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The Relationship Between Exchange Rate and Stock Market Volatilities in India: ARCH-GARCH Estimation of the Causal Effects

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Abstract

With increasing globalisation and integration of national stock exchanges, for the global investor, the portfolio risk increases not only from the local stock market volatility but also in the exchange rate risk. This paper examines the exchange rate volatility effect on volatility in stock market return from India's perspective for the period January 2010 to December 2015, applying ARCH and GARCH estimation. The daily data of the BSE SENSEX returns, exchange rates of US dollar/rupee, British pound/rupee, Euros/rupee are used. It is estimated that the Euro/rupee exchange rate volatility has a significant positive effect on the BSE SENSEX return volatility, while the effect of the US dollar/rupee and British pound/rupee exchange rate the volatilities are insignificantly negative. The larger GARCH parameter over the ARCH term indicates that the own lagged values of the stock return cause more volatility in stock returns than the innovations. There exists a highly persistent effect of shocks to the BSE SENSEX return and the volatility effect wanes only slowly.

Keywords: Exchange Rate, Stock Market Return, Volatility, ARCH and GARCH Estimation

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1. Introduction

Globalisation has resulted in numerous global links throughout the world bringing every nation close to each other and in fact, the modern world is seen as a single global village. This current wave of globalisation has not only expanded the markets for products and economic integration but also the global integration of financial institutions and financial markets. Just like as the growth of an economy is strongly related to its domestic financial markets, where much of the capital for investments is derived from the national stock market, the global financial system with which the domestic financial markets are linked through FIIs is also a critical factor in national achieving economic growth (Muktadir-Al-Mukit, 2012). Rapidly increasing international equity flows create a higher demand for and supply of currencies in which international equity prices are denominated leading to some degree of interdependence between stock market and exchange rate changes. A byproduct of such global integration of financial markets is that the vulnerability of the global financial instituitons increases not only

with global economic fluctuation but also with the national economies. The national economies are also highly vulnerable to the volatilities in the international financial markets (Karunanayake, Valadkhani and O'Brien, 2010).

The changes in global financial market also influence exchange rates, the fluctuations of which have repercussions on economies throughout the world. In market economies, the exchange rate instability is ameliorated to some extent through free-floating or managed floating exchange rates (Karoui, 2006). The instability in international markets and volatility of exchange rates affect the stock prices as well as returns in the domestic stock markets and causes stock price volatility. The stock returns volatility is the common measure of financial risk and such stock returns volatility is widely used for hedging, asset pricing, portfolio selection, etc. (Jegajeevan, 2012). Stock market volatility for long has been viewed as a disruption of the capital markets signalling to misprice stocks (Peiris and Peiris, 2011). Especially, firms and individuals with holdings of foreign equities face greater risks of the instability of exchange rates. The performance of portfolio investments and hedging the risk of foreign exchange of international investors are crucially determined by the covariance in currency and equity returns. The same is the concern of policy decision makers as the international investments are very much need for capital investments and the development of their manufacturing.

The Asian financial crisis of 1997-98 and the global financial crisis of 2007 have clearly demonstrated the dynamic links between not only the domestic stock prices and exchange rates but also of their volatilities. The emerging markets have collapsed as a result of a substantial exchange rate depreciation (in terms of US$) and a significant fall in the stock prices. This has happened not by a shift in trade flows but due to a large shift in the portfolio cross-border movement of funds.

The causal relationship between exchange rate and interest rate is well established. Similarly, there exist a well developed approach to the nexus between interest rate and the stock market performance. However, little is known on the extent of the causal relationship netween exchange rate and stock returns. Especially, how the instability of exchange rate influences the international equity returns is not clearly understood and the empirical evidence is inconstant (Mishra, 2004; Solnik, 1987; Zubair, 2013). From an asset pricing viewpoint, the relation of exchange rate with equity returns is determined by the covariance between the returns and risks in exchange and stock markets. Hau and Rey (2006) suggest that due to the portfolio rebalancing effect, the returns on foreign exchange and equity markets is to be negative. A rise in the stock market performance of a foreign country relative to a home country, induces a portfolio investor to sell foreign currency stocks as the investor is overweight in foreign currency equities. The investore then sells the foreign currency proceeds for local currency, thus ensuring neutral postion. At the same time, the foreign currency depreciates with the sale of foreign currency for local currency, while the foreign stock market is outperforming.

In contrast to the returns, the nexus between volatilities in the two markets is is less clear. Notionally, there should exist a positive association between the volatilities in exchange rate and stock markets as the risks in one market leadspills over to the other market. However, few available empirical studies have produced mixed results. The suggestion of a positive association between volatilities in exchange rate and share markets is contrasted with a negative association between them.

The main aim of this paper is to empirically examine the impact of exchange rate volatility on stock market return volatility in India. The paper uses daily market values of BSE SENSEX and the daily exchange rate values of US dollar-rupee, euro-rupee and pound-rupee exchange rates for the period from January 5, 2010 to December 31, 2015. The daily market data of BSE SENSEX is obtained from the Bombay Stock Exchange and the data on exchange rates are obtained from the Reserve Bank of India websites. The standard methods of time series data analysis are carried out. The Augmented Dickey-Fuller (ADF) test is done for stationarity. Empirically, the standard Ordinary Least Squares (OLS), Autoregressive Conditional Heteroscedasticity (ARCH) and Generalised Autoregressive Conditional Heteroscedasticity (GARCH) models are estimated.

2. Review of Literature

Theoretically, the relationship between the exchange rate market and the stock market has been explained by two alternative models: the goods market or flow-oriented model and the portfolio balance or stock-oriented model. The former theory argues that causality runs from the exchange market to the stock market while the latter theory describes that the stock market fluctuations influence the exchange rate market (Khan and Ali, 2015). In the goods market model, international competitiveness and trade balances are influenced by the instability in the exchange rate thus affecting the domestic real income and output. The domestic stock market reacts to the exchange rate changes. The future income, interest rate innovations, current investment and consumption decisions are thus linked to the volatilities in the stock prices and exchange rates (Dornbusch and Fischer, 1980). In the stock-oriented model, the exchange rate balances the demand for and supply of assets. Since stocks form a significant component of financial assets and their current values are based on the present value of their future cash flows, naturally, the movements in the stock prices are influenced by the expectations of relative currency values. Therefore, the dynamics of the shocks or innovations in both the stock prices and exchange rate are casually interrelated **(**Branson, 1983; Frankel, 1983; Zhao, 2010).

The goods market hypothesis suggests that changes in exchange rates affect the competitiveness of multinational firms and hence their earnings and stock prices. A depreciation of the local currency makes exporting goods cheaper and may lead to an increase in foreign demand and sales. Consequently, the value of an exporting firm would benefit from a depreciation of its local currency. On the other hand, because of the decrease in foreign demand of an exporting firm's products when the local currency appreciates, the firm's profit will decline and so does its stock prices. In contrast, for importing firms the sensitivity of firm value to exchange rate changes is just the opposite. An appreciation (depreciation) of the local currency leads to an increase (decrease) in the firm value of importing firms. Additionally, variations in exchange rates affect a firm's transaction exposure, i.e. exchange rate movement affects a firm's future payables (or receivables) denominated in foreign currency. For an exporter, an appreciation of the local currency reduces profits, while a depreciation of the local currency increases profits. Further, stock prices could be affected by exchange rate movements because such movements will induce equity flows.

According to the portfolio balance approach, exchange rates, like all commodities, are determined by the market mechanism. A booming stock market would attract capital flows from foreign investors and hence causes an increase in the demand of a country's currency and vice versa. As a result, rising (declining) stock prices are related to an appreciation

(depreciation) in exchange rates. Moreover, foreign investment in a country's equity securities could increase over time due to the benefits of international diversification that foreign investors would gain. In addition to returns, capital flows can be induced by the less risky investment climate of a country. An improvement in a country's investment climate such as a stable political system, a fair legal system, financial openness and liberalisation will lead to capital inflows and currency appreciation. Further, movements in stock prices may influence exchange rates since investors' wealth and money demand may depend on the performance of the stock market. For example, during the time of a crisis, a sudden dislocation of asset demands may incur because of the herding behaviour of investors or the loss of confidence in economic and political stability. This dislocation usually results in a shift of portfolio preference from domestic assets to assets denominated in other currencies, implying a decrease in the demand for money. This will lead to a decrease in the domestic interest rate which in turn leads to capital outflows causing the currency to depreciate **(**Pan et al. 2007).

Empirically, Shapiro (1975), Levi (1994) and Marston (2001) show a positive association between exchange rate and stock market volatilities in the US. It is also shown that the competitiveness and the market values of the firms are directly affected by the exchange rate. Aggarwal (1981) and Agrawal et al. (2010) also report a positive association between exchange rate and stock market volatilities. But, Branson and Henderson (1985) and Frankel (1983), using the portfolio balanced model, demonstrate that the connection between the movements of the exchange rate and the US stock market has a negative relationship. They further depict that at the macro level the domestic wealth falls as a result of a fall in the stock prices and thereby a capital outflow would occur as a result of a drop in the interest rates which creates a reduction in demand for domestic money so that domestic currency gets depreciated. However, Jorion (1990) and Bartov and Bodnar (1994) fail to find a significant contemporaneous relation between US dollar movements and stock returns for US firms. Thus, despite the theoretical association between exchange rate and stock market volatilities, early empirical studies have not produced convincing evidence to support the relationship between exchange rate and stock market movements (Jorion, 1991).

Najang and Seifert (1992) report that the absolute difference in the stock returns has a positive impact on the exchange rate volatility for US dollar movement and stock return for US firms. Sekmen (2011), using ARIMA models on stock returns for the US, observes that exchange rate volatility negatively affects stock returns. Even the availability of hedging instruments could not lessen the negative impact of exchange rate volatility on the volume of trade. Ajayi and Mougoue (1996) and Ajayi et al. (1998) provide evidence for unidirectional causality from the stock market to currency markets for advanced economies and no consistent causal relations in emerging markets.

Donnelly and Sheehy (1996) observe a significant contemporaneous relation between exchange rate and the market value of large UK exporters. Maysami and Koh (2000) argue that the interest rate and the exchange rate should also be considered as determinants of UK stock prices and that obtain a positive association between the UK stock prices and exchange rate. Zhao (2010) empirically examine the dynamic relationship between the Renminbi (RMB) real effective exchange rate and stock price in China with VAR and multivariate GARCH models for the period January 1991 to June 2009. The results show that there is not a stable long-term equilibrium relationship between RMB real effective exchange rate and stock price. There are also no mean spillovers between the foreign exchange and stock markets. Furthermore, the paper examines the cross-volatility effects between foreign exchange and

stock markets using the likelihood ratio statistic. There exist the bidirectional volatility spillovers effects between the two markets, indicating the past innovations in the stock market have a great effect on future volatility in the foreign exchange market, and vice versa.

Among the stock market studies on Asian countries, Ramasamy and Yeung (2002) examine the links between foreign exchange and stock markets and their implications for capital controls in six Asian countries (Bangladesh, Japan, Philippines, Vietnam, China, Indonesia) over the period 1995-2001. They find inconsistent results for bivariate causality between stock prices and exchange rates. Chiang and Yang (2003) show that stock returns and currency values are positively related in six Asian markets (Bangladesh, Japan, Philippines, Vietnam, China, Indonesia). Adjasi and Biekpe (2005) report that relative currency movements influence stock price volatility in these six Asian markets. Pan et al. (2007) also examine dynamic linkages between exchange rates and stock prices in these six East Asian countries. Yau and Nieh (2009) investigate the exchange rate effects of the Taiwan Dollar against the Japanese Yen on stock prices in Japan and Taiwan and find a long-term equilibrium and asymmetric causal relationships.

As far as studies on the stock market in India, Bahmani-Oskooee and Sohrabian (1992) show a bidirectional causality between stock prices measured by the S&P500 index and effective exchange rates of dollar. Apte (2002), using the E-GARCH specification proposed by Nelson (1991), examine whether changes in the volatility of the stock market affect volatility in the foreign exchange market and vice versa in India. The model specification incorporates asymmetric effects of positive and negative return surprises on volatility both within the market as well as spillovers across the two markets. Empirical analysis with one of the major stock market indices supports the hypothesis of such volatility linkages while for the other index there appears to be a spillover from the foreign exchange market to the stock market but not the other way round.

Thus, the exchange rate market and the stock market have both positive and negative associations. Some studies show that the stock market affects the foreign exchange rate while others have also observed that foreign exchange rate affect the stock market. Hence, the causality between the volatility of exchange and stock markets is inconclusive and needs further investigation.

3. Research Method

In order to study the relationship between exchange rate volatility and stock market volatility, this paper uses the daily closing data on the stock market index BSE30 (SENSEX) and the daily closing US dollar-rupee exchange rate, euros-rupee exchange rate and British pound-rupee exchange rate for six years from January 5, 2010 to December 31 2015 with 1440 observations, The stock market data are obtained from the BSE exchange and the historical exchange rate data are taken from Reserve Bank of India websites.

3.1. Generalised Autoregressive Conditional Heteroscedasticity Model

Empirically, this paper follows the generalised autoregressive conditionally heteroskedasticity (GARCH) model. The GARCH (q,p) process can be modelled as:

$$\varepsilon_t = \sigma_t x_t \quad (1)$$

where x_t is a sequence of a i.i.d. random variable and σ_t is a nonnegative process such that:

$$\sigma_t^2 = \alpha_0 + \alpha_1\varepsilon_{t-1}^2 + \cdots + \alpha_q x_{t-q}^2 + \beta_1\sigma_{t-1}^2 + \cdots + \beta_p\sigma_{t-p}^2 \quad (2)$$

and $\alpha_0 > 0\,,\ \alpha_1 \geq 0\,,\ \ i = 1, \ldots, q,\ \beta_j \geq 0,\ \ j = 1, \ldots, p$ (3)

The conditions on parameters ensure strong positivity of the conditional variance in equation (2). Writing equation (2) in terms of a lag-operator B:

$$\sigma_t^2 = \alpha_0 + \alpha(B)\varepsilon_t^2 + \beta(B)\sigma_t^2 \quad (4)$$

where $\alpha(B) = \alpha_1 B + \alpha_2 B^2 + \cdots + \alpha_q B^q$ and $\beta(B) = \beta_1 B + \beta_2 B^2 + \cdots + \alpha_p B^p$ (5)

If the roots of the characteristic equation, i.e.

$$1 - \beta_1 x - \beta_2 x^2 - \cdots \beta_p x^p = 0 \quad (6)$$

lie outside the unit circle and the process (x_t) is stationary, then equation (2) can be written as:

$$\sigma_t^2 = \frac{\alpha_0}{1-\beta(1)} + \frac{\alpha(B)\varepsilon_t^2}{1-\beta(B)} = \alpha_0^* + \sum_{t=i}^{\infty} \delta_i \varepsilon_{t-i}^2 \quad (7)$$

where $\alpha_0^* = \frac{\alpha_0}{1-\beta(1)}$ and δ_i are coefficients of B^i in the expansion of $\alpha(B)[1-\beta(B)]^{-1}$. The expression (7) shows that the GARCH (q,p) process is an ARCH process of infinite order with a fractional structure of the coefficients. From equation (1), the GARCH (1,1) process is stationary if the process (σ_t^2) is stationary.

As the data is time series, the presence of unit root and stationarity of the series using the Augmented Dickey-Fuller (ADF) test is to be performed in order to avoid constructing spurious regressions when working with nonstationary time series data. The null hypothesis is that a unit root is present in a time series sample and the alternative hypothesis says that the series doesn't have a unit root. The unit root specification is:

$$\Delta y_t = \alpha + \beta_t + \gamma y_{t-1} + \delta_1 \Delta y_{t-1} + \cdots + \delta_{p-1} \Delta y_{t-p-1} + \varepsilon_t \quad (8)$$

where α is a constant and β_t is the coefficient on time trend and p is the lag order of the autoregressive process. The unit root test is then carried out under the null hypothesis $\gamma = 0$ against the alternative hypothesis $\gamma < 0$.

Empirically, the impact of exchange rate volatility on stock market volatility is analysed first by the OLS method:

$$r_t = \beta_0 + \beta_1 (USD\_INR)_t + \beta_2 (EURO\_INR)_t + \beta_3 (GBP\_INR)_t + \varepsilon_t \quad (9)$$

where r_t is the daily stock returns calculated as the natural logarithm of the daily closing price relative to previous day i.e. $SENSEX_t$ = ln[(stock price$_t$/(stock price$_{t-1}$)], $(USD\_INR)_t$ is the logarithm of daily exchange rate i.e. $(USD\_INR)_t$ = ln[(USD_INR_t/(USD_INR_{t-1})], GBP_INR_t is the natural logarithm of daily exchange rate i.e. $(GBP\_INR)_t$ = ln[(GBP_INR_t/(GBP_INR_{t-1})], $EURO\_INR_t$ is the natural logarithm of daily exchange rate i.e. $EURO\_INR_t$= ln[($EURO\_INR_t$/($EURO\_INR_{t-1}$)], β_0, β_1 , β_2 and β_3 are the coefficients of the parameters, and u_t is the white noise error term.

The autoregressive conditional heteroscedasticity (ARCH) model describes the variance of the current error term or innovation as a function of the actual sizes of the previous period error, terms often the variance is related to the squares of the previous innovations. Let, $\varepsilon_t = x_t\sigma_t$ where ε_t is the error terms (return residuals, with respect to a mean process). ε_t are split into a stochastic piece x_t and a time-dependent standard deviation σ_t characterising the

typical size of the term. The null hypothesis is that, in the absence of ARCH components, γ_i = 0 for all i=1,2,…p. The alternative hypothesis is that, in the presence of ARCH components, at least one of the estimated γ_i coefficients must be significant. The suitability of the estimated OLS model is then tested with the ARCH test. The ARCH process is specified as follows:

$$r_t = \gamma_0 + \gamma_1(USD\_INR)_t + \gamma_2(EURO\_INR)_t + \gamma_3(GBP\_INR)_t + \varepsilon_t \quad (10)$$

$$\varepsilon_t^2 = \alpha_0 + \alpha_1\varepsilon_{t-1}^2 + \cdots + \alpha_p\varepsilon_{t-p}^2 \quad (11)$$

The generalised autoregressive conditional heteroscedasticity GARCH (p, q) process (where p is the order of the ARCH term ε^2 and q is the order of the GARCH terms σ^2) is specified as:

$$r_t = \gamma_0 + \gamma_1(USD\_INR)_t + \gamma_2(EURO\_INR)_t + \gamma_3(GBP\_INR)_t + \varepsilon_t \quad (12)$$

$$\varepsilon_t^2 = \alpha_0 + \alpha_1\varepsilon_{t-1}^2 + \cdots + \alpha_p\varepsilon_{t-p}^2 + \delta_1\sigma_{t-1}^2 + \cdots + \delta_q\sigma_{t-q}^2 \quad (13)$$

where the parameter γ_0 is the intercept, γ_1 , γ_2, and γ_3 are the coefficients of the estimated parameters of the mean equation, σ_t^2 is the conditional variance, $\alpha_1\varepsilon_{t-1}^2$ is the news about volatility from the previous period, measured as the lag of the squared residuals from the mean equation which is defined as ARCH term, and $\delta_1\sigma_{t-1}^2$ is the last period's forecast variance which is defined as the GARCH term.

The GARCH specification requires that in the conditional variance equation, parameters α_0, α_1 and α_2 to be non-negative and the sum of α_1 and α_2 to be less than one to secure the covariance stationarity of the conditional variance:

$$r_t = \phi_0 + \varepsilon_t \quad (14)$$

$$\sigma_t^2 = \phi_0 + \theta_1\varepsilon_t^2 + \theta_2\sigma_t^2 + \eta_1 v(USD\_INR)_t + \eta_2 v(EURO\_INR)_t + \eta_3(GBP\_INR)_t \quad (15)$$

where *v* represents the volatility of the exchange rates calculated through a GARCH (1,1) process to capture the impact of exchange rate volatilities on stock return volatilities.

4. Finding and Discussion

Figures 1 to 3 presents the trend exchange rates of the Indian rupee with the US dollar, euro and British pound for the period January 5 2010 to December 31 2015. All three exchange rate movements show an upward trend from 2012 and peaking at the beginning of 2014. There is also significant volatility in all three exchange rates.

Table 1 presents the variability of the variables in the empirical analysis of the causal relationship between stock prices and exchange rates in India. The skewness is to be 0 and kurtosis to be equal to 3 in order to indicate that the variables are normally distributed. The data are tested for normality through the Jarque-Bera test which shows that the JB test has passed and all variables are normally distributed.

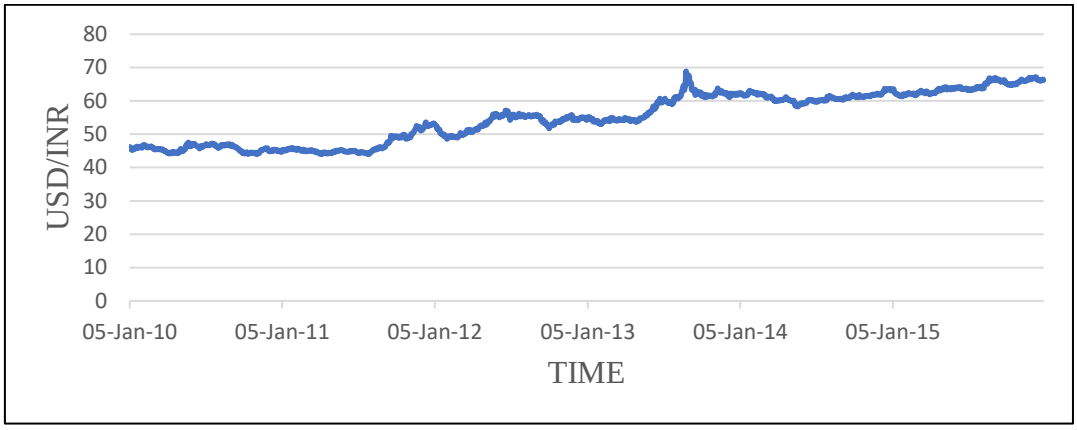

Figure 1 Trend in US Dollar-Indian Rupee Exchange Rate

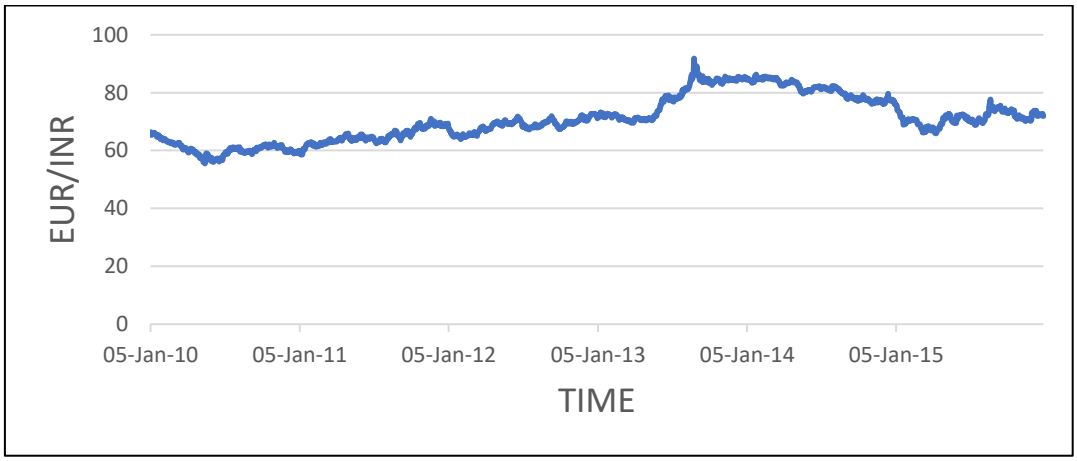

Figure 2 Trend in Euro-Indian Rupee Exchange Rate

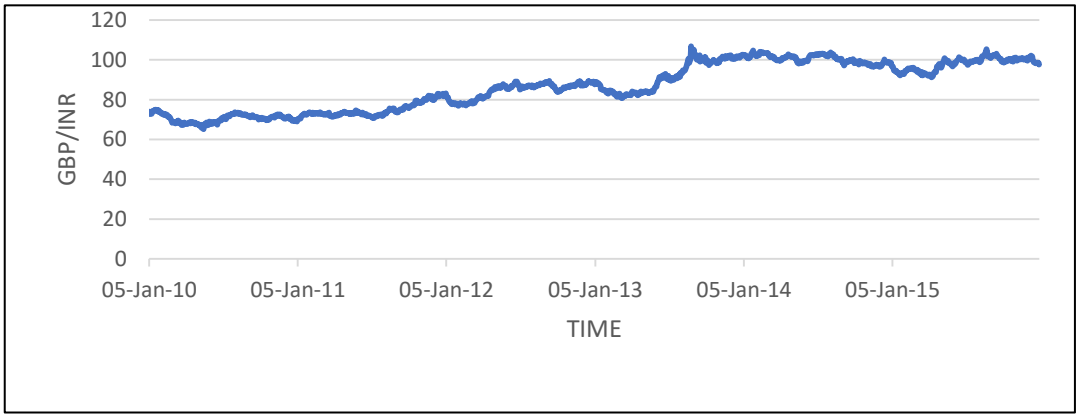

Figure 3 Trend in British Pound-Indian Rupee Exchange Rate

Table 1 Descriptive Statistics of Stock Market Index and Foreign Exchange Rates

Statistic	BSE SENSEX	USD_INR	GBP_INR	EURO_INR
Std. dev.	0.00798	0.0021	0.0038	0.0044
Skewness	0.10956	0.9642	0.1749	0.0183
Kurtosis	3.00204	3.5162	3.3233	3.6751
Jarque-Bera test	1276.26	26235.24	331.889	168.783
Obs.	1440			

The ADF test for stationarity of the variables presented in Table 2 rejects the null hypothesis of a unit root in the levels form as the probability values are less than 0.05. Therefore, all the variables are stationary at levels.

Table 2 ADF Test for Stationarity

Variable at levels	t-statistic	Prob.
BSE SENSEX RETURN	-30.765**	0.000
USD/INR	-17.392**	0.000
GBP/INR	-17.335**	0.000
EUR/INR	-17.573**	0.000

Table 3 presents OLS and GARCH estimates of the effect of exchange rates on the BSE SENSEX returns. In the OLS results, both US dollar-rupee exchange rate and euro-rupee exchange rates have a negative association with the BSE SENSEX returns whereas the nexus between the British pound-rupee exchange rate and BSE SENSEX returns are positive. However, only the US dollar-rupee exchange rate has a significant impact on the BSE SENSEX returns while the British pound-rupee and euro-rupee exchange rates are insignificant in determining the BSE SENSEX returns. The suitability of the regression OLS estimation is tested with the ARCH test if the squared residuals of OLS equation (9) contain autocorrelation or heteroscedasticity. The results of the ARCH test reject the null hypothesis at 1 percent significant level indicating that classical OLS estimated coefficients are not effectively estimated so that inferences based on such coefficients are unreliable.

In contrast to the OLS estimates, the estimated mean BSE SENSEX returns GARCH (1,1) process show that the US dollar-rupee exchange rate has an insignificant impact on BSE SENSEX returns while British pound-rupee and euro-rupee exchange rates have a significant impact on BSE SENSEX returns. However, there is no deviation from the OLS estimates with regard to the sign of the relationship between foreign exchange rates and market returns as the GARCH (1,1) model also produces a positive association between British pound-rupee exchange rate and BSE SENSEX stock market returns while a negative association with other two currencies. The results further reveal that the magnitude of the coefficients are high for the US dollar-rupee exchange rate and euro-rupee exchange rate compared to the British

pound-rupee exchange rate indicating that those currencies are having a relatively strong link with the stock market returns compared to the British pound-rupee exchange rate. The intercept term is positive and statistically significant which indicates that there is a significant time-invariant component in the return generating process.

Table 3 OLS and GARCH Estimates of the Effect of Volatility in Exchange Rates on Stock Market Returns in India

Variable	OLS	GARCH	
	BSE SENSEX return	Mean BSE SENSEX return	Volatility of BSE SENSEX return
USD	-0.334*** (0.114)	-0.111 (0.097)	-
GBP	0.092 (0.080)	0.108** (0.050)	-
EURO	-0.056 (0.064)	-0.113*** (0.038)	-
Constant	0.0005** (0.0002)	0.0005*** (0.0001)	-
R-square	0.007	-	-
Adj. R-square	0.005	-	-
Durbin-Watson statistic	1.598	-	-
F-statistic	0.020	78.795*** (0.000)	-
Obs*R-square		74.811*** (0.000)	
Variance equation			
RESID (-1)^2	-	0.162*** (0.017)	0.150*** (0.016)
GARCH (-1)	-	0.826*** (0.016)	0.819*** (0.017)
v(USD_INR)	-	-	-0.027 (0.015)
v(GBP_INR)	-	-	-0.052 (0.040)
v(EURO_INR)	-	-	0.106*** (0.026)
Constant	-	1.41E-06*** (3.15E-07)	1.14E-06 (4.43E-07)

Note: Standard errors in parentheses. *** significant at 1 percent level ** significant at 5 percent level * significant at 10 percent level.

Both the ARCH and GARCH parameters are satisfying the non-negativity condition while both parameters are significant at 1 percent significant level. The GARCH parameter is significantly greater than the ARCH term illustrating that the volatility of stock returns are

more sensitive to its own lagged values than to its new surprises. Consequently, the effect of the previous period's forecast variance is more persistent. In addition, the summation of GARCH and ARCH parameters closer to unity indicates that the shocks to the BSE SENSEX stock returns have high persistent effects and the response to volatility decays at a slower rate.

The estimated exchange rate volatilities of US dollar-rupee, British pound-rupee and euro-rupee on the volatility of BSE SENSEX returns by GARCH (1,1) model indicate a lower and significant ARCH parameter. This shows weak support for the presence of last period's shocks on stock market return volatility whereas a relatively large and statistically significant GARCH parameter provides strong evidence for the presence of previous surprises. Despite the inclusion of exchange rate volatilities, the sum of ARCH and GARCH parameters as a measure of volatility presence is still approximately closer to unity indicating a weak impact on exchange rate volatilities on the stock market return volatilities irrespective of the currency.

The empirical results on the relationship between the volatilities in the stock market index and foreign exchange rates show that the effect of euro-rupee exchange rate volatility is positive and statistically significant on the stock market return volatility. An increase in euro-rupee exchange rate volatility increases the volatility of stock returns of BSE SENSEX by about 10 percent. This is expected as the globalisation as well as open market economic policies, Indian capital market has become a potential destination for foreign investors to park their investments which creates a severe exposure to the foreign currency risk. As an emerging market economy, India still lacks a developed market for hedging instruments to mitigate potential exchange rate risk exposures. This can be a potential reason behind the positive association between euro-rupee exchange rate volatility and stock market return volatility. The empirical results further reveal that volatilities of US dollar-rupee and British pound-rupee exchange rates negatively influence the stock return volatilities but the effects are statistically insignificant.

Diagnostic tests of correlogram of squared residual test and heteroscedasticity test are performed in order to assess the suitability and reliability of the ARCH and GARCH estimation models. The estimated results of the tests are presented in Table 4. In the correlogram test, all Q statistics at all lags under the normal GARCH model are statistically insignificant at 1 percent level indicating no significant serial correlation among the residuals. On the other hand, in the heteroscedasticity test, the p-value of the Obs*R-square is insignificant indicating the non-existence of the ARCH effect.

Table 4 Correlogram of Squared Residual and Heteroscedasticity Tests

Lag	AC	PAC	Q-statistics	Prob.
1	0.036	0.036	1.8548	0.173
2	-0.004	-0.006	1.8814	0.39
3	-0.03	-0.03	3.2117	0.36
4	-0.026	-0.023	4.1591	0.385
5	-0.009	-0.008	4.2898	0.508
6	-0.003	-0.004	4.3037	0.636
7	-0.014	-0.016	4.6086	0.708
8	-0.005	-0.005	4.6387	0.795

Table 4. Continued

Lag	AC	PAC	Q-statistics	Prob.
9	0.036	0.036	6.5348	0.685
10	-0.025	-0.029	7.4414	0.683
11	-0.017	-0.015	7.8387	0.728
12	0.012	0.015	8.044	0.782
13	0.012	0.011	8.2421	0.827
14	0.019	0.017	8.773	0.845
15	-0.033	-0.035	10.379	0.795
16	0.001	0.006	10.382	0.846
17	0.029	0.03	11.625	0.822
18	-0.027	-0.033	12.217	0.808
19	-0.027	-0.024	13.806	0.795
20	-0.024	-0.02	14.62	0.79
F-statistic	1.850	Prob.		0.174
Obs*R-square	1.850	Prob. Chi-square		0.174

5. Conclusion

With the globalisation of capital markets and liberalisation of the capital account, global investors diversify their portfolios across currencies and national stock markets. Since the exchange rate risk and its association with the local stock market is an important component of the overall portfolio risk, this trend can be expected to link the stock market and the forex market more closely. This paper empirically investigates the effect of exchange rate volatility on stock market return volatility from India's perspective. The daily time series data for the BSE SENSEX stock market index and exchange rates of US dollar/rupee, British pound/rupee, Euros/rupee over a period of six years from January 2010 to December 2015 is used in the empirical analysis. In the estimation, this paper applies the ARCH and GARCH models in order to estimate the effect of exchange rate volatility on stock market return volatility. The empirical results of the study reveal that the volatility of the Euro/rupee exchange rate has a positive and significant impact on BSE SENSEX return volatility whilst the effect of the volatility of US dollar/rupee and British pound/rupee exchange rates are insignificantly negative. It is observed that the GARCH parameter is significantly greater than the ARCH term illustrating that the volatility of stock returns is more sensitive to its own lagged values than to its new surprises. The shocks to the BSE SENSEX stock returns have highly persistent effects and the response to volatility decays at a slower rate.

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