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THE RELATIONSHIP BETWEEN EXTERNAL AND DOMESTIC MARKETS IN INDIA: ARCH-GARCH ESTIMATION OF THE CAUSAL EFFECTS OF VOLATILITIES IN THE EXCHANGE RATE AND THE STOCK MARKET

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Abstract: As global investors diversify their portfolios across currencies and national stock markets, the exchange rate risk and its association with the local stock market is an important component of the overall portfolio risk. This paper empirically analyses the effect of exchange rate volatility on stock market return volatility from India's perspective, applying ARCH and GARCH estimation on daily data of the BSE SENSEX stock market index and the exchange rate of US dollar/rupee, British pound/rupee, Euros/rupee for six years from January 2010 to December 2015. The estimates reveal that the volatility of the Euro/rupee exchange rate has a significant positive effect on BSE SENSEX return volatility while the effect of the volatility of the US dollar/rupee and British pound/rupee exchange rates are insignificantly negative. The larger GARCH parameter over the ARCH term implies that the volatility of stock returns is more sensitive to its own lagged values than to its new surprises. There exists a highly persistent effect of shocks to the BSE SENSEX stock returns and the response to volatility decays at a slower rate.

Keywords: Exchange rate, stock market return, volatility, ARCH and GARCH estimation

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 resulted in a marked growth in interactions among international financial institutions and their markets. A byproduct of such global integration of financial markets is also that economies are highly vulnerable for the changes occurring in international financial markets (Karunanayake, Valadkhani and O'Brien, 2010). Just like the growth of an economy is strongly related to its domestic financial system where the national stock market plays a vital role in providing capital for investments, the global financial system with which the domestic financial markets are linked through FIIs also plays a critical role in achieving such economic growth (Muktadir-Al-Mukit, 2012).

The changes in global financial markets also influence the exchange rates, the fluctuations of which have repercussions on economies throughout the world. Karoui (2006) observes that emerging market countries are attempting to adjust their currencies around certain powerful global currencies such as US dollars, by adopting free-floating rates or managed floating exchange rates so that fluctuations in exchange rates in such currencies become too small compared to others. In this context, Joseph (2002) notes that the exchange rate directly affects the international competitiveness of the firms based on the price levels of inputs and outputs of such firms. This instability in international markets and volatility of exchange rates affect the stock prices as well as returns in the domestic stock markets and cause stock price volatility. The volatility in stock returns is frequently used as a measure of risk and such volatility in stock returns is widely used for hedging, asset pricing, portfolio selection, etc. (Jegajeevan, 2012). Peiris and Peiris (2011) demonstrate that people tend to believe volatility is a signal of market disruption where the capital markets are not functioning at the expected level together with the presence of mispriced securities. Thus, volatility in stock returns is perceived as critical so understanding the volatility of stock returns has long been a topic of considerable interest.

Especially an investor holding foreign equities is naturally exposed to exchange rate fluctuations. Both portfolio performance and the decision regarding whether to hedge foreign exchange risk depend, amongst other things, on the relationship between equity and currency returns. Policymakers care about this relationship as valuation changes induced by foreign exchange and equity returns generate significant swings in international investment positions. However, while there is vast literature on the link between interest rate differentials and exchange rates across countries, little is known about the relationship between exchange rates and international equity returns. From an asset pricing viewpoint, the correlation between exchange rates and equity returns depends on the covariance between returns and currency and stock market risks. Hau and Rey (2006) suggest that foreign exchange and equity market returns should be negatively correlated because of portfolio rebalancing. To see the mechanism, consider a portfolio manager of a country with money invested in another country. When the stock

market of that foreign country rises relative to the home country, the manager is overweight with foreign country equities and, to return to a neutral position, sells foreign country stocks and then sells the foreign currency proceeds for local currency. The sale of foreign currency for local currency causes the foreign currency to depreciate at the same time the foreign stock market is outperforming.

The nature and magnitude of the interdependence between stock prices and exchange rates have implications for a number of crucial domestic issues as well as for international finance. The relationship between a country's stock market and its foreign exchange market, especially in volatility, has been a subject of theoretical and empirical investigation for a long. However, the empirical evidence on the influence of exchange rate volatility on the volatility of stock returns is inconsistent (Mishra, 2004; Solnik, 1987; Zubair, 2013). The existence of a positive association between exchange rate and share market volatilities is also contrasted with evidence for a negative association between them.

Since the mid-1980s international equity has been increasing at a rate of 34% per annum which reflects a pattern of rapidly increasing international equity investment. An increased cross-border equity flow creates a higher demand for and supply of currencies in which international equity prices are denominated leading to some degree of interdependence between the stock market and exchange rate changes. Further, the positive and significant spillover of volatility may increase the nonsystematic residual international portfolio risk faced by international investors, hence reducing the gains from international portfolio diversification.

The Asian crisis of 1997-98 and the global financial crisis of 2007 have made a strong pitch for dynamic linkage between stock prices and exchange rates. During the crisis period, the emerging markets collapsed due to substantial depreciation of exchange rates (in terms of US$) as well as a dramatic fall in stock prices. This has become important again from the viewpoint of large cross-border movement of funds due to portfolio investment and not due to actual trade flows, though trade flows have some impact on stock prices of the companies whose main sources of revenue come from foreign exchange. Therefore, it is important to understand the interlink between financial markets and exchange rates.

The purpose of this paper is to empirically investigate the impact of exchange rate volatility on stock market return volatility in India. The paper uses the daily market values of BSE SENSEX and the daily exchange rate values of the US dollar-rupee, euro-rupee and pound-rupee exchange rates for a period of six years from January 5, 2010 to December 31, 2015. The data on daily market values of BSE SENSEX is obtained from the Bombay Stock Exchange and the 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 on the effect of exchange rate volatility on stock market return volatility.

REVIEW OF LITERATURE

Theoretically, the relationship between the exchange rate market and the stock market has been explained by two alternative models: the good 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 changes in the stock market affect the exchange market (Khan and Ali, 2015). The flow-oriented model states that changes in the exchange rate affect international competitiveness and trade balances, thereby influencing real income and output. And stock prices, generally interpreted as the present values of future cash flows of firms, react to exchange rate changes and form the link among future income, interest rate innovations, current investment and consumption decisions (Dornbusch and Fischer, 1980). The stock-oriented model views exchange rates as equating the supply and demand for assets such as stocks. Since the values of financial assets are determined by the present values of their future cash flows, expectations of relative currency values play a considerable role in their price movements. Therefore, stock price innovations may affect, or be affected by, exchange rate dynamics (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 for 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 for 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 a 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 rates 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 domestic wealth falls as a result of a fall in 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 rates and stock market volatilities, early empirical studies have not produced convincing evidence to support the relationship between exchange rates 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 the 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 examines 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 the 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 spillover effects between the two markets, indicating that 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 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 the 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 the foreign exchange rate affects the stock market. Hence, the causality between the volatility of the exchange and stock markets is inconclusive and needs further investigation.

DATA AND METHODOLOGY

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.

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:

$$\varepsilon_t = \sigma_t x_t \tag{1}$$

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

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

and

$$\alpha_0 > 0,\ \alpha_1 \geq 0,\ \ i = 1, ..., q,\ \beta_j \geq 0, \quad j = 1, ..., p \tag{3}$$

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

$$\sigma_t^2 = \alpha_0 + \alpha(B)\varepsilon_t^2 + \beta(B)\sigma_t^2 \tag{4}$$

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

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

$$1 - \beta_1 x - \beta_2 x^2 - \ldots \beta_p x^p = 0 \tag{6}$$

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

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

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:

$$\Delta y_t = \alpha + \beta_t + \gamma y_{t-1} + \delta_1 \Delta y_{t-1} + \ldots + \delta_{p-1} \Delta y_{t-p-1} + \varepsilon_t \tag{8}$$

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:

$$r_t = \beta_0 + \beta_1 (USD_INR)_t + \beta_2 (EURO_INR)_t + \beta_3 (GBP_INR)_t + \varepsilon_t \tag{9}$$

where r_t is the daily stock returns calculated as the natural logarithm of the daily closing price relative to the previous day i.e. $SENSEX_t = \ln[(\text{stock price}_t/(\text{stock price}_{t-1})]$, $(USD_INR)_t$ 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, $\gamma_i = 0$ for all $i = 1,2,\ldots p$. 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:

$$r_t = \gamma_0 + \gamma_1 (USD_INR)_t + \gamma_2 (EURO_INR)_t + \gamma_3 (GBP_INR)_t + \varepsilon_t \quad (10)$$

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

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:

$$r_t = \gamma_0 + \gamma_1 (USD_INR)_t + \gamma_2 (EURO_INR)_t + \gamma_3 (GBP_INR)_t + \varepsilon_t \quad (12)$$

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

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:

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

$$\phi_0 + \theta_1 \varepsilon_t^2 + \theta_2 \sigma_t^2 + \eta_1 v(USD_INR)_t + \eta_2 v(EURO_INR)_t + \eta_2 (GBP_INR)_t \quad (15)$$

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.

EMPIRICAL ANALYSIS

Figures 1 to 3 present 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 if the causal relationship between stock prices and exchange rates in India. The skewness is to be 0 and kurtosis is 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

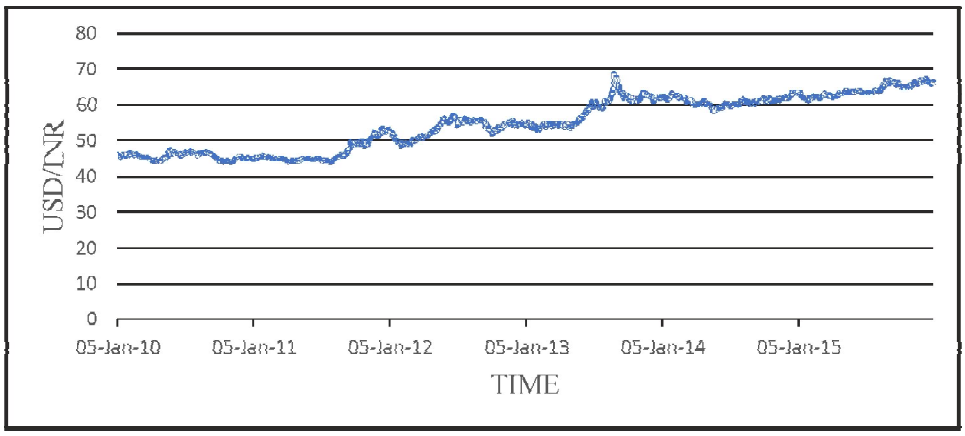

Figure 2: Trend in Euros-Indian Rupee Exchange Rate

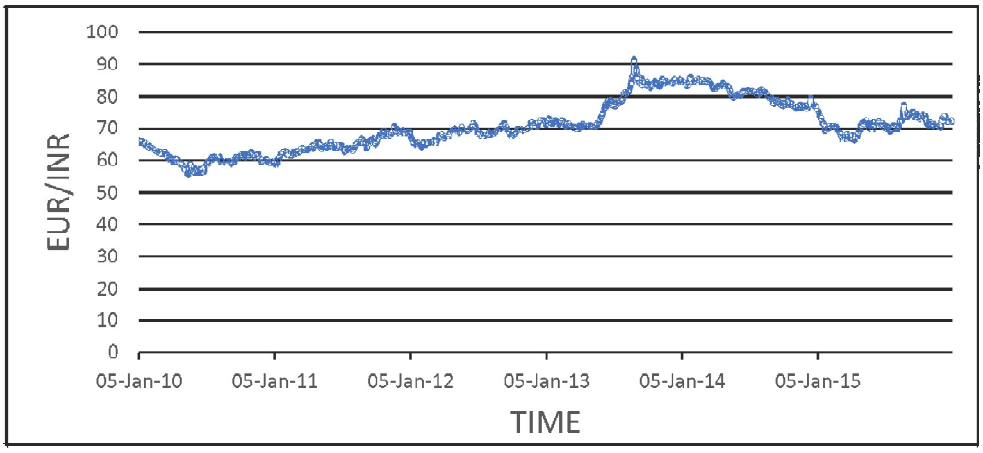

Figure 3: Trend in British Pound-Indian Rupee Exchange Rate

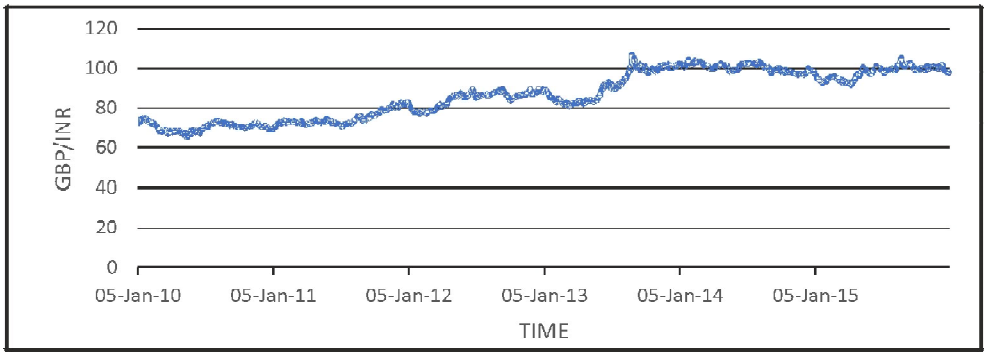

Table 1: Descriptive Statistics of Stock Market Index and Foreign Exchange Rates

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 the OLS equation (9) contain autocorrelation or heteroscedasticity. The results of the ARCH test reject the null hypothesis at 1% significant level indicating that classical OLS estimated coefficients are not effectively estimated so 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

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***	-0.111	-
	(0.114)	(0.097)	
GBP	0.092	0.108**	-
	(0.080)	(0.050)	
EURO	-0.056	-0.113***	-
	(0.064)	(0.038)	
Constant	0.0005**	0.0005***	-
	(0.0002)	(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***	0.150***
		(0.017)	(0.016)
GARCH (-1)	-	0.826***	0.819***
		(0.016)	(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***	1.14E-06
		(3.15E-07)	(4.43E-07)

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

(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.

Both the ARCH and GARCH parameters are satisfying the non-negativity condition while both parameters are significant at 1% 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 the US dollar-rupee, British pound-rupee and euro-rupee on the volatility of BSE SENSEX returns by the 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%. This is expected as the globalisation as well as open market economic policies, the 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% 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
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	

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, and 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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