C	0.0044	0.0068	0.6530	0.5137
AR(1)	0.0396	0.3553	0.1115	0.9112
MA(1)	0.0267	0.3546	0.0755	0.9398
Variance Equation				
C	0.0019	0.0004	4.6443	0
RESID(-1)^2	0.0662	0.0081	8.1747	0
RESID(-1)^2*(RESID(-1)<0)	-0.0359	0.0094	-3.7912	0.0001
GARCH(-1)	0.9312	0.0079	117.2201	0

Statistically significant EGARCH coefficient (Table 6) at 0.0255 and corresponding p value 0.03% indicating the statistical significance of the presence of asymmetric behavior of volatility of Euro/INR return series in Indian foreign exchange rate market.

We can identify the existence of leverage effect and asymmetric behavior by the TARCH coefficient. Here in Table 7 suggesting that, it is statistically significant coefficient (-0.0359) and p value being very small. Also further the leverage effect term shows the negative sign, indicating that positive shocks (good news) have large effect on next period volatility than negative shocks (bad news) of the same sign or magnitude.

4. Prime Reasons of Volatile Rupee Visavis Euro

Indian rupee has become has excessive volatile leading to sudden and sharp depreciation of Indian Rupee against Euro between range of Rs56 for one euro to Rs91 for one Euro in the entire post recession period of 2008-2016. 20th Oct 2009 at Rs68.95 rupee had gained strength by 13th May 2010 to reach Rs56.98 which was again highly volatile period. Similarly on 18th March 2013 one euro was Rs70.01 which slipped plunged to Rs91.46 on 28th Aug 2013. (Graph1) Again on 12th March 2015 Rs65.94 valuation indicating the INR gaining strength but again due to Brexit and own indigenous macro-economic factors being not good that pushed rupee into further depreciating level of Rs 75.09 for one euro. These included a combination of number of economic, social, political factors indigenously and globally given below:

1. Primarily India's CAD has brought a lot to weakened rupee as in almost doubled from 2.7 percent of GDP in 2010-11 upto 5 percent of GDP in 2012-13. The increasing CAD was accompanied by a rise in the fiscal deficit that rose from levels of 4.9 percent of GDP in 2010-11 to 5.9 percent of GDP in 2011-12. Also the disappointing GDP numbers indicated that growth fell from levels of 8.4 percent to 5 percent over the 2010-11 to 2012-13 period.
2. Slow down of Exports due to economic recession in Europe and USA. Thus volume of exports has been lowered considerably due to weak demand from India's traditional markets.
3. Indigenous economic problems like high inflation, adverse fiscal deficit, weak sentiments in capital market, high Consumer Price Index, decline in economic growth, political change expected, slow industrial growth was pushing rupee to depreciation against euro. Economic growth in India in the April-June 2013 slipped to 4.4% due to a contraction in manufacturing and mining sector.
4. Apart from economic factors the rupee remained vulnerable to geo-political tensions in the Middle East and North Africa. As there seemed to be a threat of US-led war against Syria rises, oil prices were expected to rise which will further make it difficult for the Indian government to reduce CAD. (Narang, 2014)
5. Increase in imports of oil is further putting pressure on Indian currency since India imports over 80 percent of its oil. Also a regular Increase in imports of non-productive items like gold had pushed India's trade and current account deficit wider, which further depreciated rupee.
6. The August 2013 extreme volatility of INR is mainly attributed to lower house of Parliament approving on Aug26,2013 a nearly $20 billion plan to provide cheap grain to the poor, raising concerns the country's fiscal deficit will blow out even

further named as Food Security Bill. This bad news itself of High CAD and further pressure on rupee mounted and we saw new lows of INR both visavis US Dollar and Euro. Also there were large capital outflows coupled with the increased demand for dollars by the Indian importers and banks increased pressure on dollars/euros resulting in rupee depreciation. Earlier in June-July 2013 the foreign investors pulled out a record Rs.620 bn ($10 bn) from the Indian debt and equity markets. Later on Federal Reserve decided to taper the QE program, the liquidity withdrawal continued to put pressure on the INR.

7. Similarly in Jan 2015 Indian rupee recorded strong gains at commencement on 23rd January 2015 after the European Central Bank (ECB) announced larger than expected measures to stimulate the region's sagging economy & monetary stimulus. Moreover, selling of the US currency by exporters amid sustained capital inflows alongside soaring local equities supported the rupee. Also one more positive development being that India's foreign exchange reserves rose to $328.7 billion at the end of January 2015 which was enough to boost economy. Also by end of March 2015 due to recovering dollar and post quantitative easing scenario of US, increasing inflation above 1.5% and unemployment coming down to less than 5% in US economy this made rupee depreciate against Dollar but was strengthening against Euro.
8. Due to rising global concerns and efforts to increase competitiveness among other emerging market currencies, a considerable depreciation in the rupee occurred after August 2015. Even the Central Bank (RBI) had cut interest rates by a total of 125 basis points in 2015 to bring the policy rate down to 6.8%. Inflation levels have been slowly rising upward with low crude and commodity prices globally, they helped maintain inflation levels within desired limits.
9. By March 2016 the Weakening Eurozone, fear of Brexit vote and Euro-USD valuations falling and Indian RBI Governor announcing his exit. These news items again were bringing shocks to Indian national rupee with respect to Euro.

5. Conclusion

The purpose of this study is to find out in post-recession scenario how Euro-INR currency pair has performed. There has been a continual volatile trend both upward and downward in INR with respect to Euro, due to various economic, geo-political reasons including rising CAD, rising fiscal deficit, Syria war fears, revival of US economy, QE by Fed, EU stimulus and then finally Brexit and Rexit till the period of study.

The absolute reference rates of RBI indicated there was unit root in it but the returns series showed it was stationary. We checked heteroscedasticity of residuals. The residual of series indicated there was ARCH effect and hence we framed the GARCH model, which showed persistent volatility in post recession scenario. prices of GBP/INR are stationary at Level, which strongly rejected the null hypotheses at 1% level significance. In GARCH model the volatility shocks were quite persistent, confirming that volatility clustering is observed in the Euro/INR return series. Statistically significant EGARCH coefficient showed the presence of asymmetric behavior of volatility of Euro/INR return series in Indian foreign exchange rate market. TARCH model shows the presence of leverage effect and impact of positive news being much more on present day volatility than the bad news.

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